SVERIGES GEOLOGISKA UNDERSÖKNING

SER. C. Afhandlingar och uppsatser. N:o 229

ÅRSBOK 4 (1910): N:o 1.

HISTORICAL-STRATIGRAPHICAL REVIEW

OF THE

SILURIAN OF SWEDEN

BY

JOH. CHR. MOBERG.

WITH A MAP.

Pris 3 kr.

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CENTRALTRYCKERIET, STOCKHOLM 1911.

PREFACE.

In translating this work into English and in printing it so many clerical and typographical errors crept in that the corrections of them required more time than had been anticipated. The work, principally intended to assist the participators in the Silurian excursions that had been arranged after the Geological Congress in Stockholm, could, of course, only be distributed to the members of the Congress in the form of proof-sheets — and bad ones at that. Subsequently I had the advantage of Professor TÖRNQUIST looking over the proof-sheets, for which service I am greatly indebted to him, so much the more so as he allowed me to insert a couple of bits of information of his own, previously unpublished. I have now also added an Index.

For the sake of brevity, the place of publication of the various works mentioned in the several bibliographical lists is often omitted, especially in such cases where the works are printed in the Transactions of the Geological Society in Stockholm (Geol. För. Förh.) or among the publications of the Geological Survey of Sweden (Sver. Geol. Unders.).

It should also be remembered that the annexed map showing the distribution of the Silurian through the several provinces of Sweden is only a sketch-map, which, especially as regards the northern parts of the country, is very imperfect

CHAPTER I.

Introduction.

By the name »Silurian» is here understood all our deposits characterized by trilobites or graptolites, as well as some others in which certainly the said groups of animals are not represented, or in which fossils on the whole have not been met with, but which yet are in such close relation to the first mentioned that they must distinctly be brought together with them. The Silurian, in older times here commonly called the Transition formation, occupies amongst our sedimentary deposits, apart from the Quaternary, of course, indisputably the first place. Distributed over a great many areas, of which several are of very large extent, the deposits belonging to this system are namely found scattered all over the country, even in its most widely separated parts.

If we combine all zones of Silurian proved to exist in Sweden, we can obtain a continuous series of the strata thereof, beginning with the oldest bed of the system and extending right up to, and including, its youngest. As it also happens here that one and the same zone, or contemporaneously formed deposits, in different parts of the country may not only quantitatively be more or less developed, but also pretty frequently show very dissimilar, not seldom peculiar, development for the separate localities or areas, such a grouping together also gives a complete picture of the system in all its varying multiplicity.

At many places only single zones, or a few such, are met with, whilst at other places a more considerable part of

the series of strata is represented. Amongst the provinces or parts of the country where the Silurian is distributed over fairly large areas we have first of all to mention Skåne (Scania), Västergötland, Dalarne (Dalecarlia), Jämtland, Östergötland and Närke, as well as Öland and Gotland, the two large islands exclusively built up of Silurian. Skåne and Västergötland, as well as Dalarne and Jämtland, distinguish themselves especially by the multiplicity of zones developed there, but only in the two first mentioned provinces may the sequence of strata be said to be completely represented. If we look at the coast of Småland, Öland and Gotland regarded as a particular Silurian field, although disjointed by the sea, even this latter may, especially when we include the shore shingels which represent strata concealed by the Baltic, be said to show a complete series.

Our Silurian strata have, as a rule, even if they have not entirely escaped tectonic disturbances, rarely been more strongly folded or compressed to such an extent as to destroy fossils embedded therein, or to affect them to any considerable degree. This condition is particularly conspicuous in Västergötland, where the almost horizontal Silurian strata, in a more or less complete sequence, are accessible everywhere in the many table-mountains, that have been cut out by circumdenudation. The Silurian is certainly richer and perhaps even more completely representative in Skåne, but the investigation is made difficult there, not only by the dislocations occurring everywhere, but also by the facial differences which exist in different parts of the province. It is therefore no mere accident that Västergötland's Silurian, which already for the budding research offered the most favourable starting point one can well wish for, later on formed the solid framework round which the science of modern Swedish Silurian Geology has been built. Västergötland may also with every reason be called the classical ground of Swedish Silurian Geology.

The fossils embedded in the Silurian strata were at a very early date paid attention to by Swedish investigators. Already in the year 1715 L. ROBERG, Professor at the University of Uppsala, reproduced in a »Dissertatio academica de fluviatili astaco ejusque usu medico» Trilobites in boulders from Väddö, in the archipelago of Uppland, and he spoke of them in such a manner, that it is quite obvious that he looked upon them as crustaceans. In 1727 BROMELL[1] describes and reproduces Silurian fossils from different parts of the country (Gotland, Västergötland and Skåne), and in LINNÉ's[2] writings such are mentioned in several passages. Our first real palaeontologist was very likely, however, GYLLENHAHL,[3] who, in 1772, in an excellent manner described and reproduced a couple of cystideans. By stating that the animals must have lived and died where we now find their remains, he also indicates the position of the animals in the zoological system, as well as the geological horizon of the fossils. Amongst our older Silurian palaeontologists we must further mention WAHLENBERG[4] and DALMAN,[5] HISINGER,[6] who was, however, more of a stratigrapher

[1] BROMELL, M. VON: Lithographiae svecanae specimen secundum. Upsaliae.

[2] As for example in CARL LINNAEI Öländska och Gothländska resa 1741. Stockholm 1745; CARL LINNAEI Wästgöta-resa 1746. Stockholm 1747; CARL LINNAEI Skånska resa 1749. Stockholm 1751; Museum Tessinianum. Stockholm 1753, and Systema naturae, Edit. XII. 1768.

[3] GYLLENHAHL, JOH. ABR.: Beskrifning på de så kallade Crystall-äplen och kalkbollar, såsom petreficerade Djur af Echini genus, eller dess närmaste slägtingar. (Description of the so called Crystal-apples and limestone spheroids as petrified animals of Echini genus or closely allied forms.) Kgl. sv. Vet.-Ak. Handl. för år 1772.

[4] WAHLENBERG, G.: Petrificata telluris svecanae. Nova acta Reg. Soc. scient. Upsaliensis, Vol. 8. Upsaliae 1821.

[5] DALMAN, J. W.: Om Palaeaderna eller de så kallade Trilobiterna. (On the Palaeadae or the so called Trilobites.) Kgl. sv. Vet.-Ak. Handl. för år 1826. Stockholm 1827; och Uppställning och beskrifning af de i Sverige funne Terebratuliter. (Account and Description of the Terebratulites found in Sweden.) Kgl. sv. Vet.-Ak. Handl. för 1827. Stockholm 1828.

[6] HISINGER, W.: Lethaea Svecica seu Petrificata Sveciae iconibus et characteribus illustrata. Holmiae 1837.

and collector, LOVÉN[1] and ANGELIN,[2] which latter we have also to consider as the founder of our modern Silurian Geology.

Even if our older Silurian palaeontologists by no means took their material exclusively from Västergötland, this latter province was nevertheless for all of them a source sedulously drawn upon and a very prolific one to boot. As regards the abundance of fossils, other provinces and parts of the country might very likely be able to measure themselves with Västergötland, but with respect to the stratigraphy again, Västergötland's Silurian occupies incomparably the first place on account of the striking regularity with which the different rocks, each one with its peculiar lethaea (to use a name proposed by DALMAN) recur in all the mountains that rear themselves above the Västergötland plain. Already KALM[3] gave a very good account of the sequence in the mountains of Västergötland; his statements about the succession of strata were further confirmed by LINNÉ, who also tried, as much as the elementary knowledge of those days permitted, to apply the same sequence of strata even to the Silurian of other parts of the country, something which in our time induces NATHORST[4] to call LINNÉ the founder of Stratigraphical Geology.

A safe foundation for a general stratigraphy can, however, after the experience gained, only be obtained with the aid of palaeontology. The systematic division and arrangement of the Silurian strata demanded thus a certain greater development of Silurian palaeontology. It was also first in 1854 that ANGELIN, after having finished his extensive researches into the trilobite fauna of Sweden, saw himself enabled to bring out his well

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[1] LOVÉN, S.: Svenska Trilobiter. (Swedish Trilobites.) Öfvers. Kgl. Vet.-Ak. Förh. för 1845, p. 46 and 104. Stockholm 1846.

[2] ANGELIN, N. P.: Palaeontologia Scandinavica. Lundae 1851, 1854.

[3] PEHR KALM's Wästgötha och Bahusländska resa förrättad år 1742. (Journey in Västergötland and Bohuslän in the year 1742.) Stockholm 1746.

[4] NATHORST, A. G.: Carl von Linné såsom geolog. (Carl von Linné as a geologist.) Uppsala 1907. 8:o.

known Silurian scheme, which still to day forms the basis of our Silurian stratigraphy. As the scheme in question is built upon palaeontological ground, its different divisions could be called after the fossils chiefly occurring therein, something which for several reasons must be looked upon as an advantage which it possesses above the Silurian schemes of many foreign countries whose subdivisions are, for example, designated with inexpressive, nugatory numbers or letters, or have received local appellations taken from one or another typical occurrence. The designations taken from palaeontology are certainly preferable also on account of their being more general, and thus giving a greater value to the scheme, when it is a case of parallelizing deposits from different localities. ANGELIN's scheme has also the merit of possessing a unitary ground of classification, viz. the succession of the trilobites. At the same time as the scheme has gained in force by reason of this, the power of accommodation has to a great extent been lost, as the practicability must suffer by reason of no regard, or a small such, being taken to other classes of animals than trilobites. As soon as we have to do with formations in which trilobites predominate, the scheme is excellent, but when it is a question of formations with another palaeontological facies, it happens easily that we fall short with it.

And in reality it was also proved very soon that ANGELIN's scheme was not sufficient even for Västergötland, i. e. for the province whose Silurian strata have in the first instance been a decisive factor for the scheme. As it was necessary also to take regard to Västergötland's graptolite-bearing shales, LINNARSSON tried very soon[1] to make room for these too in the general scheme. The new additions which it thus received made, of course, an end of its entity. The weakening which the scheme suffered therefrom was, however, not

[1] LINNARSSON, J. G. O.: Bidrag till Vestergötlands geologi. (Contributions to the geology of Västergötland.) Öfvers. Kgl. sv. Vet.-Ak. Förh. 1868.

very noticeable until later on, and it must at any rate be called a very great advance that the importance of the graptolites for the stratigraphy received its due.

As detailed researches of the Silurian, from having at first been principally carried out only in Västergötland, were by and by also made in other provinces, ANGELIN's scheme was put more and more to the test. For Dalarne, for example, TÖRNQUIST[1] found himself compelled to set up quite a deviating scheme, in which the petrographical nature of the strata played an important part. It was lucky that LINNARSSON, after studies made of the Silurian in Västergötland, found an opportunity of more closely examining the Silurian even in other parts of Sweden. When LINNARSSON on that occasion could prove that ANGELIN's scheme, that had been modified by him, could very well be applied to the Silurian of, for example, Dalarne, it became an important contribution towards the establishment of the old scheme.

As regards Skåne again, LINNARSSON has certainly given an account of the sequence of strata for certain parts of the graptolite-bearing shales which play such a great part here, but TULLBERG was the first to make an attempt at setting up a complete scheme for the Silurian of Skåne. Making use of LINNARSSON's preliminary work, and taking the English pattern as his guide, he sets up a scheme in 1882,[2] which certainly takes up portions of ANGELIN's scheme, but yet on the whole, especially with respect to the Ordovician, is so unlike the former, that complete parallelization between the two is hardly possible. A more careful examination of TULLBERG's scheme of the Silurian of Skåne afterwards proved

[1] TÖRNQUIST, S. L.: Om lagerföljden i Dalarnes undersiluriska bildningar. Geologiska iakttagelser. (The sequence of strata in the Ordovician deposits of Dalarne. Geol. observations.) Lunds Univ:s Årsskrift, Tome III, Afd. IV. 1867.

[2] TULLBERG, S. A.: Skånes graptoliter. I. (The Graptolites of Skåne. I.) Sver. Geol. Unders. Ser. C, N:o 50.

several inaccuracies in it, which obviously crept in just on account of faulty basis of division.[1] TULLBERG's Silurian scheme has been of great use just on account of its mistakes; we have namely learned from them to what extent the value of a scheme depends upon its having a unitary basis of division. On the whole there are now hardly more than two classes of animals, viz. the trilobites, representing deposits from shallower, and the graptolites, representing such from deeper waters, which each in its special place are of such great extent, both vertically and horizontally, that they are suitable for basing a Silurian scheme upon. And on the whole the two schemes, each built upon its class of animals as mentioned, supplement each other in a very excellent manner. Parallel schemes obtained by combining two schemes of the aforementioned kind have lately often been made use of.[2] The scheme occupies in such case as a rule still a third column indicating strata in which the two groups of animals are simultaneously represented. In several instances the brachiopods, which at any rate pretty often are the sole representatives of shore deposits, very likely merit a column of their own in the scheme, but unfortunately the succession of the littoral brachiopod faunas is not yet sufficiently known.

Before we pass on to an account of the present day general scheme for Sweden's Silurian, it might be worth while to point out, partly that our knowledge of the sequence of strata in certain cases is rather imperfect — as, for example, we know too little of the conditions concerning the Gotlandian in the said respect in districts where limestones (or tri-

[1] Such inaccuracies occur also in the scheme drawn up by LINNARSSON, but they are not quite so glaringly conspicuous there.

[2] As for example MOBERG and SEGERBERG (1906), OLIN (1906), WESTERGÅRD 1909). — It was really TÖRNQUIST, who, in 1875 (p. 56 in »Berättelse om en geologisk resa genom Skåne och Östergötland»), first stated that the graptolite shales were partly to be parallelized with, not only put in between, the limestone deposits.

lobite-bearing strata) preponderate — partly that the difference between the scheme in its older and present day shape is, of course, not noticeable with regard to the Cambrian, in which graptolites, at least in our country, do not yet appear. To judge from certain conditions it almost seems, as I have stated elsewhere,[1] as if there had also been genera or forms amongst the trilobites which, contrary to the majority, had flourished best under such conditions as existed in somewhat deeper water. If such a distinction could really be proved, we would have cause to divide the scheme into two columns also with regard to the Cambrian, of which then the one would to a certain degree correspond to the column for graptolite or deep-water facies in the remaining Silurian or, at least, play an intermediate part.

General Scheme of the Silurian of Sweden.

(From shore or shallow sea) Trilobite (and Brachiopod) facies.			(From deeper sea) Graptolite facies.
		Series C. Gotlandian.	
Regio E		Öved—Ramsåsa formation in Skåne.	
		Grind-sandstone in Dalarne.	
		Gotland's strata, viz. Sphaerocodium marl and younger.	
Encrinurus beds		Gotland's strata older than the Sphaerocodium marl.	Colonus shales.
		Pentamerus limestone and	Cyrtograptus shales.
		Quartzite with *Phacops elliptifrons* in Jämtland.	Rastrites shales.

[1] MOBERG, J. C. and SEGERBERG, C. O.: Bidrag till kännedom om ceratopygeregionen med särskild hänsyn till dess utveckling i Fogelsångstrakten. Lunds Univ. Årsskrift. N. F. Bd. 2, Afd. 2. Lund 1906. (Note on page 51).

Series B. Ordovician.

(From shore or shallow sea) Trilobite (and Brachiopod) facies.		(From deeper sea) Graptolite facies.
Regio DE. Harpes beds.	The Leptaena limestone in Dalarne.	Upper Dicellograptus shales.
	Brachiopod shale in Västergötland and other provinces.	
Regio Db. Trinucleus beds.		
Regio Da. Chasmops beds.	Middle Dicellograptus shales.	
Regio C. Asaphus beds.	Lower Dicellograptus shales.	
	Upper Didymograptus shales.	
	The upper part (zones 2 to 5) of the Lower Didymograptus shales.	
Regio BC. Ceratopyge beds.	The lowest part (zone 1) of the Lower Didymograptus shales.	
	Dictyograptus shales.	

Series A. Cambrian.

Regio A (partim). Olenus beds.	Graptolite-bearing strata are not known.
Regio B (et *A* partim). Paradoxides beds.	
Regio Fucoidarum. Olenellus beds.	

CHAPTER II.

General review of the different series.

Series C. Gotlandian.

Of those parts of the country, from which the formations belonging under this heading are known, only Skåne can point to a complete series, and one that has been at all satisfactorily cleared up with regard to the sequence of strata. We find namely there not only the whole suite of the Gotlandian graptolite shales, but also a younger division, the so called Öved-Ramsåsa formation, whose lower part, composed of limestones and shales, may be said to have a trilobite facies, whilst the very uppermost part consists of sandstones in which the fauna, which is entirely without trilobites, contains brachiopods and one *Leperditia* as the principal fossil. To judge from all the circumstances, the Öved-Ramsåsa formation very probably directly overlies the Colonus beds, and is therefore not, as TULLBERG seems to have believed at first, partly the latter's equivalent. According to some accounts of the graptolite shales by TULLBERG and TÖRNQUIST, and quite recently of the Ramsåsa formation by MOBERG and GRÖNWALL, we get the following scheme for

The Gotlandian of Skåne. C I[1].

4. Öved-Ramsåsa formation, Zones 4—1.
3. Colonus beds { Zone with *Gothograptus nassa* HOLM. / Odarslöf flags.

[1] The Roman figures (next to the letter indicating the series) designate in this work only types for a different development of the series in question.

2. Cyrtograptus beds.
- Zone of *Cyrtograptus Carruthersi* LAPW. and *Monograptus testis* BARR.
- » *Cyrtograptus rigidus* TULLB.
- » *Monograptus Riccartonensis* LAPW.
- » *Cyrtograptus Murchisoni* CARR.
- » » *Lapworthi* TULLB.
- » » *spiralis* GEIN.
- » » *Grayae* LAPW.

1. Rastrites beds.
- Zone of *Monograptus runcinatus* LAPW.
- » » *Sedgwicki* PORTL.
- » *Diplograptus cometa* GEIN.
- » » *folium* HIS.
- » *Monograptus triangulatus* HARKN.
- » » *cyphus* LAPW.
- » *Diplograptus vesiculosus* NICH.
- » » *acuminatus* LAPW.

Gotland again, the large island exclusively built up of Silurian strata belonging to this series and from which the series has just borrowed the name, shows strata of another kind, on the whole deviating so much from those of Skåne that no complete parallelization, zone for zone, has been possible. A great obstacle to parallelization is the circumstance that we are not even quite clear about the sequence of strata in the Silurian of Gotland. As is generally the case with deposits from shallower waters, synchronous deposits occur namely here, too, in a very varying habitus; we also find a caleidoscopic mixture of coral-reefs, Stromatopora-reefs, crinoid-banks, Megalomus-banks, limestones and sandstones charged with brachiopods or trilobite-bearing ones, graptolite-bearing marls etc. etc. No settled palaeontological facies exists, no group of animals (except perhaps the brachiopods) runs right through the entire series of strata in a sufficiently uninterrupted sequence that the forms belonging there, rather than others, can be used as characteristic fossils in a unitary scheme. We certainly know the sequence of strata quite well in the Visby section, at the NW.

coast of the island, where the oldest strata occur, and likewise the sequence of strata of the southern part of the island (geological map-sheet Hamra), where the youngest deposits are found, but the relation between these two parts has not yet been cleared up satisfactorily. We might, however, with great reservation be able to give about the following form to the scheme for

The Gotlandian of Gotland. C II.[1]

9. Hard limestones { Crinoid limestone or Stromatopora limestone. / Grey, somewhat lamellar limestone.
8. Ostracod limestone.
7. Girvanella[2] limestone.
6. Oolite.
5. Sandstone.
4. Girvanella[2] marl.
3. Dayia limestone (with *D. navicula* Sow.)

2. Marl-shales with limestone bands (also containing graptolites).
1. Shales with *Stricklandinia lirata* Sow.

Of the strata mentioned the »*Girvanella*»-bearing strata, together with the oolite and sandstone interstratified between them, or, as we can also say, the strata containing *Homalonotus Knighti* Kön. var. *rhinotropis* Ang. are very likely to be correlated with the lower part of the Öved-Ramsåsa formation. The Gotlandian strata lying below this would therefore be correlated with the Upper graptolite shales of Skåne, from the Colonus beds to the Rastrites beds inclusive. Whether the limestones in the said beds, or on the other hand the graptolite-bearing marl-shales occurring on Gotland, permit of any more detailed pa-

[1] When this treatise was about to be printed I received the following papers: Munthe, H.: »The sequence of strata in Southern Gotland» and Hedström, H.: »The silurian Stratigraphy in the neighbourhood of Visby», which give fresh contributions to the stratigraphy of the Gotlandian of Gotland. I regret that I can now only refer to the papers themselves, both published as guides for the 11th Intern. Geol. Congress.

[2] The fossils, which up to that time had been called *Girvanella,* were in 1908 more closely studied by Rothpletz, and by him partly described as *Sphaerocodium (gotlandicum).* Of course, we now have to write »Sphaerocodium marl» and »Sphaerocodium limestone».

rallelization must for the present be left undecided. *Monograptus dubius* SUESS and *Gothograptus nassa* HOLM are, however, common to the lower part of the Colonus beds and to the »marl-shales with limestone bands» of Gotland.

To the W. of Storsjön Lake in Jämtland the Gotlandian seems to have assumed quite a peculiar development. In the deposits found there we have the following sequence of strata for

The Gotlandian of Jämtland. C III.

3. Rastrites beds (upper part).
2. Pentamerus limestone.
1. Quartzite with *Phacops elliptifrons* ESM.

The Pentamerus limestone contains, besides *Pentamerus oblongus* SOW., trilobites such as, for example, *Encrinurus punctatus* WAHLENB., *Proetus concinnus* DALM. and *Bumastus barriensis* MURCH. — As the (Upper) Rastrites beds here have not been met with directly covering the Pentamerus limestone, it is quite possible that they may be partly parallelized. As for the Gotlandian, the Silurian of Jämtland has its nearest parallel in the Silurian of Norway.

In Dalarne, where the lower part of the Gotlandian is developed in the form of Graptolite shales, the uppermost part consists of a sandstone (»slipsandsten»=grind-sandstone) to all appearances devoid of fossils, but which yet on account of its sequence may be looked upon as pretty well corresponding to the Öved or Ramsåsa sandstone in Skåne. As we also take into account a couple of little known strata found together with the grind-sandstone, we obtain the following scheme for

The Gotlandian of Dalarne. C IV.

4. Grind-sandstone.
3. Bumastus limestone. / Grey shale poor in fossils. } = Colonus beds?
2. Retiolites beds.
1. Rastrites beds.

Besides the provinces and parts of the country quoted we find Gotlandian strata also in Västergötland and Östergötland, where we have, for example in the neighbourhood of St. Åby, shales belonging to the topmost part of the Rastrites beds.

Series B. Ordovician.

In the deposits coming under this heading we find the majority of the zones developed not only with trilobite facies, but also with graptolite facies, and more locally there appear furthermore also some deposits with another facies, such as, for example, brachiopod facies, coral or crinoid facies. In some parts of the country a trilobite facies is predominating, in others again a graptolite facies, but here the continuity is as a rule never so complete as not to cause the dominant facies to give way, at least in some zone, to that of the other type. Sometimes we find trilobite and graptolite facies alternating with each other in regular order. A combination of all the facies of one kind or another that are known to exist in different parts of the country, and come under this heading, gives us the scheme over leaf in which, however, many of the minor zones are merely of local significance.

As has been mentioned in the preceding lines, a trilobite facies exists in the Ordovician system in many parts of the country, yet, even in such a case, the very lowest strata, i. e. the lower part of the Ceratopyge region, is as a rule developed in the form of graptolite shale, the Dictyograptus shale, in which trilobites have been found at only two places. The Dictyograptus shale is, however, at many places substituted by a brachiopod facies, the Obolus beds, which have clearly been deposited in shallow water. *Typical Dictyograptus shale* is found in Skåne, Southern Öland, Östergötland, Västergötland and Ångermanland. *Obolus beds* occur in Dalarne, Northern Öland, the Silurian district of the Northern Baltic (in boulders) and possibly in Östergöt-

Table of the Ordovician. Ser. B.

	B I. (Trilobite and Brachiopod facies). Västergötland, Dalarne, Öland[1].	B II. (Trilobite-bearing strata). Skåne.	B III. (Graptolite facies). Skåne.		
5. Harpes Region	Leptaena limestone (Dalarne) as well as Brachiopod shale (Västergötl.)	Zone of *Phacops eucentra*			
4. Trinucleus Region	Staurocephalus shale Trinucleus shale (proper)	Zone of *Staurocephalus clavifrons* Zone of *Ampyx Portlocki*	Zone of *Dicellogr. complanatus*	Upper	Dicellogr. shale (3)
3. Chasmops Region	Macrourus limestone (Öland) Echinosphaerite limestone (= Cystidean limestone)	Zone of *Ampyx rostratus* and *Calymmene dilatata*	Zone of *Pleurogr. linearis* Zone of *Dicranogr. Clingani* or *Climacogr. rugosus*	Middle	
2. Asaphus Region	Ancistroceras limestone (Öland) and Centaurus limestone Platyurus limestone Gigas limestone Asaphus limestone Limbata limestone Planilimbata limestone	Shale with *Robergia microphthalma* and (in Jämtland) *Oggiocaris dilatata* Z. of *Trin. coscinorrhinus* »Orthoceras limestone»	Zone of *Nemagr. gracilis* Zone of *Diplogr. putillus* Zone of *Diplogr. Linnarssoni* Zone of *Glossogr. Hincksi* Zone of *Didymogr. geminus* Zone of *Phyllogr. typus* Zone of *Isogr. gibberulus* Zone of *Phyllogr. angustifolius* Zone of *Didymogr. balticus*	Lower Upper Lower	Didymograptus shale (2)
1. Ceratopyge Region	Ceratopyge limestone Ceratopyge shale Obolus conglomerate (Dalarne, Öland)	Zone of *Apatocephalus* Zone of *Shumardia* (or *Ceratiocaris* shale) Zone of *Hysterolenus Törnquisti*	Zone of *Tetragr. phyllograptoides* γ. Zone of *Bryogr. Kjerulfi* and *Dictyogr. flabelliformis* var. *norvegica* β. Zone of *Clonogr.* and *Bryogr. Hunnebergensis* α. Zone of *Dictyogr. flabelliformis* f. *typica.*		Dictyogr. shale (1)

[1] The zones with graptolite facies occurring in these provinces or parts of the country are, of course, not included in this column.

land. Apart from the very lowest part just mentioned, the Ordovician in Öland, as well as in Närke — where, as far as we know, only the lowest parts of the series (Ceratopyge limestone and the lower part of the Orthoceras limestone) are represented — is developed exclusively in the form of limestone facies in which, apart from some bands loaded with cystideans, trilobites predominate, and graptolites are only met with in exceptional instances. In Västergötland and Dalarne a pronounced graptolite facies has also been found at a slightly higher level, viz. in the Lower Didymograptus beds which correspond with the topmost part of the Ceratopyge region and the lower part of the Asaphus region. In these provinces we have furthermore quite a pronounced trilobite facies in whose deposits graptolites are only rarely met with in that part of the Trinucleus beds, which has been designated the »black Trinucleus shale» and which furthermore has also in Östergötland been proved to contain graptolites, and in the »Flagkalk» of Dalarne, transition beds between the Asaphus and Chasmops regions. Even in Skåne and Jämtland the Lower Didymograptus beds are met with, but in these provinces, especially in the former, the graptolite facies is conspicuous even in the younger strata. Thus we have in Skåne also an Upper Didymograptus shale, after which comes the Dicellograptus shale, which from the highest part of the Asaphus region continues right through the entire Ordovician up to the base of the Gotlandian, here and there with layers in which a more or less predominant trilobite facies is, so to say, put in. Even in Jämtland's Ordovician the Lower Dicellograptus shales are to some extent represented, and this is all the more remarkable, as a graptolite facies in Scandinavian strata of this age is otherwise only known of in Skåne (and Norway). In the deposits formed in shallow water (and especially in those developed with trilobite, coral or brachiopod facies) those belonging to the upper part of

the series also show the greatest variety with regard to the kind of the deposits. We have thus here: in Västergötland the typical Brachiopod shale, in Dalarne the »Klingkalk» (clink-limestone) and Leptaena limestone, in Skåne the zone of *Phacops eucentra* ANG. (deficient in brachiopods), and further the peculiarly developed Silurian of the Northern Baltic district, which Silurian, only known in boulders, otherwise in all particulars approaches the Esthonian Silurian.

It is also worth remarking that trilobite-bearing limestones, embedded in the graptolite-bearing shales (as, for example, the limestone with *Pliomera Törnquisti* HOLM and *Ampyx pater* HOLM, in the Lower Didymograptus shales of Dalarne, and Fågelsång's Orthoceras limestone) pretty often have a peculiar character, as well as some strata in which graptolites and trilobites occur together (as, for example, the zone of *Calymmene dilatata* developed in Skåne and the zone of *Robergia microphthalma* in Jämtland).

Series A. Cambrian.

Contrary to the conditions in the Ordovician, there exists a certain monotony in this series. It is not enough that graptolite-bearing deposits are absent here, wherefore we have to stick exclusively to a trilobite facies; in other respects, too, a uniformity makes itself felt by a practically similar development of the same zone over almost the whole area occupied by deposits that come under this heading, although in some instances the *petrographical* nature of a zone may be quite heterogeneous in different districts, a condition of which we shall soon quote an example. In some zones, however, brachiopods are so plentiful that one can talk of a brachiopod facies. This is especially the case with the zone of *Paradoxides Forchhammeri* ANG., which is thus developed partly with a trilobite facies, partly with a brachiopod facies. In

the Olenidian there certainly occur banks with masses of brachiopods, but these are interstratified and by transition connected with trilobite-bearing strata. In the sandstones of the Olenellus beds the brachiopods are also (sometimes in company with pteropods) at many places the only element of fauna, whereas the same deposits elsewhere also contain trilobites in scanty measure.

Table of the Cambrian. Series A.

			A I	A II
3. Reg. Olenorum.	Olenidian.	Upper Cambrian.	*Acerocare* zone	
			Peltura zone	
			Eurycare zone	
			Parabolina spinulosa zone	or *Orthis lenticularis* zone
			Olenus zone	
			Agnostus zone	
2. Reg. Conocorypharum.	Paradoxidian.	Middle Cambrian.	Forchhammeri beds (*Agnostus laevigatus* zone / *Centropleura Lovéni* zone)	or *Orthis exporrecta*-conglomerate.
			Tessini beds: *Paradoxides Davidis* zone	
			Tessini beds: Middle Tessini layers	
			Tessini beds: *Conocoryphe exsulans* zone	*Acrothele granulata*-conglomerate.
			Oelandicus beds (*Par. oelandicus* zone)	
1. Regio Fucoidarum.	Olenellidian.	Lower Cambrian.	*Holmia Kjerulfi* zone	*Lingulid* (or Fucoid) sandstone
			Schmidtiellus Torelli zone	*Mickwitzia* (or Eophyton) sandstone.
			Lower Hardeberga sandstone	

Only zones of any importance, or of greater extent, have been incorporated in the scheme; zones which are only locally developed will therefore be more particularly treated in the detailed descriptions in the next chapter. As will be seen from the scheme, brachiopods predominate in at least one zone in each of the three main divisions of the Cambrian, or more correctly speaking, in every division there are beds in which brachiopods are abundant. With regard to the

zone of *Orthis lenticularis* WAHLENB. it is to be noticed, though, that besides the last mentioned fossil often also *Parabolina spinulosa* WAHL. is met with in the same. *Orthis exporrecta* LINRS. is certainly also encountered together with the Forchhammeri-fauna, but on the other hand it is met with at many places, together with other brachiopods or alone by itself, filling the conglomerate which received its name therefrom. Finally, as regards the Olenellus beds, trilobites have been found therein only in Skåne, West-Dalarne, Norrland and the Northern Baltic Silurian area, whilst trilobites in synchronous deposits in the rest of Sweden are altogether absent. The first column of the scheme refers therefore (concerning the beds in question) first of all to the conditions in Skåne, its second column again chiefly to the Silurian of Västergötland.

The Cambrian deposits are of particularly great extent. Least known are really the sandstones belonging to the Olenellidian, which form the base of the Silurian system; the infrequent occurrence of fossils in the sandstones is naturally an obstacle to their being identified with certainty, and appointed a place in the scheme. One can namely not strictly parallelize the basal sandstones of the different provinces, for example those of Skåne and Västergötland. If we start from the supposition that the *Schmidtiellus*-bearing strata in Skåne are to be correlated with those in which the genus has been found in Esthonia — something which is rather uncertain, though — and that these latter by the occurrence of *Mickwitzia* and *Medusina* have been proved to be contemporaneous with the Mickwitzia sandstone (»Eophyton sandstone») in Västergötland, the result would be that the zone with *Schmidtiellus Torelli* MBG in Skåne would have to be parallelized with the Mickwitzia zone in Västergötland, which again would result in the zone of *Holmia Kjerulfi* LINRS. having to be parallelized witht he *Lingulid* sandstone. In the many instances in which no fossils at all have as yet been

found in the sandstones the uncertainty is clearly still greater, yea, it can often stretch so far as to make it altogether impossible to find out whether the sandstones in question really belong to the Cambrian. The Wemdal quartzite for example is such a rock, concerning whose geological age opinions have greatly differed and very likely still differ; the history of this we must, however, reserve until later on, when it may possibly get a chapter to itself.

The Cambrian strata have been met with on the eastern edge of the Scandinavian Mountain Range (in Lappland, Ångermanland, Jämtland, Härjedalen and Dalarne), in the Northern Baltic Silurian district, in Närke, Dalsland, Västergötland, Östergötland, on the coast of Småland (and Blekinge) with the Kalmarsund district, in Öland and Skåne. Everywhere here one finds Lower Cambrian strata, often developed to a great thickness; the Middle Cambrian is to be found in Västerbotten, Ångermanland, Jämtland, West-Dalarne, Närke, Västergötland, Östergötland, Öland and Skåne, the *Upper Cambrian* in the same parts of the country, with the exception of West-Dalarne. The very uppermost part, the *Acerocare* zone, has only been met with in Skåne and in the southern part of Öland.

As has been previously mentioned, the rocks, especially in the Middle Cambrian, vary considerably in the different areas. Thus the zone of *Paradoxides oelandicus* SJÖGR. in Öland, Närke and Östergötland is a greenish-grey argillaceous shale, in Jämtland, on the other hand, an alum shale. In Skåne there occurs on the corresponding horizon a limestone filled with fossil fragments, the »Fragment limestone». The zone of *Paradoxides Tessini* BRONGN., which in Skåne, Västergötland and Jämtland consists of alum shales, is in Östergötland and Närke formed of greyish-green argillaceous shales, but in Öland of a partly calcareous, shaly sandstone. The rock of the Forchhammeri zone is generally either a bi-

tuminous limestone or an alum shale,[1] but may in a lot of occurrences be called a conglomerate in which brachiopods, especially *Orthis exporrecta* LINRS., after which the formation has also been called the »Exporrecta conglomerate», predominate. This conglomerate is specially known from Jämtland, Öland and Västergötland (in Gudhem); the zone is otherwise known from Skåne (the »Andrarum limestone»), Östergötland, Närke and Ångermanland (at Tåsjö).

[1] In Ångermanland, however, the zone is partially built up of a bluish-grey, gritty and shaly limestone.

CHAPTER III.

Detailed description

of the various divisions and zones mentioned in Chapter II.

Series C. The Gotlandian.

C I. The Gotlandian of Skåne.

C I: 4. The Öved-Ramsåsa formation.

Literature.

1872. Erdmann, E.: Beskrifning öfver Skånes stenkolsförande formation. (Description of the coal-bearing formation of Skåne.) Sver. Geol. Unders. Ser. C, No. 3.

1874. Lundgren, B.: Om den vid Ramsåsa och Öfvedskloster i Skåne förekommande sandstenen. (The sandstone occurring at Ramsåsa and Övedskloster in Skåne.)

1875. Linnarsson, G.: Anteckningar från en resa i Skånes silurtrakter år 1874. (Notes from a journey in the silurian districts of Skåne in the year 1874.)

1882. Tullberg, S. A.: Skånes graptoliter. I. (The Graptolites of Skåne. I.)

1888. Eichstädt, F.: Anteckningar om de yngsta öfversiluriska aflagringarna i Skåne. (Notes on the youngest deposits of the Upper Silurian in Skåne.)

1897. Grönwall, K. A.: Öfversikt af Skånes yngre öfversiluriska bildningar. (Review of the younger deposits of the Upper Silurian of Skåne.)

1904. Törnebohm, A. E. and Hennig, A.: Beskrifning till Blad 1 & 2 etc. (Explanation to sheet 1 & 2 etc.) Sver. Geol. Unders. Ser. A 1, a.

1909. Moberg, J. C. and Grönwall, K. A.: Om Fyledalens Gotlandium. (On the Gotlandian of the valley of Fylan.)

(In the last mentioned work a more complete account of the elder literature is given.)

The deposits coming under this heading, mentioned in the literature already in the first half of the 18th century, were by HISINGER (1831) and SV. NILSSON (1841) included in the Keuper, by FORCHHAMMER in 1854 reckoned to the Devonian, by MURCHISON in 1847 to the Silurian, so also in 1862 by N. P. ANGELIN, but in 1872 by E. ERDMANN again to the Keuper. It was not until 1874 that LINNARSSON and LUNDGREN set the age of the deposit down to the Upper Silurian. Thereafter the most important question was the relation of the deposits to the Colonus beds. According to TULLBERG they would be interstratified and partly equivalent to the said beds. EICHSTÄDT again advances the opinion that they are younger; the deposits, which by him, on account of the petrographical development at Klinta, were divided up into six different zones, are presumed to have got their present geographical distribution by reason of folding (the occurrences would be lying on the anticlines of the folds). GRÖNWALL adopted EICHSTÄDT's opinion, but amalgamated EICHSTÄDT's three lowest layers into one, so that instead of 6 zones we have 4. It is this latter classification we have followed in the scheme.

The Öved-Ramsåsa formation is besides those localities, Övedskloster and Ramsåsa, from which their appellation has been derived, also met with at Bjersjölagård, as well as in some minor occurrences situated on a line drawn between the last mentioned spot and Övedskloster. Amongst them we have to mention Skartofta, Tulesbo, Kärrby and Elestorp; at all these localities shales with limestone bands similar to those at Bjersjölagård are met with.

A table showing the sequence of strata at the different localities has the following appearance:

Zone 4.

Klinta. Sandstone, red.
Öved-Bjersjölagård. Sandstone, red.
Ramsåsa. Sandstone, red (with shales).

Zone 3.

Klinta. Shale, greyish-blue.
Öved-Bjersjölagård. Shale, greyish-blue.
Ramsåsa. Shale, light-red.

Zone 2.

Klinta. Sandstone, yellow and white.
Öved-Bjersjölagård. Sandstone, yellow and white.
Ramsåsa. ?

Zone 1.

Klinta. Shale, grey with limestone bands.
Öved-Bjersjölagård. { b. Limestone and shale in the quarry.
a. Shale with limestone bands NW. of the quarry.
Ramsåsa. Shale, grey with limestone bands.

In the red sandstone, which is very deficient in fossils, only scanty, mostly badly preserved shells have been found, further a couple of brachiopods, *Lingula minima* Sow. and *Lingula cornea* Sow., and poorly preserved ostracods, amongst which a large *Leperditia inaequalis* Grönwall is the most characteristic fossil.

As the sandstone forms a beautiful building material, large quarries, especially at Helvetesgrafven in Öved, but also at Klinta and Ramsåsa, have been started in the same. The quarries in Öved are remarkable, partly on account of the sandstone's being traversed by the so called Frualid diabase, partly by reason of Törnebohm's and Hennig's (1904) wanting, in my opinion without any valid reasons, to include the uppermost parts of the strata existing there to the Keuper. At Ramsåsa a flexure-like dislocation in the strata is to be found.

In the shale lying next under, an abundant fauna is met with, in which especially lamellibranchiates and ostracods occur

in great numbers, not only as regards individuals, but also as regards species; even annelids, bryozoa, brachiopods, gastropods (mostly *Bellerophon* spp.), pteropods, cephalopods, trilobites, as well as Gigantostraca and Pisces are here represented. In order to quote some of the commonest or most characteristic species we may mention: *Pholidops antiqua* SCHLOTH., *Chonetes striatella* DALM., *Cucullella ovata* SOW., *Sanguinolites anguliferus* M'COY, *Bellerophon expansus* SOW., *Tentaculites tenuis* SOW., and *T. annulatus* SCHLOTH., *Hyolithus scanicus* GRÖNWALL, *Orthoceras* spp., *Aparchites obsoletus* JONES et HOLL, *Primitia mundula* JONES, *Beyrichia Buchiana* JONES, *B. Maccoyiana* JONES, *B. nodulosa* BOLL, *B. scanensis* KOLM., *B. Steusloffi* KRAUSE, *Kloedenia Kiesowi* KRAUSE, *Kl. Wilckensiana* JONES, *Thlipsura tetragona* KRAUSE, *Cytherellina siliqua* JONES, *Bythocypris triangularis* GRÖNWALL, *Phacops Downingiae* MURCH., *Calymmene intermedia* LINDSTR. and *Ceratiocaris* sp.

In zone *2* lamellibranchiates and gastropods have only scantily been met with.

Amongst the fossils characteristic for zone *1* may be mentioned *Aviculopecten reticulatus* HIS. and *A. Danbyi* M'COY, *Platyceras cornutum* HIS., *Beyrichia gotlandica* KIES. and *B. lauensis* KIES. as well as *Homalonotus Knighti* KÖN. var. *rhinotropis* ANG. A great many of the ostracods and others mentioned from zone *3* appear already here. At Bjersjölagård GRÖNWALL has in the zone *1* distinguished an upper and a lower part. The former, *1 b*, which is quarried in the limestone quarry itself, consists partly of a rock prolific in corals (*Labechia conferta* E. H., *Favosites Forbesi* E. H. and *F. Labechei* E. H., *Heliolites interstinctus* L., *Cyathophyllum dianthus* LONSD., *Pholidophyllum tubulatum* SCHLOTH., *Actinocystis Grayi* E. H.), *Coenites intertextus* E. H., *Stromatopora discoidea* SOW. and crinoids, partly of banks filled with »*Girvanella problematica* NICH.» (*Sphaerocodium?*). A couple of graptolite fragments have also been found here. Right on top there are rather shaly por-

tions (shales with minor limestone-like portions) rich in *Eurypterus* fragments and annelid jaws, besides which shells and brachiopods of different kinds are common here. In the lowest part, *1 a*, ostracods are plentiful in the lower layers, higher up corals and crinoids become more abundant.

It is to be noticed in general that in the Öved-Ramsåsa formation the separate zones form together an even transition, so that definite characteristic fossils cannot be given for the different zones, which were originally settled on account of the change that occurs in the rocks in the different parts of the Klinta district.

On drawing a comparison with the correlating strata of England, zones *1* and *2* of the Öved-Ramsåsa formation may very easily be parallelized with the *Rhynchonella flags* and *Chonetes flags* or the Lower and Upper Whitcliffe, zones *3* and *4* with Downton Castle and Temeside (Eurypterus shales).

C I: 3. The Colonus beds.

Literature.

1875. Linnarsson, G.: Anteckningar från en resa i Skånes silurtrakter år 1874. (Notes from a journey in the Silurian districts of Skåne in 1874.)

1880. Tullberg, S. A.: Om lagerföljden i de kambriska och siluriska aflagringarne vid Röstånga. (On the succession of strata in the Cambrian and Silurian deposits at Röstånga.)

1882.] Tullberg, S. A.: Skånes graptoliter. I, II. (The
1883.] Graptolites of Skåne.)

1882. Marr, J. E.: On the Cambrian (Sedgw.) and Silurian Rocks of Scandinavia. Q. J. of G. S.

1887. De Geer, G.: Beskrifning till kartbladet Lund. (Explanation to the map-sheet Lund.)

1889. Törnquist, S. L.: Några anmärkningar om vestra Europas kambriska och siluriska korologi. (Some Re-

marks about the Cambrian and Silurian chorology of Western Europe.)

1892. HOLST, N. O.: Beskrifning till kartbladet Simrishamn. (Explanation to the map-sheet Simrishamn.)

1892. SCHMALENSEE, G. C. VON: Om lagerföljden inom Dalarnes silurområden. (On the succession of stratain the Silurian areas of Dalarne.)

1899. HOLM, G.: Om de öfre graptolitskiffrarne på Kinnekulle. (The Upper Graptolite shales at Kinnekulle.)

1909. MOBERG, J. C. and GRÖNWALL, K. A.: Om Fyledalens gotlandium. (The Gotlandian of the valley of Fylan.)

1909. MOBERG, J. C. and TÖRNQUIST, S. L.: Retioloidea från Skånes colonusskiffer. (Retioloidea from the Colonus shale of Skåne.)

TULLBERG was the first to separate (1880) these strata from the Upper graptolite shales in general. The designation »Cardiola shale» introduced by him (or the term »Marl shale» generally used in the older publications of the Geolog. Survey of Sweden) was subsequently the current name for a time. In 1889 TÖRNQUIST employed the name Colonus shale, a denomination which has now gained preference.

Colonus shale is in Sweden with absolute certainty only known of from Skåne, where it is of very great extent (greater than any other Silurian bed of the province), in a belt running from SE. towards the NE. in the map-sheets Sandhammaren (at Ö. Hoby), Simrishamn (at Skillinge, the valley of Tommarp—Jerrestad), Söfdeborg (at Ullstorp, Tolånga and the valley of Fylan), Övedskloster (at Röfvarekulan), Lund (at Odarslöf, S. Strö and the valley of the Kjeflinge river), Trolleholm (at the W. and NW. of Lake Ringsjön up to Kågeröd) as well as Hälsingborg (at Sireköpinge and Tågarp).

MARR (in 1882) thought that at Kinnekulle in Västergötland he had found boulders of these shales immediately below the diabase, but, according to HOLM, MARR's suppositions must

be due to a faulty determination. SCHMALENSEE mentions Colonus shale containing *Monograptus scanicus* TULLB. from the uppermost shales immediately below the grind-sandstone below the waterfall at Stygforsen in Dalarne. Nothing further is, however, known with regard to this observation.

In 1880 TULLBERG says that the Colonus shale is lying below the Klinta Group, but afterwards he expresses himself about it in such vague terms that it appears as though he considered it to be partly equivalent to the Öved-Ramsåsa formation. According to MOBERG and GRÖNWALL (1909) it is probably most nearly equivalent to the Aymestry Group in England.

The rock consists of more or less calcareous, grey shales, in certain layers approaching a sandstone, rich in small laminae of white mica. Embedded in the shales are limestone bands and more or less large, highly calcareous lenses, sometimes in great quantities and of quite considerable sizes. Apart from rare layers or bands full of fossils, the rock is generally very deficient in such.

Besides *Cardiola interrupta* SOW., *Monograptus colonus* BARR. is the most commonly occurring fossil. Amongst other graptolites are to be noted *Monogr. bohemicus* BARR., *Monogr. dubius* SUESS, *Monogr. scanicus* TULLB., as well as *Monogr. Nilssoni* BARR. and *Monogr. uncinatus* TULLB., of which the two last mentioned only are stated for the older strata. Here and there layers with a more varying fauna, trilobites, ostracods etc., have been met with, mostly, however, without being able to decide their place in the complex of layers more definitely. LINNARSSON, for example, mentions from Stehag shale coming under this heading, which contains *Calymmene tuberculata* BRÜNN., *Encrinurus punctatus* WAHLENB., *Orthoceras* sp., as well as brachiopods, and in the Explanation to the map-sheet Simrishamn HOLST (1892) mentions from the Colonus shale at Smedstorp a slightly calcareous stratum rich in fossils, amongst which *Acidaspis*, *Phacops*, *Proetus*, *Cardiola*

interrupta Sow., *Gothograptus nassa* Holm, *Orthoceras* and pelecypods are named.

Moberg and Törnquist (1909) were able to prove some strata in Röddinge, in which, besides the usual fossils of the Colonus beds, Retioloidea, such as *Plectograptus macilentus* Törnquist, *Retiolites spinosus* Wood and *Gothograptus nassa* Holm, form a considerable portion of the fossil fauna.

It is certain that we have to distinguish different subdivisions in the Colonus beds; no complete classification could, however, be carried out yet. As we pointed out in the scheme on page 14 we might yet with certainty be able to distinguish a lower part, the so called Odarslöf flags, in which sandstones, with (or without) scantily interstratified shales, predominate, and, slightly higher, another argillaceous part in which retioloid graptolites occur plentifully. In the Odarslöf flags, which are most often devoid of fossils, there occur, however, sometimes graptolites, as, for example, at Odarslöf (very rares) and at Tullstorp's windmill, where the bed is stated to be rich in *Monograptus colonus* Barr. and *Monograptus bohemicus* Barr. The Odarslöf flags have, besides the occurrences stated, also been proved to exist in Ö. Hoby (map-sheet Sandhammaren), in the valley of Fylan (map-sheet Söfdeborg), SE. of Hurfva railway station, as well as at Emnaröd, in the parish of Stehag (both in the map-sheet Lund).

C I: 2 and C I: 1. The Cyrtograptus beds and Rastrites beds together with deposits of the same facies in other provinces.

(Compare the scheme on page 15).

Literature:

1869. Linnarsson, G.: Om Vestergötlands Cambriska och Siluriska aflagringar. (On the Cambrian and Silurian deposits of Västergötland.)

1875. Törnquist, S. L.: Berättelse om en geologisk resa genom Skånes och Östergötlands paleozoiska trakter som-

maren 1875. (Account of a geological journey through the palaeozoic districts of Skåne and Östergötland, in the summer of 1875.)

1877. Linnarsson, G.: Om graptolitskiffern vid Kongslena i Vestergötland. (The Graptolite shale at Kongslena in Västergötland.)

1879. Törnquist, S. L.: Några iakttagelser öfver Dalarnes graptolitskiffrar. (Some Observations on the Graptolite shales of Dalarne.)

1879. Linnarsson, G.: Om Gotlands graptoliter. (On the Graptolites of Gotland.)

1880. Tullberg, S. A.: Om lagerföljden i de kambriska och siluriska aflagringarna vid Röstånga. (On the succession of strata in the Cambrian and Silurian deposits at Röstånga.)

1881. Linnarsson, G.: Graptolitskiffrar med Monograptus turriculatus vid Klubbudden nära Motala. (Graptolite shales with Monograptus turriculatus at Klubbudden near Motala.)

1881. Törnquist, S. L.: Om några graptolitarter från Dalarne. (Some species of Graptolites from Dalarne.)

1882. Kurck, C.: Några nya graptolitarter från Skåne. (Some new species of Graptolites from Skåne.)

1882, 1883. Tullberg, S. A.: Skånes graptoliter. I, II. (The Graptolites of Skåne.)

1883. Törnquist, S. L.: Öfversigt öfver bergbygnaden inom Siljansområdet i Dalarne. (A Review of the Tectonic in the Siljan district in Dalarne.)

1883. Törnquist, S. L.: Några komparativt-geologiska anteckningar från en resa i Vestergötlands silurområde sommaren 1883. (Comparative-geological notes from a journey in the Silurian area of Västergötland, in the summer of 1883.)

1890. Holm, G.: Gotlands graptoliter. (The Graptolites of Gotland.)

1890, 1892. Törnquist, S. L.: Undersökningar öfver Siljansområdets graptoliter. I, II. (Researches into the Graptolites of the Siljan district.) Lunds Univ. Årsskr. Afd. 2, Tom. 26, 28.

1893. Moberg, J. C.: En Monograptus försedd med discus. (A Monograptus provided with a discus.)

1894. Wiman, C.: Ueber die Silurformation in Jemtland. Bull. Geol. Inst. Upsala. Vol. I, Pt 2. 1893.

1896. Moberg, J. C.: Geologisk vägvisare inom Fogelsångstrakten. (Geological guide to the Fågelsång district.)

1897. Törnquist, S. L.: On the Diplograptidae and Heteroprionidae of the Scanian Rastrites beds. Lunds Univ. Årsskr., Afd. 2, Tom. 33.

1899. Törnquist, S. L.: Några anteckningar om Vestergötlands öfversiluriska graptolitskiffrar. (Notes on the Gotlandian Graptolite shales of Västergötland.)

1899. Törnquist, S. L.: Researches into the Monograptidae of the Scanian Rastrites beds. Lunds Univ. Årsskr. Afd. 2, Tom. 35.

1899. Holm, G.: Om de öfre graptolitskiffrarne på Kinnekulle. (On the Upper Graptolite shales at Kinnekulle.)

1901. Holm, G.: Kinnekulle, dess geologi och den tekniska användningen af dess bergarter. (Kinnekulle, its geology and the technical use of its rocks.)

1910. Moberg, J. C.: Geological guide to Röstånga (with the lake Odensjön) and Skäralid.

The Cyrtograptus beds and the Rastrites beds are together equivalent to what was formerly called the Upper graptolite shales, a designation which, as regards Sweden, was first introduced by Linnarsson[1] in the year 1869. In his

[1] Linnarsson on this occasion corrected also an earlier statement made by himself (Om de siluriska bildningarna i mellersta Westergötland. — The Silurian Deposits in Middle Västergötland. 1866.) that these shales were lying under the Brachiopod shale, and therefore Ordovician, a (faulty) statement which had also already in 1856 been made by F. Roemer.

work of 1875 TÖRNQUIST divided (p. 57) these »Upper graptolite shales» up into a lower part, Lobiferus shale, and an upper, Retiolites shale, designations which were retained for a long time. In 1880 TULLBERG proposed the name »Cyrtograptus shale» for that part of the Scanian graptolite shales which is situated between the Colonus beds and the Retiolites beds.

In the year 1881 LINNARSSON gave an account of the graptolite shales with *Monograptus turriculatus* BARR. at Klubbudden, near Motala, which contain a fauna of a somewhat younger age than the previously known Lobiferus shale, and to a certain degree are at the transition to the Retiolites shales. For these so called Klubbudd shales and Lobiferus shales he proposed the name »Rastrites shales» as a common designation.

In 1882 TULLBERG gave the following scheme for the Upper graptolite shales of Skåne, which is specially worth noting on account of the extent here given to the Cyrtograptus beds.

Cyrtograptus beds:

Zone of *Cyrtograptus Carruthersi* LAPW. (and *Monograptus testis* BARR.)
» » *rigidus* TULLB.
» » *Murchisoni* CARR.
» *Monograptus Riccartonensis* LAPW.
» *Cyrtograptus Lapworthi* TULLB.
» » *spiralis* GEIN.
» » *Grayae* LAPW.

Rastrites beds:

Zone of *Monograptus runcinatus* LAPW.
» *Rastrites maximus* CARR.
» *Cephalograptus cometa* GEIN. (and *Monograptus Sedgwicki* M'COY)
» *Monograptus convolutus* HIS. (and *Monograptus leptotheca* LAPW.)

Zone of *Monograptus gregarius* LAPW. (and *Monograptus triangulatus* HARKN.)
» » *cyphus* LAPW.

In part II of »Skånes graptoliter», published in 1883, some alterations had been made. The zones of *Cyrtogr. Murchisoni* and of *Monogr. Riccartonensis* change places. *Retiolites Geinitzianus* BARR., which begins at the base of the Cyrtograptus beds, continues then through all the zones right up to, and including, the zone of *Cyrtogr. Murchisoni*; this lower part of the Cyrtograptus beds might on the whole be correlated to the Retiolites beds of Västergötland and Dalarne.

The upper part, again, seems rather to be characterized by *Monogr. Flemingi* SALTER and the very highest zone has from its most commonly occurring fossil, *Monogr. testis* BARR., also received the name »Testis shale». Moreover, the scheme was at the same time enlarged by the zone af *Diplogr. acuminatus* NICH., the oldest part of the Rastrites beds which had been discovered at Tommarp.

In 1890 and 1892 TÖRNQUIST gave an account of the graptolite fauna of Dalarne, on which occasion he set up the following scheme:[1]

Retiolites beds.
Transition bed.

Rastrites beds:
- Zone of *Monograptus proteus* BARR.
- » » *turriculatus* BARR.
- » » *Sedgwicki* PORTL.
- » *Cephalograptus cometa* GEIN.
- » *Monograptus gregarius* LAPW.
- » » *leptotheca* LAPW.

[1] Both in 1879 and 1883 TÖRNQUIST had made some preliminary attempts at getting some order into the Rastrites beds of Dalarne, of which only 2 zones (the zone of *Rastrites peregrinus* BARR. and *Cephalogr. folium* HIS., as well as the zone of *Monogr. turriculatus* BARR. and *Diplogr. palmeus* BARR.) were to be found in solid rocks.

He adds however, that the order between the two lowest zones of the Rastrites beds (which is contrary to the one given by TULLBERG for Skåne) is uncertain, and that such is also the case with the order between its two uppermost zones.

MOBERG proposed in 1892 (in HOLST's Explanation to the map-sheet Simrishamn) to alter the designation »zone of *Monograptus gregarius*» in TULLBERG's scheme to »zone of *Monogr. triangulatus*»; and finally TÖRNQUIST in 1897 drew up the scheme which I have reproduced on page 15. This differs, apart from some changes in names (for example that the zone of *Monograptus gregarius* is now called zone of *Monogr. triangulatus,* and that the zone of *Monogr. convolutus* received the name of zone of *Diplograptus folium*) from TULLBERG's scheme mainly by the fact of the zone of *Cephalograptus cometa* and *Monogr. Sedgwicki* having been divided up into 2 zones, each one characterized by one of the two last mentioned graptolites, besides which the zone of *Rastrites maximus,* which TULLBERG incorporated in his scheme exclusively after the English pattern, is omitted. — In 1899 TÖRNQUIST calls attention to the great similarity which the Rastrites beds of Västergötland and Skåne show, not only to each other, but also to those of Dalarne. In all these provinces he considers himself able to distinguish a »transition bed» between the Rastrites shales (the zone of *Monogr. runcinatus*) and the Retiolites shales. Whether any special zone, characterized by *Monogr. proteus* BARR., ought to be intercalated between »the transition bed» and the zone of *Monogr. runcinatus* seems to him on the other hand now doubtful.

In 1910 MOBERG advances the possibility that the zone of *Diplogr. vesiculosus* NICH., which in England forms the oldest zone but one of the division, may also be represented in Sweden, viz. at Röstånga.

The Upper graptolite shales are known from Skåne, Västergötland, Östergötland, Dalarne and Jämtland. A fairly

complete series of strata occurs only in Skåne, where both the Cyrtograptus beds and the Rastrites beds are developed in the neighbourhood of Röstånga, Jerrestad-Tommarp, Tosterup-Bollerup, as well as in the northern and north-eastern parts of the Fågelsång district, besides which the Rastrites beds alone are met with at Kiviks-Esperöd (boulders) and at the fishing village of Nyhamn, on the west coast of the province. The upper part of the Cyrtograptus beds is met with only in Skåne. In Västergötland there occur in Kinnekulle both Retiolites beds and Rastrites beds, whilst Billingen and Falbygden Mountains only show Rastrites beds. In Östergötland Rastrites beds have been met with (at St. Åby and at Klubbudden near Motala), but Retiolites shales are mentioned (in 1875 by TÖRNQUIST) only from a locality N. of Motala Works. In Dalarne Retiolites beds have been found at several places, viz. at Stygforsen (in Cement shale and Spheroid shale), at Nittsjö, in Sollerön, between Digerberget and Orsa Lake, at Kallholn and Kallmora, as well as at several other places. Rastrites beds occur there partly as solid rock (at Kallholn and Osmundsberget), partly in boulders at several places, as for example at Gulleråsen, Nittsjö and Furudal. In Jämtland shales have been found in the parishes of Offerdal and Alsen, which appear to be a transition bed between the Rastrites beds and the Retiolites beds.

As regards the petrological character it has to be noted that the Rastrites beds, with the exception of the topmost zone, consist as a rule of hard, black shales, whilst on the other hand the Cyrtograptus beds pretty well all through are formed of soft, grey shales, in which rather frequently concretions of limestone are embedded. Even if these strata are not so thick as the Colonus beds, the thickness is yet quite considerable. HOLM gives it as 50 m. for Västergötland. In Skåne the thickness is, however, at least 2 to 3 times as great, although the numerous dislocations there make a fixed measurement

impossible. Complete lists of fossils for the Cyrtograptus beds of Skåne are given by TULLBERG in »Skånes graptoliter. II», and for the Rastrites beds of Skåne, as well as for the Retiolites and Rastrites beds of Dalarne by TÖRNQUIST in 1899 and 1892 respectively.[1]

C II. The Gotlandian of Gotland.

(Compare the scheme on p. 16).

With regard to the Silurian of Gotland we have a very rich literature, which has received particularly abundant contributions from G. LINDSTRÖM, whose scientific activity was almost exclusively centered upon the geology of his native island. A complete list of the literature relating to Gotland's Silurian would take up far too much space here, wherefore we are compelled to limit ourselves to giving only the most important works concerning the same.

1727. BROMELL, M. VON: Lithographiae Suecanae specimen secundum.

1745. LINNÉ, C. VON: Corallia baltica.

1745. CARL LINNAEI Öländska och Gothländska resa 1741. (A journey to Öland and Gotland in 1741.)

1798. HISINGER, W.: Minerographiske anmärkningar öfver Gotland. (Minerographic remarks on Gotland.)

1818. WAHLENBERG, G.: Om svenska jordens bildning. (On the Formation of the Earth of Sweden.) Svea. I.

[1] It is worth while noting here that LINDSTRÖM's lists (in »List of the fossil faunas of Sweden») of the graptolites of the Upper graptolite shale are quite misleading. Some of the species belonging to the Upper Cyrtograptus beds, such as *Cyrtograptus Carruthersi* LAPW., *Cyrtogr. Lundgreni* TULLB. and the characteristic *Monograptus testis* BARR. are not included in the lists. From the Gotlandian (Upper Silurian) there are quoted, besides some species found in Gotland, only those of the Colonus beds and 8 species from the Scanian Cyrtograptus beds, besides which a few species from the Cyrtograptus and Rastrites beds of Dalarne also are quoted. At the same time the majority of the Gotlandian species, with the exception only of those of the Testis beds, are enumerated from the Ordovician (Lower Silurian).

1826. HISINGER, W.: Gotland geognostiskt beskrifvit. (Gotland geognostically described.) — The work is found reprinted in a scarcely altered form in 1828 in vol. 4 of HISINGER's »Anteckningar i Physik och Geognosie».)

1847. MURCHISON, R. I.: On the Silurian and Associated Rocks in Dalecarlia and on the Succession from Lower to Upper Silurian in Smoland, Öland and Gothland and in Scania. Q. J. G. S.

1848. VERNEUIL, E. DE: Note sur quelques Brachiopodes de l'île de Gothland.

1856. ROEMER, FERD.: Bericht von einer geologisch-paläontologischen Reise nach Schweden. Neues Jahrb. f. Min. etc.

1858. LINDSTRÖM, G.: Till Gotlands geologi. (On the Geology of Gotland. Öfvers. Kgl. Vet.-Ak. Förh.)

1859. SCHMIDT, FR.: Beitrag zur Geologie der Insel Gotland.

1860. LINDSTRÖM, G.: Bidrag till kännedomen om Gotlands brachiopoder. (Contribution toward the knowledge of the Brachiopods of Gotland.)

1865. LINDSTRÖM, G.: Några iakttagelser öfver Zoantharia rugosa. (Some Observations on Z. r.)

1868. Om tvenne nya öfversiluriska koraller från Gotland. (Two New Upper Silurian corals from Gotland.)

1869. KOLMODIN, L.: Bidrag till kännedomen om Sveriges siluriska ostracoder. (Contribution towards the knowledge of the Silurian Ostracods of Sweden.)

1873. SCHMIDT, FR.: Miscellanea silurica. I. Ueber die russischen Leperditien. (With a »Nachtrag» 1883.)

1878. ANGELIN, N. P.: Iconographia Crinoideorum in stratis Sueciae siluricis fossilium.

1879. KOLMODIN, L.: Ostracoda silurica Gotlandiae.

1879. LINNARSSON, G.: Om Gotlands graptoliter. (On the Graptolites of Gotland.)

1880. ANGELIN, N. P. and LINDSTRÖM, G.: Fragmenta silurica e dono Caroli Henrici Wegelini.

1882. HINDE, G. J.: On annelid remains from the silurian strata of the isle of Gotland.

1882. MARR, J. E.: On the Cambrian (SEDGW.) and Silurian Rocks of Scandinavia.

1882. LINDSTRÖM, G.: Anteckningar om silurlagren på Carlsöarne. (Notes on the Silurian deposits on the Carl Islands.)

1882. LINDSTRÖM, G.: Om de palaeozoiska formationernas operkelbärande koraller. (On the operculated Corals of the Palaeozoic formations.)

1884. LINDSTRÖM, G.: On the silurian Gastropoda and Pteropoda of Gotland.

1885. LINDSTRÖM, G.; Förteckning på Gotlands siluriska Crustacéer. (List of the Silurian Crustaceans of Gotland.)

1885. LINDSTRÖM, G. and THORELL, T.: On a silurian scorpion from Gotland. Kgl. Vet.-Ak. Handl.

1887. JONES, RUPERT T.: Notes on silurian Ostracoda from Gotland.

1888. LINDSTRÖM, G.: Ueber die Schichtenfolge des Silur auf der Insel Gotland. Neues Jahrb. f. Min. etc.

1888. KIESOW, J.: Ueber Gotländische Beyrichien.

1888. JONES, R. and WOODWARD, H.: On some Scandinavian Phyllocarida.

1890. LINDSTRÖM, G.: The Ascoceratidae and the Lituitidae of the Upper Silurian formation of Gotland.

1890. HOLM, G.: Gotlands graptoliter. (The Graptolites of Gotland.)

1890. SCHMIDT, FR.: Bemerkungen ueber die Schichtenfolge des Silur auf Gotland.

1890. DAMES, W.: Ueber die Schichtenfolge der Silurbildungen Gotlands und ihre Beziehungen zu obersilurischen Geschieben Norddeutschlands.

1891. SCHMIDT, FR.: Einige Bemerkungen ueber das Baltische Obersilur in Veranlassung der Arbeit des Prof. W. DAMES ueber die Schichtenfolge der Silurbildungen Gotlands.

1892. AURIVILLIUS, C. W. S.: Ueber einige Ober-Silurische Cirripeden aus Gotland. Bih. till Kgl. Vet.-Ak. Handl.

1892. HOLM, G.: Förevisar i Geol. För. i Stockholm en i Palaeophonus-lagret vid Visby af v. SCHMALENSEE funnen insekt. (Exhibits in the Geol. Society in Stockholm an insect discovered by v. SCHMALENSEE in the Palaeophonus bed at Visby.)

1893. BATHER, F. A.: The crinoidea of Gotland. Part I. The crinoidea inadunata.

1893, 1894. RAUFF, H.: Palaeospongiologie.

1895. LINDSTRÖM, G.: On remains of a Cyathaspis from the Silurian strata of Gotland.

1895. WESTERBERG, A.: En dolomitisk öfversilurisk kalksten på Gotland. (A dolomitic Upper Silurian Limestone from the island of Gotland.)

1896. LINDSTRÖM, G.: Beschreibung einiger obersilurischen Korallen aus der Insel Gotland.

1897. STOLLEY, E.: Die silurische Algenfacies und ihre Verbreitung im skandinavisch-baltischen Silurgebiet.

1897. WIMAN, C.: Ueber silurische Korallenriffe in Gotland.

1899. LINDSTRÖM, G.: Remarks on the Heliolithidae.

1900. STOLLEY, E.: Geologische Mittheilungen von der Insel Sylt. II.

1901. WIMAN, C.: Ueber die Borkholmer Schicht im Mittelbaltischen Silurgebiet. Bull. Geol. Inst. Upsala. Vol. 5.

1901. HOLM, G.: Uttalande om Gotlands lagerföljd, i »Upplysningar till geol. öfversiktskarta öfver Sveriges berggrund, upprättad och utgifven af Sver. Geol. Unders.» (A statement about the succession of strata in Gotland, in Explanatory remarks to accompany the geological general map of the pre-quaternary systems of Sweden.)

1901. CHAPMAN, F.: On some fossils of Wenlock age from Mulde, near Klinteberg, Gotland.

1902. MUNTHE, H.: Stratigrafiska studier öfver Gotlands silurlager. (Stratigraphic studies on the Silurian deposits of Gotland.)

1904. HEDSTRÖM, H.: Detaljprofil från Skorpionfyndorten — Pterygotus-lagret — i siluren strax söder om Visby. (Detail section from the Scorpion locality — the Pterygotus bed — in the Silurian immediately S. of Visby.)

1905, 1906, 1908. HENNIG, A.: Gotlands Silur-Bryozoer 1—3. (The Silurian Bryozoa of Gotland.)

1907. MUNTHE, H.: Om stratigrafien inom Syd-Gotlands silur. — Föredrag i Geol. Fören. i Stockholm jemte yttranden med anledning däraf. (On the Stratigraphy of the Silurian of South Gotland.— Lecture and Remarks bearing upon this delivered before the Geol. Society in Stockholm.)

1908. KIÆR, J.: Das Obersilur im Kristianiagebiete. Vid.-Selsk. Skr. Math. Naturv. Kl. 1906. Christiania.

1908. ROTHPLETZ, A.: Ueber Algen und Hydrozoen im Silur von Gotland und Oesel. Kgl. sv. Vet.-Ak. Handl. N. S., Vol. 43, N:o 5.

1910. HOEPEN, E. C. N. VAN: De Bouw van het Silur van Gotland. (The Structure of the Silurian System of Gotland.)

(See also the first note on page 16).

The Island of Gotland, situated between the islands of Öland and Ösel, although somewhat nearer to the former, has (if we take away Fårön and that part of the main island immediately bordering it, as well as the part lying S. of the ness at Fide) as nearly as possible the configuration of a rhombus whose longer diagonal, running NNE.—SSW. between Hall in the N. and Näsudden in the S., is about doubly as long as the other diagonal, running from Östergarn to the neighbourhood of Vestergarn. The rock ground consists exclusively of Silurian (Gotlandian). The strata consisting of marl-shales and limestones, rather seldom of sandstone and clay, are generally easily accessible, not only in the shore

cliffs which are sometimes rising sheer, but also in the interior of the island, especially in the barren lands (»alfvar») that are at many places here of vast extent. Already in early days the abundant fossils, as well as the deposits peculiar also in other respects, attracted the attention of investigators. Fossils from this part of the world were already described by Bromell (1726) and by Linné.

The first person to pay attention to the stratigraphical conditions was very likely Hisinger, who, in 1798, distinguished two strata on the island of Gotland, viz. the limestone and the sandstone, of which the latter, visible only at the southern promontory, lies below the limestone. According to his annexed map the sandstone should be visible along the coast, not only on the western, but also upon the eastern side of the southern promontory.

In 1818 Wahlenberg, too, who includes the Gotland strata into the »Transition Formation», believed that the sandstone forms the basis of the great limestone bed. Hisinger in 1826 distinguished a lower division, the Encrinite limestone, forming the bulk of the island, and an upper division built up of oolite, marly limestone and sandstone. It is said of the Encrinite limestone that it belongs to the youngest part of the »Transition Formation», or possibly to the Mountain limestone, whereas the upper division is considered as possibly belonging to the Jurassic. Hisinger sticks to this opinion not only in 1828, when the paper from the year 1826 was reprinted in a very slightly altered form, but also in 1837 in Lethaea Suecica, where he (page 118) mentions the sandstone and the oolite in the same group as the Hör sandstone and the rocks of the Höganäs formation, but the limestone under the heading »formationes transitionis.»

After his visit in 1845, Murchison (1847) fixed the age of all the Gotland strata to Upper Silurian. According to him the strata on the whole dip towards the SE., so that we have the oldest strata in the NW., in the Visby

district or Northern Gotland, and the youngest in Southern Gotland. He divides the strata in the following manner.

(Hoburgen) *Southern Gotland*	k = coral limestone, covered by crinoid limestone (k^*)	Upper Ludlow
	j = oolite	
	i = sandstone (and concretionary limestone, i^*)	
(Klinteberg and Djupvik) *Central Gotland*	h = limestone	Aymestry
	g = shale	Lower Ludlow
(Visby) *Northern Gotland*	f = crinoid limestone (besides an upper grey limestone with concretions f^*)	Wenlock limestone
	e = shale	

As MURCHISON believed himself able to determine a couple of fossils found in Southern Gotland as the Devonian species *Leptaena Fischeri* and *Calceola sandalina*, he considered that we had even here a transition to the Devonian. FERD. ROEMER and HELMERSEN were of an opposite opinion to MURCHISON. The former expresses namely in 1856 as his opinion, in support of which he also refers to a verbal expression of opinion by ANGELIN, that the strata appearing in Southern Gotland are older than those in Northern Gotland. The different strata are, says he, certainly not identical, but together they yet form a uniform deposit of the same age as that of Wenlock in England. LINDSTRÖM, too, in 1858 attempted to make us believe that the sandstone did not, as had been assumed by MURCHISON, overlie the northernmost limestone; according to LINDSTRÖM the sandstone N. of Hummelbos-Ness (on the east coast) would in the horizontal plane merge into a marl-shale, which somewhat further in the N. dips down under the northern limestone which in Burs appears in a steep wall. Sandstone and marl-shale would thus be facies of contemporaneous deposits, older than the limestone, both in the N. and

S., an opinion which, further developed, forms the clue to the schemes subsequently drawn up by LINDSTRÖM for the Silurian of Gotland.

FR. SCHMIDT, in 1859, gives a detailed account of Gotland's stratigraphy. Adopting MURCHISON's view, except in so far as there can be no mention of any transition to the Devonian, as the fossils, upon which MURCHISON had based his opinion, had not been correctly determined by the latter, he divides the Gotland Silurian up into 3 divisions: The north-western or Visby zone, the middle zone and the south-eastern or Ludlow zone, of which the last is the youngest. The middle zone is divided up into a lower one with *Pentamerus estonus*, and an upper one with *Pentamerus conchidium*. On an accompanying map the limits of the different divisions are given.

In 1860 LINDSTRÖM describes the fossil brachiopods of Gotland, and at the same time he gives a stratigraphical survey, in which he on the whole adopts MURCHISON's and SCHMIDT's view, deviating from the latter in so far as he does not divide Middle Gotland into an Estonus and a Conchidium zone, and as he collocates the boundaries between the 3 main divisions or groups somewhat differently, reducing especially the Visby group so as to embrace almost only the strip of coast between Gnisvärd and Hallshuk. In all the different divisions, 3 to 4 zones are distinguished, which, however, do not receive special denominations. When stating the vertical distribution of the fossils, reference is made to all these zones.

In 1882 LINDSTRÖM holds forth that great dislocations occur in the Gotland strata concerning which we can therefore not talk of a general dip in any certain direction, and furthermore he points out, by a comparison between the faunas at Lerberget on St. Karlsön, Djupvik, Petesvik and Westergarn, thus at four spots situated fairly close together on the west coast, that the agreement is greatest in the case of the two localities that are farthest apart, viz. Lerberget and Wester-

garn. According to LINDSTRÖM the dissimilarities between the faunas of the near lying localities seem most likely to be due to the difference of the former sea-bottom or to the limited areas of distribution of the species: it was impossible for him to prove any superstratification which might indicate differences with respect to the age of the various formations.

As the result, to a certain extent, of just the observations published in 1858 and 1882 we can certainly number the scheme which LINDSTRÖM gave us in *1884*, in the introduction to his work on Gotland's gastropoda and pteropoda, an introduction in which all the deposits are divided into 3 strata, viz.

3) The topmost limestone covering all the other strata (c).

2) Slaty limestone, interstratified in the North by shales, in the South by oolite (b).

1) The oldest shale and the sandstone (a).

A red marl containing, amongst other fossils, *Phacops elliptifrons* and *Arachnophyllum typus,* is also mentioned in the same work. The marl is found in boulders, cast up on the shore N. of Visby, and may be supposed as forming the basis for the strata visible along the NW. coast. — The lowest part of zone *a* is parallelized with the Upper Llandovery.

LINDSTRÖM, in *1885*, in his »Förteckning på Gotlands siluriska Crustacéer», again gives a new scheme.

4) The uppermost limestone, Encrinite limestone etc. = Ludlow.

3) The lower limestone with marl-bands, merging into oolite in the S. = Wenlock limestone.

2) The upper marl-shale, merging into sandstone in the S. = Wenlock shales.

1) The lowest marl-shale at Visby = Upper Llandovery.

Finally, in *1888*, LINDSTRÖM gave a very detailed scheme.

h. Cephalopod and Stromatopora beds = Upper Ludlow.

g. Megalomus banks = Guelph limestone (Canada).

f.	Crinoid and Coral limestone	= Aymestry or Ludlow.
e.	Pterygotus beds	= Base of Ludlow.
d.	Limestone with marlbands or Oolite	= Wenlock Limestone.
c.	Marl-shales or Sandstone	= Wenlock Shale.
b.	Stricklandinia marl	= Upper Llandovery.
a.	Oldest red Arachnophyllum marl-shale	= Llandovery

The red shale mentioned already in 1884 is here thus quoted as the base of the Gotlandian of Gotland. The two species previously mentioned therefrom are now named *Phacops quadrilineata* Ang. and *Arachnophyllum diffluens* E. H., besides which some new ones are given, such as *Syringophyllum organum* L. and *Goniophyllum pyramidale* var. Furthermore, it is noted that in zone *c* of this scheme several different faunas or faunistic areas are to be distinguished, viz. c^1 the Visby fauna, c^2 the Vestergarn fauna, c^3 the Central area (Fröjel, Eksta; Follingbo, Bara, Atlingbo; Slite—Fårösund), c^4 the Petesvik—Habblingbo fauna, c^5 the Sandstone fauna in Southern Gotland. — The Cephalopod and Stromatopora beds stretch over the whole of Gotland like a cover wherever limestone appears at all; Hoburgen forms an exception, as a red Crinoid limestone with *Crotalocrinus* is lying uppermost there, possibly on account of an inversion of the strata. As the Stricklandinia marl is really only visible at the beach or in the steep cliffs, zone *c* is of course the oldest visible in the accompanying map. This latter distinguishes in zone *c* between the marl-shale and the sandstone; even in zone *d* a distinction is made between limestone with marl-bands and oolite; all the zones *f* to *h*, on the other hand, have a common designation. It becomes at once quite apparent that the uppermost zones, right from the northern point of the island, form a continuous area right down to the Carl Islands, where it is abruptly cut off along a line

running in a direction from E. to W.; S. of this line only solitary shelves are met with right until the limestone again covers the whole island south of a line drawn over Vamlingbo from E. to W., with the exception of a narrow strip on the west coast. From Gothemshammar, however, a gap cuts in towards the SW., and in this gap the upper marl-shale is exposed. It strikes one as peculiar to see the oolite on the map surrounding the sandstone which is clearly seen to form a belt running from NNE. to SSW.

By reason of LINDSTRÖM's account here referred to, SCHMIDT in 1890 again entered the arena with regard to the question relating to the sequence of strata in Gotland. Using as his starting point the supposition that in all probability the sequence of strata in Gotland is similar to that in Ösel, where corresponding deposits had been closely investigated by him, SCHMIDT explains that the last table set up by LINDSTRÖM does not strike him as feasible, and that the map issued in 1888 gives one more the impression of having been founded mostly upon a petrographic basis. LINDSTRÖM had, says SCHMIDT, as the result of his own researches into the relation between the faunas on Great Carl Island (St. Karlsö, »Lerberget») and the neighbouring localities on the west coast given proof of identical faunas being found at places situated on the same line running from SW. to NE., whilst on the other hand, if one proceeds towards the SE., a gradually progressive change in the fauna can be proved, wherefore, even if an immediate superimposing cannot be directly observed, such must yet exist. With regard to the Megalomus banks which are met with partly in Northern Gotland (at Lansa in Fårön, at Storveda, Heinum and Lärbro), partly in the northern zone of Southern Gotland (at Östergarn, between Etelhem and Butle and at Kräklingbo), SCHMIDT thinks it probable that the *Megalomus*-species of the separate areas are not quite identical, but are possibly different varieties; neither

are the accompanying faunas the same. Furthermore, it is to be noted that SCHMIDT by no means sticks to his older division in all its details. The subzone of *Pentamerus estonus* is rejected, the subzone of *P. conchidium* is referred to Southern Gotland. LINDSTRÖM's zone *a* is characterized as incompletely known, and not as yet precisely parallelized.

In the same year DAMES, after having travelled through Gotland under LINDSTRÖM's guidance, contributed towards the opinion advanced by LINDSTRÖM. In some points, however, he holds an opinion of his own and slightly deviating. LINDSTRÖM's zones *f* to *h* are amalgamated in so far as the Crinoid limestone, the Stromatopora banks and Megalomus banks are looked upon as a separate zone, whilst the cephalopod-bearing limestones are divided up into two zones, one of which coincides with the Stromatopora beds (as LINDSTRÖM meant it), but the other one overlies all the other zones, and thus forms the youngest part of Gotland's Silurian. As a locality for these upper Cephalopod beds, in which the genus *Ascoceras* is entirely absent, Storveda, to the E. of Visby, is cited. No inversion of the strata in Hoburgen exists; all the layers there really also belong, according to DAMES' classification, to the same zone in whose different parts the faunistic facies is very varying. In other respects DAMES agrees absolutely with LINDSTRÖM.

Because of DAMES' contribution SCHMIDT finally, in the year 1891, makes some remarks on the Baltic Silurian, in which he still sticks to his opinion that Gotland and Ösel, which are both homologically situated parts of the deposits in the Baltic Silurian basin, must have a similar structure; in Gotland we therefore proceed from the NW. edge, where the older formations are visible, towards the SE. to younger and younger deposits. Of LINDSTRÖM's zones three, *b*, *c* and *d*, are visible in the cliffs at Visby; zone *e* is only of local importance, but zone *f* is also met with (right on top) in the cliff, where it

is represented by a Crinoid and Coral limestone, which is, however, difficult of palaeontological determination; farther in the interior of the island the Megalomus, Cephalopod and Stromatopora banks, which can be followed toward the NE. right up to Slite and Fårö and which are in close connection with the »Central marl-area», are met with; this latter area can in its turn be followed from Follingbo to Slite and Fårö. All this northern district is characterized by the occurrence of *Leperditia baltica* (*pectinata*). Of about the same age is the Pentamerus limestone with *P. oblongus*, immediately to the SE. This *northern* division is Wenlock or SCHMIDT's Ösel, zone I.

The *southern* division, synchronous with England's Wenlock, or SCHMIDT's zone K, has a sharply marked northern border in the strata characterized by *Pentamerus conchidium*, which, from the upper part of L. Carlsön (Little Charles Island) via Klinteberg, Heide, Väte, Wicklou and Ganthem, can probably be traced right to the mouth of the Gothem River. Here are also included the marl-fauna of Petesvik—Habblingbo (which continues as far as Östergarn) as well as the southern Stromatopora and Cephalopod strata from Sandarfve and Linde away to Torsborgen and Östergarn. Farthest in the SE. we have the oolite with sandstone below and Hoburgen limestone on top, all showing a SW. to NE. distribution.

BATHER (1893, l. c., page 16) entirely followed LINDSTRÖM, remarking, however, that his own top zone (*h*) more closely agreed with DAMES' top zone (*g*). In order to avoid confusion, however, he retains LINDSTRÖM's zone *g* (the Megalomus bank).

STOLLEY in 1897 unconditionally agrees with the above mentioned view relating to the succession of layers expressed by LINDSTRÖM-DAMES, chiefly on account of the »Girvanella» limestone and oolite being met with together, both at Visby and in Southern Gotland, and since a recrudescence of a Girvanella facies in a stratum of a younger age appears to him improbable. At the same time he advances (note 1, page 124)

the opinion that the red Arachnophyllum marl, which LINDSTRÖM called the lowest zone (*a*) of the Silurian of Gotland, is in reality nothing else but the upper part of the Leptaena limestone, which in this area, where the limestone facies rule, is also to be expected below the Stricklandinia marl. The fauna seems also to be conformable. It is more especially for this reason that LINDSTRÖM's zone *a* has been excluded from our table of Gotland.

STOLLEY proved in 1900 that *Astylospongia* (*praemorsa* GOLDF.), *Hindea*, *Aulocopium* and several other sponges, which according to LINDSTRÖM, should have their habitat in his zones *b* and *c*, are undoubtedly there only found as boulders, which originate from deposits of the age of the Jewe or Lyckholm beds.

In his description of the Borkholm beds in the Middle Baltic Silurian area, WIMAN in 1901 confirms STOLLEY's supposition; in some flints which, according to WIMAN's research, belong to the Borkholm beds and which had been collected on the NW.-coast of Gotland, all the spongiae referred to have been found. According to WIMAN, l. c., page 162, these beds form the direct downward continuation of the Silurian of Gotland.

Through the surveying of the Swedish Geological Survey, which commenced in the map-sheet Hamra (the southernmost part of Gotland), the untenableness of LINDSTRÖM's views became apparent. Zones running SW. to NE. could namely be clearly distinguished here. In company with Prof. HOLM, LINDSTRÖM also afterwards started upon a journey of revision, the principal result of which very likely is the statement made by HOLM (1901, pp. 37, 38), that only two great divisions could be distinguished in Gotland. The lower one consists of marl-shales with concretions and layers of limestone, as well as (quite on top) sandstone (Burgsvik sandstone) and oolite. The entire deposit dips towards the SSE., so

that the sandstone and oolite are only found in the southern part of the island. The upper division which almost exclusively consists of limestone, to a great extent old coral-reefs[1], lies on the whole horizontal and rests, with some slight unconformity, upon the lower section. At the boundary between the two sections conglomerates are not rare. The discordance, together with the discovery of a scorpion in a bed near the unconformity, indicate dry land during the middle part of the Upper Silurian period.

In 1902 MUNTHE holds forth that the main cause of the difficulty in clearing up the stratigraphy in Gotland's Silurian might be due to the conspicuously heterogenous character of the strata, both with regard to the petrographical nature and the fauna, which makes it difficult or impossible to follow the »type bed» over any great areas without thorough detail researches. On account of his investigations, chiefly in the neighbourhood of Lau, MUNTHE sets up a general table, whose zones he considers parallelizable without any difficulty with the strata *c* to *f* in LINDSTRÖM's scheme, in so far as this district is considered; whether such is feasible also for strata *c* to *f* which LINDSTRÖM gives for other parts of Gotland would at present be impossible to decide. MUNTHE furthermore states that, besides several more or less marked folds with a north-eastern axis, faults in the same direction also very likely play an important part. Such a one borders the NW.-coast of the island; the most conspicuous dislocation of this kind in Gotland itself is found a little to the NW. of Lau; this is marked partly by depressions in the rockground, partly by cliffs whose direction indicates that even faults with a direction from N. to S. occur here. Another such fault- or fold-zone has its SE.-border in the line Klinteberg to Gothem, its NE.-border in a line drawn from Stenkumla to Bäl (Hejnum).

[1] Compare WIMAN 1897 and DAMES, which latter in 1890 also designates the Stromatoporae as reef builders.

In 1907 MUNTHE set up the sequence of strata for Gotland which in our scheme, page 16, has been given as zones 9 to 3, of which zone 3 rests upon the »marl-shales with limestone bands», which he cites as equivalent to LINDSTRÖM's stratum *c*. MUNTHE himself says that his scheme differs from LINDSTRÖM's in as far as the Sphaerocodium marl has by LINDSTRÖM been amalgamated with deposits younger than the sandstone, and from SCHMIDT's in the *Rhizophyllum*-bearing limestone of the Lau Hills (Sphaerocodium limestone), which by SCHMIDT is parallelized with the Petesvik marl, now being placed considerably higher up (above the oolite). Whether STOLLEY's parallelization of oolite and »Girvanella»-bearing rocks from Southern Gotland with such from the Visby district is justified, is considered a question that has not yet been settled. To judge from the conditions prevalent in England it might be challenged if we were to consider the zone of *P. conchidium* at Klinteberg as older than the zone of *Dayia navicula*.

1908 (l. c., p. 560) KLÆR states, that LINDSTRÖM's zone *c* includes several different zones, on account of which SCHMIDT is undoubtedly right with regard to this question.

VAN HOEPEN, who as late as 1910 minutely treated the stratigraphy of Gotland's Silurian, declares himself as on the whole sharing MUNTHE's view as regards Southern Gotland, even if he does not entirely agree with him in every particular. According to VAN HOEPEN we can in Gotland distinguish the following divisions, reckoned from the younger to the older:

ζ Southern Gotland
ε Hemse Marl
δ Klinte Limestone
γ Klinte Marl
β Highest Visby Group
α Lowest » »

which are all again subdivided into several zones, succeeding

each other from the oldest in the NW. to the youngest in the SE. and mostly bearing local names. The only exceptions to the last mentioned rule are that the lowest zone of α is called »Stricklandinia marl» and the lowest zone of γ »Baltica marl» (after *Leperditia baltica* His.); besides which the middle zone of ε receives the name »Lauensis marl» (from *Beyrichia Lauensis* Kies.) and the highest zone of the same division is called »Phacites limestone». Lauensis marl corresponds about to Munthe's Sphaerocodium marl, which is, however, considered only more locally to be quite characteristic, especially as Sphaerocodium marls occur also at other places in the sequence of strata. The Phacites limestone corresponds to the oolite, Spaerocodium limestone and Ostracod limestone, all together, in Munthe's scheme. The dislocations running from NE. to SW., marked by steep cliffs and mentioned by Munthe (and Nathorst), are, according to van Hoepen, only outcrops of strata; these cliffs have been formed through the denudation of the underlying marl when the sea was higher and the undermined limestone strata thereupon collapsing. — As regards the distribution of the various divisions we can say that the limits given on the map agree to a certain extent with those given by Schmidt for his zones. If we except the section α, which already Lindström distinguished as Stricklandinia marl, and of whose extent no difference of opinion ever existed, it will be seen that the division β (the highest Visby group) pretty well coincides with Schmidt's Northern Gotland, except that in the northern part it extends somewhat further E., so as to reach Stenstuguviken and Fårösund — and further, that the southern border of the division γ very closely agrees with the southern limit of Schmidt's zone of *Pentamerus estonus*, apart from the fact that not only Fårön, but also some parts situated between Slite and Fårösund are by van Hoepen included in his higher division δ. The southern border of the division δ (the Klinte limestone) coincides certainly in the extreme NE. with the

one of SCHMIDT's zone of *Pentamerus conchidium*, but in its continuation towards the SW. it assumes a more northerly direction, to the N. of Etelhem and Lojsta, from which last mentioned place the boundary runs first W., right away to Rovide, and then to the innermost part of Långslite bay, thus reducing the division here to quite a small strip. The southern part of Gotland is finally divided up into two divisions, ε and ζ (the Hemse marl and the Southern Gotland), of which the last mentioned forms partly the very southernmost part (reaching on the East-coast up to and embracing Faludden), partly the heights at Bommunds (and further to the NE.) as well as from Linde up towards Östergarn.

It is, moreover, worth noting that VAN HOEPEN states a decided increase of the calcareous matter towards the E. For the division ε (Hemse marl) an eastern and a western facies is also distinguished.

Although there can be no question of giving here a list of the fauna, it might yet be mentioned as an instance of its abundance that LINDSTRÖM already in 1888 was able to cite 960 species from 20 orders (or classes), but that he estimated the number at close upon 1,500. Amongst the classes that had until that time been the subject of close study, gastropods, crinoidea and brachiopods show the greatest number of species, or about half of the whole fossil fauna.

C III. The Gotlandian of Jämtland.

(Cfr p. 17).

The following works are to be mentioned as more directly touching upon Jämtland's Gotlandian.

1872. TÖRNEBOHM, A. E.: En geognostisk profil öfver den skandinaviska fjällryggen mellan Östersund och Levanger. (A geognostical Section of the Scandinavian Mountain Ridges between Östersund and Levanger.)

1872. LINNARSSON, G.: Anteckningar om den kambrisk-siluska lagerserien i Jemtland. (Notes on the Cambro-Silurian series of strata in Jämtland.)
1872. LINDSTRÖM, G.: Förteckning på siluriska koraller från Jemtland, samlade af D:r G. LINNARSSON. (List of Silurian Corals from Jämtland collected by D:r G. LINNARSSON.)
1894. WIMAN, C.: Ueber die Silurformation in Jemtland.
1894. HÖGBOM, A. G.: Geologisk beskrifning öfver Jemtlands län. (Geological description of Jämtland's Län.)
1897. WIMAN, C.: Kambrisch-silurische Faciesbildungen in Jemtland.

C III: 3. The Rastrites beds.

At Berge and Lejtorp in Offerdal, as well as at Vongen and Sjöböle in Alsen, thus to the NW. of the Lakes Alsen and Nälden (NW. of Lake Storsjön) there are black shales with a grey streak, at one place in Lejtorp coarse and micaceous, in which graptolites characterizing the upper part of the Rastrites beds (Klubbudd shales in Östergötland) have been found. Some of the species indicate, however, a somewhat later, some an earlier age. The species found here are according to WIMAN, who was the first to determine the age of the shales:

Cyrtograptus sp.
Diplograptus palmeus BARR.
Monograptus discus TÖRNQU.
» *Flemingi* SALTER
» *jaculum* LAPW.
» *Linnarssoni* TULLB.
Monograptus lobifer M'COY
» *priodon* BRONN
» *tortilis* LINRS.
» *turriculatus* BARR.
Retiolites sp.

WIMAN, who justly draws attention to the peculiar mixture of species (to give an example we have here *Monogr. lobifer* together with *M. Flemingi*) which seems to exist here,

states, however, that, as far as he had been able to discover, they belong to one and the same geological horizon. The relation of the shales to the Pentamerus limestone is not specially known, because, as previously (p. 17) mentioned, no boundary layers could be observed between the shales and the Pentamerus limestone.

C III: 2. The Pentamerus Limestone.

These strata were by TÖRNEBOHM, on account of the remains of Crinoidea that quite commonly occur therein, originally called Crinoid limestone, but received from LINNARSSON, after *Pentamerus oblongus* SOW. which was also found in it, the name used above. The deposit has its nearest parallel in the Pentamerus belt of Norway (Etage *5* KJERULF, Etage *6b* »Skifer og kalkboller med *Stricklandinia lens*» according to BJÖRLYKKE). Its distribution is very wide in the country to the WNW. and NW. of Lake Storsjön. According to HÖGBOM all the limestone occurrences in the western part of Jämtland's Silurian area are to be numbered with the Pentamerus limestone. WIMAN gives the following localities: Ullån in the parish of Åre, Sölfsved in Kall, Rista Falls in Undersåker, Alsen and Offerdal. According to HÖGBOM the Pentamerus limestone is also met with between Mörsil and Undersåker, at Skärvången (NW. of Föllinge), in Rör and Sikås on Lake Kallsjön, and at Nordhallen to the W. of Mullfjället Mountain. A limestone occurring far up in the N., at Rörvattnet, W. of Hotagen, near the Norwegian frontier is supposed also to belong here.

On a fresh fracture the Pentamerus limestone is almost black, after weathering blue-grey. It is a rather impure limestone, divided into more or less distinct banks of greatly varying thickness. The frequently somewhat dolomitic limestone (HÖGBOM quotes two analyses, showing a percentage of 10.25 and 3.87 $MgCO_3$ respectively) has often, especially in the

vicinity of the underlying quartzite, into which it seems to merge, a peculiar structure, in as much as more impure (clayey) lamellae divide the limestone into small, irregular lenticular parts (a structure which is also very common to the Orthoceras limestone of Jämtland). When weathered this rock assumes a cellular appearance. Through the pressure it becomes not infrequently slaty or stretched (as for example at Berge, Rista Falls, Ullån and Sikås). Fossils occur in most cases sparely and sporadically in this rock, but at some places it may be charged with *Pentamerus oblongus* Sow. or with corals, which sometimes seem to have accumulated into quite a reef. WIMAN mentions from here nearly 40 different species, of which, however, only the following, most of them already quoted by LINNARSSON and LINDSTRÖM, are determined with reference to their species:

Encrinurus punctatus WAHLENB.
Proetus concinnus DALM.
Bumastus barriensis MURCH.
Orthoceras cochleatum SCHLOTH.
Strophomena euglypha DALM.
» *Lovéni* VERN.
» *rhomboidalis* WILCKENS
Favosites Forbesi E. H.
Favosites gotlandicus L.
» *Hisingeri* E. H.
» *Lonsdalei* D'ORB.
» *maximus* QUENST.
Halysites catenularius L.
» *escharoides* LAM.
Cyathophyllum favosum LINDSTR.
Cystiphyllum cylindricum LONSD.

According to HÖGBOM it is possible that the black shales, which at some places appear in connection with the Pentamerus limestone, at others again are absent, are partly replaced by the limestone; to judge from certain statements of WIMAN's it seems on the other hand as if the shales might entirely represent the limestone in the central part of the field which is surrounded by the Pentamerus limestone.

C III: 1. Quartzite bearing Phacops elliptifrons Esm.

In a great part of the area in which the Pentamerus limestone occurs we find, between the latter and the underlying Brachiopod shale, and thus forming the base of the Gotlandian, a Quartzite of very varying colour and thickness, amongst whose particularly scanty fossils the above mentioned trilobite has also been met with, from which the zone, which is also known in Norway, has received its name. Amongst other fossils from this zone are to be mentioned *Cyphaspis* sp., *Lichas* sp., some cephalopods and gastropods, brachiopods (amongst which *Strophomena pecten* L.), *Ptilodictya* sp., *Favosites Forbesi* E. H. and *Halysites catenularius* L. The quartzite which is sometimes blue-grey, like the blue-quartz, sometimes grey or pure white, has a glassy or clearly grained fracture and is often traversed by veins of white quartz. Sometimes the rock, which may be alternating with the Brachiopod shale, as well as with the Pentamerus limestone, is less compact and developed as a real lime-sandstone. The thickness, which frequently changes very rapidly, may reach 10 m., but is often hardly more than half a meter. Similarly to the above mentioned Pentamerus limestone it may often even thin out so that one can find now one, now the other of them, developed alone and interstratified between younger and older shales. Not seldom the quartzite has, through inversion, its position above the Pentamerus limestone, as for example at Berge, Nordbyn, Rista Falls and Sikås.

C IV. The Gotlandian of Dalarne.

(Cfr p. 17).

As a detailed account of the principal literature relating to the Upper graptolite shales of Dalarne has already been given on p. 33—35 under the heading »C I:2 and C I:1,» we can confine ourselves here to the following list of works, which

more especially touch upon the youngest Silurian strata of Dalarne:

1819. HISINGER, W.: Anteckningar i Physik och Geognosie under resor uti Sverige och Norrige. H. 1. (Notes on Physics and Geognosy during journeys in Sweden and Norway.)

1831. HISINGER, W.: Ibidem. H. 5.

1847. MURCHISON, R. I.: On the Silurian and Associated Rocks in Dalecarlia etc.

1847. VERNEUIL, E. DE: Postscript to the Memoir on the Silurian Rocks of parts of Sweden by MURCHISON.

1867. TORELL, O.: Bidrag till Sparagmitetagens geognosi och palaeontologi. (Contributions to the Geognosy and Palaeontology of the Sparagmite beds.)

1867. TÖRNQUIST, S. L.: Om lagerföljden i Dalarnes undersiluriska bildningar. (On the succession of strata in the Lower Silurian of Dalarne.)

1871. TÖRNQUIST, S. L.: Geologiska iakttagelser öfver den kambriska och siluriska lagföljden i Siljanstrakten. (Geological observations on the Cambrian and Silurian succession of strata in the Siljan district.)

1871. LINNARSSON, G.: Jemförelse mellan de Siluriska aflagringarna i Dalarne och Vestergötland. (A comparison between the Silurian deposits in Dalarne and Västergötland.)

1872. STOLPE, M.: Om Siljanstraktens sandstenar. 1. (On the Sandstones of the Siljan district. 1.)

1874. TÖRNQUIST, S. L.: Om Siljanstraktens paleozoiska formationsled. (On the Palaeozoic deposits in the Siljan district.)

1875. TÖRNQUIST, S. L.: Berättelse om en geologisk resa genom Skånes och Östergötlands paleozoiska trakter, sommaren 1875. (Account of a geological journey through the palaeozoic districts, of Skåne and Östergötland, in the summer of 1875.)

1883. Törnquist, S. L.: Öfversigt öfver bergbygnaden inom Siljansområdet i Dalarne. (A Review of the Tectonic in the Siljan district in Dalarne.)
1884. Stolpe, M.: Om Siljanstraktens sandstenar. 2. (On the Sandstones of the Siljan district. 2.)
1885. Nathorst, A. G.: Några ord om slipsandstenen i Dalarne. (A few words on the Grind-sandstone in Dalarne.)
1886. Törnquist, S. L.: Några iakttagelser från sommaren 1885 öfver omtvistade delar af lagföljden inom Dalarnes silurområde. (A few observations from the summer of 1885 about disputed parts of the Succession of strata in the Silurian area of Dalarne.)
1892. Schmalensee, G. C. von: Om lagerföljden inom Dalarnes silurområden. (On the succession of strata in the Silurian areas of Dalarne.)
1910. Warburg, Elsa: Geological description of Nittsjö and its environs in Dalarne.

C IV: 4. The Grind-sandstone.

The grind-sandstone is a loose, felspathic sandstone, devoid of fossils, of a white, grey or red colour, in the latter case with or without light spots. In some beds it is conglomeratic or brecciated, here and there with small, flattened portions of red or green clay and shale embedded. The sandstone, which is widely spread, partly in the country between Orsa Lake and Skattungen, partly round Ore Lake and thence southward past Boda, and which is also found in Sollerön Island, is first mentioned by Hisinger, who at first (1819) seems to be somewhat doubtful as to its age, as he partly says that the limestone in Sollerön Island rests upon the sandstone, partly again states that the sandstone at Gullerås and Osmundsberget is distinctly surrounded by lime-

stone and subordinate to this. When MURCHISON placed the sandstone in question at the base of the Silurian, DE VERNEUIL, his companion during his journey in Dalarne, protested against this, because in VERNEUIL's opinion the sandstone was the youngest layer of the Silurian of Dalarne, but this opinion seems to have passed unnoticed. At least those who expressed themselves on the question, e. g. TORELL (1867), unhesitatingly agree with MURCHISON's view. STOLPE certainly (1872) admits »that several circumstances go to make it probable that the sandstone might occur interstratified or close to the older limestones in the Siljan District», but he gives a table in which the grind-sandstone comes immediately above the Upper graptolite shale. In 1884 STOLPE again voices his opinion, and he especially states that VON SCHMALENSEE had been able to prove in Orsa, between Åberga and Ore, a grey, highly calcareous and somewhat arenaceous limestone, dipping under the grind-sandstone. In this limestone *Bumastus Barriensis* MURCH., *Encrinurus punctatus* WAHLENB., *Phacops quadrilineata* ANG., *Spirifera exporrecta* WAHLENB., and a *Strophomena* closely resembling *S. Walmstedti* LINDSTR. had been found, thus fossils characteristic to Gotland. STOLPE states also that the Obolus conglomerate rests directly upon the Archaean which had supplied the material for the conglomérate, wherefore no Cambrian sandstone could be underlying here.

After NATHORST in 1885, in pointing to the fact of the sandstone's present-day relative situation in several instances obviously having been caused through dislocations of the strata, expressed himself to the same effect as STOLPE, that the grind-sandstone is younger than the Upper graptolite shales, which — in view of the fact that the Leptaena limestone, which yet for a time was by the majority considered to be younger than the sandstone, was afterwards proved to be older than the Upper graptolite shale — means that the grind-sandstone is the youngest

Silurian deposit of Dalarne. — As fossils are absent, we are, of course, not absolutely certain whether the grind-sandstone may not be younger than the Silurian; it has therefore also sometimes been proposed that it might possibly be parallelized with the Devonian sandstone in the Christiania district, something which is stated by, for example, TÖRNEBOHM in 1901 in »Upplysningar till geologisk öfversiktskarta öfver Sveriges berggrund» (Explanatory remarks to accompany the geological general-map of the pre-quaternary systems of Sweden) and by ELSA WARBURG in the scheme for the Silurian of Dalarna drawn up by her.

C IV: 3. The Bumastus limestone and the Colonus shale.

The Gotlandian limestone with *Bumastus Barriensis* MURCH. mentioned in the preceding page, and found in Orsa by VON SCHMALENSEE, was in 1886 called Bumastus limestone by TÖRNQUIST, who considered this limestone, not previously known of from Dalarne, to represent a stratum of its own, whose closer position in relation to the others could not as yet be considered fully determined. Besides the limestone there is found a grey shale deficient in fossils. As regards the relative age of the three strata, TÖRNQUIST says that one would, to judge from the conditions at Nederberga, get about the following order from the bottom upwards: grey shale deficient of fossils, Bumastus limestone, grind-sandstone.

VON SCHMALENSEE (1892) states that he had found *Monograptus colonus* BARR. in the »highest part of the shale immediately below the grind-sandstone, a little way below the waterfall at Stygforsen». As previously mentioned, a similar position is given for the Bumastus limestone. As it would appear from this as if the Bumastus bed and the above mentioned shale bearing *M. colonus* were really of the same age, I have considered myself in a position to parallelize them, as has been done in the table previously given on page 17.

C IV:2 and C IV:1. The Retiolites beds and the Rastrites beds.

I have already accounted for the division into zones and the distribution of these shales, namely in connection with the description of the synchronous deposits of Skåne. A few words with regard to the historical development of the table might, however, be appropiate here.

In 1867 TÖRNQUIST divided the Silurian deposits of Dalarne (herein not included the sandstone placed under the Cambrian by him) into 3 divisions, according to the following table:

3. Upper limestone of Dalarne.
2. b. Shale with marl-spheroids.
   a. Graptolite limestone (with Trinucleus shale).
1. b. Cystidean limestone.
   a. Orthoceras limestone.

The graptolites in *2a* and *2b* are said to be of the same species for the greater part[1]. Amongst them are quoted a couple which, according to what we know now, belong to the Rastrites beds.

TÖRNQUIST, in 1871, retained the same scheme, but altered the name Graptolite limestone to »Cement limestone» (including the Trinucleus shale) and gave to division *2b* the name »Spheroid-shale». Immediately afterwards, LINNARSSON subjected TÖRNQUIST's table to a revision, and found himself induced to separate the Trinucleus shale, which had erroneously been confounded with it, from TÖRNQUIST's division *2* embracing the Cement limestone and the Spheroid shale, both of which belong to the Upper graptolite shale. In 1874 TÖRNQUIST

[1] That the graptolite-bearing strata have without further ado been included in the Trinucleus shale is certainly due to ANGELIN's including the greater part of the graptolite-bearing strata in his Regio Trinucleorum, speaking of which he says »Graptolithi passim mirum sane abundant».

divides the Upper graptolite shale of Dalarne, from the top downwards, up intot he following strata: The Stygfors stratum (Spheroid shale and Cement limestone) and the Kallholn stratum (shale and limestone).

In 1875 he also distinguishes two strata, the younger of which (the Stygfors stratum) now receives the name »Retiolites shale», the older one (the Kallholn stratum) that of »Lobiferus shale». In 1883 TÖRNQUIST finally adopts the name Rastrites shale proposed by LINNARSSON (1881), instead of the name Lobiferus shale. We are herewith quite initiated into the nomenclature employed by TÖRNQUIST in his latest works on the Upper graptolite shale of Dalarne, and which we have already previously, pages 37 and 38, mentioned.

The Retiolites shale is developed partly as so called »Cement shale», yellowish-grey or reddish-grey, deposited in seams of a couple of cm. thickness, and often separated by more or less thick bands or lamellae of thin-leaved shale, partly as »Spheroid shale», a soft, grey, slaty rock with hard limestone spheroids embedded. The Rastrites shale is black and of varying hardness.

Series B. The Ordovician.

As previously mentioned, the Ordovician is chiefly composed of two different kinds of deposits, one of which consists of limestones, generally with plenty of trilobites, the other one of shales, commonly bearing graptolites; the deposits are nowhere right through of one or the other kind, even if at many places one of them is predominant. Furthermore, it should be remembered that we have not so few deposits which, besides a prevailing fauna of one kind, contain scanty representatives of a fauna of the other, or, as it also occasionally happens, subordinate layers in which the latter is prevalent. The table we have previously given for the Ordovician (on page 19) has therefore been divided up into 3 columns, B I—III. The first one, B I, contains principally deposits from shallow water, limestones (or more rarely shales) with a predominant trilobite fauna; here has also been included the Obolus conglomerate. B III contains the series of graptolite-bearing shales representing deposits from deeper water. The only province where this latter series is represented as completely as given in the table, is Skåne, but even there we have by no means an uninterrupted series; on the contrary, strata with trilobite facies are there intercalated pretty well everywhere, and, in order not to give an absolutely misleading table, the series of graptolite-bearing shales in column B III has therefore been supplemented in column B II with the trilobite-bearing strata, which are either lying between the graptolite-bearing ones or containing them, so to say, wedged in; some of the »zones» included in column B II are in reality only founded upon trilobites only sporadically appearing in the graptolite shales.

Öland is to be looked upon as the westernmost outpost of the Russian Baltic Silurian area that is exclusively characterized by shore- and shallow-sea-deposits; and in entire agreement with this, Öland's Ordovician is (apart from the there rather sporadically appearing Dictyograptus shale) entirely developed with a limestone facies. When talking about our group B I we could also with advantage have started from Öland, if the upper part of the series of strata had not been missing there, at least as far as the solid rock is concerned. As things are now, it might be more appropriate to choose the Silurian of Västergötland as a general pattern for the limestone facies of the Ordovician, in order to subsequently more minutely scan the changes and divergences that occur in corresponding deposits elsewhere. For the present we shall not trouble about a detailed account of the graptolite-bearing deposits that occur even in Västergötland, because these had better be treated in connection with the account of the Ordovician of Skåne, B III and B II.

B I. Trilobite (and Brachiopod) facies of the Ordovician.

(Compare the scheme on page 19.)

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a) The Ordovician of Västergötland.

In such an extensive area as Västergötland the Silurian strata are naturally — in spite of their being on the whole undisturbed, and although the plateaus, that are now separate, surely once formed a connected whole — of a varying kind and development in different parts of the province. The Silurian is there principally met with in 3 separate districts, viz. in *Halleberg* and *Hunneberg* (farthest West), in *Kinnekulle* (on the eastern shore of Lake Vänern) and in *Falbygden Mountains* (in the eastern part of the province). The *Falbygden Mountains* have by MUNTHE been subdivided so that the northern part, *Billingen*, by a line drawn through Skultorp—Häggum—Lake Hornborgasjön, is separated from the southern part, or Falbygden proper, within which there may again be distinguished N., E. and W. Falbygden. The Silurian is, besides, found on the Lugnås Height to the N. of Billingen, east (or ENE.) of Kinnekulle, where, however, only the lower parts of the Cambrian have been preserved.

Of all the mountains in Västergötland Kinnekulle can show the most complete sequence of strata, but nevertheless certain of the zones incorporated in the following table do not appear to be developed there.

The Ordovician of Västergötland

shows the following strata, from the top downwards.

5. Brachiopod shale

4. Trinucleus shale
   - Staurocephalus shale (transition bed)
   - Trinucleus shale (proper)
     - dark or variegated
     - red
     - green or black

3. Chasmops limestone
   - (Macrourus limestone)
   - Chasmops limestone (proper)
   - (Echinosphaerite limestone)

2. Orthoceras limestone (Asaphid limestone)
   - Ancistroceras limestone
   - (Centaurus limestone)
   - (Gigas limestone)
   - Asaphus limestone
   - Limbata limestone
   - Planilimbata limestone

1. Ceratopyge limestone with glauconite shale or
   - Zone of Phyllogr. angustifolius — Lower Didymogr. shale
   - » Didymogr. balticus — Lower Didymogr. shale
   - » Tetragr. phyllograptoides — Lower Didymogr. shale
   - » Clonogr. tenellus — Dictyogr. shale
   - » Dictyogr. flabelliformis f. typica — Dictyogr. shale

Before we pass on to an account of the different strata into which the Ordovician of Västergötland has been divided up, the main characteristics of the development of the scheme ought to be indicated.

As is well known, the older writers, such as, for example, KALM, LINNÉ, HISINGER, distinguished five divisions, viz. sandstone, alum shale with stinkstone, limestone, clay shale and diabase. Of these the limestone forms what we now call the Ordovician. In 1854 this series was by ANGELIN divided up into 4 regions: reg. Harparum (highest), reg. Trinucleorum, reg. Asaphorum and reg. Ceratopygarum (lowest), besides which reg. Tri-

nucleorum was subdivided into an upper and a lower division[1].

LINNARSSON, in 1869, distinguished in this part of the series the following divisions:

Brachiopod shale	=	ANGELIN's Reg.	Harparum
Trinucleus shale	=	»	» Trinucleorum, upper part
Beyrichia limestone	=	»	» Trinucleorum, lower part
Orthoceras limestone	=	»	» Asaphorum
Lower Graptolite shale			
Ceratopyge limestone	=	»	» Ceratopygarum.

In 1871 he exchanged the name »Beyrichia limestone» for that of »Chasmops limestone». If we thus add that the Dictyograptus shale (which was by LINNARSSON, after his journey in Skåne, in 1875 separated as a zone of its own, belonging to the highest Cambrian under the name of Dictyonema shale), which was originally included in the »Alum shale» or ANGELIN's Regio Olenorum, was in 1900 proved by MOBERG to belong to the Ceratopyge region and thus forms the base of the Ordovician, we have given the story for the chief traits of the scheme.

For the subdivisions see the following special accounts.

Division 5. The Brachiopod shale.

This shale, which is only a few metres thick, is, as far as the nature of the rock is concerned, very varying, not only in different localities, but also in more limited areas. The typical rock is a compact, light-grey to greenish, thick-leaved, calcareous shale with numerous brachiopods (hence the name), although they are mostly only preserved in the form of casts or moulds. But besides the typical rock we find another darker grey or blackish, well stratified shale, which is sometimes

[1] As A. H. WESTERGÅRD (in his Index to N. P. ANGELIN's Palaeontologia Scandinavica, with notes. Lund 1910) has shown, ANGELIN, when he (in 1851) published Palaeontologia Svecica, distinguished only 2 of these divisions: Regio Trinucleorum and Regio Asaphorum.

the preponderating rock. Banks of a hard, grey, indistinctly stratified limestone occur commonly, especially in the lower or middle part of the Brachiopod shale. On weathering the Brachiopod shale is transformed into a soft, brownish pulp. According to HOLM (1901) the Brachiopod shale is more os less plentifully mixed with quartz-sand, and at some places it shows discordant stratification, wherefore it must have been deposited in shallow water. Of trilobites, a class of animals that is here comparatively sparsely represented, might be mentioned *Phacops mucronatus* BRONGN., *Homalonotus platynotus* ANG., *Harpes* sp., *Lichas laciniatus* WAHLENB., among others. Pteropods, gastropods, pelecypods, and orthoceratites occur very sparsely; bryozoans and ostracods, and chiefly brachiopods and corals, on the other hand, are common.

In the fauna there can in many instances, as is quite natural, be traced a certain relationship with the Gotlandian, and BARRANDE also wanted, in his »Parallèle» (page 27) to look upon the Brachiopod shale as belonging to the last mentioned series (étage E in Bohemia). Even MUNTHE (1905 and 1906) includes the Brachiopod shale in the Gotlandian. ROEMER, who had an idea that the Brachiopod shale lies on top of the »Upper graptolite shale», calls it »*Deiphon* Gestein», or more correctly, he says that ANGELIN might (»möchte») distinguish it by that name.

At Billingen the highest and thickest part of the Brachiopod beds consists of a dark or blackish shale, deficient in brachiopods, in which *Calymmene tuberculata* BRÜNN., *Acidaspis centrina* DALM. and a *Leptaena* sp. are the most commonly occurring fossils. LINNARSSON, who proposes the appellation »Acidaspis shale» for the same, quotes as localities for the latter, besides Billingen, also the other mountains in the northern part of Falbygden; in the southern part, as for example in Ålleberg and Mösseberg, the Acidaspis shale is entirely absent.

Brachiopod shale is met with both in Kinnekulle and

Billingen—Falbygden. ANGELIN united with it also the deposit which is so plentifully developed in Dalarne, and which afterwards received the name »Leptaena limestone». Even in Dalarne, viz. at Gällkärn (Gulleråsen) a rock is met with, however, which more closely resembles the typical Brachiopod shale. We have also to collocate with the latter the »Klingkalk» (clink-limestone) of Dalarne and the Scanian zone of *Phacops eucentra* ANG., which show, however, another development to a certain degree. Besides in the provinces mentioned, the Brachiopod shale is also met with at several places in Jämtland, as well as in Östergötland (at Råsnäs and, in boulders, at Borenshult).

Division 4. The Trinucleus shale.

As the lowest part of the Brachiopod shale LINNARSSON mentions a variegated shale which is well developed in Falbygden, especially on Ålleberg Mountain, but also on Fårdalaberget Mountain (= Hvarfsberget Mountain + Gerumsberget Mountain), Högstenaberget Mountain (= Plantaberget Mountain on later maps) and several other places; the fauna in this shale shows a mixture of species belonging to the Brachiopod and the Trinucleus shales. The stratum occurs possibly also at Billingen. LINNARSSON calls the shale in question »Staurocephalus shale» from the *Staurocephalus clavifrons* ANG. which appears in it. By TULLBERG (in »On the succession of strata in the Cambrian and Silurian deposits at Röstånga», 1880), and also by later writers, as for example HOLM and OLIN, it is, however, included in the Trinucleus shale — with which it agrees most, from a faunistic point of view — as its highest part. MUNTHE hints, however, as more correct to look upon the Staurocephalus bed as the boundary between the Ordovicianand Gotlandian.

Apart from the Staurocephalus shale there may be distinguished mostly three different beds in the Trinucleus shale of Västergötland, of which beds the middle one, which

forms the greater part, consists of a reddish-brown, soft shale generally both on top and at the bottom bordered by dark, green or black shales. More accidentally, concretions or bands of an impure limestone are met with, besides which a 2 to 4 metres thick bank of dark-grey, compact, brittle (almost flinty) limestone, devoid of fossils and traversed by lighter veins of calcite, is met with below the red shale. The shales which form the lowest part of the Trinucleus beds are not, or very little, developed in the Falbygden Mountains. Among the abundant fossils may be mentioned *Trinucleus Wahlenbergi* ROUAULT, *Ampyx Portlocki* BARR., *Cybele verrucosa* DALM., *Dionide euglypta* ANG., *Remopleurides radians* BARR., *Aeglina? oblongula* ANG. and *Agnostus trinodus* SALTER. From the lower strata in Kinnekulle are noted *Trinucleus seticornis* HIS. and *Diplograptus pristis* HIS. Amongst other fossils brachiopods are common, but not so predominant here as in the Brachiopod shale.

Besides Västergötland (Kinnekulle, Billingen and Falbygden), the Trinucleus shale proper is known of from Östergötland, Dalarne and Skåne, in which last mentioned province it has, however, another development, and is never red in colour.

Division 3. The Chasmops limestone.

The limestone coming under this heading is partly hard, dark, black-grey or blue-black, flinty, partly especially in the upper layers somewhat lighter, green or greenish-grey. The light limestone is not flinty, and has a greater percentage of calcium carbonate than the dark variety. Besides the hard limestone, there occurs also a greenish shale, which, as is the case at Kinnekulle, can even be the predominant rock in the division. On weathering, boulders of the flinty limestone just mentioned assume a thick, whitish-yellow, rusty-brown or rust-spotted crust.

Of the particularly plenteous fauna (LINDSTRÖM enume-

rates in his »List of the fossil Faunas of Sweden» 105 species belonging here) we may mention only a few of the commonest, more characteristic crustaceans, as *Ampyx costatus* Boeck, *A. rostratus* Sars, *Ptychopyge glabrata* Ang., *Lichas laxatus* M'Coy, *Remopleurides sexlineatus* Ang., various species of *Chasmops*, as well as *Beyrichia costata* Linrs. Amongst the brachiopods may be mentioned *Orthis biforata* Schloth., *O. dorsata* His., *Strophomena imbrex* Pander and *Leptaena sericea* Sow.

Already in 1871 Törnquist distinguished in the Silurian of Dalarne, amongst other layers that come under this heading, a division which he called Cystidean limestone. Linnarsson subsequently (1882, in Explanation to the map-sheet Vreta kloster) distinguished in Östergötland's Chasmops limestone a lower division, which he called Cystidean limestone, and an upper one, specially characterized by the occurrence in the same of *Chasmops macrourus* Sjögren. Tullberg, in 1882, divided the Chasmops limestone of Öland into a lower division, the »Echinosphaerite limestone», and an upper one, »the Younger Chasmops limestone». Remelé proposed in 1883 the name »Macrourus limestone» for the last mentioned, a designation which he, according to his own statement, used already in 1880 for boulders of the rock in question. According to Holm the name Cystidean limestone (or Echinosphaerite limestone) is not to be used for any rock at Kinnekulle, because cystideans on the whole occur extremely sparsely in the Chasmops beds there. From other statements it looks, however, as if *Echinosphaera aurantium* Gyllenh. occurred generally in the oldest part of the Chasmops limestone in other localities in Västergötland. For example, a lower horizon bearing *Echinosphaera aurantium* has been observed at Mösseberg (above Jonstorp, near Klefva), at Ålleberg, according to Wallerius, and at Billingen (partly NW. of Ryd Estate, partly NE. of Öglunda church). Whether any closer resemblance to the Macrourus limestone of Öland (and Östergötland) really exists

in Västergötland seems on the other hand rather doubtful. *Phacops (Chasmops) macrourus* is certainly mentioned by LINNARSSON (1869), although with some hesitation, in boulders from Kinnekulle, which, however, he supposed to belong to the lower part of the Chasmops limestone.

Chasmops limestone has, besides in the provinces mentioned, also been met with in Jämtland and Skåne, where it is certainly partly replaced by graptolite-bearing shales, but can even be proved to contain limestone banks which, similarly to those of Västergötland, are generally very siliceous, hard, almost flinty.

Division 2. The Orthoceras limestone.

As far as I have been able to discover, HISINGER is the first to use (1828, in the fourth part of »Notes on Physic and Geognosy») the name »Orthoceratite limestone» for the mighty series of limestones, which in Västergötland and several other provinces are lying between the alum shale and the Upper graptolite shale. ANGELIN divided, as is well known, this limestone suite up into several regions, of which regio Asaphorum, which embraces the most important part of the limestone suite, still retains the name Orthoceras limestone. This corresponds practically with the Russian Glauconite limestone and Vaginatum limestone; the Orthoceras limestone of Norway, on the other hand, corresponds only with a small part of the Swedish Orthoceras limestone, viz. the »Gigas limestone» (and possibly parts of the zones adjoining the latter). That such a great series of strata should, on closer examination, be found divisible into several separate beds is quite natural. In 1874, TÖRNQUIST divided the Orthoceras limestone of Dalarne into the following strata:

Upper grey Orthoceras limestone
» red »
Lower grey »

Lower red Orthoceras limestone
Green limestone (Glauconite limestone).

Glauconite limestone is mentioned by LINNARSSON (1875) from Närke and Falbygden, and afterwards by several other writers from the boundary layers between the Orthoceras limestone and the Ceratopyge limestone, often without it having been possible to determine to which of these divisions it belongs at one place or another. Leaving therefore out of consideration this latter deposit which, if not specially mentioned in any other connection, can in most instances be supposed to have been included in the Orthoceras limestone, we may say that TÖRNQUIST's proposal was generally adopted and applied even to other parts of the country, something which clearly goes to prove that the Orthoceras limestone on the whole has quite a uniform development over large areas. LINNARSSON, who in 1876 travelled through Öland, seems to have found TÖRNQUIST's division applicable even to this part of the country. According to a memorandum sent to NATHORST (see A. G. NATHORST's paper: »Om GUSTAF LINNARSSON och hans bidrag till den svenska kambrisk-siluriska formationens geologi och paleontologi», in Geol. För. Förh. 1880) he divided namely Öland's Orthoceras limestone into four divisions, Upper grey, Upper red, Lower grey and Lower red, a division which even HOLM followed at first, for example in 1883, on page 32, in his work »De svenska arterna af trilobitslägtet Illænus (DALMAN).» The same table also forms the basis for TULLBERG's division (1882) of the same series of strata. According to him the sequence of strata is namely as follows: The lowest stratum, Lower grey glauconite-bearing limestone, Upper red limestone and Upper grey limestone, devoid of glauconite. In his »List of the fossil faunas of Sweden» (1888) LINDSTRÖM used TÖRNQUIST's division and gave the latter by means of the lists of fossils mentioned therein

so to say a palaeontological foundation. In 1890, I gave (in »Anteckningar om Ölands orthocerkalk») a more specified division that was chiefly based upon the trilobites. According to this the sequence of strata from the top downwards looks as follows:

Moberg		Older authors	
Ancistroceras limestone[1]		= Upper grey	Orthoceras limestone
Centaurus limestone[2]			
Platyurus limestone		= Upper red	
Gigas limestone			
Asaphus limestone	Upper Asaphus limestone	= Lower grey	
	Sphaeronite bank		
	Lower Asaphus limestone		
Limbata limestone		= Lower red	
Planilimbata limestone			

According to Wiman (»Ueber die Silurformation in Jemtland», 1894) the table could be used for the Orthoceras limestone of Jämtland, and Munthe says (1906) that in the main parts it can also be applied to that of Västergötland.

In 1895 Holm mentioned *Isograptus gibberulus* Nich. and several other graptolites found in the Lower Asaphus limestone at Hälludden in the parish of Böda, on the Island of Öland. That the Asaphus limestone corresponds with the highest zone of the Lower Didymograptus shale is thus not to be doubted. According to Moberg's account (1906) of the sequence of strata in Hunneberg, it is also quite certain that the Ceratopyge limestone is represented by the lowest zone of the Lower Didymograptus shale. Consequently we must be able to parallelize the Planilimbata limestone and the Limbata limestone with the middle zones of the Lower Didymograptus shale.

[1] The original denomination was Strombolituit limestone; after Holm in 1891 (»Om mynningen hos Lituites Breyn.») had stated that *Strombolituites* is a younger synonym for *Ancistroceras*, the term was corrected.

[2] The synonym for *Illaenus Centaurus* Ang., the fossil characteristic of this stratum, has been disputed, as Holm wanted to call this species *I. Chiron* Holm. On account of this the name Chiron limestone has frequently been employed for the Centaurus limestone. Cfr A. H. Westergård: Index to N. P. Angelin's Pal. Scand., with notes. Lunds Univ. Årsskr. Afd. 2. N. F. Bd 6. 1910.

The Orthoceras limestone is found in all the Vestrogothian Mountains (with the exception of Halleberg and Hunneberg Mountains), furthermore in Östergötland, Närke, the Siljan district in Dalarne, Härjedalen, Jämtland, Gästrikland (in Limön Island in the Bay of Gäfle[1]), Lappland (at Granliden), in the Island of Öland and in Skåne. The regular change of colour in the greater part of its area of distribution, into red and grey of somewhat different tints, is remarkable. The Scanian Orthoceras limestone on the other hand is always grey or blackish-grey. As we possibly get an opportunity further on of entering upon the question concerning the cause of the change of colour, we shall only point out that the stratigraphical conditions concerning the same have played a certain part. (Cfr MOBERG 1904).

The table given above will very likely already by the names of the different strata have indicated the nature of the fauna quite clearly. Besides the trilobites, which are common right through the whole sequence of strata, and amongst which Asaphides (*Megalaspis*, *Asaphus*, *Ptychopyge*, *Niobe*, *Nileus* and *Illaenus*) are preponderating, although even some others belonging to such genera as *Phacops*, *Chirurus*, *Cyrtometopus* and *Agnostus* are represented, we find certain zones crowded with cephalopods, a class of animals which here for the first time appears more frequently. It is also upon these that HOLM founded the division of the series of strata which we give further on. The trilobites are, however, very probably more suitable for the division, partly because forms belonging to this category everywhere, and lighter than the cephalopods, are met with in a determinable state, partly because we preserve by this means a common basis of division suitable for the entire series. Among other classes of animals might

[1] Here met with as solid rock already in 1859 (see A. H. WAHLQUIST: Några ord till upplysning om bladet »Leufsta». — A few words as a guide to the map-sheet »Leufsta». Sver. Geol. Unders. Ser. Aa, No. 29. Stockholm 1868).

be mentioned the cystideans, e. g. *Sphaeronis pomum* GYLLENHAHL which appears in the Asaphus limestone forming real banks; brachiopods and gastropods are more scanty. Pelecypods, rarely found in the lowest part of the Limbata limestone in the Island of Öland, make herewith their first entry into our Silurian. It has already been mentioned that even graptolites occur here, although extremely rares.

In 1893 HOLM in his work »Sveriges kambrisk-siluriska Hyolithidae och Conulariidae» (The Cambro-Silurian Hyolithidae and Conulariidae of Sweden) gave, on page 42, the following division of the strata here in question.

Lituites Region
- Lit. perfectus zone (Grey Lituites limestone)
- Lit. lituus zone
- Lit. discors zone (Red Lituites limestone).

Vaginatum Region (Grey Vaginatum limestone).

This table, whose terms HOLM also used already in 1891 (»Om mynningen hos Lituites BREYN» — The mouth of *Lituites* BREYN), was supplemented in 1901, when HOLM came out with the following table relating to the Orthoceras limestone of Kinnekulle, a table which was afterwards used by MUNTHE for the map-sheets of Västergötland published by him, whilst on

Palaeontological division	Popular division	
	Kinnekulle	Öland, Dalarne etc.
Lituites Limestone	»Lefversten» (Liver-stone)	Upper grey Orthoceras limest.
Vaginatum Limestone	Upper Red-stone	Upper red Orthoceras limest.
	»Täljsten» (Pot-stone)	Lower grey Orthoceras limest.
Limbata Limestone	Lower Red-stone	Lower red Orthoceras limest.

the other hand the division given by me came into use for the explanations to the map-sheets of Öland published by MUNTHE, HEDSTRÖM and SVEDMARK.

About the division given by me is to be remarked that, just as the different strata of the Orthoceras limestone in general are not sharply separated from each other, even the division as a whole, both on top and below, shows a very indistinctly marked boundary. As regards the upper part of the Orthoceras limestone it has been proved that *Illaenus centaurus* ANG., even if rarely, has also been found in the hard Ancistroceras limestone, wherefore it is possible that this latter is only to be considered as a more local development of the Centaurus limestone. And even immediately on top of the Ancistroceras bank a limestone band has been met with at one place (at Slagerstad in the Island of Öland), in which probably *Illaenus centaurus* occurred besides *Echinosphaera aurantium*. In connection with the said limestone band there occurred a flaky limestone, probably corresponding with the lower part of the »flagkalk» distinguished by TÖRNQUIST in Dalarne. About this latter, which is quoted as the bottom stratum of the Chasmops limestone, TÖRNQUIST further says himself (1883), that its lower, slaty part might possibly be separated as a layer of its own.

As regards the lower limit of the Orthoceras limestone again, it has been proved that the Ceratopyge limestone at many places imperceptibly merges into the Planilimbata limestone.

As we have seen from the preceding, the so called Orthoceras limestone embraces a great many different strata. It is clearly therefore of importance to be able to determine in every separate case which stratum, or which strata, occur within the several areas. Unfortunately minute researches in this respect have so far not been carried out everywhere. This applies especially to Skåne, about whose Orthoceras limestone we know scarcely much more than that the

upper part of the Orthoceras limestone of the Island of Öland is in Skåne replaced by the Geminus shale and the Lower Dicellograptus shale. The Geminus shale and the Centaurus limestone, which contain *Ogygiocaris dilatata* BRÜNN. and *Didymograptus geminus* HIS. in common, are namely equivalent. TULLBERG (1882) divided the Orthoceras limestone of Skåne into an upper section α, in which was included Fågelsång's dark limestone with a peculiar trilobite fauna described by ANGELIN, and a lower section β, a lighter, grey limestone appearing in south-eastern Skåne and bearing, amongst other fossils, *Megalaspis planilimbata* ANG.

Division 1. The Ceratopyge limestone.

ANGELIN, who first distinguished a Regio Ceratopygarum, knew the same only from Hunneberg (and Norway). Starting from the (erroneous) supposition that Orthoceras limestone at Kinnekulle was lying directly upon the Olenid shale, in the same manner as Ceratopyge limestone in Hunneberg, BARRANDE (1856), in his Parallèle, wanted to make the latter equivalent to the Orthoceras limestone. In 1868 LINNARSSON was, however, able to mention the occurrence of Ceratopyge limestone also in Kinnekulle, where it was separated from the Orthoceras limestone by the »Lower graptolite shale», and in 1869 he states how the division referred to certainly in respect of its trilobite fauna shows a great resemblance to the Orthoceras limestone, but yet has several peculiar trilobite genera which easily justify its separation from the latter. The pecularity of this fauna is still more strongly accentuated by BRÖGGER in his work published in 1896: »Ueber die Verbreitung der Euloma-Niobe-Fauna (der Ceratopygenkalkfauna) in Europa».

Amongst the more characteristic fossils are to be mentioned: *Ceratopyge forficula* SARS, *Euloma ornatum* ANG., *Symphysurus angustatus* S. et B., *Niobe insignis* LINRS., *Orome-*

topus elatifrons Ang., *Apatocephalus serratus* S. et B., *Dicellocephalina dicraeura* Ang., *Cyrtometopus primigenus* Ang., *Harpides rugosus* S. et B., *Triarthrus Angelini* Linrs. and *Agnostus Sidenbladhi* Linrs. — *Megalaspis planilimbata* Ang. is, as has previously been mentioned, common to the Ceratopyge limestone and the lowest part of the Orthoceras limestone, which is not very sharply defined from the former. A particularly common fossil is *Orthis Christianiae* Kjerulf, which also occasionally, together with other brachiopods, can crowd the whole rock. Only one rarely occurring cephalopod, *Orthoceras atavus* Brögger, is known from there. In the Ceratopyge limestone proper other classes of animals are either very sparsely, or not at all, represented.

The limestone is generally hard, compact, with plenty of iron-pyrites, which sometimes occurs distributed in irregular nests and lumps, which, on weathering, may leave behind a more or less cavernous rock. The colour, which varies at different places, is generally either black or light-grey, more rarely greenish or reddish. The limestone is, as a rule, distributed in thick banks, sometimes interstratified by alum shales, but may even occur in the shape of lenses embedded in the glauconite shale. It is often accompanied by a dark, sometimes, for example in the Falbygden Mountains, phosphorite-bearing glauconitic limestone, which not rarely both underlies and covers the fossil-bearing Ceratopyge limestone proper, which it is said to substitute to a certain extent. The glauconite limestone is as a rule devoid of fossils; the glauconite shale and the limestone lenses embedded therein may, on the other hand, often contain plenty of brachiopods.

In Västergötland the Ceratopyge limestone has, besides the places mentioned, Hunneberg and Kinnekulle, also been proved to exist in the Billingen—Falbygden Mountains, in Östergötland (at Berg), in Närke (at Latorp, Lanna and several other places), probably in Gästrikland (in Limön, accor-

ding to WIMAN 1893 and 1907), in Härjedalen (at Glöte), in Jämtland, in the »Lappmark» of Västerbotten (at several places), in the Island of Öland (along the west coast from Ottenby in the S., where it is particularly well developed and easily accessible, right up to the cliff of Köping at Borgholm, as well as at Äleklinta and Horns Ness) and in Skåne, where it is, however, not met with fully developed at more than one single spot, at Fågelsång. In 1906, WIMAN pointed out a limestone at Sjurberg, in Dalarne, which he considers ought to be interpreted as Ceratopyge limestone. In Jämtland, too, there occur limestones whose fauna has not been minutely examined yet, but which, for stratigraphical reasons, we must place in the same category as the Ceratopyge limestone. LINNARSSON mentions namely such a one from Tossåsen; I myself have found the same limestone also at Klöfsjö. And according to LINNARSSON (1872), the stratum here in question might, perhaps, also be met with at Iffelnäs and Mjäla.

The division is of rather varying thickness at different places. Whilst in the western part of Kinnekulle it reaches 2 m. (in the eastern however only 0.5 m.) it is for example in Billingen—Falbygden not more than 0.9 m. thick, and sometimes it does not even reach more than 0.1 m.

Besides the Ceratopyge limestone proper, which we have, together with the accompanying glauconite, designated as the zone of *Apatocephalus*, there is at many places met with also a lower part belonging to the Ceratopyge region and which, after the trilobite genus *Shumardia*, which plentifully occurs therein, has been called the »Shumardia zone». The rock is sometimes, as for example at Fågelsång, a small-crystalline, highly pyritic, light-grey, impure limestone, which on weathering loses its lime without crumbling and changes to a mouldy, dark brown rock; more often, however, it is an alum shale, petrographically fully coinciding with the underlying Dictyograptus shale from which it was only lately

distinguished on account of the nature of the fauna. It was BRÖGGER who, in 1882 (Die silurischen Etagen 2 und 3), was the first to distinguish this part in the Silurian of Norway, and these layers received, on account of the nature of the rock there, the name »Ceratopyge shale». MOBERG (1890) pointed out at Ottenby, in the Island of Öland, an alum shale with *Ceratopyge forficula* SARS and *Shumardia pusilla* SARS[1], which is equivalent to the Ceratopyge shale of Norway. Of deposits which are to be included in the Shumardia zone there are, besides the alum shale at Ottenby already mentioned, a shale found by WIMAN (1903) at Biludden in the Bay of Gäfle, besides which probably also the highest alum shale at Äleklinta may possibly belong here. However, it appears that alum shale can also be inserted between banks of the Ceratopyge limestone, whence it is credible that the *Shumardia*-bearing shale can appear at several levels, which in geological age are somewhat different. At least, it does not strike one as impossible that the *Shumardia*-bearing shale at Ventlinge, in the Island of Öland, might be of a somewhat younger age than the previously mentioned one. Again, as regards the »Shumardia shale» which WIMAN in 1905 described from Lanna in Närke, it does not appear to be comparable with the Shumardia zone proper, which is at least partly equivalent to the Ceratopyge shale of Norway, and of which we spoke in the preceding lines. It is rather to be looked upon as a transition bed between the Ceratopyge limestone and the Planilimbata limestone. Such a transition bed is also very likely a greenish-grey marl-shale at Berg, in Östergötland, lying below the Orthoceras limestone and accreted with the latter, and which by LINNARSSON and TULLBERG in their

[1] According to LINDSTRÖM's »List of the fossil faunas of Sweden, I» the fossil in question is said to have been previously found in the Lower red Orthoceras limestone at Äleklinta in the Island of Öland by Prof. G. HOLM. According to information given by WIMAN in 1905 the determination is, however, incorrect, and even the age of the bed seems to be somewhat uncertain.

explanation to the map-sheet Vreta kloster (1882) has been put down under the Ceratopyge limestone.

b) The Ordovician of Dalarne.

The deposits coming under this heading, which are the oldest found in the Siljan district, were already in early times accorded some attention, as for example by HISINGER who, in 1804, published »Minerografiske anmärkningar öfver Flötserne i Rättvik och närgränsande socknar i Dalarne» (Minerographical remarks about the strata in Rättvik and adjoining parishes in Dalarne). But they were not completely investigated or more minutely studied until TÖRNQUIST devoted many years of uninterrupted work to them. The unravelling of the succession of strata has also been united with great difficulties, not only on account of the partially peculiar development of the Silurian strata, but also on account of the great dislocations that have taken place there. As the result of the investigations of TÖRNQUIST and others we are enabled to present the following

Table of the Ordovician of Dalarne.

5. Brachiopod shale, »Klingkalk» (Clink-limestone) or Leptaena limestone.

4. Trinucleus beds	Red shale. Grey limestone. Black shale. »Masur» limestone.
3. Chasmops beds	Macrourus limestone. Echinosphaerite limestone (»Cystidean limestone»).
2. The Asaphid beds (Orthoceras limestone)	Ancistroceras limestone. Centaurus limestone. Platyurus limestone. Gigas limestone. Asaphus limestone. Limbata limestone. Planilimbata limestone (»green limestone»). Lower Didymograptus shale.

1. Ceratopyge beds	Ceratopyge limestone. Glauconite sand (»Obolus limestone»). Obolus conglomerate.

5. The Brachiopod shale, »Klingkalk» and Leptaena limestone.

This table agrees very well with the one previously given from Västergötland, except in so far as the development of the youngest and oldest strata is concerned. As we have already previously mentioned, the highest stratum of the Ordovician, however, in an isolated occurrence (Gällkärn) is developed quite as the typical Brachiopod shale in Västergötland. Such is, according to E. WARBURG (1910), very likely also the case at Nittsjö. But as a rule there exists great irregularity here. At the level of the Brachiopod shale there occurs namely the so called Klingkalk with which, for reasons which we shall mention later on, even the Leptaena limestone is to be parallelized.

»Klingkalken» (The Clink-limestone). In the year 1872 STOLPE (»Om Siljanstraktens sandstenar». I) mentioned from Nittsjö a grey, fine-grained, thinly bedded limestone with grains of quartz, which limestone he supposed as possibly to correspond with LINNARSSON's Brachiopod shale. In 1874 TÖRNQUIST mentions the same grey limestone from Nittsjö, as well as a similar one from Skattungsbyn; in his table it receives, even if with some hesitation, its place between the Trinucleus shale and the Upper graptolite shale. In 1883 he again mentions this limestone, which is now called »Klingkalk». Besides the previously mentioned occurrences is now also mentioned Enån. The Klingkalk from Skattungsbyn is described as a stratified limestone, about 3 metres thick, which in a fresh condition is blue-black, tough and hard, giving off a sound when struck with a hammer. On the weathered surface, which is always grey and has a crystalline, granular appearance,

fossils are visible, corals and brachiopods; among the fossils are mentioned *Orthis* sp. and *Ptychophyllum craigense* M'Coy.

The Leptaena limestone. This deposit, which in our country is found as solid rock only in this province, is widely distributed there. According to J. G. Andersson (1893) and C. Wiman (1907) the rock is also found in the Baltic immediately to the east of the Island of Öland, as is indicated by some boulders found in that island; and if we follow Stolley (1897, page 124, note 1) and consider Lindström's Red Arachnophyllum marl from Gotland as the highest part of the Leptaena limestone, the former would certainly also rest on the sea bottom to the NW. of Gotland (Visby). Boulders of Leptaena limestone found by Wiman (1907) seem to indicate that this rock also occurs in the northern Baltic area.

According to Törnquist the Leptaena limestone is exposed in Dalarne at the following places: Kallholn, Skattungsbyn, Furudal, Arfvet, Dalbyn, Gulleråsen, Osmundsberg, Änderåsen, Boda, Västanå, Solberga, Östbjörka, Kulsberget, Rättviks hed and Nittsjö lerberg. The rock, which mostly contains plenty of fossils, is very varying both as to colour (white, grey, greenish, light red brick red, black) as to grain, sometimes compact, hard and splintery, at other times distinctly stratified and sometimes with lamellae of shale between the layers. The total thickness is by Törnquist estimated at about 150 metres. The bulk of this consists of a compact, white, red or brown thickly banked limestone. Amongst the fossils trilobites, brachiopods and corals are particularly plentiful, nor are gastropods and cephalopods missing. Of the trilobites, which amount to over 40, may be mentioned *Lichas dalecarlicus* Ang., *L. conformis* Ang., *L. laxatus* M'Coy, and *L. palmatus* Barr., *Planimetopus planifrons* Ang., *Calymmene leptaenarum* Törnqu. and *C. foveolata* Törnqu., *Chirurus speciosus* His. and *C. tenuispinus* Törnqu., *Sphaerexochus mirus* Beyr., *Pseudosphaerexochus conformis* Ang., *Sphaerocoryphe granulata* Ang., *Deiphon punctatus* Ang.,

Encrinurus multisegmentatus PORTL., *Bronteus laticauda* WAHL., a lot of species of *Illaenus,* such as *I. vivax* HOLM, *I. Linnarssoni* HOLM and *I. fallax* HOLM, as well as *Isocolus Sjögreni* ANG. ANGELIN also quotes *Harpes Wegelini* ANG. and *Harpes costatus* ANG., after which he called his »regio Harparum», in which the Leptaena limestone was included by him. Amongst the brachiopods are to be noted *Orthis biforata* SCHLOTH., *Strophomena imbrex* PAND., and *S. luna* TÖRNQU., *Leptaena Schmidti* TÖRNQU. and *Meristella crassa* SOW., amongst the corals *Heliolithes dubius* SCHMIDT, *Plasmopora conferta* E. H., *Halysites catenularius* L. and *H. escharoides* LAM., *Syringophyllum organum* L. and *Ptychophyllum craigense* M'COY. According to STOLLEY there are furthermore such quantities of Siphoneae *(Palaeoporella, Vermiporella* etc.) in the Leptaena limestone that we can here speak of a real algous facies.

No other geological formation comparable with the Leptaena limestone is, as has been mentioned, met with in the mainland of Sweden.

Not only the Lyckholm and Borkholm strata of Esthonia, but also the Etage 5 of Norway, the Keisley Limestone in England and the Irish Kildare Limestone appear, however, to resemble the same very closely, both with regard to the fauna and the rock.

The determining of the position of the Leptaena limestone in the stratigraphical scheme has met with great difficulties. Before we resume the different opinions advanced concerning the geological age of the deposit we may here give a list of the more important works relating to the Leptaena limestone.

1854. ANGELIN, N. P.: Palaeontologia Scandinavica. H. 2.
1859. SCHMIDT, F.: Beitrag zur Geologie der Insel Gotland nebst einigen Bemerkungen über die untersilurische Formation des Festlandes von Schweden, etc., S. 59 (459).

1867. TÖRNQUIST, S. L.: Om lagerföljden i Dalarnes undersiluriska bildningar. (On the succession of strata in the Lower Silurian deposits of Dalarne.)

1869. LINNARSSON, G.: Om Vestergötlands Cambriska och Siluriska aflagringar. (On the Cambrian and Silurian deposits of Västergötland.)

1869. TÖRNQUIST, S. L.: Geologiska iakttagelser öfver den kambriska och siluriska lagerföljden i Siljanstrakten. (Geological observations relating to the Cambrian and Silurian sequence of strata in the Siljan district.) Öfvers. Kgl. Vet.-Akad. Förh.

1871. LINNARSSON, G.: Geologiska iakttagelser öfver den kambriska och siluriska lagerföljden i Siljanstrakten. (Geological Observations on the Cambrian and Silurian succession of strata in the Siljan district.)

1871. LINNARSSON, G.: Jemförelse mellan de siluriska aflagringarne i Dalarne och Vestergötland. (Comparison between the Silurian deposits in Dalarne and Västergötland.)

1874. TÖRNQUIST, S. L.: Om Siljanstraktens paleozoiska formationsled. (On the Palaeozoic deposits in the Siljan district.)

1875. TÖRNQUIST, S. L.: Berättelse om en geologisk resa genom Skånes och Östergötlands paleozoiska trakter sommaren 1875. (Account of a geological journey through the Palaeozoic districts of Skåne and Östergötland, in the summer of 1875.) Öfvers. Kgl. Vet.-Ak. Förh.

1879. TÖRNQUIST, S. L.: Berättelse om en resa i England, Wales och Skottland. (Account of a journey in England, Wales and Scotland.) Öfvers. Kgl. Vet.-Ak. Förh.

1882. TULLBERG, S. A.: Skånes graptoliter. I. (The Graptolites of Skåne.)

1883. TÖRNQUIST, S. L.: Öfversikt öfver bergbygnaden inom Siljansområdet i Dalarne. (A review of the Tectonic in the Siljan district of Dalarne.)

1884. SCHMALENSEE, G. C. VON: Om leptaenakalkens plats i den siluriska lagerserien. (On the Position of the Leptaena limestone in the Silurian System.)

1884. BRÖGGER, W. C.: Spaltenverwerfungen in der Gegend Langesund—Skien. Nyt Mag. for Naturv.

1884. TÖRNQUIST, S. L.: Till spörsmålet om leptaenakalkens ålder, med anledning af G. C. VON SCHMALENSÉES bestämning af densamma. (About the Age of the Leptaena limestone, on account of v. SCHMALENSEE's determination of the same.)

1885. NATHORST, A. G.: Några ord om slipsandstenen i Dalarne. (A few words about the Grind-sandstone in Dalarne.)

1886. TÖRNQUIST, S. L.: Några iakttagelser från sommaren 1885 öfver omtvistade delar af lagerföljden inom Dalarnes siluromräden. (Some observations on disputed parts of the sequence of strata in the Silurian areas of Dalarne made in the summer of 1885.)

1891. NICHOLSON, H. A. and MARR, J. E.: The Cross Fell Inlier. Q. J. G. S. of London, Vol. 47.

1892. SCHMALENSEE, G. C. VON: Om lagerföljden inom Dalarnes siluromräden. (On the Succession of strata in the Silurian areas of Dalarne.)

1892. TÖRNQUIST, S. L.: Några ytterligare anmärkningar om leptaenakalken i Dalarne. (A few further Remarks on the Leptaena limestone of Dalarne.)

1892. TÖRNQUIST, S. L.: Anmärkningar med anledning af G. C. VON SCHMALENSEES uppsats »Om lagerföljden inom Dalarnes siluromräden». (Remarks with regard to v. SCHMALENSEE's Paper »On the succession of strata in the Silurian areas of Dalarne.»)

1893. ANDERSSON, J. G.: Ueber Blöcke aus dem jüngeren Untersilur auf der Insel Öland vorkommend.
1894. HEDSTRÖM, H.: Geologiska notiser från Dalarna. 1 och 2. (Geological notes from Dalarne. 1 and 2.)
1896. STOLLEY, E.: Ueber gesteinsbildende Algen und die Mitwirkung solcher bei der Bildung der skandinavisch-baltischen Silurablagerungen.
1896. HEDSTRÖM, H.: Till frågan om fosforitlagrens uppträdande och förekomst i de geologiska formationerna. (About the manner of appearance and occurrence of the phosphorite-bearing strata in the geological formations.)
1897. STOLLEY, E.: Die silurische Algenfacies und ihre Verbreitung im skandinavisch-baltischen Silurgebiet.
1897. COWPER REED., F. R.: The fauna of the Keisley limestone. Q. J. G. S. of London, Vol. 53.
1897. KIAER, J.: Faunistische Uebersicht der Etage 5 des norwegischen Silursystems.
1906. TÖRNQUIST, S. L.: Sundry geological and palaeontological Notes. I. A retrospect of the history of the Leptaena limestone.
1907. WIMAN, C.: Ueber die Fauna des westbaltischen Leptaenakalks.
1907. WIMAN, C.: Studien über das nordbaltische Silurgebiet. 2.
1910. WARBURG, E.: Geological description of Nittsjö and its environs in Dalarne.

ANGELIN in 1854 included this deposit in his »regio Harparum» (DE), and in 1859 SCHMIDT pointed out its agreement with the youngest Ordovician of Esthonia, the Borkholm and Lyckholm strata, on which occasion he also protests against BARRANDE's view of ANGELIN's regio DE having to be included in the Gotlandian. Even TÖRNQUIST in 1867 in his first work on the Silurian of Dalarne collocates this »Up-

per limestone of Dalarne» with ANGELIN's regio DE and KJERULF's Etage 5 a (»the Gastropod limestone») in Norway. He places, however, this »Upper limestone» above the Upper graptolite shales which he mixes up with the Trinucleus shale. In 1869 LINNARSSON expresses his doubts about the succession of strata given by TÖRNQUIST, and seems inclined to place the »Upper limestone» (regio DE) below the shales. In 1871 TÖRNQUIST changed the appellation »Upper limestone of Dalarne» to »Leptaena limestone». When therefore LINNARSSON immediately afterwards (1871) had separated the Upper graptolite shale from the Trinucleus shale, a conflict would naturally have arisen between the opinion of the stratigraphy of Dalarne and that of the Vestrogothian sequence, unless the Leptaena limestone is to be considered of »Upper Silurian» age. This conception was advanced by LINNARSSON, and he therefore accepted TÖRNQUIST's view that the Leptaena limestone layes on top of all the shales.

In 1874 TÖRNQUIST still places the Leptaena limestone highest in the table of the Silurian of Dalarna, and he declares that the stratigraphical conditions on several places indicate that the Leptaena limestone is really younger than the other Silurian deposits, and in 1875 he comes out with the idea that the Leptaena limestone is contemporaneous with the highest part of the Scanian Retiolites shale. Anteceded by the fauna of the Brachiopod shale, which fauna was rather deficient in species, the fauna of the Leptaena limestone was in all probability developed in parts of the world foreign to us (in our Eastern neighbouring country?) contemporaneously with the Upper graptolite shales.

After a visit to England TÖRNQUIST (1879) was very doubtful about the position of the Leptaena limestone in the succession of strata. Comparing the fauna of the Leptaena limestone with that of Englands Llandovery he thinks of the possibility of placing the Leptaena limestone between the Lobiferus and

Retiolites shales. But if it were younger than the Retiolites shales (and then belonging to Wenlock) we must imagine its fauna, having immigrated at a late period into Dalarne, survived there still after it had in England been obliged to give way to a younger fauna.

In 1882 TULLBERG, with some hesitation, places the Leptaena limestone side by side with the lower zones of the Rastrites shale (Zone of *Monogr. cyphus* and Zone of *M. gregarius* LAPW.) whose presence has not been proved in Dalarne. In 1883 TÖRNQUIST, however, still places the Leptaena limestone above the Retiolites shale. It cannot be inserted anywhere else, as the series of strata, neither between the Rastrites shale and the Retiolites shale, nor between the Rastrites shale and the Trinucleus shale shows any gap large enough to enable the Leptaena limestone being accommodated. The rocks have secondarily been displaced (probably due to undermining) which prevents a clear observation of the relation between the Leptaena limestone and adjoining formations.

In 1884 BRÖGGER pointed out the great resemblance between the fauna of the Gastropod limestone and that of the Leptaena limestone.

In the same year SCHMALENSEE put in a good word and tried to show that stratigraphical data also actually spoke in favour of placing the Leptaena limestone below the Rastrites shales; it is certainly missing at this place in several otherwise complete sections, but this is due to the stratum thinning out there. TÖRNQUIST, who still sticks to this last point of view, remarks in 1884 with reference to SCHMALENSEE's writing that the sections the latter had mentioned to support his opinion are unreliable.

In laying stress upon the fact that the grind-sandstone is certainly lying immediately upon the Retiolites shale, NATHORST, in 1885, states that the only possible place for the Leptaena limestone is below the Rastrites shale. As such a

thinning out as SCHMALENSEE opined does not seem plausible, NATHORST advances the hypothesis that the Leptaena limestone was actually a coral reef, built up contemporaneously with the Klingkalk. Rising above strata of the latter it was subsequently surrounded or covered by the Upper graptolite shales (and the grind-sandstone). Secondary disturbances, caused by the glaciers of the ice period, have probably taken place.

In 1886 TÖRNQUIST says that although a great part of the fauna of the Leptaena limestone is such that that alone would appoint to this limestone a lower position in the system than the one he himself had allocated it as probable, yet stratigraphical reasons seem to place insurmountable obstacles in the way of such an position.

In 1892 TÖRNQUIST lodges a new protest on account of a paper »The Cross Fell Inlier» by H. A. NICHOLSON and J. E. MARR. The Keisley limestone mentioned there, which has a certain similarityt o the Leptaena limestone, both in the manner of its occurrence and the fauna, has namely been considered to have reached its present position by thrusting. TÖRNQUIST means now that we ought also to take such a possibility into consideration when it is a question of explaining the stratigraphy of the Leptaena limestone. — In 1892 SCHMALENSEE again advocates his previously expressed opinion. He considers himself having proved that Colonus shale is lying concordant below the Grind-sandstone, just like Retiolites shale upon Rastrites shale, and the latter again (at Osmundsberget) directly upon Leptaena limestone.

In his reply to SCHMALENSEE immediately afterwards TÖRNQUIST (1892) says that he now assigns greater importance to the Silurian fauna of the Leptaena limestone in the inquiry relating to its age than he had done before, and he considers that the stratigraphical conditions will be made to agree with the preponderating character of the fauna.

J. G. ANDERSSON, in 1893, mentions the occurrence of

boulders of limestone containing *Leptaena Schmidti* TÖRNQU., consequently of the age of the Leptaena limestone, in the Island of Öland. The strata are with certainty accepted as having rested in the vicinity of the coast of Öland. WIMAN, who (1907) more minutely examined the fauna in which he had found 24 definable species, confirms ANDERSSON's conclusion. TÖRNQUIST, in his review of the point in dispute issued by himself in 1906, lays still further stress upon his point of view, when he says: »Ever since that time (1892) I have been of opinion that the Leptaena limestone must be placed between the Trinucleus beds and the Rastrites shales».

WARBURG (1910) in her review of the Silurian of the Nittsjö district also gives an account of the Leptaena limestone.

That the history has been rather explicitly treated is due to the fact that that part is of special interest in showing how, by tackling one theory after the other, according to their coming into vogue, an attempt has been made to get out of the predicament we had got into. We see therefore in this question a theory of migration (partly in connection with a relict-theory), a theory of dislocation and a theory of thrusting, each in its turn brought forward as possibly containing a solution of the problem.

4. *The Trinucleus beds.*

The thickness of the Trinucleus beds is estimated by TÖRNQUIST at 30 to 50 m. At Fjecka we find both the bottom-stratum and the overlying black Trinucleus shale well exposed. The continuation of the strata upward can be traced at Vikarbyn, Nittsjö, Gulleråsen and Skattungsbyn. Just as in Västergötland, the stratum is principally formed of shales. Just as there, quite thick limestone beds are interstratified, though. In the zonal division given by TÖRNQUIST we have a lower limestone bed, »Masur limestone», and an upper

one, viz. the grey limestone interstratified between the black and the red shale. According to WARBURG (1910), even the Upper limestone bed may at some places be developed as a Masur limestone.

The »*Masur limestone*» (curled limestone), sometimes also called »Knyckel limestone», is a 10 to 15 m. thick bed of hard, grey nodulous limestone, whose uneven banks are traversed by calcite. Determinable fossils are not found in it. As has been said, it occurs at Fjecka where it lies directly over the Macrourus limestone. The lowest part of the Trinucleus bed has also been met with outside Dalarne with the development just mentioned. Masur limestone exists namely at Rödbergsudden in Östergötland where it directly overlies the Macrourus limestone [see page 20 in Explanation to the map-sheet Motala. Sver. Geol. Unders. Ser. Aa, No 102 and WIMAN 1907, »Studien über das Nordbaltische Silurgebiet», II]. Boulders of Masur limestone are mentioned by WIMAN, l. c., also from the North-Baltic Silurian area.

3. *The Chasmops beds.*

The Chasmops beds were by TÖRNQUIST (1883) divided up into three divisions, viz. (from the top downwards) the Bryozoan stratum, the Cystidean stratum and the »Flagkalk» (flaky limestone). The Bryozoan stratum, about 9 m. thick, is composed of alternating marl-shale and thin limestone bands. The stratum, whose highest part TÖRNQUIST at first under the name Grey Trinucleus shale included in the Trinucleus bed, is found at Fjecka and Kårgärde. Amongst the fossils may be mentioned *Orthis dorsata* HIS., *Orthis biforata* SCHLOTH., *Illaenus Linnarssoni* HOLM, *I. parvulus* HOLM and *Chasmops maximus* SCHMIDT. Although *Chasmops macrourus* SJÖGR. is not found here, the general character of the fauna no doubt entitles us to call it Macrourus limestone. The Cystidean limestone (Eschinosphaerite limestone) is, according to TÖRNQUIST,

found at Kårgärde, Fjecka, Vika (parish of Mora), in Sollerön Island, at Enån in the parish of Orsa, Orsbleck, Åberga, Gulleråsen, Osmundsberget Mountain and Nittsjö. Its thickness is given as about 15 m. As previously mentioned, we consider the »Flagkalk» as a transition bed, or perhaps most nearly corresponding to the Ancistroceras limestone.

2. *The Orthoceras limestone.*

The Orthoceras limestone is the Silurian deposit most widely distributed in Dalarne. At Kårgärde, Fjecka, Vikarbyn, Skattungsbyn, Sjurberg and Granmor this stratum is easily accessible. Its whole thickness is estimated at 30 to 50 m. We have previously mentioned the division of this deposit into zones, which well agree with those of the Orthoceras limestone of the Middle Sweden in general. A circumstance of more general interest ought no doubt to be specially emphasized here. In the »Upper red Orthoceras limestone» interstratifications of shale are common. According to TÖRNQUIST the fauna in the shale is said to be homogeneous right through the whole division and distinct from the fairly varying trilobite fauna that appears in the limestone. As dominant genera in the shale he mentions *Agnostus, Remopleurides, Cybele, Aeglina* and *Acidaspis.* As I have mentioned before, it looks as if amongst the trilobites one could distinguish between such as preferably had their habitat in shallow water, and such as have lived in deeper water. The former, whose remains are now found in the limestones, I would like to call titanophiles, the latter, which are now found in the shale, I would on the other hand like to call pelophiles.

With regard to the Orthoceras limestone we have only to state that the Planilimbata limestone is at Skattungsbyn replaced by Lower Didymograptus shale. The shale and its fauna will be accounted for later on when describing the graptolite facies of Skåne. Here may only be mentioned that

HOLM in 1882 (»Ueber einige Trilobiten aus dem Phyllograptusschiefer Dalekarliens»), in thin layers or lenses of an impure, green limestone embedded in the Lower Didymograptus shale, found a peculiar trilobite fauna, in which, together with the fellowing species described by HOLM, *Pliomera Törnquisti*, *Megalaspis Dalecarlicus*, *Ampyx pater*, *Agnostus Törnquisti* and *Trilobites brevifrons*, there was only a single previously known species, viz. *Niobe laeviceps* DALM., a species, which unfortunately is far too much spread vertically to enable one on its account to more closely correlate this limestone with any other of fully determined age. TULLBERG, in 1882 (in the Explanation to the map-sheet Vreta Kloster), believed himself able to determine a couple of trilobites found at Berg in Östergötland in a greenish-grey shale lying immediately below the Orthoceras limestone, viz. *Megalaspis dalecarlicus* HOLM and *Ampyx pater* HOLM, and wanted to include the shale in question in the Ceratopyge limestone. MOBERG and SEGERBERG consider (1906, page 21 in »Bidrag till kännedom om ceratopygeregionen etc.») TULLBERG's definition of the two trilobites in question erroneous, and presume the limestone interstrafied in the Phyllograptus shale at Skattungsbyn to belong to the transition between the Ceratopyge limestone and the Orthoceras limestone. That it is not considered younger depends on the fact that certain of the fossils, viz. *Ceratopyge* sp., *Dicellograptus* sp. and an *Agnostus* related to *A. Sidenbladhi* LINRS., indicate quite a close relationship to the fauna of the first mentioned bed.

1. *The Ceratopyge beds.*

The graptolite facies, which in the greater part of Sweden characterizes the lowest part of the Ceratopyge region, viz. the Dictyograptus shale, is here altogether absent, and is replaced by a shallow water deposit directly upon the weathered primitive rock, and forms thus the oldest Silurian deposit

of the Siljan district. Nor was any layer corresponding to the Ceratopyge limestone (the Apatocephalus zone), which in other localities forms the main portion of the upper part of the region known of here until WIMAN in 1906 was able to prove such a one at Sjurberg.

TÖRNQUIST (1874) looked upon the *Obolus limestone* as the oldest stratum of the Silurian of the Siljan district, and he subdivided it into two layers, an upper Obolus limestone (»gruskalk») and a lower, Obolus conglomerate, of which sometimes one and sometimes the other may be missing. The thickness of the entire deposit (including the Ceratopyge limestone) is at the most 2 to 3 metres, but may drop to scarcely $^1/_2$ m., which is the case at Sjurberg, for example. The conglomerate forms as a rule the chief part of the deposit.

The Ceratopyge limestone at Sjurberg, 0.14 to 0.16 m. thick, consists of a greenish-grey, compact limestone, here and there with portions containing plenty of glauconite. Besides fragments of archaean rocks sprinkled in, small nodules of phosphorite and fragments of *Obolus* shells there is here also found a brachiopod, *Lycophoria laevis* STOLLEY, which WIMAN looks upon as a characteristic fossil for the Ceratopyge limestone. No trilobites are found here. WIMAN also mentions for example limestones and clays from Vikarbyn, Kårgärde, Skattungsbyn and Bråmabo, which he considers as possibly being equivalent to the Ceratopyge limestone.

The Obolus limestone is, according to TÖRNQUIST, a crystalline, shingly, white or green limestone with grains of glauconite. WIMAN, again, characterizes the Obolus limestone at Sjurberg as a glauconite sand with fragments of archaean rocks and phosphorite grains. The Obolus conglomerate, which after the original place of discovery was at first called the »Klittberg conglomerate», is a gray mass of limestone, enclosing minor, rounded pebbles of quartz and felspar, as well as phosphorite concretions from the size of a pea to that of a wal-

nut. According to J. G. ANDERSSON (1896, »Ueber cambrische und silurische phosphoritführende Gesteine») the bulk, which to a large extend is formed of grains of quartz and other fragments of the underlying weathered archaean, is sometimes deficient of calcium carbonate, often, however, cemented together with a crystalline calcite. Among the stones in the conglomerate are mentioned, besides those from the rock ground and phosphorite, also such of phosphoritic sandstone and jasper.

Both in the limestone and in the conglomerate *Obolus Apollinis* EICHW. is abundantly met with; MICKWITZ mentions from here also *O. triangularis* MICKW. The fossils occur, however, mostly in a very fragmentary condition. As Obolus sandstone in Esthonia, as MICKWITZ (1896) has shown, alternates with layers of Dictyograptus shale, the Obolus conglomerate is, of course, to be looked upon as equivalent to the latter. According to WIMAN'S assumption the Obolus limestone would rather correspond to the Ceratopyge limestone. *Obolus Apollinis* would then have come in secundarily from the underlying conglomerate.

Besides Klittberg, where the Obolus conglomerate was observed by H. VON POST already in 1844, Obolus beds have been found at Vikarbyn, Gulleråsen, Sjurberg and Bäck.

The conglomerate forms, as a rule, the chief part of the strata in question, which only in exceptional cases may reach a thickness of more than 2 m.

From the history relating to the Obolus strata the following may here be mentioned:

When we first made the acquaintance of the Obolus beds in Dalarne, we were, to begin with, rather uncertain about their place in the succession of strata. In 1871 TÖRNQUIST wanted to place them amongst the Cystidean limestone (or at their upper limit), which was, however, corrected by STOLPE in the same year; the latter stated (in the Report of the

Phosphorite Commission, pages 5 and 39) that their place was between the Archaean and the oldest Silurian strata.

In 1882 TULLBERG mentioned an Obolus-bearing glauconite shale found between Köping and Borgholm, as well as at Karlevi in the Island of Öland, which shale he parallelized with the Obolus conglomerate of Dalarne, and HOLM, in the same year, mentioned a conglomerate with fragments of Paradoxides shale and Olenus shale in an Obolus-bearing cement, found at Horn in the Island of Öland under the greensand there, which conglomerate he looks upon as a connecting link between the Obolus strata of Esthonia and the Obolus conglomerate in Dalarne. Herewith the position of the Obolus beds in the sequence of strata may be said to have been determined. That they can also be parallelized with the Dictyograptus shale by reason of MICKWITZ's observations, has already been previously mentioned.

Some deposits that probably come under this heading are, besides those from Dalarne and Öland, also known of from Östergötland and Västergötland. TULLBERG mentions namely (in Explanation to the map-sheet Vreta Kloster) from Knifvinge and Storberg a greensand lying between Planilimbata limestone and Dictyograptus shale. And as a formation belonging to a shallow water facies treated of here we may very likely also reckon the sandstone underlying the Dictyograptus shale at Knifvinge, which was described by HOLM in 1885 (»Om Vettern och Visingsöformationen»).

Boulders of Obolus sandstone were found by WIMAN in the Fanton Island in the Singö-fairway near Östhammar. This sandstone has therefore, as one could already assume a priori, been resting also in the North Baltic Silurian area.

c) The Ordovician of the Island of Öland.

To the bibliography previously mentioned on pages 69—75 the following addition may here be made:

1851. SJÖGREN, A.: Anteckningar om Öland, ett bidrag till Sveriges geologi. (Notes on Öland, a contribution to the Geology of Sweden.) Öfvers. Kgl. Vet.-Ak. Förh.

1883. REMELÉ, A.: Über die versteinerungsführenden Diluvialgeschiebe des norddeutschen Flachlandes.

1893. ANDERSSON, J. G.: Über Blöcke aus dem jüngeren Untersilur auf der Insel Öland vorkommend.

1893. ANDERSSON, J. G.: Über das Alter der Isochilina canaliculata-Fauna.

1896. ANDERSSON, J. G.: Über cambrische und silurische phosphoritführende Gesteine aus Schweden.

1906. HEDSTRÖM, H. and WIMAN, C.: Beskrifning till blad 5 etc. Sver. Geol. Unders. Ser. A1, a. (Explanation to the map-sheet 5 etc.)

1907. WIMAN, C.: Über die Fauna des westbaltischen Leptaenakalks.

It has already been mentioned in the preceding pages how a trilobite facies is predominant almost throughout the Ordovician system of Öland. As the rockground, especially in the southern part of the island, on the vast barren lands (the »Alfvar») is lying quite exposed, the sequence of strata could be followed with all the requisite care, right from the base of the Ordovician up to the Echinosphaerite limestone, which is the youngest silurian stratum here.

The upper part of the Ordovician is namely only represented by boulders, which yet partly occur very plentifully and at some places form such large, connected parties as to make one believe at first that it is solid rock. On account of the abundant boulders, especially in the country round Hulterstad, J. G. ANDERSSON distinguished (1893, »Ueber Blöcke — — — auf der Insel Öland vorkommend») here several horizons, viz.:

Limestone with *Leptaena Schmidti* TÖRNQU. (youngest).
Red marl shale and limestone with *Trinucleus* sp.

Grey marl shale and limestone with *Trinucleus seticornis* His.

Macrourus limestone (oldest).

The Limestone with *Leptaena Schmidti*, whose fauna was in 1907 described by Wiman, is both faunistically and petrographically developed as Leptaena limestone, and therefore represents the Brachiopod shale. As the two middle horizons belong to the Trinucleus bed, all the divisions, Brachiopod shale, Trinucleus shale and upper Chasmops limestone, which are not found in the rocky floor, are yet represented here by the boulders in question.

Whereas boulders belonging to the three upper horizons have only been found on the east coast, in the neighbourhood of Hulterstad, boulders of Macrourus limestone have been observed at several other places, not only upon the east coast, as for example at Stenåsa and in Össby brook S. of Gräsgård, where the boulders are lying as if it were solid rock, but also on the west coast, at Eriksöre and Borgholm, at the swimming-baths.

The Macrourus limestone, which was mentioned for the first time in 1851 by Sjögren and had already then been correctly stated as being younger than the other limestones of Öland, received the appellation of Macrourus limestone by Remelé in 1883. After Linnarsson, in 1876, had shown that its place in the sequence of strata must be the upper part of the Chasmops beds, absolute unity regarding its age has always existed. J. G. Andersson proved in 1893 that some boulders characterized by *Isochilina canaliculata* Krause, about whose age there was some uncertainty, are to be included here.

The Lower Chasmops limestone, or Echinosphaerite limestone, is only met with in northern Öland, where it occurs along the west-coast from Persnäs, in the S., to Böda, in the N.

We have previously accounted for the various zones of the *Orthoceras limestone*, and, as the division into zones has

originally been settled for Öland, we have here only to mention that on the whole the zones run in the form of narrow bands in the lengthwise direction of the island — the youngest in the east, the older ones in their proper order farther to the west. The oldest, the Planilimbata limestone, is (just as the Ceratopyge limestone) pretty often only exposed in the cliffs that are generally formed by the western margin of the limestone suite. It is, however, worth stating that the Asaphus limestone has here a somewhat different development than is generally the case. Through a bed crowded with *Sphaeronis pomum* GYLLENH. it is divided into two parts, Upper and Lower Asaphus limestone, of which the latter one is mostly (yet by no means always) of a grey colour, whilst the Upper Asaphus limestone is generally formed by a thickly banked, reddish, rarely white, crystalline limestone. The Lower Asaphus limestone corresponds in every respect with that of the mainland — *Asaphus expansus* L. is not found in Öland, though — but nothing to correspond to the Upper Asaphus limestone is found elsewhere. The fauna of this latter is almost exclusively composed of small forms, which seem largely to be undescribed yet.

We have here also to remember the conglomerate with *Strophomena Jentzschi* GAGEL, which according to J. G. ANDERSSON is a litoral deposit equivalent to Öland's Lower Asaphus limestone. The cement in the conglomerate is a light-grey limestone, partly coarsely crystalline, partly compact, more rarely merging into a coarse-grained, glauconitic sandstone with a cement of calcite. Besides the leading fossil there have here also been found *Platystrophia biforata* SCHLOTH., *Illaenus* sp. and others. Of the embedded stones, phosphorite and phosphorite sandstone, those of the first mentioned kind bear fossils belonging to all parts of the Upper Cambrian. The description of rock just given refers in the first instance to a boulder found by J. G. ANDERSSON at Sten-

åsa, in Öland. Subsequently similar such have also been found in Gotland and Gotska Sandön. The conglomerate was first observed by GAGEL (1890) as boulders (»Geschiebe») in East-Prussia, but its age could not be determined until J. G. ANDERSSON had proved the occurence of *Str. Jentzschi* in the Lower Asaphus limestone at several places, at Hälludden, Byerums Sandvik and Horn, all of them situated in northern Öland. According to J. G. ANDERSSON (1896) it is probable that the conglomerate rests upon Lower Cambrian sandstone, whereas other Cambrian deposits must have been either denudated off or also never happened to be deposited in the middle Baltic Silurian area.

The *Ceratopyge region* is particularly well developed in Öland. We find namely here from the upper part of the region both Ceratopyge limestone and Ceratopyge shale, and of the lower part not only the litoral beds, the Obolus conglomerate, but also the deep water deposit, the Dictyograptus shale with all its subzones, of which more further on.

The *Ceratopyge limestone*, which in the southernmost occurrence at Ottenby is both well developed and easily accessible, is of a leight grey colour there; including the glauconite beds it has a thickness of something more than 1 metre. At the northernmost occurrence, from which this limestone is certainly known in Öland, viz. in the section between Köping and Borgholm, it is, on the other hand, of a reddish brown colour. — Besides the limestone there occur at Ottenby glauconite layers (glauconite limestone, shale and sand). Below these deposits come alum shales, Ceratopyge shale, in which *Shumardia pusilla* SARS, *Ceratopyge forficula* SARS and other fossils have been found. It has not been possible to draw a sharp faunistic boundary between the Ceratopyge limestone and the Ceratopyge shale.

The underlying *Dictyograptus shale* could from a point slightly S. of Ottenby be traced at or near the shore along

the west coast right up to St. Dalby (a little to the north of Kastlösa), but it must thin out there, as it is entirely absent in the sections immediately north of the spot named. Deposits coming under this heading could thereafter not be proved until north of Borgholm, where they were found at scattered points, viz. at Äleklinta, at Grönviken (SW. of Djupvikshamn) and at Horns Ness. At Äleklinta an alum shale is found whose upper, greater part is to be reckoned as Ceratopyge shale, but whose lower part bears *Dictyograptus flabelliformis* EICHW. This alum shale is sometimes underlain by a conglomerate deposited in hollows on an anthraconite (with *Agnostus pisiformis* L.), which again is separated from the strata of the Tessini zone by an alum shale and a conglomerate underlying this. At Grönviken we have exactly the same sequence of strata, except that no *Dictyograptus* is reported as having been found in the upper alum shale. But in the upper conglomerate, which quite resembles the corresponding one at Äleklinta, the graptolite mentioned is found in the cementing rock, together with a thick-shelled *Obolus* (probably *O. Apollinis*), *Olenus* sp., *A. pisiformis* L. var. *obesus* BELT and *Agnostus pisiformis* L. The conglomerate, which at Horn is subjacent to the Dictyograptus shale, rests there directly upon strata of the Tessini zone. In the cement of the conglomerate at Horn there are found, besides *Obolus Apollinis* EICHW., a mixed assortment of *Paradoxides Tessini* L., *Olenus gibbosus* WAHLENB., as well as *Agnosti.*

Finally, J. G. ANDERSSON has found in the Northern tongue of Öland boulders of a sedimentary breccia in which great, angular pieces of a limestone belonging to the zone of *Paradoxides oelandicus* SJÖGR. are cemented by a conglomerate-like stink-stone. In this latter were found *Obolus* and also (as is common in these conglomerates) *Agnostus pisiformis.* — It looks as if the stratum underlying the Obolus conglomerate were of a greater geological age the farther north we come.

d) **On the Silurian boulders at Humlenäs in Småland.**

Since Ordovician (and Cambrian) strata have been stated to rest at Humlenäs, a few words about them ought here to be said.

Literature:

1826. HISINGER, W.: Underrättelse om Lager af petrificatförande Kalksten på Humlenäs i Calmar Län m. m. (Some information about strata of fossil-bearing limestone at Humlenäs in the Kalmar Län etc.) Kgl. Vet.-Ak. Handl. för år 1825.

1878. LINNARSSON, G.: De paleozoiska lagren vid Humlenäs i Småland. (The palaeozoic strata at Humlenäs in Smoland.) Sver. Geol. Unders. Ser. C, N:o 28.

1892. DE GEER, G.. [Yttrande med anledning af E. SVEDMARKS föredrag om förekomsten af kalksten och sandsten vid Humlenäs]. (Remarks on E. SVEDMARK's lecture concerning the occurrence of limestone and sandstone at Humlenäs.) G. F. F. Bd 14.

1904. SVEDMARK, E.: Beskrifning till kartbladet Oskarshamn (Explanation to the map-sheet Oskarshamn). Sver. Geol. Unders. Ser. Ac, N:o 5.

South of Lake Hummeln, situated about 16 km. NW. of Oskarshamn, Silurian boulders have been met with piled up in such a way into a low, long and narrow ridge running SE. (i. e. in the direction of the glacial striae) that some believed that Silurian was resting there. The first to mention the occurrence was HISINGER. He was of opinion that the Orthoceras limestone, exactly like the Grey Limestone in Öland, existed here as solid rock. LINNARSSON, who stated the height of the locality above sea-level to be about 60 m., proved that also Red Limestone existed there. From here he knew of the following Silurian rocks: Limbata limestone, Asa-

phus limestone, stink-stone with *Agnostus pisiformis* L. (but no alum shale), Paradoxides shale and Lower Cambrian sandstone. He further mentions boulders of a breccia which is also found in situ in the Archaean rocks at the lake-shore (here first observed by NATHORST) and in which pieces of Archaean rocks are held together by a pretty fine gravel generated through weathering of the rock. LINNARSSON considered the Silurian still to remain as solid rock here, or at least in the neighbourhood. SVEDMARK, who in 1891 was able to prove through digging that the limestone does not remain here, mentions further in 1892 that similar boulders (both sandstones and limestones) were found more occasionally both NE. and SE. of Lake Hummeln. He says too, that no other breccia-deposit than the previously mentioned one had been met with, so that we could not obtain any support thereof for the assumption that a dislocation had occurred here, and that the solid rocks from which the boulders originate were to be sought for at the bottom of the lake.

This was, however, DE GEER's opinion, and he says that it did not appear to him as if there were any reason to abandon the opinion held till then, that the Silurian had there been protected from total erosion by means of faults. In 1904 SVEDMARK, besides his previous statements, gives a list of those strata that are represented in boulders at Humlenäs. These strata are: Lower Asaphus limestone, Limbata limestone, Planilimbata limestone, stink-stone with *Agnostus pisiformis* (obviously the same rock as accompanies the Obolus conglomerate in northern Öland), Tessini sandstone, Oelandicus shale and Lower Cambrian sandstone. Manifestly influenced by DE GEER's above rendered statement, SVEDMARK now also wants to seek the mother rock for the Silurian boulders of Humlenäs at the bottom of Lake Hummeln.

As no solid rock could be proved to exist at Humlenäs, and having certain knowledge from Öland of quite considerable

portions of Silurian having been moved a long distance in an almost continuous condition, and as Lake Hummeln is situated far to the west of the western limit of the Baltic Silurian area, I consider that the theory of the Silurian remaining at the bottom of Lake Hummeln is unjustified and incorrect.[1]

B II and B III: The Ordovician of Skåne (and corresponding deposits in other parts of Sweden).

a) The Ordovician of Skåne.

(Compare the scheme on p. 19.)

Literature:

1837, 1840. HISINGER, W.: Lethaea suecica seu Petrificata Sueciae. Supplementum primum and Supplementum secundum.

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1865. TÖRNQUIST, S. L.: Om Fågelsångstraktens Undersiluriska lager. (On the Lower Silurian strata of the Fågelsång district.)

1869. LINNARSSON, G.: Om Vestergötlands Cambriska och Siluriska aflagringar. (On the Cambrian and Silurian deposits of Västergötland.)

1871. LINNARSSON, G.: Om några försteningar från Sveriges och Norges »Primordialzon». (About some fossils from the »Primordial Zone» of Sweden and Norway.)

1874. LINNARSSON, G.: Ueber eine Reise nach Böhmen und den russischen Ostseeprovinzen. Zeitschr. d. D. geol. Gesellschaft.

[1] TORELL was also of opinion that the Silurian at Humlenäs were only boulders (carried as morainic matter from the Baltic area N. of Öland). Cfr page 113, Geol. Fören. Förh. Bd 18 (1896).

1874. LUNDGREN, B.: Om i Skåne förekommande bildningar, som motsvara Brachiopodskiffern i Vestergötland. (About some deposits occurring in Skåne and corresponding with the Brachiopod shale of Västergötland.)

1875. LINNARSSON, G.: Anteckningar från en resa i Skånes silurtrakter 1874. (Notes from a journey in the Silurian districts of Skåne in 1874.)

1875. LINNARSSON, G.: En egendomlig Trilobitfauna från Jemtland. (A peculiar Trilobite-fauna from Jämtland.) Geol. För. Förh. Bd 2.

1875. TÖRNQUIST, S. L.: Berättelse om en geologisk resa genom Skånes och Östergötlands paleozoiska trakter, sommaren 1875. (Report of a geological journey through the palaeozoic districts of Skåne and Östergötland in the summer of 1875.)

1876. TÖRNQUIST, S. L.: Nyblottad profil med Phyllograptusskiffer i Dalarne. (A newly exposed section with Phyllograptus shale in Dalarne.)

1876. LINNARSSON, G.: On the vertical range of the graptolitic types in Sweden. Geol. Mag. Dec. II, Vol. 3.

1876. NICHOLSON, H. A.: Notes on the correlation of the graptolitic deposits of Sweden with those of Britain. Geol. Mag. Dec. II, Vol. 3.

1879. LINNARSSON, G.: Iakttagelser öfver de graptolitförande skiffrarne i Skåne. (Observations on the graptolite-bearing shales in Skåne.)

1879. TÖRNQUIST, S. L.: Några iakttagelser öfver Dalarnes graptolitskiffer. (Some notes on the graptolite shales of Dalarne.)

1879. TÖRNQUIST, S. L.: Berättelse om en — — — — resa i England, Wales och Skotland. (Report of a — — — — journey in England, Wales and Scotland.)

1880. TULLBERG, S. A.: Om lagerföljden i de kambriska och siluriska aflagringarne vid Röstånga. (On the succession of strata in the Cambrian and Silurian deposits at Röstånga.)

1880. TULLBERG, S. A.: Några Didymograptus-arter i undre graptolitskiffer vid Kiviks-Esperöd. (Some Didymograptus species in Lower graptolite shales at Kiviks-Esperöd.)

1880. TULLBERG, S. A.: Tvenne nya graptolitslägten. (Two new genera of Graptolites.)

1880. LINDSTRÖM, AXEL: Beskrifning till kartbladen Kullen och Höganäs. (Explanation to the map-sheets Kullen and Höganäs.) Sver. Geol. Unders. Ser. Aa, No. 77 and 78.

1881. HOLM, G.: Bidrag till kännedomen om Skandinaviens graptoliter. I. Pterograptus, ett nytt graptolitslägte. — II. Tvenne nya slägten af familjen Dichograptidæ LAPW. (Contributions towards the knowledge of the Graptolites of Scandinavia. I. Pterograptus, a new genus of Graptolites. — II. Two new genera of the family Dichograptidae LAPW.) Öfvers. Kgl. Vet.-Ak. Förh.

1882. TULLBERG, S. A.: On the Graptolites described by Hisinger and the older Swedish authors. Bih. Kgl. Vet.-Ak. Handl.

1882, 1883. TULLBERG, S. A.: Skånes graptoliter. I och II. (The Graptolites of Skåne. I and II.)

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1885. NATHORST, A. G.: Beskrifning till kartbladet Trolleholm. (Explanation to the map-sheet Trolleholm.) Sver. Geol. Unders. Ser. Aa, No. 87.

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1889. TÖRNQUIST, S. L.: Några anmärkningar om vestra Europas kambriska och siluriska korologi. (Sundry notes on the Western-European Cambrian and Silurian chorology.)

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1892. HOLST, N. O.: Beskrifning till kartbladet Simrishamn. (Explanation to the map-sheet Simrishamn.) Sver. Geol. Unders. Ser. Aa, No. 109.

1892. MOBERG, J. C.: Om skiffern med Clonograptus tenellus, dess fauna och geologiska ålder. (On the shale with Clonograptus tenellus, its fauna and geological age.)

1892. MOBERG, J. C.: Om den af Trinucleus coscinorrhinus ANG. karakteriserade kalkens ålder. (On the age of the limestone characterized by Trinucleus coscinorrhinus ANG.).

1892. MOBERG, J. C.: Om en Hemipter från Sveriges undre graptolitskiffer. (On a Hemipter from the Lower graptolite shale of Sweden.)

1892. MOBERG, J. C.: Om några nya graptoliter från Skånes undre graptolitskiffer. (On some new Graptolites from the Lower graptolite shale of Skåne).

1895. MOBERG, J. C.: Beskrifning till kartbladet Sandhammaren. (Explanation to the map-sheet Sandhammaren.) Sver. Geol. Unders. Ser. Aa, No. 110.

1895. HOLM, G.: Om Didymograptus, Tetragraptus och Phyllograptus. Sver. Geol. Unders. Ser. C, No. 150.

1896. MOBERG, J. C.: Geologisk vägvisare inom Fogelsångstrakten. (A geological guide into the Fågelsång district.)

1897. ANDERSSON, J. G.: Om fosforitbildning och fosforitförande sediment. (On phosphorite deposit and phosphoritic sediments.)

1898. MOBERG, J. C.: En trilobit från Skånes Dictyograptusskiffer. (A trilobite from the Dictyograptus shale of Skåne.)

1900. MOBERG, J. C.: Nya bidrag till utredning af frågan om gränsen mellan undersilur och kambrium. (Fresh contributions towards solving the problem of the boundary between Ordovician and Cambrian.)

1900. (NILSSON-)WESTERGÅRD, A. H. och TELLANDER, A.: Geologiska åldern af skiffern med Clonograptus cfr flexilis HALL vid Fogelsång. (The geological age of the shales with Clonograptus cfr flexilis HALL at Fågelsång).

1901. MOBERG, J. C.: Pterograptus scanicus n. sp.

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1903. WIMAN, C.: »Ueber Robergia microphthalmus LNS. und Triarthrus jemtlandicus LNS.» and »Ein neuer Trilobit im Dictyonemaschiefer». (Palaeontologische Notizen, No. 3 and 5.) Bull. Geol. Inst. Upsala. No. 11, Vol. VI. 1902—1903.

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1907. Moberg, J. C.: Ett par bidrag till kännedom om Skånes dicellograptusskiffer. (A few contributions towards the knowledge of the Scanian Dicellograptus shale.)

1908. Nörregaard, E. M.: Nogle Bemærkninger om Orthoceratitkalkens petrografi. (Sundry remarks on the petrography of the Orthoceratite limestone.) Meddel. fra Dansk Geol. Foren. Bd 3.

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1910. Moberg, J. C.: Guide for the principal Silurian districts of Skåne (with notes on some localities of Mesozoic beds).

As we have previously indicated, it is characteristic of the Scanian Ordovician that graptolite-bearing shales predominate, although trilobite-bearing shales and limestones are by no means rare in certain horizons or in certain parts of the province. Strata built up of eruptive material so common in the Ordovician of England seem to be totally missing here, whereas traversing diabase dikes are very common. The Silurian of Skåne forms altogether a belt 15 to 20 km. wide, which from the south-eastern corner of the province stretches about for 100 km. towards NW., where the Mesozoic beds begin, whereafter

the Silurian is not again exposed until at Kullaberg in the north-westernmost part of the province. The Ordovician beds occupy quite a small part of this Silurian area, but is yet found represented at several places within its different parts, both in the extreme NW. and in the extreme SW. and in between. Apart from the small occurrence at Kullaberg (Nyhamn), where only a few strata of the Ordovician are exposed, one can observe a certain dissimilarity in the development of the Ordovician in the south-eastern occurrences and of those that are situated closer to the north-western end of the Silurian band, or the one we want to call the western part. In the eastern area beds coming under this heading are known of at Jerrestad and Tommarp, in the country east of Hoby—Hammenhög—Smedstorp, between Borrby and Hannas, at Löderup, in the district between Bollerup and Tosterup, in Kvärrestad, from Flagabro up towards Andrarum, as well as east of Andrarum, besides which such are to be found at Kiviks-Esperöd (N. of Stenshufvud Mountain), where there occurs a small party isolated from the remaining Silurian. In the western district we include the Fågelsång and Röstånga areas, as well as that of Räfvatofta (situated SW. of the latter), from where however only so called Orthis shale is known. The difference between the two areas we thus distinguish, consists mainly in the fact that in the eastern part trilobite-bearing horizons a little more often interstratify the graptolite-bearing shales, or also that the formation of the former horizons continued for a longer period, so that the gaps, which owing to the depositing of the trilobite-bearing beds must enter into the succession of the graptolite zones, become greater the further in the NW. we get. If we compare, for example, the succession of strata at Jerrestad, in eastern Skåne, with Fågelsång, in western Skåne (see MOBERG 1910, »Geological guide through the valley Jerrestad—Tommarp»), we find that the Lower Didymograptus beds are only feebly developed at Fågelsång, but, on the other

hand, well at Jerrestad; the Upper Didymograptus shale and the Lower Dicellograptus shale, again, which are both well developed at Fågelsång, are absent at Jerrestad; the lowest part of the *Middle Dicellograptus shale* is at Jerrestad (normally) developed as the zone of *Dicranograptus Clingani* CARR. (such is also the case further to the SE. on the island of Bornholm), whilst at Fågelsång it is characterized by *Climacograptus rugosus* TULLB., whereas the uppermost part of the beds, the zone of *Pleurograptus linearis* CARR., has only been met with at Jerrestad.

Apart from such differences as must be considered to be due in one respect or another to a different development, there are other, so to say, secondary ones. As by no means every zone is to be found in every area, but, on the contrary, at some places one, at others another is absent, this may only be due to the circumstance that in the Scanian plain thick Quaternary deposits pretty often, conceal one or another part of them, or also, and rather often to tectonic causes. In the Scanian Silurian plications are certainly rare, as compared with that in the Moffat district of Scotland, for example, but slight faults are all the more common, through which one or another part of the strata, which upon the whole are quite level, may exceptionally happen to be concealed. I said exceptionally, because the downthrow (or upthrow) on the step faults is generally inconsiderable, and the different parts are as a rule depressed like a flight of stairs, so that yet on the abraded surface the zones often enough succeed each other in regular order.

As will be seen from our general table, the sequence of the graptolite zones is normal, everywhere the same as in other countries; a single exception (whether seeming or real, I do not venture to say) exists, though. In England the zone of *Dicellograptus anceps* NICH. forms the highest part of the Ordovician. Here, on the other hand, *D. anceps* appears to

be at home in a lower horizon than the zone of *Dicellograptus complanatus* LAPW., which is also known from England.

As has already been pointed out previously, we have nowhere a sequence of strata with a pure graptolite facies all through the Ordovician; sometimes here, sometimes there intercalated zones with a trilobite facies are met with. As an illustrative example of the succession of strata in separate districts of the Scanian Ordovician, the following three local tables may here be given.

The Fågelsång area (West-Skåne).	**Röstånga (West-Skåne).**
	Zone of *Phacops eucentra* ANG.
Zone of *Staurocephalus clavifrons* ANG.	Zone of *Staurocephalus clavifrons* ANG. and *Dicellogr. complanatus* LAPW.
	Zone of *Ampyx Portlocki* BARR.[1]
Zone of *Calymmene dilatata* TULLB. (= the *Orthis* shale) and *Climacogr. rugosus* TULLB.	Zone of *Calymmene dilatata* TULLB. and *Climacogr. rugosus* TULLB.
» *Nemagr. gracilis* HALL	
» *Diplogr. putillus* HALL	
» » *Linnarssoni* TULLB.	Lower Dicellograptus shale (scarcely accessible).
» *Glossogr. Hincksi* NICH.	
» *Didymogr. geminus* HIS.	Zone of *Didymogr. geminus* HIS. (hardly accessible).
» *Phyllogr. typus* HALL	
Orthoceras limestone (in the upper part containing *Trinucleus coscinorrhinus* ANG.)	Orthoceras limestone (hardly accessible).

To be continued.

[1] In my »Geological guide through the valley Jerrestad-Tommarp», on page 88, I have, when comparing the Silurian of East- with that of West-Skåne, by mistake given the zone of *Ampyx Portlocki* for Fågelsång too. The last mentioned species is certainly also found there, viz. together with *Staurocephalus clavifrons* ANG., but it would be more correct not to enumerate any separate »zone of *Ampyx Portlocki*» for Fågelsång, as has been done in my paper »Geological guide into the Silurian area of the Fogelsång district», published at the same time [compare also the foot-note to page 117 in my »Geological guide to Röstånga (with Lake Odensjön) and Skäralid»].

The Fågelsång area (continued)	**Röstånga** (continued)
Lower Didymograptus shale (feebly developed).	(No lower strata visible).
Zone of *Apatocephalus* (Ceratopyge limestone).	
Zone of *Shumardia* (Ceratopyge shale).	
Dictyograptus shale: Subzone of *Bryogr. Kjerulfi* Lapw.	
» *Clonogr. tenellus* Linrs.	
» *Dictyogr. flabelliformis* Eichw. and *Hysterolenus Törnquisti* Mbg.	

Jerrestad—Tommarp (East-Skåne.)

Zone of *Phacops eucentra* Ang.
» *Ampyx Portlocki* Barr.
» *Pleurogr. linearis* Carr.
» *Dicranogr. Clingani* Carr.
» *Trinucleus coscinorrhinus* Ang.
Orthoceras limestone
Lower Didymograptus shale: Zone of *Isogr. gibberulus* Nich.; » *Phyllogr. angustifolius* Hall.; » *Didymogr. balticus* Tullb.
Ceratopyge limestone (feebly developed).
Ceratiocaris shale (= Ceratopyge shale).
Dictyograptus shale: Zone of *Bryogr. Kjerulfi* Lapw.; » *Clonogr. tenellus* Linrs.; » *Dictyogr. flabelliformis* Eichw.

Before we are going further in our account it might be advisable to give a short review of the course of development of our knowledge of the Ordovician of Skåne, especially with regard to the systematical arrangement of the graptolite-bearing shales.

Hisinger, who as early as 1837 described a graptolite, *Diplograptus pristis* from Draggå River in Dalarne, in 1840 also described some graptolites from Fågelsång, viz. *Diplogr. teretiusculus* and *Didymogr. geminus*. There could of course at that time not be any question as regards their place in the system. A real system for Sweden's Silurian we did not namely receive, as is well known, until 1854 by Angelin, whose table, however, does not take any regard to the graptolites, a class of animals that was then but little known. An-

GELIN mentions from his Regio Olenorum the occurrence of *Dictyograptus flabelliformis,* for which he even wants to establish a new genus, *Phyllograpta.* When talking about the fauna in his Regio Conocorypharum he says very peculiarly: »Inter Zoophyta non nisi Graptolithi et quidem rarissime occurrunt». This statement might easily be interpreted that, if graptolites possibly occurred, they must in that case be rare. As he knew *Dictyograptus* from his regio Olenorum, he could have surmised the occurrence of graptolites even in his Regio Conocorypharum, which he (erroneously) supposed to be the younger. In Regio Trinucleorum graptolites are said to occur in great masses at some places. Even from Regio Asaphorum and Regio Encrinurorum the occurrence of rare or very rare graptolites is stated.

In 1865 TÖRNQUIST gave an account of his researches into the Silurian of the Fågelsång area. The chief value of this publication lies in the local descriptions given therein.

In 1869 LINNARSSON determined the position and extent of the »Lower graptolite shales» (= Lower Didymograptus shale, now to day) for the province of Västergötland. The Fågelsång strata mentioned by TÖRNQUIST, which LINNARSSON supposed to come under this heading, belong of a certainty to the upper part of the Dictyograptus shales. LINNARSSON in 1871 described *Clonograptus (Dichograptus) tenellus* from Hunneberg, which fossil he stated to belong to the Olenus beds. The Dictograptus shale, to which the fossil actually belongs, had namely at that time not yet been separated from the former. This happened namely first in 1875, in LINNARSSON's account of his first Scanian excursion. The denomination »Middle graptolite shale» (= the Middle and Lower Dicellograptus shale, as well as the Geminus shale, according to our terminology) he had introduced already in 1874.

In his said work of 1875 LINNARSSON made a lot of important contributions towards the Silurian geology of Skåne

In the Fågelsång area he distinguished, besides a greenish-grey shale with *Lichas laxatus* M'Coy, which is by him included in the Chasmops limestone, also a black, thick-leaved shale with *Orthis argentea* His. (commonly called Orthis shale), which he hesitatingly wants to class with the Trinucleus shale, furthermore »the Middle graptolite shale», which was also quoted from Jämtland, and finally the zone of *Phyllograptus typus,* which he wants to include in the »Lower graptolite shale», if it is perhaps not merely an interstratification in the Orthoceras limestone. From Nyhamn Brachiopod shale is mentioned (from here, from Röstånga and from Jerrestad, however, previously mentioned by Lundgren in 1874), from Tosterup Dictyograptus shale and »Middle graptolite shale» and finally from Jerrestad-Tommarp Dictyograptus shale, Ceratopyge limestone, »Lower graptolite shale», Chasmops beds and Brachiopod shale. In another treatise of the same year Linnarsson described a peculiar trilobite fauna from the »Middle graptolite shale» of Jämtland, amongst which we notice especially *Robergia (Remopleurides) microphthalma,* which is afterwards also found in the Lower Dicellograptus shale of Skåne.

Törnquist also in 1875 accounted for his continued researches into the geology of Skåne. He proposes the denominations »*Dicranograptus shale*» for the Middle graptolite shale, and »*Phyllograptus shale*» for the Lower graptolite shale.[1] And for the first time it is held forth here how »we had far too much enrolled the formation of the shales into periods between the times for limestone deposits», and he says that »limestone strata and graptolite shales form two, not only petrographically, but also palaeontologically, separate parallel

[1] Without being aware of this proposal of Törnquist's, Linnarsson, too, in 1876 proposed the same appellations, but soon changed his mind (1879) on account of the extent of his and Törnquist's zones of the same names not being the same. Törnquist included namely the zone of *Phyllograptus typus* in the lower division, the Phyllograptus shale, whilst Linnarsson wanted to include it in the upper, the Dicranograptus shale.

series of beds», thoughts which not until very much later came into their full right in our geological table. He proves that shale with *Phyllograptus typus* is at one spot in Fågelsång found above the Orthoceras limestone, which thus forms a layer in the Phyllograptus shale; he considers however that the Orthoceras limestone of Dalarne corresponds in its entirety to the Phyllograptus shale and the dark Orthoceras limestone of Skåne together; the Dicranograptus shale, again, corresponds not to the Cystidean limestone only, but is presumably also equivalent in its upper part to a greater or lesser part of the Trinucleus shale of Dalarne.

In 1879 NICHOLSON (with the support of LINNARSSON's survey of the vertical distribution of the graptolite-types in Sweden, issued at the same time) set up 5 graptolite zones for Sweden, viz. the *Dictyograptus shale* = Tremadoc, the *Lower graptolite shale* = Skiddaw, the *Middle graptolite shale* = the Lower part of the Moffat series, the *Upper graptolite shale* = the Upper part of the Moffat series or Coniston mudstone, and the *Upper Silurian* = Coniston flags or True Upper Silurian. His Upper graptolite shale would therefore only correspond to our Rastrites shale. Although NICHOLSON's table thus pretty well coincides with our present conception, it very likely exercised no real influence upon the development of our table, though. The testimony he bears to the reciprocity that took place between the graptolite researches of England and Sweden is, however, of interest. NICHOLSON says namely: »In the first place, D:r LINNARSSON has shown (what British palaeontologists have long been trying to prove) that certain species and genera of Graptolites are restricted to certain very definite horizons. He has thus added fresh force to the opinion (which some have regarded as exceedingly doubtful) that the graptolites may be safely relied upon as guides in stratigraphical arrangement, their value in this respect being at least equal to that of the Trilobites».

In 1879 LINNARSSON reported upon his continued researches into the graptolite shales of Skåne. The »Middle graptolite shale» is said to have been found at Nyhamn.[1] Besides the statement of some new localities for the »Lower graptolite shale» (Tosterup, Jerrestad and Gislöfshammar) a minute account of the »Middle graptolite shale» at Fågelsång is here given, so that we have the following series of strata in descending order:

η.	Zone of	*Orthis argentea* HIS.
ζ.	»	*Dicranogr. Clingani* CARR.
ε.	»	*Climacogr. Scharenbergi* LAPW.
δ.	»	*Diplogr.* cfr *mucronatus* HALL
γ.	»	*Glossogr. Hincksi* HOPK.
β.	»	*Didymogr. geminus* HIS.
α.	»	*Phyllogr. typus* HALL.

As the direct superstratum to the zone of *Orthis argentea* had nowhere been visible, it was impossible to quite exactly define the age of the zone, or to decide whether it belongs to the Trinucleus beds or to the Chasmops beds. (At Jerrestad and Tosterup no Orthis shale is to be found between the Trinucleus shale and the Dicranograptus shale.) Otherwise LINNARSSON agrees with TÖRNQUIST's opinion, that his (LINNARSSON's) »Middle Graptolite shale» is equal to the Orthoceras limestone and the Chasmops limestone of other districts, and possibly also to the Trinucleus shale.

Apart from the zone of *Nemagraptus gracilis* HALL[2] that was not discovered until later (by TULLBERG), and whose

[1] In the Explanation to the map-sheets Kullen and Höganäs no Middle graptolite shale is mentioned amongst the Silurian strata found at Nyhamn. But in »Skånes graptoliter. I» TULLBERG mentions that a shale belonging to the middle part of the Geminus shale is to be found there.

[2] The leading fossil itself had, however, by TÖRNQUIST already in 1865 been mentioned and reproduced from Fågelsång under the name of *Dendrograptus gracilis* HALL, yet the locality then stated does not appear to be absolutely certain.

place is between the zones ε and ζ, LINNARSSON's table coincides well with that we have given on page 124; the difference is merelely formal, as partly the name of the zone of *Climacograptus Scharenbergi* has been exchanged for the appellation »zone of *Diplogr. putillus* HALL», which latter species has a scantier vertical distribution, and partly the species mentioned by LINNARSSON as *Diplogr.* cfr *mucronatus* HALL was afterwards by TULLBERG called *Gymnograptus (Diplogr.) Linnarssoni.*

In 1880 TULLBERG described the succession of strata at **Röstånga**. The table given at that time may here be cited as far as it concerns the Ordovician.

Brachiopod shale:	Lower Birkhill?
Gray shale with *Phacops mucronata.*	
Trinucleus shale:	Upper Birkhill.
Loose, greyish-green shales with bands of black graptolite shale.	
d) with *Staurocephalus clavifrons, Phacops mucronata* etc.	= Zone of *Dicellogr. acuminatus*
c) with *Dicellogr. complanatus, Trinucleus Wahlenbergi,* »*Niobe lata* ANG.» etc.	
b) with *Diplogr. truncatus, D. quadrimucronatus, D. foliaceus.*	Lower Hartfell. = Zone of *Pleurogr. linearis.*
a) with *Trinucleus* and *Ampyx.*	
Chasmops-limestone:	
Alternating bands of grey shale and limestone, lowest graptolite-bearing.	
c) with *Ampyx rostratus, Beyrichia costata, Orthis argentea* etc.	

(To be continued.)

(continued.)	
b) grey shales with thin bands of limestone.	
a) with *Climacogr. tubulifer us, Diplogr. foliaceus, Orthis argentea* etc.	= Zone of *Pleurogr. linearis.*
Middle graptolite shale:	
Black shales.	
(The highest zone) with *Dicranogr. Clingani, Dicellogr. Forchhammeri, Climacogr. bicornis* etc.	= Zone of *Dicranogr. Clingani.*

In 1882 TULLBERG, as an introduction to his description of the Graptolites of Skåne, published a synopsis of the sequence of strata in the Scanian Silurian in general. It might be appropriate to anticipate and make a few remarks concerning the table given there.

In the same way as in the above quoted table from Röstånga TULLBERG here introduces amongst other zones even some that he sets up merely on account of dissimilarity of colour or some other petrographical habitus, or only on account of the absence of determinable or characteristic fossils. This is manifestly done with the intention of afterwards, without disturbing the numbering of the zones, if so would be desired, being able to supplement the table, which TULLBERG really also did at several passages in the revised summary published in the following year.

It must also be remembered that just that part of the table belonging to the Ordovician presented greater difficulties than its other parts. The Gotlandian of Skåne has namely, as far as the graptolite-bearing shales are concerned, such a great likeness to that of Scotland, that LAPWORTH's table of the latter may very well be applied also to our shales. And as regards the Cambrian of Skåne, NATHORST and LINNARSSON had in every essential point settled a minute

table. But the matter was quite different with the Ordovician of Skåne. LINNARSSON had certainly accounted for the succession of strata in what he called the »Middle graptolite shale», but there was no detailed coherent table for the whole series. Moreover, the dissimilarity in facies existing in the graptolite-bearing shales in different parts of the province was as yet unobserved, nor were we quite aware of the difference presented by the trilobite-bearing layers intercalated here and there, not only in relation to those of the rest of Sweden contemporaneous with them, but also amongst themselves. If we add to this that the small dislocations and subsidences that are the rule in the Scanian Silurian are to a great extent hampering in the unravelling of stratigraphical problems, it will easily be seen that a general table applicable to the whole of Skåne could not possibly be given at that time, just as such a one can hardly be said to be fully assured in every detail even at the present time. TULLBERG's table may also be looked upon merely as a first attempt at giving a total view of the Silurian of Skåne; at all events, as such has been of great importance. Through its very mistakes it stimulated to attaining a clearer insight into the subject.

That the table was only preliminary is also shown by TULLBERG himself in the summary in the German language, issued in the following year, making not so few alterations and additions, a circumstance that may easily be overlooked by the Swedish reader. In the following we shall render the table in the form it obtained in *1883*.

Trusting that with these introductory remarks we have in some measure contributed towards a better comprehension of the conditions under which the table came into being, and which must be taken into account when judging it we render here:

TULLBERG'S table of the Ordovician of Skåne.

Upper Stage

a) Zone of *Climacogr. scalaris* L.
b) » *Phacops mucronata* BRONGN.
c) » *Staurocephalus clavifrons* ANG.
d) Marl shale without fossils
e) Zone of *Niobe lata* ANG. and *Dicellogr. complanatus* LAPW.
f) » *Diplogr. pristis* HIS.
g) » *Diplogr. 4-mucronatus* HALL
h) » Olive-brown, greyish-green shales with *Trinucleus* sp.
i) » *Calymmene dilatata* TULLB. (= LINNARSSON'S *Orthis* shale).
k) » Grey and black shales without fossils.

Middle Stage (»The middle graptolite shales»)

a) Zone of *Climacogr. rugosus* TULLB.
*b) » » *styloideus* LAPW.
*c) Black shales without fossils
d) Zone of *Trinucleus coscinorrhinus* ANG.
e) » *Dicranogr. Clingani* CARR. (α, β and γ)
*f) » *Climacogr. Vasae* TULLB.
*g) Shales without fossils (α and β)
h) Zone of *Coenogr. gracilis* HALL
i) A thin band of phosphorite
k) Zone of *Diplogr. putillus* HALL
l) » *Glossograptus* sp.
m) » *Gymnogr. Linnarssoni* TULLB.
n) » *Glossogr.* cfr *Hincksi* HOPK.
o) » *Didymogr. geminus* HIS.
  - α with *Diplogr. perexcavatus* LAPW. and *Lonchogr. ovatus* TULLB.
  - β with *Pterogr. elegans* HOLM
  - γ with *Didymogr. bifidus* HALL and *Climacogr. confertus* LAPW.

Lower Stage
- a) Zone of *Phyllogr.* cfr *typus* HALL
- b) *Orthoceras* limestone
  - α: The black Fågelsång limestone with *Megalaspis limbata* S. et B.
  - β: The grey limestone of Eastern Skåne with *Meg. planilimbata* ANG.
- c) *Tetragraptus* shale (»Lower graptolite shale»).
- d) *Ceratopyge* limestone.

The four zones marked * are met with only in the Island of Bornholm (Denmark). The Dictyograptus shale, which in TULLBERG's table is included in the Cambrian, or as TULLBERG wrote, the Primordial Silurian, is there divided up into two sub-zones, an upper of *Bryogr. Kjerulfi* LAPW. and a lower of *Dictyogr. flabelliformis* EICHW.

In the particularly well written, critical account of all the literature on the Silurian of Sweden published by REMELÉ in 1883, he amalgamates the zones *l*, *m* and *n* in TULLBERG's preceding table into a single zone, which he calls the »Glossograptus zone». REMELÉ remarks that the lowest of TULLBERG's zones just mentioned is equivalent to LINNARSSON's »zone of *Glossogr. Hincksi*», a denomination that TULLBERG wanted to avoid on account of LAPWORTH's doubts of the identity between the Swedish and the English species.

The Explanation to the map-sheet Trolleholm (1885) gives with regard to the Silurian on the whole scarcely more than an account of TULLBERG's researches. Yet the occurrence of *Orthis shale* at Räfvatofta is mentioned here, as well as some interesting results from a boring made from the bottom of a shaft in Stabbarp coal-mine, which is situated practically half way between Röstånga and Fågelsång. Silurian beds were found there at a depth of nearly 57 m., Chasmops beds between 86 and 92 m., and shale belonging to the zone of *Phyllogr. typus*

at a depth of 102 m., all reckoned from the surface of the soil.

The account of this is interesting, as it shows that the so called »Middle graptolite shale», which according to TULLBERG should be 130 to 133[1] m., is here only about 10 m. thick. In this connection it may be mentioned that TULLBERG's statements as to the thickness of the series of strata are generally exaggerated; the existence of faults has namely apparently been completely overlooked when calculating the thicknesses.

The Explanation to the map-sheet Lund, published in 1887, is also chiefly based upon TULLBERG's works; it is only remarkable that on account of a misconception some erroneous statements have crept in, such as for example, that the sub-zone of *Clonograptus tenellus* has been put down as »Tetragraptus bed», and that *Dictyograptus* should occur together with *Olenus*.

In his interesting paper on the Cambrian and Silurian Chorology of Western Europe TÖRNQUIST, amongst other things, gives a review of the faunistic and bathymetrical conditions existing during the various phases of the Silurian period in different parts of our country too. A recapitulation of the contents is outside the scope of our present work. Here will be mentioned only such statements as are more remarkable from a stratigraphical point of view. For the Ordovician graptolite-bearing shales, that come above the Ceratopyge limestone, he proposes the following table, deviating somewhat from that of TULLBERG's:

TULLBERG (1882—1883).		TÖRNQUIST (1889).	
Upper stage, the zones	*a* — *c.*	Brachiopod shale.	
	d — *h.*	Upper	Dicellograptus shale.
	i — *k.*	Middle	
Middle stage, » »	*a* — *g.*		

[1] In the Explanation to the said map-sheet this figure is erroneously given as 33.

Middle stage, the zones *h* — *o*.	Lower Dicellograptus shale.
Lower stage.	Phyllograptus shale.

As will be seen from the table, TÖRNQUIST reckoned the zone of *Phyllograptus* cfr *typus* as an upper bed of the Phyllograptus shale, in which then the *Scanian* Orthoceras limestone is interstratified. (With regard to the Orthoceras limestone in other parts of Sweden he says that the physical conditions, that cause the change of colour, also exercised their influence upon the fauna.) The part of his »Lower Dicellograptus shale» which is above the Geminus shale together with the »Middle Dicellograptus shale» are looked upon as equivalent to the Chasmops limestone of other districts, with the Macrourus limestone of which again is to parallelize the Bryozoan marl of Dalarne. About the »Upper Dicellograptus shale» it is said that it distinguishes itself from the lower parts of the same division by trilobites appearing in it at various levels in greater profusion as to species and individuals, whereby these upper beds approach those of the same age of the rest of Sweden, which, besides the prevailing trilobites, bear also graptolites.

In 1892 MOBERG showed that the shale with *Clonograptus* (*Dichograptus*) *tenellus* LINRS. at Hunneberg does not belong to the Olenid shale, but to the *Dictyograptus* shale, and in another treatise of the same year he showed that TULLBERG's zone of *Trinucleus coscinorrhinus* ANG. does not, as TULLBERG had stated, lie above the zone of *Dicranogr. Clingani*, but has its place immediately above the Orthoceras limestone, a correction which is of importance for interpreting the relation between TULLBERG's zone of *Climacograptus rugosus* and the zone of *Dicranogr. Clingani*. Even for the conception of the Fågelsång Orthoceras limestone the correction is of interest. ANGELIN's statement that *Tr. coscinorrhinus* also occurs in the last mentioned strata, TULLBERG had considered himself obliged to doubt, as that could, of course, not fit in with

the high position in the series of strata he (TULLBERG) had claimed for his zone of *Trinucleus coscinorrhinus*.

In the same year MOBERG described some new graptolites from a zone that proved to be the youngest, and until then unobserved, part of our »Lower Didymograptus shale».

HOLM, in 1895, described some graptolites from the Lower Asaphus limestone in Öland. As also *Isogr. gibberulus* NICH., which characterizes the highest part of the Lower Didymograptus shale, occurs amongst them, the Lower Asaphus limestone is therefore to be parallelized with the last shale named.

In 1896 MOBERG in »Geologisk vägvisare inom Fogelsångstrakten» vindicates his opinion that TULLBERG's zone of *Climacogr. rugosus* and the zone of *Dicranogr. Clingani* are to be looked upon as one and the same zone, only slightly differently developed in various localities. He states namely that the former is exclusively found in West-Skåne, the latter just as exclusively in South-eastern Skåne, furthermore, that two of the three zones, which according to TULLBERG should have their place between the two zones in question, are never found in Sweden, but only in Bornholm, whilst the third, the zone of *Trinucleus coscinorrhinus*, had already been proved to underlie the zone of *Dicranogr. Clingani*, and finally that the faunas are also on the whole identical. — Here (p. 20, note 1) doubts are also expressed as to the authority for separating the zone of *Phyllogr. typus* from the Geminus shale. — In the same work the appellation »Shumardia zone» is proposed for some beds found below the Ceratopyge limestone at Fågelsång and which were later on proved to directly overlie the Bryograptus shale.

In 1898 MOBERG described a trilobite *Hysterolenus Törnquisti*, which he had found in the lower part of the Dictyograptus shale at Sandby, a discovery which, besides some observations made in Öland, later on (in 1900) induced him to

make the statement that the Dictyograptus shale is to be looked upon as belonging to the Ordovician (the Ceratopyge region).

In the last mentioned year WESTERGÅRD and TELLANDER showed that beds at Fågelsång characterized by *Clonogr.* cfr *flexilis,* which TULLBERG in 1883 had mentioned as belonging to the upper part of his sub-zone of *Dictyograptus flabelliformis,* but which in the Explanation to the map-sheet Lund (and on this account also in MOBERG's »Geologisk vägvisare inom Fogelsångstrakten») was reckoned amongst the Tetragraptus shale, really occupy the position stated by TULLBERG, but yet form a zone or sub-zone of their own between the Bryograptus shale and the Dictyograptus shale proper, or the sub-zone of *D. flabelliformis* f. typica.

In 1901 STRANDMARK found at a few places along the Fågelsång rivulet beds belonging to the Lower Didymograptus shale. Of them the beds of *Phyllogr. cor* STRANDMARK are of especial interest, partly by reason of the peculiar fossil mentioned, but partly also on account of their appearing to be interstratified in the Orthoceras limestone, from which again the above named partial correlation between the Orthoceras limestone and the Lower Didymograptus shale becomes manifest.

In the same year TÖRNQUIST exchanges his earlier denomination of Phyllograptus shale for the name »Phyllo-Tetragraptus shale», and divides the latter up into five zones, of which the highest, the zone of *Phyllogr.* cfr *typus,* by a gap filled by the Orthoceras limestone, is separated from the lower zones of the division, which are, in a descending order, zone of *Isogr. gibberulus,* zone of *Phyllograptus densus* TÖRNQU. (= *Ph. angustifolius* HALL), zone of *Didymogr. balticus* TULLB. and zone of *Tetragraptus phyllograptoides* LINRS.

In 1902 MOBERG adopts TÖRNQUIST's zones now mentioned, but considers the name Phyllo-Tetragraptus shale unsuitable. He proposes instead the name »Didymograptus shale»

as embracing the Geminus shale, the zone of *Phyllogr. typus* and the Lower graptolite shale (to the extent which LINNARSSON gave to this term). The Geminus shale and the zone of *Phyllogr. typus* then became the »Upper Didymograptus shale», the remainder the »Lower Didymograptus shale», a proposition which TÖRNQUIST also afterwards (1906) adopted.

As the preceding summary shows, it was during the twenty years immediately succeeding the publication of TULLBERG's table that chiefly the lower part of the Scanian Ordovician, built up of graptolite-bearing shales with their interstratified limestone bands, were gradually revised. The Brachiopod shale is here really feebly developed, and therefore hardly inductive to a closer study. As we remember, TULLBERG mentions as the highest stratum of the Ordovician a zone of *Climacogr. scalaris*. Already in the Explanation to the map-sheet Simrishamn, I pointed out that at least one of the few localities, at which the »zone» was stated to occur, a *Monogr.* cfr *tenuis* PORTL. was found, wherefore these beds must be included in the Gotlandian; and quite lately (1910) in »Geological guide to Röstånga etc.» I have concerning another of the stated localities mentioned how the beds W. of the road towards Ask probably represent the zones of *Diplogr. acuminatus* and *Diplogr. vesiculosus* NICH. and consequently belong to the Gotlandian. There is therefore probably no actual reasons for the retention of TULLBERG's said zone.

The next youngest deposits, corresponding to the Trinucleus shale and the Chasmops limestone in Västergötland received no revision until in 1906 by OLIN. In some deposits coming under this heading and found in four different areas, Jerrestad-Tommarp, Tosterup-Bollerup, Fågelsång and Röstånga-Räfvatofta, the rock in the upper part consists chiefly of loose, greyish-green shale, generally deficient in fossils, with subordinate interstratifications of partly limestones, partly darker graptolite-bearing shales, in the

lower part again of dark shales, generally highly graptolite-bearing, with banks of hard siliceous limestone.

According to OLIN the table for this part of the Ordovician sequence of strata is as follows:

	Trilobite facies	Graptolite facies
Trinucleus beds	Zone of *Staurocephalus clavifrons* ANG. and *Phacops eucentra* ANG. Zone of *Ampyx Portlocki* BARR. and *Asaphus ingens* BARR.	Zone of *Dicellogr. complanatus* LAPW.
Chasmops beds	Zone of *Ampyx rostratus* SARS and *Calymmene dilatata* TULLB.	Zone of *Pleurogr. linearis* CARR. Zone of *Dicranogr. Clingani* CARR. or of *Climacogr. rugosus* TULLB.

Before we proceed to a comparison between OLIN's and TULLBERG's tables it ought, perhaps, be stated that *Phacops mucronata* BRONGN. and *Niobe lata* ANG. of the latter are, according to OLIN, to be called *Ph. eucentra* ANG. and *Asaphus ingens* BARR. respectively. Apart from this we find, however, that the difference between the two tables is pretty great. Besides such zones as TULLBERG established, mostly on account of the dissimilarity of the rocks, the zone of *Diplogr. pristis* and the zone of *Diplogr. quadrimucronatus* are now also discarded; the former because of *Diplogr. pristis*, which really seems to be rather rare in Skåne, having been found at Röstånga at several horizons both in the Chasmops beds and in the Trinucleus beds, the latter, again, because *Diplogr. 4-mucronatus* both in the Fågelsång area and at Jerrestad has been found in layers belonging to the zone of *Dicranogr. Clingani*, wherefore it can not be set up as a leading fossil for

a zone of its own. A novelty in the table given by OLIN is the zone of *Pleurogr. linearis*. This last zone, long known from England, was found in Sweden first by OLIN, who discovered it at two places at Jerrestad, where it overlies the zone of *Dicranogr. Clingani* and forms the highest part of the Chasmops beds.

At Jerrestad, Tommarp and Röstånga the boundary stratum between the Trinucleus beds and Chasmops beds is formed by a shale crowded with iron pyrites (partly in big lumps). The Trinucleus shale has a particularly rich trilobite fauna. OLIN enumerates 43 species, 13 of which are also met with in the Silurian of Bohemia, with which country it has even such a singular type as the genus *Areia* in common. Among the graptolites found in the Scanian Trinucleus beds *Diplogr. truncatus* LAPW. is especially remarkable, because it appears to occur everywhere plentifully in the lowest part of the Trinucleus beds, where it seems to be especially common in a horizon between the zone of *Pleurogr. linearis* and the zone of *Dicellogr. complanatus*.

The Chasmops beds, in whose upper part we find the hard Orthis shale as local interstratifications, have a trilobite fauna much more deficient in species than the Trinucleus beds. Amongst 14 species occurring in the Chasmops beds and mentioned by OLIN, the following only may be mentioned: *Phacops macrourus* SJÖGR., *Chirurus insignis* BEYR., *Lichas laxatus* M'COY, *L. quadrispinus* ANG., *Remopleurides 6-lineatus* ANG., *R. latus* OLIN, *Calymmene dilatata* TULLB., *Ptychopyge glabrata* ANG. and *Ampyx rostratus* SARS. The lowest part of the Chasmops beds is formed by the zone of *Dicranogr. Clingani*, which has plenty of fossils. OLIN alleges to have found a specimen of *Dicranogr. Clingani* in the zone of *Climacogr. rugosus* at Fågelsång, which further confirms the equivalence of the two zones.

From a systematic point of view OLIN's discovery of

Robergia microphthalma LINRS. in the Lower Dicellograptus shale at Röstånga is also remarkable. This species, which in 1875 was first described by LINNARSSON from the »Middle graptolite shale» of Jämtland under the generic name of *Remopleurides*, is in 1903 again mentioned by WIMAN, who also found *Oggiocaris dilatata* together with it. As the Oggiocaris shale, in which also *Illaenus centaurus* ANG. has been found, is in other districts (at least partly) replaced by the Centaurus limestone, we cannot avoid including the Lower Dicellograptus shale in the Asaphus region. At all events, it is more closely related to the Geminus shale than to the zone of *Dicranogr. Clingani*.

In 1907 MOBERG reproduced the Scanian finds of *Pleurogr. linearis* and *Robergia microphthalma* and proved simultaneously how the division of the Dicellograptus shale proposed by him harmonizes very well with the one used for the Moffat Series. We obtain namely:

Upper Hartfell = Upper
Lower Hartfell = Middle } Dicellograptus shale
Upper Glenkiln = Lower

There is also drawn up a parallel table for the Scanian Ordovician, which almost coincides with the one given in page 19. The only difference is that the zone of *Trinucleus coscinorrhinus* in the parallelization of 1907 was placed as high as possible in the Asaphus beds (so that it was in a line with the zone of *Didymogr. geminus*, a practice which was vindicated by the fact of this trilobite being found in Norway in the Ampyx limestone (4 a β), consequently, above the Geminus shale proper (4 a α). But, as has already been pointed out, at Fågelsång, the only Swedish locality where the Geminus shale is both easily accessible and fully developed, the species is never found in this latter, nor in the next lower zone, that of *Phyllogr. typus*, but first in the

underlying Orthoceras limestone. It is easy to imagine that the species appears somewhat sooner in Sweden than in Norway, but it may also be possible that the species is titanophile (or pelophobe, as one might also call it) and really has a greater vertical distribution than we know at present. At any rate, it seems to me more correct to let the Scanian table reflect, as faithfully as possible, the conditions directly observed in Skåne. And in that case the zone of *Trinucleus coscinorrhinus* must in our table be moved down as has now been done.

In 1909 WESTERGÅRD investigated the Dictyograptus shale and its boundary layers. What had previously been called *Clonograptus* cfr *flexilis* is now proved to be *Clonogr. tenellus* LINRS. var. *Callavei* LAPW. The tripartition, which WESTERGÅRD himself was already in 1900 able to state with regard to the Dictyograptus shale at Fågelsång, is now proved in many other localities. At Jerrestad, in Skåne, and at Grönhögen, in Öland, the series of strata is complete, so that we find there all the three consecutive sub-zones of the Dictyograptus shale. With the exception of the zone of *Clonogr. tenellus* from Hunneberg, known of old if also misunderstood, the two upper sub-zones of the Dictyograptus shale had until then not been known of outside Skåne. WESTERGÅRD has proved the middle sub-zone, the zone of *Clonogr. tenellus*, besides at the previously mentioned localities, also at Storberg in Östergötland and at Degerhamn in Southern Öland. Farther N. in Öland, only the oldest sub-zone, the zone of *Dictyograptus flabelliformis*, is found. — On the boundary between the highest Dictyograptus shale, or the zone of *Bryograptus Kjerulfi*, and the Ceratopyge limestone, a shale crowded with fragments of a *Ceratiocaris* (*C. scanicus* WGD) is found at Jerrestad. On account of its stratigraphical position this »Ceratiocaris shale», which is also found at Åkarpsmölla in Western Skåne, is considered to be equivalent to the Shumardia zone or the Ceratopyge shale of other localities.

This review of that part of the Silurian literature which concerns the Ordovician of Skåne or similar formations at other places has on the whole been limited to bringing out such data as show the course of development of the stratigraphical scheme. The purely palaeontological literature whose importance as a ruling basis for the stratigraphy is here, perhaps, more than elsewhere manifest, could therefore only be considered in passing. In referring to the introductory bibliography, which very likely includes all our more important palaeontological works relating to the Ordovician graptolite fauna of Sweden, it may here only be pointed out how this fauna, apart from minor contributions by HISINGER, LINNARSSON and HOLM, has been treated chiefly by TÖRNQUIST, TULLBERG, MOBERG and WESTERGÅRD. The fauna of the trilobite-bearing strata occurring together with the graptolite shales, or interstratified in them, has been described by ANGELIN, MOBERG, SEGERBERG and OLIN, besides which smaller contributions have also been made by TULLBERG, HOLM and WIMAN.

As this work is only intended to give a concise review of the Silurian of Sweden, we have generally abstained from giving quite complete lists of fossils. As regards the graptolite-bearing strata especially, the mere designation of the various zones will very likely, on account of the analogous succession of the graptolite faunas everywhere, give the contents of their respective faunas minutely enough.

We have therefore furthermore only to present a summary of the distribution of the various Ordovician graptolite horizons in Sweden.

The Upper and Middle Dicellograptus shales have only been found in Skåne (the former at Röstånga, the latter at Fågelsång, Röstånga, Tosterup, Tommarp, Jerrestad and, less accessible, also at Åkarpsmölla and Löderup).

From the »black Trinuncleus shale» of Dalarne, which is

really equivalent to the lowest part of the Upper Dicellograptus shales, TÖRNQUIST, in 1890 and 1892, quotes the following graptolites: *Dicellogr. anceps* NICH., *Diplogr. pristis* HIS., *Diplogr. truncatus* LAPW. and *Lasiogr. margaritatus* LAPW.

The Lower Dicellograptus shales occur typically developed only at Fågelsång and (scarcely accessible) at Röstånga, therefore exclusively in Skåne.

Yet, from several reasons it looks as if the Ogygiocaris shale of Jämtland might, partly at least, also be included here.

The Upper division of the Didymograptus shales is only met with in Skåne. The Lower, on the other hand, has quite an extensive distribution, even if by no means all its zones are developed everywhere it occurs. It has namely, besides a lot of places in Skåne, also been met with in Västergötland, Dalarne and Jämtland. It is also possible that the greyish-green marl, previously mentioned in this work, which at Berg in Östergötland directly underlies the Orthoceras limestone, may partly be included here, even if only as a sort of equivalent; in the Explanation to the map-sheet Vreta Kloster some graptolites are namely mentioned from there as »possibly *Phyllograptus* and *Didymograptus*». It has previously been mentioned that the strata under this heading at Skattungsbyn, in Dalarne, include a trilobite-bearing horizon. Even at Tossåsen in Jämtland such a condition occurs.

Dictyograptus beds are found in Skåne, Öland, Östergötland, Västergötland and, at Tåsjöberg, in Ångermanland (according to WIMAN 1903). At Sandby, in Skåne, and at Tåsjöberg trilobite-bearing strata are met with in the lowest subzone of these beds.

Before we close our account of the Ordovician it might be advisable here to give a short review of the development of the series in Jämtland and Östergötland, two of our most

important Silurian areas, which have really been mentioned in the preceding pages, although only cursorily.

The Ordovician of Jämtland.

Literature:

1837. HISINGER, W.: Anteckningar i Physik och Geognosie. H. 6. (Notes on Physics and Geognosy. Vol. 6.)

1872. LINNARSSON, G.: Anteckningar om den kambrisk-siluriska lagerserien i Jemtland. (Notes on the Cambro-Silurian series of strata in Jämtland.)

1875. LINNARSSON, G.: En egendomlig Trilobitfauna från Jemtland. (A peculiar Trilobite-fauna from Jämtland.)

1894. WIMAN, C.: Über die Silurformation in Jemtland.

1894. HÖGBOM, A.: Geologisk beskrifning öfver Jemtlands län. (Geological description of Jämtland's Län.) Sver. Geol. Unders. Ser. C, N:o 140.

1897. HOLM, G.: Om Bohemilla (?) denticulata LINRS. och Remopleurides microphthalmus LINRS. (On B. denticulata LINRS. and R. microphthalmus LINRS.)

1897. WIMAN, C.: Kambrisch-silurische Faciesbildungen in Jemtland. Bull. Geol. Inst. Upsala. Vol. 3 (1896—97).

1900. WIMAN, C.: Eine untersilurische Litoralfacies bei Locknesjön in Jemtland. Bull. Geol. Inst. Upsala. Vol. 4 (1898—99).

1903. WIMAN, C.: Über Robergia microphthalmus LNS. und Triarthrus jemtlandicus LNS.

In Jämtland one of our largest Silurian areas is found in the neighbourhood of Lake Storsjön. Hence the Silurian continues as a narrow zone along the eastern margin of the Mountain range, both to the NNE. and to the SSW. Towards the West it appears as if the silicic matter in the rocks increased quite considerably, so that quartzites play a great part in the Silurian rocks here; but no doubt as to the classification of these formations amongst the Silurian need

arise. Close up to the Norwegian frontier, both to the W. of Lake Storsjön and in the Northernmost part of Jämtland mica slate and gneissoid rocks, which some want to include in the Silurian, are met with. They would in that case be highly metamorphosed sediments, but from the Bergen peninsula, in Norway, we have an example of Silurian fossils preserved in a mica slate. It is for these western Mountain districts that TÖRNEBOHM in 1894 (p. 66, 2:nd ed. of his »Grunddragen af Sveriges geologi») proposed the denomination West-Scandinavian Silurian facies (subsequently also called the »mountain facies» of the Silurian), to distinguish it from the Silurian of an eastern or normal facies. According to TÖRNEBOHM, this »mountain facies» distinguishes itself by the deficiency of limestones; and greenstone-material derived from eruptions in these districts during the deposition of the strata is, on the other hand, plentifully encountered in the deposits belonging to this »facies». In certain Silurian strata of England there certainly enters a large amount of eruptive material, but something resembling our so called »mountain Silurian» has to my knowledge nowhere there been developed. But whatever the case may be, I consider myself in a position to leave the »mountain Silurian» quite out of the account, as I shall now proceed to the Ordovician of Jämtland.

In 1872 LINNARSSON for the first time gave an account of the Silurian of Jämtland. It was not until 1894 that we received a new one from WIMAN, whereof I shall give a short summary here. WIMAN's later report of 1900, as well as the few additions which I myself am able to make, will also be given.

The Brachiopod shale is here a grey, rusty shale with numerous twisted, mostly indeterminable impressions of brachiopods. Only few of the fossils, viz. *Encrinurus multisegmentatus* PORTL., *Atrypa crassicosta* DALM., *Strophomena rhomboidalis* WILCKENS and *Plasmopora conferta* E. H. could be determined

as to their species. This shale is especially widely spread in the area N. of Lake Storsjön. Amongst the localities are mentioned Lejtorp, Berge, Ånge, Kjönsta and Ede in the parish of Offerdal, as well as Västbacken in Alsen.

No *Trinucleus shale* is encountered. WIMAN, in his table of 1894, certainly hesitatingly mentions a »black shale» between the Brachiopod shale and the Chasmops limestone, but in the text he says that he never found the substratum of the Brachiopod shale. In 1900 he also mentions boulders of a greenly *Trinucleus*-bearing shale from Tand.

Chasmops limestone is certainly mentioned already in 1894, but then only as boulders, which seemed originally to have been embedded in (black) shale. In 1900 WIMAN was able, however, to mention from the neighbourhood of Lake Locknesjön some green limestones with shale coming under this heading and remaining at Tand, Lappgrubban, and several other places. Partly from the solid rock, partly from boulders, there are amongst other fossils mentioned *Asaphus ludibundus* TÖRNQU., *Illaenus fallax* HOLM, *I. gigas* HOLM and *Caryocystis granatum* WAHLENB. The Chasmops limestone is here seen overlying the Orthoceras limestone.

The Ogygiocaris shale, which was mentioned by LINNARSSON as belonging to the Chasmops limestone but is now considered to be a facies of the highest part of the Orthoceras limestone, is sometimes, as e. g. at Gäle, in Andersö, Norderö and Utö Islands, at Önsvedsbäcken and Lake Räcksjön in the parish of Sunne, as well as at Bölåsen in the parish of Oviken, developed as a black shale with lenses or thin bands of a black limestone in which trilobites and numerous, but badly preserved, graptolites occur. At Ringsta, in the parish of Lith, and Österåsen, in the parish of Häggenås, the shale contains only some scattered limestone ellipsoides, which there reach a good size. Amongst the fossils may be mentioned *Ogygiocaris dilatata* BRÜNN., *Triarthrus jemtlandicus* LINRS.,

Dicellocephalus Billingsi LINRS., *Robergia microphthalma* LINRS., *Illaenus centaurus* ANG., *Ampyx rostratus* SARS, *Chirurus exsul* BEYR., *Didymogr.* sp., *Dicellograptus* sp., *Diplogr. teretiusculus* HIS. and *Nemagraptus* sp. We seem therefore to have species together here, of which some are known from the Centaurus limestone, some, again, from the Lower Dicellograptus shale.

The Orthoceras limestone proper has a wide distribution in Jämtland. From the northernmost locality, Hafsnäs in the parish of Alanäs, it can, in scattered occurrences, be traced southward across the frontier of the province and into Härjedalen, where its southernmost occurrence is Häggingsåsen, in the parish of Linsäll. It is particularly well developed in the country N. of Brunflo, and between Brunflo and Östersund. WIMAN was able to distinguish in this area Limbata, Asaphus, Gigas and Platyurus limestone. The limestone has here a thickness of 37 m. Amongst other localities may be mentioned Andersö Island, Tossåsen, Klöfsjö and Skalängen, at which last mentioned place it has a thickness up to about 90 m. In the country round Lake Locknesjön the Orthoceras limestone has a peculiar development. It is there partly represented by the so called »Loftar stone», with which its strata also sometimes alternate, and from which it seems difficult to separate it with certainty. The Loftar stone, which is only through a sedimentary breccia separated from the underlying Archaean rock, whence it has received the bulk of its material, can replace not only the Orthoceras limestone, but also a portion of the Chasmops limestone. The Loftar stone, which may have quite a varying size of grains, but is always well stratified, sometimes contains larger stones and boulders of Archaean rock, alum shale and Orthoceras limestone. As has been mentioned, the rock may without limits merge into Orthoceras limestone. WIMAN also mentions an »Orthoceras conglomerate».

In its typical development the Orthoceras limestone of

Jämtland is generally very impure, mixed with clay. The clayey material may sometimes be accumulated between the various limestone banks or in their superficial parts, sometimes, again, in the shape of thin crusts, it divides the entire mass of the bank into small, irregular parts, whereby the rock can get an appearence resembling mosaic.

The Phyllograptus shale, which formes the substratum of the Orthoceras limestone, is a greyish shale with trilobite-bearing limestone in scattered lenses or continuous bands embedded in it. This shale has been found at Mörkullatjärn, at Näs (at Lake Näckten), at the Bilsta River and Mjäla in the parish of Mysjö, at Tossåsen, as well as between Skålan and Skalängen. WIMAN enumerates among the ordinary fossils from this zone, strange to say, also *Clonogr. tenellus* LINRS., found in black shales from a pit in Loke (parish of Lockne). The Phyllograptus shale may possibly also occur at Klöfsjö, where I found grey shale between the Orthoceras limestone and the subjacent stratum.

The Ceratopyge limestone. As such I consider a few limestone bands, which I found, both at Tossåsen and at Klöfsjö, directly overlying the Olenid shales. At Tossåsen, where these layers are specially easily accessible, there is above the stink-stone with *Ctenopyge flagellifera* ANG. first a loose layer containing plenty of material derived from the Olenid shale, on top of that a band of knobby limestone richly sprinkled with glauconite, and than a couple of layers of a purer limestone, compact or fine-grained, crystalline, its colour shifting from a light to a dark grey. Even in the upper part of the limestone one can find some lump or other of stink-stone, although such are rare there. I have here found *Orthis Christianiae* KJERULF, *Niobe laeviceps* ANG. and a *Cyrtometopus*, possibly *foveolatus* ANG. It is, however, difficult to get the fossils from the splintery limestone. In a similar rock found S. of Klöfsjö, which I also want to include here, I have, besides some apparently as yet undescribed Brachio-

pods, found a *Niobe insignis* LINRS., and a *Megalaspis stenorhachis* ANG.? The rock, which in this highly dislocated area has been subject to strong pressure, is traversed by fine, straight fissures only noticeable by their darker colour.

The Ordovician of Östergötland.

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1882. LINNARSSON, G. and TULLBERG, S. A.: Beskrifning till kartbladet Vreta kloster. (Explanation to the map-sheet Vreta Kloster.) Sver. Geol. Unders. Ser. Aa, No. 83.

1885. HOLM, G.: Om Vättern och Visingsöformationen. (On the Lake Vättern and the Visingsö formation.)

1887. JÖNSSON, J.: Beskrifning till kartbladet Motala. (Explanation to the map-sheet Motala.) Sver. Geol. Unders. Ser. Aa, No. 102.

1903. WIMAN, C.: Ett nytt fynd af Obolussandsten i Östergötland. (A new discovery of Obolus sandstone in Östergötland.)

1905. BLOMBERG, A.: Beskrifning till kartbladet Vadstena. (Explanation to the map-sheet Vadstena.) Sver. Geol. Unders. Ser. Aa, No. 130.

1909. WESTERGÅRD, A. H.: Studier öfver Dictyograptusskiffern och dess gränslager. (Researches into the Dictyograptus shale and adjoining strata.)

The Silurian area of Östergötland, whose northern margin practically follows the Göta Canal, forms in the map a wedge-shaped portion with the thin end of the wedge towards the east, whilst the base of the wedge, running along the

eastern shore of Lake Vättern, from the northern slope of Omberg Mountain, stretches northward until a little way beyond the town of Motala, situated at the mouth of the Göta Canal. In the extreme East, close to Lake Roxen, we find the well known Silurian localities of Berg and Knifvinge. Along the Canal we find, furthermore, in a westerly order, Skarpåsen (Ljung), Kungs Norrby and Västanå (Husbyfjöl), the latter locality situated at the eastern end of Lake Boren. On the northern shore of Lake Boren is situated Storberg, at its southern Ulfåsa. All these localities belong to the map-sheet Vreta Kloster. At the western end of Lake Boren we have Borenshult, in the map-sheet Motala. On the shore of Lake Vättern we find, in the map-sheet Vadstena, Borghamn and Hofvanäs, immediately N. of Omberg Mountain and, a little further in the N., Ullnäs. Thereafter the Silurian in the map-sheet Motala is exposed at several places right up to, and past, Motala, NW. of which we have the well known locality of N. Freberga.

In this area the following Ordovician deposits have been proved.

Brachiopod shale. This is not found at more places than Råsnäset, situated to the W. of Motala, where a green shale with lumps and layers of a grey limestone, underlying Gotlandian shales, rests upon red Trinucleus shale, from which it is sometimes separated by a layer of a conglomerate-like limestone with spheroids of Trinucleus shale; this conglomerate-like layer is about 0.5 m. thick.

Trinucleus shale. Such is encountered, as mentioned, at Råsnäset. Furthermore, we find this formation at, and near, Rödbergsudden (immediately S. of Motala), where, besides the red Trinucleus shale, also black Trinucleus shale and »Masur limestone» occur. We have here thus strata with the same development as in Dalarne. Black Trinucleus shale is also met with S. of Ulfåsa (in the map-sheet Vreta Kloster).

Chasmops limestone is also developed here. Of this both the younger strata, the *Macrourus limestone*, and the older ones, the *Echinosphaerite limestone*, are found. The former is met with W. of Ulfåsa, the latter partly at Karstorp (somewhat S. of the eastern end of Lake Boren), partly at N. Freberga and the country round about there. Even from Rödbergsudden and from S. Freberga, and several other places S. and SE. of Motala, the occurrence of strata coming under this heading is reported.

The *Orthoceras limestone* has, here as well as in many of our Silurian areas, a wider distribution than any other deposits of the system. This limestone was extensively quarried for the construction of the Göta Canal in the beginning of the 19:th century, and for building the fortress of Karlsborg. A good many of the trilobites, which in 1827 were described by DALMAN in his work: »Om Palæaderna eller de s. k. Trilobiterna» emanate just from Östergötland. Amongst the many localities may be mentioned Borghamn and Hofvanäs, where there are large quarries, Ullnäs, Palsgården and Vadstena (all in the map-sheet Vadstena), furthermore Västanå (Husbyfjöl), Storberg, Skarpåsen (Ljung), Knifvinge and Berg, all of them in the map-sheet Vreta Kloster. Even in the map-sheet Motala there are some strata somewhat SSE. to N. Freberga, which probably come under this heading. The older classification according to a regulary shiftning colour has not proved itself applicable to the Orthoceras limestone of Östergötland. In his Explanation to the map-sheet Vreta kloster, TULLBERG mentioned for Västanå the following succession of strata in descending order:

Expansus limestone, greenish or (at another spot) red,
Grey limestone,
Heros limestone (with *Megalaspis Heros* ANG.),
Reddish limestone and
Planilimbata limestone.

As has already been more minutely mentioned before, there is found at Berg a greyish-green marl, which I suppose to be a transition between the Orthoceras limestone and the Ceratopyge limestone, but which TULLBERG hesitatingly wants to include in the latter.

No *Ceratopyge limestone* has been proved. Between the Orthoceras limestone and the Dictyograptus shale at Västanå, Storberg, Pålstorp and Knifvinge there is, however, found a glauconitic marl, which, perchance, might also be considered equivalent to the Ceratopyge limestone or Ceratopyge shale, or to both. According to WESTERGÅRD the glauconitic marl, which at Pålstorp is separated from the underlying Dictyograptus shale by a yellow marl, seems probably to thin out at some places at Knifvinge.

Dictyograptus shale underlies the glauconitic marl at all the places just mentioned. At Storberg, where it reaches a thickness of up to 3,5 m., WESTERGÅRD has also found the middle sub-zone, characterized by *Clonogr. tenellus* LINRS., developed; otherwise only the lowest sub-zone is met with here. It is characteristic of the Dictyograptus shale of Östergötland, that its lowest part at Storberg, Knifvinge and Västanå, i. e. everywhere it is visible, is replaced by a sandstone which is at Västanå above 2 m. thick. This sandstone, which has long been known, was first in 1903 determined by WIMAN as »Obolus sandstone»; but this was only done for stratigraphical reasons, as no fossils have been found in it. WESTERGÅRD alleges, however, to have found some brachiopod shells in the sandstone at Storberg.

Not only Obolus sandstone, but also »Obolus conglomerate» are very likely to be found in Östergötland. HOLM mentions namely (1885) boulders of conglomerate with phosphorite concretions and rubbles of stink-stone derived from the Upper and Middle Cambrian, as well as of quartz, which boulders he discovered at the northern end of Omberg Mountain.

Some pieces of the conglomerate were found at the mouth of an abandoned shaft in Borghamn limestone quarry, wherefore the rock must be considered resting there. Amongst the others one was found strongly resembling the Obolus conglomerate of Dalarne.

Series A. The Cambrian.

Literature:

1727. BROMELL, H. VON: Lithographiae Suecanae specimen secundum. Upsaliae.

1751. LINNÉ, C. VON: Carl Linnæi Skånska resa 1749. (Carl Linnaei Scanian journey of 1749.)

1753. LINNÉ, C. VON: Museum Tessinianum.

1821. WAHLENBERG, G.: Petrificata telluris Suecanae.

1851, 1854. ANGELIN, N. P.: Palaeontologia scandinavica.

1852. SJÖGREN, A.: Anteckningar om Öland, ett bidrag till Sveriges geologi. (Notes on Öland, a contribution to the Geology of Sweden.) Öfvers. Kgl. Vet.-Ak. Förh. för 1851.

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1868. WALLIN, J. A.: Bidrag till kännedomen om Vestgötabergens byggnad. I. (Contributions to the knowledge relating the structure of the Vestrogothian mountains.) Thesis for the doctor's degree, Lund.

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1877. NATHORST, A. G.: Om de kambriska och siluriska lagren vid Kiviks Esperöd i Skåne, jemte anmärkningar om primordialfaunans lager vid Andrarum. (On the Cambrian and Silurian strata at Kiviks Esperöd in Skåne, together with some Remarks on the strata of the primordial fauna at Andrarum.)

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1910. MOBERG, Guide to the principal Silurian districts of Scania (with Notes on some localities of Mesozoic beds).

In this list are also to be included the Explanations to the following map-sheets of the Sveriges Geologiska Undersökning.

For Skåne: Båstad (HUMMEL, 1877), Engelholm (A. LINDSTRÖM, 1880), Övedskloster (TULLBERG, 1882), Trolleholm (NATHORST, 1885), Lund (DE GEER, 1887), Vidtsköfle (DE GEER, 1889), Simrishamn (HOLST, 1892), Sandhammaren (MOBERG, 1895).

For Småland and Öland: Ottenby (MUNTHE, 1902), Kalmar (MUNTHE, 1902), Oskarshamn (SVEDMARK, 1904), Mönsterås and Högby (MUNTHE & HEDSTRÖM, 1904) and sheet 5 of Ser. A 1, a (HEDSTRÖM & WIMAN, 1906).

For Östergötland: Vreta Kloster (LINNARSSON & TULLBERG, 1882), Motala (JÖNSSON, 1887), Vadstena (BLOMBERG, 1905).

For Västergötland: Venersborg (Ser. Aa, by SIDENBLADH, 1870 and Ser. Ab, by A. LINDSTRÖM, 1887), Skara (MUNTHE, 1903), Sköfde (MUNTHE, 1905), Tidaholm (MUNTHE, 1906), Falköping (MUNTHE, 1906).

For Närke: Latorp (LINNARSSON, 1875).

As our table, page 22, shows, three different divisions are distinguished in the Cambrian series: the Upper Cambrian

or Olenus beds, the Middle Cambrian or Paradoxides beds and the Lower Cambrian or Olenellus beds.

Already ANGELIN divided (1854) the strata coming under this heading into three divisions, viz. Regio Conocorypharum, Regio Olenorum and Regio Fucoidarum, of which the first two represent the alum shale (with limestones embedded therein), the last, again, the lowest sandstone. With Regio Conocorypharum ANGELIN really designated only the strata characterized by *Paradoxides Forchhammeri*. Their most remarkable part consists of a limestone, from the only then known Swedish occurrence, Andrarum, called the »Andrarum limestone», which name was afterwards often used as a designation for the region in general. In 1868 LINNARSSON distinguished in the Vestrogothian alum shale five divisions in a descending order, viz.

5. Zone of *Peltura*[1] *scarabaeoides* and *Sphaerophthalmus*[1] *alatus*.
4. Zone of *Eurycare*[1] *latum*, *Orthis lenticularis*, *Parabolina*[1] *spinulosa*, *Olenus gibbosus* and *Agnostus pisiformis*.
3. Zone of *Agnostus laevigatus*.
2. Zone of *Paradoxides*, granulated (therefore *P. Forchhammeri*).
1. Zone of *Paradoxides Tessini*.

The lower part, the zones *1* to *3*, was looked upon as representing ANGELIN's Regio Conocorypharum, whose place under the Olenus beds was thereby given. LINNARSSON, in 1869 in his great work on the Cambrian and Silurian deposits of Västergötland, adheres to the same classification. The upper part, zones *4* and *5*, he there calls »Olenid shale», the lower »Conocoryphe shale», denominations which he exchanges again (in his »Reise nach Böhmen und den russischen Ostseeprovinzen im Sommer 1872») for »Olenus shale» and »Paradoxides shale». From the above mentioned table of

[1] LINNARSSON wrote *Olenus*.

1868 it is already apparent that LINNARSSON included the zone of *Paradoxides Tessini* in the lowest division, a fact which is worth remarking upon, as it appears from ANGELIN'S statements that ANGELIN placed *P. Tessini* within his Regio Olenorum.

Herewith the boundary between the Upper and Middle Cambrian had certainly been determined, but the extent of these two divisions was by no means the same as that in our present table. The Dictyograptus shale was namely united with the Olenus beds, and this classification was continued long after LINNARSSON (in 1875 in his »Anteckningar från en resa i Skånes silurtrakter») had distinguished the highest part of the Olenus shale as a zone of its own, the »Dictyonema shale». It was not until 1900 that MOBERG proved that the Dictyograptus shale belongs to the lower part of the Ceratopyge region and must therefore be separated from the Cambrian.

Even for the Paradoxides beds the condition was somewhat similar. Apart from the fact that before 1872 we had not even an idea of the existence of the zone of Paradoxides oelandicus, the lower limit of the Paradoxides beds was by no means entirely determined at the time when LINNARSSON's last named table came into existence. ANGELIN had certainly already in 1862 grouped together with the lowest sandstone a greywacke shale overlying it at Andrarum, but this greywacke shale was soon after (1870) classed with the Paradoxides beds, viz. by TORELL, who from there mentions a *Paradoxides Wahlenbergi,* by which name the fossil described in 1871 by LINNARSSON as *P. Kjerulfi* must be meant, and which LINNARSSON at the same time stated to be older than any other trilobite until then described from Scandinavia. In 1875 BRÖGGER points out that *Paradoxides Kjerulfi* was very closely related to *Paradoxides* (*Olenellus*) *Thompsoni* HALL, and in 1877 LINNARSSON says that, if genus *Olenellus* is to be retained

as a separate genus, *P. Kjerulfi* must be included in it. Finally BRÖGGER, in 1878, went a step further and wrote *Olenellus* (*Paradoxides*) *Kjerulfi*. Even LINNARSSON in his last work (1882) has the term *Olenellus Kjerulfi*, but nevertheless, both he and TULLBERG included the strata characterized by the fossil in question in the Paradoxides shales. In America, where the Olenellus fauna is splendidly developed, these strata were, under the name of Georgian assumed to be Middle Cambrian, whilst the Paradoxides beds, which are called Acadian, were supposed to be Lower Cambrian. In 1886 BRÖGGER showed, however, that in conformity with the conditions in Scandinavia the Georgian must be older than the Acadian, something which, said en passant, American geologists were afterwards also able to prove directly. In his work referred to BRÖGGER introduces the name »Olenellus zone» for KJERULF's Etage 1 b, i. e. for the strata characterized by *Olenellus Kjerulfi*. KJERULF's Etage 1 a, the sparagmite, corresponding to our lowest sandstones, was, however, not included in this zone. It was not until 1888, when SCHMIDT had proved the occurrence of *Olenellus* together with *Mickwitzia monilifera* LINRS. previously known from the so called Eophyton sandstone of Västergötland, that it became manifest that our lowest sandstone must also be included in the Olenellus beds.

After we have now thus shown the way in which the three divisions, into which the Cambrian is divided up, gradually had their limits determined, we shall account a little more minutely for every separate bed.

A 3. The Olenus beds.

The strata coming under this heading are everywhere developed as alum shale, with stink-stone embedded. This stink stone occurs at several different horizons, either as scattered ellipsoids or in real connected layers. At Billingen an

impure coal, so called »kolm», which has lately been worked for the production of radium, has also been found. At Kinnekulle HOLM has observed a conglomerate corresponding to the zones of *Orthis lenticularis, Parabolina spinulosa* and *Eurycare latum,* which zones, he states, seem to be absent there. At the same place HOLM also found in some stink-stones belonging to the Peltura zone some minor, vein-like lots of flint. Such a flint has really already been reported from here by LINNÉ, and according to MUNTHE it very likely also occurs at Billingen.

Of special interest are the geological conditions at Månsberget Mountain, 20 km. NW. of the church of the parish Dorotea, in Västerbotten, mentioned by HOLST in 1889 (»Om en mäktig qvartsit yngre än olenusskiffer»). He gives from here the following section:

Quartzite		
Black shale	0,6	m.
Quartzite, resembling greywacke	0,7	»
Dark shale	0,2	»
Quartzite, greenish, slaty	0,3	»
Dark shale	0,4	»
Quartzite, solid bank	0,6	»
Black shale	4,0	»
Limestone bed, resembling stink-stone. Herein *Olenus (gibbosus?)*	0,5	»
Greywacke shale	2,5	»
Limestone bed with *O. gibbosus*	0,6	»
Greywacke shale	0,2	»
Limestone bed	1,4	»
Greywacke shale.		

The conditions of stratification thus prove that the Quartzite here rests upon, and by alternate stratification merges into, Olenus shale.

Fossils may, in general, be found in both shale and stink-stone, some times in such quantities as to entirely crowd the rock. But safest, and at the same time best preserved, they are found in the stink-stone, in layers where the stink-stone is not too highly crystallized. At some places a younger fauna is found in every higher limestone band or in every higher stink-stone horizon, at others, again, it may happen that the same fauna runs through several such, or vice versa that, for example, we find one fauna in the upper part and another in the lower part of one and the same limestone band.

In the preceding pages it has already been mentioned how LINNARSSON in his table of 1868 divided the strata coming under this heading into two separate divisions. An upper one with *Peltura* and *Sphaerophthalmus*, and a lower one, zone *4* of his table, from which latter he quotes some species, which, apart from the fact that *Orthis lenticularis* should really be collocated with *Parabolina spinulosa* into one zone, are in the present table all independent leading fossils for successive zones, which follow each other just in the order in which the species have been enumerated by LINNARSSON. Although the species are quoted together, it is yet pointed out by him that they belong to different zones, even if they, such as is the case with *Eurycare latum* and *Parabolina spinulosa*, have been met with in the same limestone band. In 1869 NATHORST gave an entirely similar table for Andrarum, but this was to some extent garbled in the process of printing. After correction, made (1877) by NATHORST himself, his table has the following form:

Zone of *Acerocare* (?).
» *Peltura* and *Sphaerophthalmus*.
» *Eurycare* and *Leptoplastus*.
» *Orthis* and *Parabolina*.
» *Olenus* and *Agnostus*.

NATHORST thus introduces a new zone into the table, a

zone characterized by *Acerocare*. In 1875 LINNARSSON gives the succession of strata for the alum shale of Närke: zone of *Peltura* and *Sphaerophthalmus;* z. of *Leptoplastus stenotus;* z. of *Parabolina spinulosa* and *Orthis;* z. of *Beyrichia Angelini;* z. of *Olenus gibbosus* and *O. truncatus,* as well as *Agnostus pisiformis*. Of these, the zone of *Leptoplastus* and the zone of *Beyrichia* are in Närke only locally developed. And in the following year (1876) he stated the series of fossils in the strata of the Olenid shale at S. Möckleby in Öland as follows:

Z. of *Peltura scarabaeoides* and *Sphaerophthalmus alatus.*
» *Eurycare latum* and *Leptoplastus.*
» *Orthis lenticularis.*
» *Olenus gibbosus.*
» *Beyrichia Angelini.*
» *Agnostus pisiformis.*

In 1880 LINNARSSON mentions en passant that beds bearing Acerocare and Cyclognathus cover the Peltura beds in Skåne, which latter beds are considered to be everywhere else superimposed by the Ordovician, i. e. by the Dictyograptus shale.

NATHORST, just as LINNARSSON, gives at first *Agnostus pisiformis* and *Olenus gibbosus* as belonging to the same zone. TULLBERG showed in 1880 (in his Memoir »Om Agnostusarterna i de kambriska aflagringarne vid Andrarum») that, besides the typical *Agnostus pisiformis,* which appears already below the strata with *Olenus gibbosus*, there is a variety or mutation, described by TULLBERG as var. *socialis*, but which, after what LAKE in 1906 (in »A Monograph of British Cambrian Trilobites». Palæontogr. Soc. London) showed, had already in 1867 been described by BELT as var. *obesus*, which form belongs to a somewhat higher level than the main species. It is var. *obesus* that is found together with *Olenus.*[1]

In the table of the Scanian Olenid shale set up by

[1] See also the foot-note to page 174.

TULLBERG in 1882 he gave as the youngest zone the one bearing *Acerocare ecorne*, below which comes the *Dictyograptus* shale, which in its turn is stated to overlie the zone of *Acerocare micropygum*, under which the *Peltura* zone is said to come. In 1883 he changes his table in such a manner that the zone of *Acerocare ecorne* is moved down below the Dictyograptus shale. Apart from this last mentioned zone, which we now include in the Ordovician, TULLBERG's table obtained thus the following appearance:

Zone of *Acerocare ecorne*.
» *Cyclognathus micropygus*.
» *Peltura scarabaeoides* (herein also *Sphaerophthalmus alatus* and *Ctenopyge* spp.).
» *Eurycare camuricorne* (herein also *Leptoplastus*).
» *Parabolina spinulosa*.
» *Ceratopyge* sp. (herein also *Beyrichia Angelini*).
» *Olenus* (herein also *Agnostus pisiformis* var. *obesus* BELT and *Ceratopyge* sp.).
» *Leperditia* sp.
» *Agnostus pisiformis* f. typica.
Alum shale devoid of fossils.

This table of TULLBERG's is, as is seen, very detailed; yet partly it is not quite correct, as we shall soon prove; and at all events, it is hardly more than of local interest, as it gives only the succession of strata at Andrarum.

In 1898 MOBERG and MÖLLER showed that the genus *Cyclognathus* LINRS. is not to be distinguished from the genus *Acerocare* ANG. The various species of this seem generally to have quite a local horizontal distribution. A species of *Parabolina* belonging to the Acerocare zone, viz. *P. heres* BRÖGG., has, on the other hand, a great horizontal distribution, wherefore the question might be raised, whether we not ought to talk of a Heres zone rather than of an Acerocare zone (compare with this WESTERGÅRD's observations in 1909).

MOBERG and MÖLLER believed themselves able to distinguish the following sub-zones (reckoned from the top downwards):

4 .Sub-zone of *Acerocare micropygum*.[1]
3. » *Parabolina heres*[1] together with *A granulatum* and *A. paradoxum*.
2. » *Parabolina megalops*.
1. » *Parabolina acanthura* and *A. ecorne*.

For a comparison between the upper Olenid shale of Sweden and Norway it is to be noted, partly that the species mentioned by BRÖGGER under the name of *Protopeltura acanthura* and occurring in Norway at the bottom of the Peltura zone, is not, as was believed, identical with our *Parabolina acanthura* (but a new species, which in 1909 received the name of *Peltura praecursor* WESTERGÅRD), partly that the species quoted by BRÖGGER from the Norwegian Ceratopyge limestone under the name of *Cyclognathus micropygus* is not the same as LINNARSSON's, but quite a new species which by MOBERG and MÖLLER has been called *Acerocare norvegicum*.

In 1904 PERSSON commenced an scrutiny of the fauna in the beds of Eurycare and Leptoplastus at Andrarum. *Eurycare camuricorne* is shown to be synonymous with *E. latum* BOECK. The table giving the succession of strata in the Olenid shales at Andrarum is according to PERSSON.

9. Zone of *Acerocare* and *Parabolina heres*.
8. » *Peltura scarabaeoides*, *Sphaerophthalmus alatus* and *Ctenopyge* sp.
7. » *Ctenopyge* spp.
5 and 6. » *Eurycare angustatum* and *Leptoplastus stenotus*.
4 (bis). » *Eurycare latum* and *Leptoplastus ovatus*.
3 (bis). » *Parabolina spinulosa*.
4. » *Eurycare latum* and *Leptoplastus ovatus*.

[1] According to WESTERGÅRD (1909) *P. heres* occurs at Jerretsad together with *A. micropygum*.

3. Zone of *Parabolina spinulosa.*
2. » *Olenus* s.s.
1. » *Agnostus pisiformis.*

Apart from the fact that PERSSON has introduced a separate zone for *Ctenopyge* spp., his table is remarkable by reason of the repetition of the zones 3 and 4. No fault is to be thought of as the cause of this. (Curiously enough NATHORST, in 1877, also queries such a repetition. He says that, according to his older notes, *Parabolina spinulosa* should occur not only above, but also below the zone of *Olenus* s. s. But he adds that this must, however, be due to an error.) As we know now, the genus *Parabolina* continues right up into the Acerocare zone, and it seems therefore not absolutely impossible that *P. spinulosa*, perchance partly represented by some varieties closely allied to the chief form, has a greater vertical distribution than had hitherto been supposed. It should be sufficient for explaining the seeming anomalies in the succession of strata at Andrarum.

A similar example is also already presented with reference to the vertical distribution of *Beyrichia Angelini* BARR.[1] As will be seen from the tables relating to the succession of strata given in the preceding pages, there has at several places been distinguished a zone of *Beyrichia Angelini*. In Öland this zone should lie below the zone of *Olenus* s. s., whilst in Skåne and Närke, for example, it is stated to overlie the

[1] From the history of this species the following may be worth while quoting. Reproduced in 1854 by ANGELIN on Tab. A, intended as a supplement to Pal. Scand., but never published, the species received its name in 1872 from BARRANDE in Suppl. au Vol. I of his »Syst. Silurien». In his »Öfversigt af Nerikes öfvergångsbildningar» (1875) LINNARSSON finally described the same and reproduced it on a table attached to the work, which table is, however, missing in that part of the edition belonging to the publications of Sveriges Geologiska Undersökning, because the copies intended for them were destroyed by fire. In 1893 HOLM points out (l. c. note to page 110) that the latter, as well as some other related Crustaceans with a chitineous shell, might be *Phyllocarida* rather than, as had until then been generally supposed, *Ostracoda*.

same zone. When NATHORST, in 1884, reproduced the table for the Olenid shales of Öland, he drew attention to this circumstance, which he believed to be due to a clerical error. The condition finds, however, after what has subsequently been discovered, its explanation in the fact that the species has a greater vertical occurrence than had previously been believed. It is therefore unsuitable as a leading fossil.

In 1909 WESTERGÅRD proved at Grönhögen, in Öland, between the Dictyograptus shale and the Peltura beds two zones belonging to the Acerocare beds, viz. an upper one of *Parabolina heres* and a lower one of *Peltura corniger* WGD, a species only known from this spot. Hereby the Acerocare zone was therefore proved the first time outside Skåne. At the same time he mentions more minutely some Trilobites zoologically belonging to the Ordovician fauna, but appearing already in the Acerocare beds at Jerrestad and S. Sandby; amongst these *Euloma primordiale* and *Niobe primaeva* are described as new species.

Other forerunners to the Ordovician fauna are found in yet older strata. In 1903 MOBERG described namely such a one, *Schmalenseeia amphionura* from the zone of *Agnostus pisiformis* in Öland. Later on an analogous form, *Burlingia Hectori*, was described by WALCOTT (Cambrian Trilobites. Smithsonian Miscellaneous Collections. Vol. 53. 1908) from the Middel Cambrian of Canada.

Olenid shale is found more or less completely developed in the majority of the Swedish Silurian areas. In Skåne it has been met with in a lot of localities, most of which are situated in the south-eastern part of the province. Before others we have here to mention Andrarum, where the series of strata is quite complete, and several zones not observed elsewhere are to be met with. Furthermore, we have S. Sandby, Åkarpsmölla and Jerrestad, three localities where the Acerocare zone is encountered, as well as Röstånga,

Kvasa (at Kiviks Esperöd), Tosterup, Löderup and several others.

In Öland the Olenid shales begin a few km. N. of the Southern tongue, continue thence, following the western shore northwards across the map-sheets Ottenby and Kalmar, at which latter they cease close to W. Sörby a couple of km. from the northern limit of the map-sheet. (At Öland's Alum factory the strata are well exposed.) Farther to the North deposits coming under this heading are almost only found as boulders in the previously mentioned conglomerates between the strata of the Ceratopyge region and the Tessini zone. From Äleklinta and Grönviken a stink-stone with *Agnostus pisiformis* occurring between the two conglomerates is mentioned, though.[1] In Östergötland Olenid shale is met with at Knifvinge, Pålstorp, Sjögestad, Storberg, Odenfors and Västanå, in the map-sheet Vreta kloster, and at Aludden, in the map-sheet Motala. The alum shale resting in Guldkullen (map-sheet Vadstena) comes also under this heading, since *Agnostus pisiformis* f. typica has been found there, according to information kindly supplied by Professor TÖRNQUIST. From Närke LINNARSSON describes a score of occurrences surrounding the great sandstone area that extends westward from Lake Hjälmaren. One of the largest slate quarries is to be found at Latorp.

Strata coming under this heading are also found in Jämtland. All the zones are represented there, at least in boulders. At Brunflo, where the succession of strata is otherwise rather complete, all the lower zones of the Olenidian right up to, and including, the zone of *Parabolina spinulosa* are said, according to WIMAN, to be represented, at least at some places, by a conglomerate. Other localities mentioned are Funäs in the parish of Mysjö, Tossåsen and a place situated between

[1] It must be remembered, however, that *Agnostus pisiformis* (var.?) at several places in Öland, e. g. W. of Mörbylilla, is met with even in strata below the Par. Forchhammeri bed.

Skålan and Skalängen, and in 1908 I found at Klöfsjö strata of stink-stone containing *Parabolina spinulosa* WAHLENB. — In Ångermanland there is an occurrence at the Abborr Falls near W. Lake Tåsjön. — In Lappland blocks of Olenid beds, viz. from the Peltura zone, the P. spinulosa zone and the Olenus zone, are met with at Skikkiberget Mountain, in the parish of Stensele, as well as at Storberget Mountain, Granhöjden, Skansholmen, Djupdalsberget Mountain and Bäcksele, in the parish of Wilhelmina.

The fauna of the Acerocare zone has been treated by MOBERG and MÖLLER, and partly by WESTERGÅRD, that of the Peltura zone by LINNARSSON, and that of the Eurycare-Leptoplastus zone, partly at least, by PERSSON. Otherwise the fauna, with the exception of the Agnostus species treated by TULLBERG, is scarcely known. The occurrence of Trilobites resembling *Ceratopyge* is remarkable; nothing is known, though, of their structure (only a couple of tails have been found). NATHORST has furthermore found in these strata a mysterious, graptolite-like fossil, which was subsequently described and reproduced by MOBERG (1907).

In our table, page 22, we have given the zone of *Orthis lenticularis* WAHL. as a special brachiopod facies. Not infrequently we find namely this brachiopod by itself crowding entire limestone bands. It occurs, however, very often together with *Parabolina spinulosa*, especially in the shales.

A 2. The Paradoxides beds.

In the part of the text to »Geological Map of Skåne», that was printed in 1862 ANGELIN says distinctly of the Andrarum limestone (= his Regio Conocorypharum) that its right chronological place had not yet been determined, and that it (in his table) had been allocated its position on account of zoological reasons. And in the preceding pages we have mentioned how LINNARSSON, in 1868, in the lower

part of the alum shale of Västergötland found a parallel to ANGELIN'S Regio Conocorypharum, whose position below the Olenid shale was thereby determined, and furthermore that LINNARSSON, in 1869, proposed the name »Conocoryphe shale» for this lower division, which appellation he exchanged in 1873 for »Paradoxides shale».

BRÖGGER, in 1882 (l. c, p. 163), pointed out the important role the *Agnosti* are playing in the Paradoxides beds, and proposed to denominate these beds the »Agnostus stage», but this proposal of him was never followed.

It has previously been mentioned how LINNARSSON through *Paradoxides (Olenellus) Kjerulfi*, discovered and described by him in 1871, determined a previously unknown zone belonging to the Cambrian, which zone had at first been looked upon as the lowest part of the Paradoxides beds, but which subsequently (1886) was separated from the same by BRÖGGER and set up as a bed of its own, the »Olenellus bed». And finally, we have mentioned that A. SJÖGREN through the strata of *Par. oelandicus* SJÖGREN, discovered by him in Öland (in 1872), really added a new zone to the Paradoxides beds.

Herewith all zones coming under this heading were known, but by no means their respective ages. A pretty long time elapsed ere the relative position of the zone of *Par. oelandicus* was fully determined. When SJÖGREN discovered in Öland the zone of *Par. Tessini*, developed as a sandstone, and thus lithologically more resembling the lowest Cambrian sandstone than was the case with the zone of *Par. oelandicus* developed as a marl, he accepted it quite as a matter of course that the latter must be the younger of the two Paradoxides zones mentioned. According to SJÖGREN'S researches the zone of *Par. Forchhammeri* appeared also to be missing in Öland, a circumstance[1] which of course

[1] That it exists there, though, was mentioned by LINNARSSON already in 1874 (see Geol. Fören. Förh. Vol. II, page 79).

helped to a certain extent to increase the uncertainty as to the right place for the zone of *Par. oelandicus* in the succession of strata. Already in 1873 LINNARSSON, in his lecture (at the 11:th Meeting of Scandinavian Naturalists in Copenhagen) on »Jemförelse mellan den kambrisk-siluriska lagerföljden i Sverige, Böhmen och Ryska Östersjöprovinserna», called attention to the circumstance that the relative position between the Oelandicus zone and the Forchhammeri zone was not quite determined.

In 1876 LINNARSSON, in the report of his journey ot Öland, expresses grave doubts as to the accepted relative position between the zone of *Par. Tessini* and the zone of *Par. oelandicus*. At Äleklinta and S. Möckleby he thought he had found that the last mentioned zone must be the lower. The conditions at Borgholm, however, made him uncertain again, so that he even advances as a possibility of the Tessini sandstone being a subordinate deposit within the argillaceous shales of the Oelandicus zone. That, however, even at the last mentioned place the zone of *Par. oelandicus* underlies the zone of *Par. Tessini* was first proved by NATHORST and DAMES in the course of a journey to Öland made in each other's company in 1881. DAMES reported this in his travelling memoirs published the same year, and he adds that we can scarcely doubt that the zone of *Par. oelandicus*, which was only observed in Öland and Jämtland, is an eastern equivalent of the zone of *Paradoxides Kjerulfi*, which was met with in Skåne and Norway. The two zones would consequently be really of the same age. NATHORST not only in the account of the age of the Oelandicus zone (as it seems published before DAMES' memoirs), but also in a later treatise,[1] declared such a supposition to be

[1] On the mutual age of the zones of *Olenellus Kjerulfi* and *Paradoxides oelandicus* (Geol. För. Förh. 1882). Before the publication of this NATHORST had received information of BRÖGGER's discovery of the Oelandicus zone in Norway.

inadmissible, on the contrary, the so called »Fragment limestone», which at Andrarum overlies the greywacke shale with *Olenellus Kjerulfi* might probably be the equivalent of the Oelandicus zone. In his paper »Paradoxides oelandicus-nivået ved Ringsaker i Norge» (Geol. För. Förh. Vol. II) BRÖGGER mentions (1882) the discovery of the fact that in the neighbourhood of Mjösen both the Kjerulfi zone and the Oelandicus zone are developed, the latter distinctly overlying the former.

As we have set forth in the general characteristics in the commencement of this work, the development of the various zones of the Paradoxides beds changes very considerably in different areas, a circumstance which is also proved by the fact that certain strata, characteristic in one province, are entirely missing in another, or perhaps very poorly developed. Through this, the succession of strata given for different areas gets quite a different appearance. But it is quite clear that attempts have been made, as far as possible, and therefore pretty often on very slender grounds, to make every zone already given in an older table enter into every new one, whereby the different tables received greater uniformity than would otherwise have been the case. Locally appearing zones can, however, not find a place in the general table. We must therefore put down in our table only three zones coming under this heading, viz. the zone of *Paradoxides Forchhammeri*, the zone of *Par. Tessini* and the zone of *Par. oelandicus*. The other zones given in the many tables that have been set up for different areas permit, however, of their being placed in one of the three mentioned.

As an example for showing the development of the table for this part of the series of strata we give here the following tables, from which we exclude, however, as a rule the zone of *Olenellus Kjerulfi*, when this occurs in them.

In 1868 LINNARSSON distinguished in Västergötland

Zone of *Agnostus laevigatus* (highest).
» *Paradoxides* (granulated).
» *Paradoxides Tessini* (lowest).

In 1869 he supplements this table by mentioning, besides *Agn. laevigatus,* also *Liostracus costatus* in the highest zone; and from the middle zone *Par. Forchhammeri* is expressedly quoted.

In NATHORST's table (1869) of Andrarum the following succession of strata is given:

Andrarum limestone.
Alum shale with stink-stone { herein *Par. Davidis?* and (in other layers) *Microdiscus.*
»Ritskiffer» (Drawing-slate).
»Gråkalk» (Grey limestone) with fragments of fossils (1877 by NATHORST called »Fragment limestone»).
»Ritskiffer» (Drawing-slate).

TORELL, in 1870, gave the following table for Andrarum:

Strata faunae primordialis { *Agnosti laevigati* strata.
Selenopleurae[1] strata.
Paradoxidis Davidis strata.
Paradoxidis Hicksii strata.
Paradoxidis Wahlenbergii strata.

To »Agnosti laevigati strata» the remark is added there, that they are the highest Swedish strata in which *Paradoxides* occur. From »Selenopleurae strata», which zone is parallelized with ANGELIN's Regio Conocorypharum, *Par. Forchhammeri* is quoted. From »*Par. Hicksii* strata», *Par. Tessini*, too, is mentioned. By *Par. Wahlenbergi* is meant, as we have previously mentioned, *Olenellus Kjerulfi.* According to LINNARS-

[1] BARRANDE had in 1856 written *Selenopleura* instead of ANGELIN's *Solenopleura,* and BARRANDE'S example was followed by all later authors until LINDSTRÖM, in 1888, in his »List of the fossil faunas of Sweden. I,» advocated the original spelling.

SON (1882) all strata older than the »*Selenopleurae* strata» were first discovered by NATHORST, but we may yet say that it was by TORELL that at least the zone of *Par. Davidis* was first introduced into the table.

In the introduction to his work »On the Brachiopoda of the Paradoxides beds of Sweden» LINNARSSON (1876) was also able to enumerate six zones coming under this heading, viz.

Zone of *Agnostus laevigatus* (highest).
» *Par. Forchhammeri.*
» *Par. oelandicus.*
» *Par. Davidis.*
» *Par. Tessini* (lowest).

In »Skånes graptoliter» (TULLBERG 1882) we obtain, according to LINNARSSON's and TULLBERG's observations, a particularly minute table, chiefly based upon the conditions at Andrarum:

a) Zone of *Agnostus laevigatus* (alone in stink-stone).
b) Zone of *Paradoxides Forchhammeri:*
α) shale with *Agn. laevigatus.*
β) Andrarum limestone.
γ) shale and Hyolithus limestone.
c) » *Agnostus Lundgreni* (alone).
d) » *Paradoxides Davidis.*
e) » *Conocoryphe æqualis.*
f) » *Agnostus rex.*
g) » *Agnostus intermedius.*
h) » *Microdiscus scanicus.*
i) » *Conocoryphe exsulans.*
k) » *Agnostus atavus.*
l) Fragment limestone.
m) Black alum shale.

On closer examination of TULLBERG's annexed lists of fossils, as well as of other information given in connection therewith, we easily find that a considerable reduction of the number of

zones can be made, and that the table thereby assumes a more acceptable form. First of all it may be remarked that the zone of *Agnostus atavus* can, for several reasons, be omitted, and, of course, also the »black alum shale», which has been introduced as the bottom stratum of this table. *Agn. atavus* is namely never met with at any other place than Andrarum, and there only in a loose (fallen) stink-stone lying at the bottom of the Verka River. Furthermore, *Par. Tessini* is found in all zones, from the zone of *Par. Davidis* to the zone of *Conocoryphe exsulans*, both inclusive. *Agnostus Lundgreni*, as well as *Agn. laevigatus*, belongs to the fauna of the Forchhammeri zone. In Västergötland, where the zone of *Agn laevigatus* was first distinguished, it is, contrary to what is the case in Skåne, strongly developed and there also characterized by *Liostracus costatus*, which trilobite is never found in Skåne. That a separate zone of *Agn. laevigatus* has been mentioned from Andrarum, too, is clearly due to the endeavour to get the Andrarum table to agree with the Vestrogothian table. We unite therefore with the Forchhammeri zone both the upper strata, in which *Agn. laevigatus*, and the lower ones, in which *Agn. Lundgreni* predominate. The zone of the last mentioned species is for the rest only mentioned from Andrarum. And finally we must call to mind NATHORST's highly probable supposition of the »Fragment limestone» being an equivalent to the Oelandicus zone of more northerly areas.

We obtain therefore:

c)	Zone of *Par. Forchhammeri*	= (TULLBERG's zones	a—c).
b)	» *Par. Tessini*	= (» »	d—i).
a)	? » *Par. oelandicus* (= shale with Fragment limestone embedded)	= (» »	l—m).

The thickness of the Paradoxides beds is generally much less than that of the Olenus beds. For example, in Djupadalen in Falbygden the former reaches 10 m., at Kinnekulle

and the northern end of Billingen (at Stolan) only 6 m. TULLBERG estimates the thickness at Andrarum at about 4 to 5 m.

When accounting for the different zones we shall more closely refer to such sub-zones as may be of more general interest.

c) The zone of Paradoxides Forchhammeri.

This zone is developed partly with a Trilobite facies, partly with a Brachiopod facies. In the former we have to include the »Andrarum limestone», the formation upon which the zone was first founded, and which by ANGELIN just on account of its great abundance of fossils was first supposed to lie above the Olenid shale. True Andrarum limestone has outside Skåne only a slender development, as, for example, in Västergötland it is encountered near Råbäck at Kinnekulle (see LINNARSSON 1873 and also HOLM 1901), and possibly also at Hunneberg (see Explanation to the map-sheet Venersborg 1887). In Knifvinge, in Östergötland, there is below the upper sub-zone characterized by *Agnostus laevigatus* a dark limestone bearing *Par. Forchhammeri* and Brachiopods. Whether this limestone is to be looked upon as being Andrarum limestone or belonging to the »Exporrecta conglomerate» mentioned further on, I do not venture to decide. From the parish of Ljung, again, there is mentioned *Par. Forchhammeri* from alum shale with stink-stone, which might, perhaps, be included here. From Vrana, in Närke, is mentioned (LINNARSSON 1875) an alum shale bearing *Par. Forchhammeri.* In Ångermanland, where the zone is met with at Högnäså River and at the mouth of the Sjougdälf River (near W. Tåsjö Lake), it is also developed as an alum shale, here with partly black bituminous, partly bluish-grey, sandy and laminated limestone. In Skåne the Andrarum limestone is, besides Andrarum, encountered at several places in the south-eastern part of the province, viz. at Baskemölla, Kiviks Espe-

röd, and according to HOLST (in Explanation to the map-sheet Simrishamn) probably also in the brook N. of Fågeltofta church. At Andrarum there is found in its lowest part a limestone band embedded in shale, about 0.15 m. thick, particularly rich in species of the genus *Hyolithus*, and therefore by LINNARSSON (1882) called the »Hyolithus limestone».

More commonly the zone is, however, developed as a conglomerate-like limestone crowded with brachiopods. After *Orthis exporrecta* LINRS., which is plentiful everywhere in it, it received (1894 by WIMAN) the name »Exporrecta conglomerate». With this development the zone is met with at several places, in southern Öland, viz. in the map-sheets Ottenby and Kalmar, where its occurrence seems, however, to be very sporadic (in the northern part of Öland the zone is entirely absent), in Västergötland (Kinnekulle, Hunneberg, Falbygden[1]), in Närke, possibly at Ullavi, in Jämtland (Brunflo, Hillsand, Vedjeön and at the mouth of the Fallå River), as well as at Lubbträsk (parish of Stensele), in Lappland.

As has previously been stated, the upper part of the strata coming under this heading is especially well developed in Västergötland, so that it is there reckoned as a separate zone, the »zone of Agn. laevigatus», also characterized by *Liostracus costatus* and *Leperditia primordialis*. This part, which here reaches a thickness of 3 to 4 metres (whilst the rest of the zone is no thicker than 0.5 m.) was specially described in 1895 by I. D. WALLERIUS, who with the support of sections from Djupadalen and Gudhem in Falbygden divided it up into several sub-zones, as is shown by the following table.[2]

[1] At Billingen and the neighbouring part of Falbygden no Paradoxides beds at all have been met with, as the soil conceals this zone.

[2] As *Leperditia primordialis* is also found in the Exsculptus beds and is said to be missing in the lower part of the Primordialis beds, the denominations in this table are clearly quite unreasonable.

Sub-zone of *Agn. laevigatus*
- Exsculptus bed with *Agn. exsculptus.*
- Primordialis bed
  - *Upper,* **with** *Leperditia primordialis.*
  - *Lower,* **without** *Leperditia primordialis.*

This part of the zone appears to have a comparatively wide spreading. It is met with in Västergötland, not only in Falbygden, where it is best developed, but also at Kinnekulle. In Östergötland it has been proved at Pålstorp and between Sjögestad and Knifvinge. In Närke it has been encountered at several places, for example at Ö. Ryninge, Vrana, Sättran and Vinala. In Skåne it is, as has been said before, feebly developed. In Lappland some boulders, which possibly come under this heading, have been found at Lubbträsk, and in 1889 HOLST (»Om en mäktig qvartsit, yngre än olenus-skiffern.» — On a thick quartzite younger than the Olenus shale.) mentions strata bearing *Agnostus laevigatus* from a couple of occurrences situated at or near the Arksjöå River, in the province of Västerbotten.

b) The zone of Paradoxides Tessini.

Of the many sub-zones which LINNARSSON and TULLBERG distinguished at Andrarum in this zone, there are really only two that are of any general interest, viz. the sub-zone of *Paradoxides Davidis* SALTER and that of *Conocoryphe exsulans* LINRS.

Paradoxides Davidis, which has in Sweden with certainty only been found at Andrarum[1], where it characterizes the

[1] According to NATHORST (1877) the Davidis strata are possibly also resting at Kiviks Esperöd; likewise at Baskemölla. According to TULLBERG some boulders found at Traneröd, a little N. of Åkarpsmölla, indicate the occurrence of the said strata also in the vicinity of this locality. At none of these places has, however, *Par. Davidis* itself been found. It is generally *Agnostus punctuosus* which has in these cases been looked upon as the leading fossil of the sub-zone.

highest strata in the zone of *Par. Tessini*, was first described by SALTER (1863) from St. Davids in Wales, and is therefore of interest as a form common to the Swedish Paradoxides beds and England's Menevian.

Conocoryphe exsulans, again, characterizes the lowest part of the Tessini zone. A limestone belonging to this horizon had already in 1870 been observed by NATHORST (in local boulders) in the Fågelsång district, but did not attract any closer attention, until NATHORST afterwards encountered it in the solid rock at Kiviks Esperöd. After the common fossil, which had at first been determined as a Spanish form described by BARRANDE, *Conocoryphe coronatus*, NATHORST called the deposit »Coronatus limestone».

In 1879 LINNARSSON described the fauna minutely. The *Conocoryphe* referred to was then found to be a new species, which received the name *C. exsulans*, wherefore the strata were afterwards called »Exsulans limestone». Besides the named fossil and several other fossils of the Tessini zone, there occur here also *Paradoxides Tessini* itself and *Par. Hicksi*, or more correctly, a variety thereof, var. *palpebrosus* LINRS. Already at the above mentioned time LINNARSSON knew the Exsulans limestone also from Andrarum, where SCHMALENSEE found it, and in local boulders from Gislöf, S. of Simrishamn. MOBERG has proved it to exist at Brantevik.

Even in southern Öland the Exsulans limestone has been found somewhat S. of Mörbylånga, viz. in Bredinge ditch and W. of Risinge; the 11 cm. thick stratum, consisting of black, gritty and impure limestone, is here resting upon *Acrothele granulata* conglomerate (of which more further on). *Conocoryphe exsulans* and several other fossils distinguishing the zone have at Borgehage in Öland (map-sheet Mönsterås) been found in a highly fossiliferous boulder of light calcareous sandstone (»the northern Ölandian facies of the Scanian Exulans limestone» as MUNTHE writes in Explanation to the map-sheet

Mönsterås). According to information kindly given by TÖRNQUIST, Exsulans limestone is also met with at Rosenfors near Borgholm, in Öland, where it covers the *A. granulata* conglomerate.

As a bottom stratum of the Tessini zone we have to consider the so called »Acrothele granulata conglomerate» in Öland. In the account of his observations during a journey in Öland, LINNARSSON, in 1876, mentions a limestone with plenty of phosphorite concretions, which he had encountered in the neighbourhood of Borgholm, and he advances the supposition that this may be the »conglomeratum calcareum» bearing *Par. Tessini*, which ANGELIN already in 1851 mentions from there. It is clearly the same stratum, which NATHORST mentions in 1881 from the same place and which he proved to belong to the very lowest part of the zone of *Par. Tessini*, whose border stratum towards the Oelandicus zone it therefore is. HOLM, accounting for *Hyolithus socialis*, which he had also found in this conglomerate, calls it (1893) the »Acrothele conglomerate», after the brachiopod *A. granulata* LINRS., which is very plentiful in it. J. G. ANDERSSON, who in a lecture in 1892 (Bull. Geol. Inst. Upsala, Vol. I, p. 93), had called the conglomerate in question »Oelandicus-Tessini conglomerate», found it later (in 1896) more suitable to call it »Acrothele granulata conglomerate», in agreement with HOLM. Besides the original locality (Rosenfors), it has also been observed on the shore between Borgholm and Köping, at Runsbäck, in the parish of Torslunda, and, as previously mentioned, at Risinge, where it underlies the Exsulans limestone.

The middle part of the Tessini zone is, as has been said previously, particularly well developed and also easily accessible at Andrarum. It is there developed as alum shale, but appears elsewhere in Skåne, for example at Brantevik (partly at least) to be composed of conglomerate-like limestone. In Öland the Tessini strata are generally developed as a slaty, often

calcareous sandstone, in which exceptionally cone-in-cone structure in minor parties has been observed. The sandstone sometimes alternates with a greenish-blue clay resembling that occurring in the underlying Oelandicus zone. Sometimes, as for example at Bredinge, ellipsoids of a greenish-grey limestone are met with in the calcareous sandstone. At Borgholm, Äleklinta and Horn ellipsoids or concretionary layers of green stink-stone have been encountered in the highest part of the zone. The Tessini zone, which commences (on the west coast) a little to the N. of Ventlinge, can then be traced northward up to the limit between Alböke and Föra (in the map-sheet Mönsterås). It reaches a thickness of up to 25 or 30 m. in the environs of Borgholm. In the northernmost part of Öland the zone appears to be missing. To judge from shore-boulders, the strata of the Tessini zone, however, very likely extended a little further northward. HOLM found namely at Rörstensudde boulders of green stink-stone with seams of sandstone bearing *Ellipsocephalus muticus* ANG. But the zone probably does not reach much further north, as J. G. ANDERSSON on the northwestern tongue of Öland has found boulders, which show that the Obolus strata have been deposited directly upon the Oelandicus strata, wherefore no Tessini zone could be found here (cfr J. G. ANDERSSON 1896, »Ueber cambrische und silurische phosphoritführende Gesteine», page 37).

In Västergötland the rock is chiefly alum shale and stinkstone, except the very lowest part. At Djupadalen it consists (according to WALLERIUS) of a dark blue alum shale, which downwards merges into a light yellow sandstone, and at Hvalstad, in the south-easternmost part of Falbygden, (according to MUNTHE) of a black, somewhat micaceous, argillaceous shale overlying a sandstone which probably belongs to the Oelandicus zone. The Tessini zone is met with not only at Hunneberg and Kinnekulle, where it is only a few cm. thick,

but also in Falbygden (at Djupadalen, Gudhem and in older times at Oltorp).

In Östergötland there occurs at Berg a greenish-grey limestone bearing *Par. Tessini*, mentioned already in 1881 by NATHORST. TULLBERG reports (in the Explanation to the map-sheet Vreta Kloster) from here also *Par. oelandicus*, and considers the strata referred to as transition beds between the Tessini and Oelandicus zones.

From Närke (Hjulsta, Tomta, Vinala and Vrana) LINNARSSON mentions a blue-green, lamellated clay, with limestone embedded, bearing *Par. Tessini*. From its upper limit at Hjulsta a conglomerate (or a crack-filling) of dark, bituminous limestone, bearing *Agnostus pisiformis* and *Acrothele coriacea*, is also mentioned. The similarity of the blue-green rock to the Oelandicus zone in Öland is drawn attention to.

From West-Dalarne SCHMALENSEE mentions (1892) Tessini shales with stink-stone encountered at Skärvagen.

In Jämtland, where this zone is developed as alum shale with stink-stone, it is poorly represented. WIMAN reports strata coming under this heading from Brunflo (E. of Östersund) as well as from northern Jämtland, where SVENONIUS found them at Kopparrökhällarna in the parish of Alanäs. To judge from boulders, this zone very likely also occurs in Lappland (at Norrliden, Lubbträsk, Skikkiberget, in the parish of Stensele, and at Strömnäs, Granhöjden and Skansholmen, in the parish of Wilhelmina).

a) The zone of Paradoxides oelandicus.

As we have already previously mentioned in detail, this zone was first distinguished in Öland. The rock there is a light, greyish-green argillaceous shale or lamellated clay with scattered lenses of a likewise greyish-green limestone. More seldom the rock is somewhat sandy and resembles then certain varieties of the Tessini sandstone. The same rock is

found in the majority of the districts where this zone is encountered. A remarkable exception is Jämtland, where the rock is alum shale with stink-stone.

In Öland the zone begins about 4.5 km. S. of Mörbylånga, continues thence, with a width which on the whole corresponds approximately to half the strip of shore below the western land-height (»Landborgen»), northward across the map-sheets Ottenby, Kalmar and Mönsterås, in which latter, about 5 km. N. of Köping's church, it dips down below the surface of the sea. That it continues, however, (submarine) still further towards the N. becomes apparent from the shore-boulders that have been mentioned more minutely under the Tessini zone in the preceding pages.

When LINNARSSON, in 1877, described the fauna of the zone, he did not as yet know the strata coming under this heading from any other place than Öland, but yet presumes that such, as he mentions already in 1876, also occur in Jämtland. Nowadays the zone, more or less well developed, is known from many of our Silurian areas. In Jämtland, where, as previously mentioned, the rock consists of laum shale and stink-stone, the zone occurs, according to WIMAN, at the following places: Brunflo, Hofverberget, Westskucku and Bingsta, as well as between Skålan and Skalängen near Tossåsen.

In Närke the zone was first in 1893 definitely proved to exist at Hjortsberga by J. G. ANDERSSON. It is there developed as a blue-grey argillaceous shale with limestone, bearing, amongst other fossils, *Par. Sjögreni* and *Acrothele granulata*. The strata are, however, somewhat disturbed.

In Västergötland the zone is not known with certainty, but MUNTHE presumes (Explanation to the map-sheet Tidaholm) that a grey to greyish-green, clayey and slaty sandstone, devoid of fossils, which at Hvalsta rests below the black, micaceous argillite belonging to the Tessini zone, from which it is clearly separated, represents the Oelandicus zone

there. According to MUNTHE (l. c., p. 33) HOLM has at Kinnekulle found a corresponding shale, which is by him »supposed to belong to the Ölandicus zone».

As has previously been mentioned, the so called »Fragment limestone» at Andrarum is, according to NATHORST, probably a Scanian parallel to the Oelandicus zone.

From Norrland it is also known, namely in the form of boulders of grey, hard, almost compact limestone from Kyrkberg and Tallträsk, both in the parish of Stensele.

A 1. The Olenellus beds.

It was observed already of old that the lowest part of the Silurian, or, as it was said then, the Transition formation, is built up of sandstone. On account of the circumstance that in the latter, or rather on certain surfaces of layers in it, irregular, often ramifying, ripple-like ridges occur, which we now, according to NATHORST, mostly interpret as the tracks of some lower animals, but which at first were believed to be the impressions of algae, this sandstone was called Fucoid sandstone (cfr ANGELIN's Regio Fucoidarum). But by and by even real fossils were found in the Fucoid sandstone, first of all Brachiopods, and amongst those also a very characteristic form, *Mickwitzia monilifera,* from which a certain part of the sandstone later on received the name »Mickwitzia sandstone». And when SCHMIDT, in 1888, found a trilobite, *Olenellus (Schmidtiellus) Mickwitzi* SCHMIDT, together with *Mickwitzia* in the lowest sandstone of Esthonia, it was clear that even the lowest Cambrian sandstone of Sweden had to be included in the Olenellus beds. Already previous to SCHMIDT's said discovery the appellation »Olenellus zone» had been introduced for the so called greywacke shale, which at Andrarum and in Norway directly overlies the bottom sandstone, and in which another *Olenellus, O. (Holmia) Kjerulfi* LINRS., had

been found. That the Kjerulfi strata, which directly underlie the Paradoxides beds, and at first had even been looked upon as their lowest part, were afterwards put down as a younger division of the Olenellus beds is easily to understand. As, however, no *Olenellus*-bearing beds had been proved either above the Esthonian (or the contemporaneous Vestrogothian Mickwitzia sandstone) or below the greywacke with *O. Kjerulfi*, it was in reality on very loose grounds that a younger zone of *Holmia Kjerulfi* and an older one of *Schmidtiellus* had been distinguished in the Olenellus beds. That the sandstone, which at Andrarum underlies the greywacke, is absolutely contemporaneous with the Vestrogothian »Mickwitzia sandstone» is clearly, strictly speaking, unproved. The supposition gains, however, a certain amount of support from the fact that MOBERG found, somewhat S. of Brantevik (in the neighhourhood of Simrishamn), both *Olenellus* (*Schmidtiellus*) *Torelli* MBG and *O. (Holmia) Kjerulfi*, the former in the upper part of the sandstone, the latter in a greywacke-like shale closely connected with strata belonging to the Paradoxides beds. The species found in Esthonia is so little known that its relation to *O.* (*Schmidtiellus*) *Torelli* MBG cannot be determined with certainty, yet it seems as if they belonged at least to one and the same group (characterized, amongst other things, by a long thoracic horizontal spine) definitely separate from the sub-genus *Holmia*, which is at any rate also represented in the sandstone of Skåne. The parallelization between the Scanian »Torelli sandstone» and the Vestrogothian »Mickwitzia sandstone» is thus not so absolutely safe. At present it is the most probable, though. Starting from this we must parallelize the Scanian greywacke and the Vestrogothian »Lingulid sandstone», as both are resting, we presume, on deposits corresponding to each other. In our table we have, however, put down the strata of Skåne and Västergötland separately, as representing, the former a Trilobite facies, the latter a Brachiopod facies of our Lowest Cam-

brian. After these general remarks we can pass on to the more detailed account of the different strata.

A 1. I. The Olenellus beds of Skåne and deposits analogous with them.

b) *The zone of Olenellus (Holmia) Kjerulfi. (The Greywacke shale).*

Everywhere this zone has been encountered it is developed as a greywacke shale. In it is found a characteristic, but poor, fauna with the following determinable species: *Olenellus Kjerulfi* LINRS. (originally by TORELL called *Paradoxides Wahlenbergi*), *Ellipsocephalus Nordenskiöldi* LINRS., *Arionellus primævus* BRÖGGER, *Hyolithus Hermelini* HOLM and *Lingulella? Nathorsti* LINRS. Peculiarly enough, LINDSTRÖM enumerates amongst the fossils of the Kjerulfi zone, even if with hesitation, also *Agnostus atavus*, of which we have spoken previously, and which can certainly not belong to this zone.[1]

Already in 1862 ANGELIN distinguished (in that part of the text to this Geological Map of Skåne which was then printed) the greywacke shale, which he counted as the highest (4:th) zone of the »First or oldest sandstone group». It was then quoted by him from all hitherto known occurrences of Skåne, viz. from Forsemölla, at Andrarum, from Röstånga, Kiviks Esperöd and Gislöfshammar. ANGELIN knew, however, no fossils from there. The leading fossil of the zone, which was first found by NATHORST at Forsemölla, is in the rest of Skåne only found at Gislöfshammar.

In Lappland the zone has been met with at several places. HOLM, in 1893 (l. c., p. 52), mentions a grey, hard argillaceous schist bearing *O. Kjerulfi* from Storuman, and in a similar rock from Peuraur and Ö. Ramanvare *Hyolithus Hermelini*, and from Skeldavare *Hyolithus* sp. Even in boulders

[1] According to GAVELIN (1909) *Torellella laevigata*, which in Sweden is found in the Mickwitzia zone only, also is encountered in the Kjerulfi zone at Tomten in Norway.

from Kyrkberget, in the parish of Stensele, *Olenellus Kjerulfi* has (according to HOLM 1890) been encountered. And on Luopahta, at Torneträsk, MOBERG (1908) found in the upper part of a greywacke-like argillite, which was resting upon the sandstone, a fossil-rich, impure limestone bearing *Arionellus primaevus, Ellipsocephalus Nordenskiöldi* and *Obolus* (*favosus* LINRS.?).

a) *The zone of Olenellus* (*Schmidtiellus*) *Torelli.*

In 1862 ANGELIN divided the oldest Scanian sandstone into the following strata:

3) Hardeberga sandstone (or Fucoid sandstone)
2) Qvartzite
1) Lugnås sandstone.

He says about the Hardeberga sandstone, which in its typical form is composed of rather large, rounded grains of white quartz cemented by silica, that it is fine-grained in its upper part and often passing into greywacke shale. »Fossils», only found in the upper part, were considered to be fucoids or trails of sandworms (Arenicolae). This sandstone has in Skåne a great distribution, from the vicinity of Simrishamn right up to Kullaberg. The Quartzite, which is partly a breccia, occurs only at a few points: Munka Tågarp (at Tosterup), Röstånga, as well as at Killegården and Båuf on Söderåsen. As Lugnås sandstone ANGELIN distinguished the lowest, arkose-like, often red strata, which are only encountered at Delperöd and Forsemölla (at Rörum), at which last mentioned place they are said to occur in alternate layers with the gneiss, which therefore with no little probability should be looked upon as a metamorphosed arkose.

In 1867 TORELL, who uses KJERULF's denomination »Sparagmit» for the sandstone in question, describes some so called

fossils, amongst others *Eophyton Linnaeanum* TORELL,[1] *Psammichnites (Arenicolites) gigas* TORELL and *Cordaites? Nilssoni* TORELL; the two last mentioned he states to be from the Simrishamn district.

As will be more particularly mentioned in the account of Västergötland's Cambrian sandstones, WALLIN (1868) called the lower part of it after *Eophyton Linnaeanum*, which occurs plentifully therein, »Eophyton sandstone», a name which was afterwards also used for the Scanian sandstone. It was not until 1873 that NATHORST in his thesis for the doctor's degree showed that the majority of the »fossils» from the Eophyton sandstone, which had at that time been described, were only trails or tracks partly caused quite mechanically, partly of animals in motion.

In 1892 MOBERG mentioned (in his paper »Om Olenellusledet i sydliga Skandinavien») the discovery of two species of *Olenellus* in the Scanian sandstone. One of them, *O. (Holmia) Lundgreni* MBG, of which a badly preserved, indeterminable specimen, already mentioned by LUNDGREN in 1874, had only been met with in loose boulders at Lake Tunbyholmssjön in a grey, brown-speckled sandstone in which also *Hyolithus De Geeri* HOLM occurred. From Gladsax and a spot W. of Tunbyholm fossils had also, although not in a determinable condition, been found in a sandstone similar to the boulders previously mentioned. The other one, *O.* (*Schmidtiellus*) *Torelli*, had been found in the solid rock immediately S. of Simrishamn in a blue-grey, strongly calcareous sandstone embedded in the ordinary grey-green sandstone there. Besides *O. Torelli* there was a plentiful occurrence of brachiopods, *Obolella Mobergi* WALCOTT and *O. Lindströmi* WALCOTT. These species, together with *Hyolithus De Geeri*, have also been encountered

[1] Two of the originals are derived from Västergötland, but one from Skåne in »saxo arenaceo formationis siluricae inferioris ad lacum Ringsjön». Only Gotlandian sandstone is, however, resting there.

at Sularp, here in a loose brown sandstone, intermingled in the grey-green, brown-speckled, hard sandstone common there. In a similar rock the same fossils were subsequently proved at S. Sandby. Even between Brantevik and Gislöfshammar an *Olenellus* had been found in grey-green sandstone resting there. I was then inclined to consider the strata bearing *O. Torelli* as being somewhat older than the rock in which *O. Lundgreni* had been found, but all these strata as younger than the strata of *O. Mickwitzi* SCHMIDT. If there really may be any difference of age between the said three species, it can, however, hardly be very great.

At Hardeberga, as well as at Simrishamn, one can clearly see the greenish sandstone directly overlying a white, thickly banked, hard sandstone, the typical Hardeberga sandstone. If the green sandstone which bears *Olenellus Torelli* is parallelized with the Mickwitzia sandstone in Västergötland, which rests directly upon the Archaean, the lower white sandstone in Skåne is, of course, older than any that has been encountered in Västergötland.

During the construction of the harbour of Simrishamn there was a good opportunity a few years ago of studying sections in the lower sandstone. Pretty thick greywacke-like strata were at some places found between the hard sandstone banks, at other places, however, slaty sandstone, rich in a *Hyolithus*, all unfortunately far too badly preserved to be determined as to the species, was found.

The sandstone is easily accessible in the Simrishamn district in the bare shore-rocks, giving a splendid opportunity for studying the sequence of strata. The many small dislocations met with here are, however, a serious check. HOLST tried, in 1893, to set forth the succession of strata in the lower sandstone, partly in the Kalmarsund district, about which more later on, partly in South-eastern Skåne. According to HOLST we meet in the last mentioned area 1) the *bottom-stratum,* a

red, richly felspathic sandstone, at Raskarum, Forsemölla (parish of Rörum), Glimminge (parish of Bolshög) and near the southern end of Lake Gyllebosjön. There is of course no transition between the sandstone and the gneiss at Forsemölla, such as ANGELIN thought he saw; it is only the great amount of unweathered felspar which could have caused ANGELIN's statement. At Ekeröd a conglomerate is found in boulders, with pebbles of quartz and felspar in a cementing matter like the rock of the bottom stratum. After this come:

2) blue-grey or black sandstone with tracks, 3) whitish sandstone with grey seams (with tracks), 4) sandstone with *Diplocraterion* (Jerrestadshall and Brantevik are occurrences especially to be mentioned), immediately above which there follow in the said two localities 5) shelfs bearing *Psammichnites* (*Arenicolites*) *gigas* TORELL and *Cordaites? Nilssoni* TORELL (herein a sandstone-conglomerate); above these strata come first 6) grey, thereupon 7) dirty-grey and greenish sandstones, the former reminding one of the green shales at Bornholm, which bear *Hyolithus*, the latter reminding one of the sandstone shingles at Kalmarsund, and finally highest up 8) a phosphorite-bearing, dark sandstone which in its highest layer is filled with lumps of iron pyrites.

In the sandstone at the coast of Småland (and Blekinge), along Kalmarsund, HOLST proved a similar sequence. He has here as bottom stratum 1) *sandstone-conglomerate* with pebbles of quartz, more rarely of Archaean rock, thereafter (yet only in the extreme North) 2) *red-striped sandstone*, then 3) *white* or *red sandstone* with *Scolithus linearis* TORELL (well developed on Furön Island) and 4) *green-grey sandstone* with winding worm-trails, *Scolithus errans* TORELL. Furthermore is mentioned 5) *sandstone* with *Diplocraterion*, of which HOLST does not know, though, whether it may not possibly be older than the sandstone bearing *Scolithus errans* just mentioned. In connection

with the *Diplocraterion*-bearing sandstone comes 6) *white*, partly *calcareous sandstone*.

In Mörbylånga, the only place in Öland where solid rock of lower Cambrian sandstone has been observed, one can find a partly grey, partly black, bituminous sandstone, superimposed by the Oelandicus zone (HOLST 1893). But otherwise only a grey or green (glauconite-bearing), partly phosphorite-bearing sandstone of Lower Cambrian age is met with in plenty of stones cast up out of the sea, in the skerries in Kalmarsund, as well as in the west-coast of Öland; in these stones has been found a fauna described by MOBERG in 1892. The most common fossils are *Hyolithus confusus* HOLM and a small brachiopod, *Discinella Holsti* MBG. After the last mentioned, very characteristic fossil (which unfortunately, however, could never be proved in solid rock [1]) the strata are often called »the zone of *Discinella Holsti*». It is clear that this zone belongs to the Olenellus beds, but its nearer position in relation to the other fossiliferous horizons of the sandstones cannot be stated. *Discinella Holsti* was also met with in a boulder of a rusty sandstone from Mariehamn (Åland). WIMAN is, however, inclined to believe that the boulder was carried thither as ballast.

Olenellus sp., besides a new *Arionellus*, and a new *Ellipsocephalus* are mentioned (1903) by WIMAN from a North Baltic boulder. From such ones are furthermore mentioned a couple of forms previously known from the sandstone of Västergötland, viz. *Mickwitzia monilifera* LINRS. and *Torellella laevigata* LINRS., together with a lot of ostracods and brachiopods. Furthermore WIMAN has found fragments of a trilobite, which he wants to interpret as a *Paradoxides*, in a sandstone from Åland. If the interpretation were correct, we would here have also Paradoxides strata with sandstone-facies, and it would be difficult,

[1] *Discinella Holsti* has been eagerly but vainly searched for by the author, especially in the *Hyolithus*-bearing strata in the harbour of Simrishamn.

as WIMAN himself remarks, to determine which of the many new species described from here would have to be included in the Paradoxides beds, or which of them belong to the Olenellus beds. To judge from the list of fossils, it seems scarcely credible that all of them belong to one and the same faunistic horizon.

A 1. II. The Lower Cambrian of Västergötland.

Sandstone forms, as is known of old, the bottom stratum in all the mountains of Västergötland. A minute investigation into this sandstone was first made by J. A. WALLIN, who, in 1868, distinguished in it the following strata:

3) Fucoid sandstone (loose, greyish-white)

2) Eophyton sandstone[1] (hard and with numerous »plant-fossils»)

1) Conglomerate (with well rolled quartz pebbles).

As we have mentioned previously, the so called plant-fossils were described by TORELL (1867 and 1870), and LINNARSSON also contributed (1869 and 1871) towards an increase in their number. It has also been mentioned before, how NATHORST, already in 1874, showed that the majority of these »plant-fossils» were mere tracks. He published further works in this direction in 1881 and 1886. Some of the new species described by LINNARSSON from the Cambrian sandstone of Västergötland were, however, genuine fossils. Already in 1868 he mentioned a *Lingula* from the Fucoid sandstone in Djupadalen, and afterwards another, better preserved, which he, in 1869 (»Om några försteningar från Vestergötlands sandstenslager»), called *Lingula? favosa*. At the same time he described from the Lower sandstone under the name of *Lingula monilifera* the brachiopod which SCHMIDT, on account of its having been found by MICKWITZ in Esthonia, too, later called *Mick-*

[1] The term Eophyton sandstone was here used for the first time.

witzia monilifera, and which afterwards had to give the name to the zone. And in 1871 LINNARSSON described from the same beds *Hyolithus laevigatus* (by HOLM in 1893 called *Torellella laevigata*), and under the names of *Agelacrinus* and *Astylospongia* two fossils which NATHORST in 1881, after having come to the conclusion that they were impressions of Medusae, called *Medusites*.[1] NATHORST also drew the conclusion that, when the sandstone with interstratified clay layers was deposited at Lugnås, where the fossil Medusae were found, there had been a long, shallow, periodically emerging shore. In 1885 and 1886 he confirmed his evidence still further by showing that the quartz pebbles in the conglomerate were sandworn.

In 1901 HOLM proposed to exchange the appellations Fucoid sandstone and Eophyton sandstone, which had until that time been generally used, for the more up-to-date names of Lingulid sandstone and Mickwitzia sandstone. Already LINNARSSON (for example in 1869, in his Memoir alluded to above) considers it more suitable to group the bottom conglomerate together with the overlying Eophyton sandstone into one division. On Kinnekulle the thickness of the Mickwitzia sandstone is, according to HOLM (1901), 10 m., whilst the Lingulid sandstone, which everywhere has a much greater thickness than the former, reaches 24 m. The Mickwitzia sandstone, the lower of the two divisions, is generally scarcely accessible, at least not in natural sections. But in the small Lugnås Hill, to the East of Kinnekulle, where the sandstone is only to a small extent covered by alum shale, from which LINNARSSON mentions the fossils characteristic for the Olenid shale, we have at many places penetrated

[1] As the generic name *Medusites* was previously used by GERMAR for some problematical fossils that were by GOLDFUSS referred to Lumbricaria, WALCOTT (Fossil Medusæ. Monogr. U. S. Geol. Surv. Vol. 30. Washington 1898) proposed the name *Medusina* instead.

the sandstone in the millstone quarries, in order to get down to the weathered Archaean (millstone rock) which forms the substratum, and there the lower strata of the sandstone are quite accessible. It is also there that the greater part of the fossils of the sandstone were found.

b) *The Lingulid sandstone* is generally very thickly banked, loose, light-grey, usually with yellowish-brown, rusty flares and spots on surfaces exposed to the atmosphere, caused by the weathering of the iron pyrites interspersed in it. Fossils (scarce brachiopods) are only found at Djupadalen (NE. of Ålleberg) and in Kinnekulle. One of the upper sandstone banks of Kinnekulle is highly calcareous, and the uppermost surface of this stratum itself full of small pebbles of a sandstone highly impregnated with iron pyrites. This conglomerate is, however, fairly thin. The boundary between the Lingulid sandstone and the Mickwitzia sandstone is never marked in Kinnekulle, but at Presttorp, at the northern end of Billingen, there is, according to LINNARSSON (1871), a conglomerate at the said boundary.

a) *The Mickwitzia sandstone* is hard, grey, but weathered somewhat reddish. The sandstone, which is rich in mica, is as a rule divided into thin beds interstratified with thinner seams of a greenish-grey clay. That it is a beach-formation is also shown by its common ripplemarks and pyramidal stones. The fossils are mentioned in the foregoing.

Even in the provinces adjacent to Västergötland the substratum of the Paradoxides beds, where this is exposed, is formed of a sandstone resembling the Lingulid sandstone. In Östergötland this latter has been encountered only at Svartån River and at Motala River. In Närke the extent of the sandstone is rather considerable, but even there it is rarely directly exposed.

In Dalsland GAVELIN (1909) found in the skerries along the shore of Lake Vänern, about 20 km. S. of Åmål, a grey-green, at certain places conglomeratic, sandstone bearing *M. monilifera*, *Torellella laevigata* and a Lingulid. This sandstone is deposited in clefts in the Archaean rock. The occurrences observed are Räfkulteholmen and adjoining skerries, as well as an islet situated 5 km. further south, at Örneklofvarna.

According to SCHMALENSEE (1892) and HOLM (1893, p. 148), HOLST found a gravelly sandstone with *Torellella lævigata* LINRS. at Knallarna, SE. of Lake Guttusjön, in the parish of Idre, in West-Dalarne. *T. laevigata* has by O. E. SCHIÖTZ also been found in lime-sandstone resting on another locality, viz. at Lomviken, near the Norwegian frontier, SW. of the afore mentioned place. According to HOLM (1893 p. 148, note 2) some fragments of *Olenellus* have also been met with in the same lime-sandstone. These fossils are also frequently found together with *Mickwitzia* in boulders of sandstone and conglomerate from the North-Baltic Silurian.

Beginning in West-Dalarne, a belt of sandstones extends, with comparatively few interruptions, northwards along the Mountain range and past Torneträsk. In the geological general map of Sweden compiled by TÖRNEBOHM in 1901 (Sver. Geol. Unders. Ser. Ba, N:o 6) these sandstones pass chiefly under the appellations: Dala sandstone, Wemdal quartzite and Cambrian sandstone. The two first named are now by TÖRNEBOHM reckoned to the Algonkian. As Dala sandstone is also signified a sandstone deposit between Gästrikland's Lake Storsjön and the Bay of Gäfle. I only want to call to mind here TÖRNEBOHM's earlier statement of 1877 (»Om sandstensbäckenet i Gestrikland.» — Geol. För. Förh. Vol. 3) to the effect that this sandstone was deposited contemporaneously with the Orthoceras limestone. At that time he presumed namely that the formation of the Dala sandstone

continued during the Ordovician. The occurrence of Silurian deposits (Orthoceras limestone and Ceratopyge shales) resting on Limön Island, in the Bay of Gäfle, seems, in my opinion, to entitle some hesitation as to TÖRNEBOHM's determinations of the age of this sandstone. The Wemdal quartzite, a stratum in TÖRNEBOHM's Seve group, is said to extend from the northern end of Dalarne, through Härjedalen and Jämtland, up to Lappland. What little I have seen of this formation, about whose age especially TÖRNEBOHM (as well as HÖGBOM) at different times have had very divergent opinions which have given rise to a literature of its own, does not entitle me to express any definite opinion on this matter. Yet I think I ought to mention that I have not been able to find any special reasons why this sandstone should not be of Cambrian age. At Klöfsjö Lake the border towards the considerably folded and broken Silurian deposits is quite the work of a dislocation.

In the northern part of the sandstone E. of the mountain ridge SVENONIUS has at several places, especially in the mountains at Lake Tjäggelvas, in the parish of Arjeploug, and at Lake Peuraur, in the parish of Jokkmokk, but besides that also at the more northerly situated lakes Lajdaur, Satisjaur and Kajtumjaur, found *Hyolithus* in sandstones and argillites.

Already in 1884 SVENONIUS distinguished (»Nya olivinstensförekomster i Norrland.» Geol. För. Förh., Vol. 7) these fossiliferous strata as a zone of its own, the »Hyolithus zone». In his work »Om berggrunden i Norrbottens län etc.» (Sver. Geol. Unders. Ser. C, N:o 126) he has a special table for the sequence of strata in the Hyolithus zone. On the lowest division, gneiss and hälleflinta, there are *Scolithus* sandstone, thereafter grey-green shale with *Hyolithus,* then black argillite together with phosphorite-conglomerate and, highest up, so called »Raman shale». The Kurravaara area at Torne River is considered as petrographically equal, but no fossils have been found therein.

At Lake Torneträsk, where I have myself minutely investigated the lower strata of the division in Luopahta, Kaisepakte and Pessinenjokk, a 15 metres thick green argillite devoid of fossils is encountered below the above mentioned 1.72 m. thick, fossiliferous, grey argillite of the Kjerulfi zone. Under the green argillite there commenced sandstone, 50 m., which in its highest part had a thin band of impure limestone and was also otherwise of a very varying appearance. Especially remarkable were a »Leopard sandstone», white, with big brown spots, as well as a greenish, thinly lamellated, and another yellowish-grey, slaty sandstone, with black clay coatings, which on some surfaces showed particularly beautiful narrow, sinuous »trails» traversing each other. Under this sandstone there are some green and red, fine argillites (30 m.), in which *Platysolenites antiquissimus* EICHW. and *Hyolithus* sp. were infrequently found. Hereunder followed sandstones of varying kinds (8 m.); below these a shale resembling greywacke with unknown organisms. In the immediate vicinity of this coherent section the Archaean was seen covered by a coarse conglomerate, generated by weathering of the rock-ground, upon which conglomerate we find sandstone of varying appearance (8 m.) underlying greywacke shale.

Thus we have here below the Kjerulfi beds a series of argillaceous shales and sandstones (the latter predominating) of at least 76 m. thickness. The sandstones are partly so like those belonging to the Lower Olenellus beds in Skåne that it is easy to mix them up.

We know of old that the Silurian deposits in Sweden partly harmonize with those of England, partly with those of Russia, or in other words, that the conditions relating to the formation were similar in certain parts of the country for certain periods, sometimes to those of a more south-wes-

terly area, sometimes to those of a more north-easterly area. Several questions here concerned have of late been brought nearer to their solution, partly through J. G. Andersson's studies (1896) of the conglomerates of Öland, to which attention had first been drawn by Holm's journey in Öland (1882), and of boulders found in Öland, partly through Wiman's reconstruction of the North Baltic Silurian (1903 and 1907).

Even Grönwall's researches into the Scandinavian Paradoxides beds (1902) deserve in this connection to be remembered. For that part of the Silurian period when these were deposited Grönwall considered himself able to distinguish two different Scandinavian Silurian areas, a south-westerly and a north-easterly, which in certain points show a developement different to each other. In the former he includes Bornholm, Skåne (and the Christiania district), in the latter Öland, Östergötland, Närke and Jämtland (as well as Ringsaker in Norway). Västergötland stands upon the transition between the two. Through its well developed Oelandicus zone, Öland is, as Grönwall has pointed out, really in very close connection with Östergötland, Närke and Jämtland (in which last mentioned province the nature of the rock indicates, however, conditions which better agree with those of Skåne), but in southern Öland the remaining Cambrian, and chiefly the oldest Ordovician strata, agree so closely with corresponding deposits in Skåne, that I want to look upon southern Öland as belonging to the south-eastern Silurian area right until somewhat after the end of the Cambrian period. First after that, even this part of Öland passes over to the north-eastern area. Jämtland (as well as Norway), on the other hand, show great analogies with Skåne during the older part of the Ordovician period, while, on the other hand, the more southerly situated Silurian of Dalarne, which during the middle Ordovician period nearly agrees with that of Västergötland,

otherwise both in its lowest and in its highest Ordovician deposits bears an Eastern Baltic impress. The Gotlandian of Jämtland shows greatest analogy with that of Norway, that of Gotland with the Russian, that of Middle Sweden with the Scanian (and that of England).

To trace the varying course of the development from district to district, from period to period, would certainly have been interesting. But for several reasons the remarks made in the preceding must suffice. It is not enough to be able to combine, in our times it is also necessary to have facts to combine. And, unfortunately, our knowledge of the Silurian geology of Sweden is as yet much too defective. As long as we discuss in full earnest the question relating to overthrust areas 100 km. broad, where the Archaean is hiding the Silurian deposits, or concerning mighty Silurian beds whose highest parts, right through entire series of strata, have been metamorphosed into irrecognisability, whilst the Silurian bottom strata, at the spot, or at least in the immediate vicinity, are normally developed and preserved, so long it is clearly impossible to obtain or give any reliable review of the general chorology.

I would only like to add one thing. Pretty often we see in our geological literature more or less direct statements to the effect that the Silurian sea has entirely covered Sweden, and this with the meaning that at one time the sea has occupied the entire area belonging to Sweden. The strata then deposited would afterwards through dislocations have been divided up into separate areas, of which the denudation has generally left behind only those most depressed. That more or less local elevations and depressions occurred already during the Silurian period can hardly be more clearly shown than through the conglomerates and gaps in the series of strata which in Öland have been observed from the upper part of the Cambrian and the lowest part of the Ordovician

series. It is quite manifest that such oscillations, due to whatever cause, occurred even in the rest of Sweden, and were there of consequence for the limits of the sea, as well as for the distribution of the sediments. If we further look at such facts as that, that the Silurian in Dalarne commences with the Ordovician, or that the Mickwitzia beds of Västergötland rest directly upon the Archaean, whilst the corresponding horizon in the sandstone of Skåne certainly belongs to the upper part of the sandstones, from which it is thus seen that the Silurian sea must have encroached upon different parts of the country at different periods, it strikes me as most probable that parts of Sweden at times lay above sea level during the Silurian period, as well as that the depth of the sea changed during different periods, at different places.

I did, of course, not in any way want to deny with this that foldings and dislocations played a part with regard to the distribution of the Silurian areas such as they now are.

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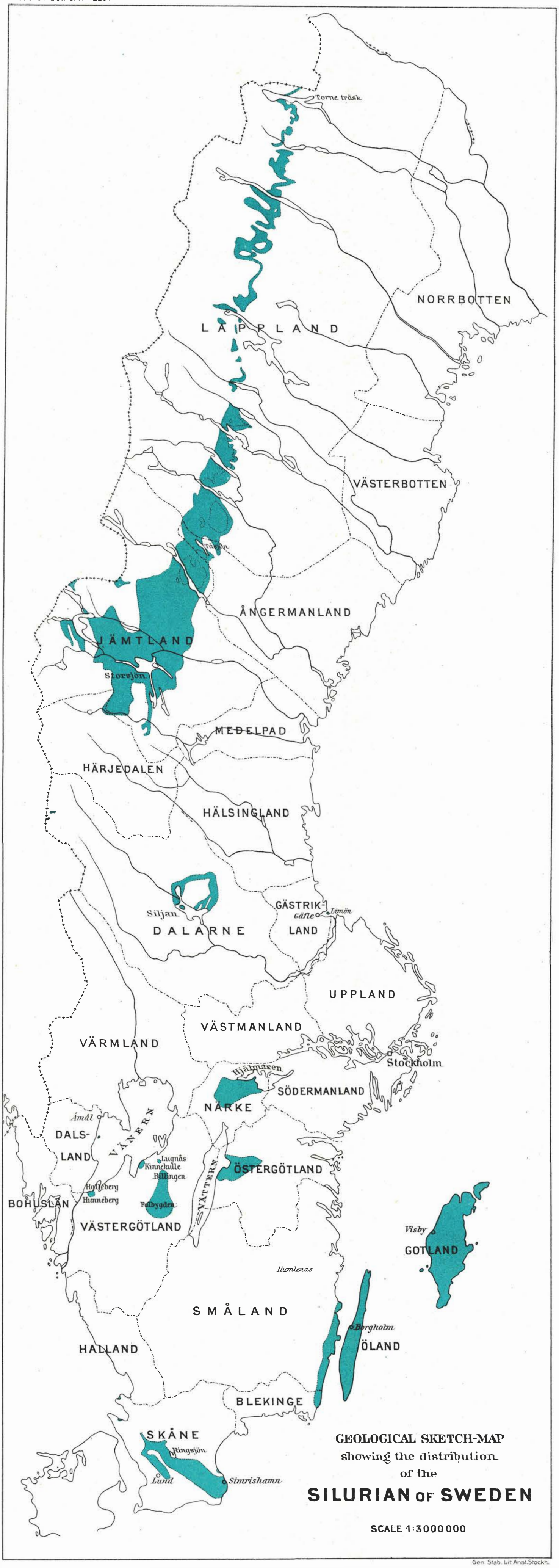

GEOLOGICAL SKETCH-MAP
showing the distribution
of the
SILURIAN OF SWEDEN

SCALE 1:3000000

Gen. Stab. Lit Anst. Stockh.