# The Viruan (Middle Ordovician) of Öland

By

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Abstract.—The stratigraphy and lithology of the Viruan (Middle Ordovician) limestones of the bed-rock of Öland are described based on three bores and on field work in the outcrop area. A combined litho- and bio-stratigraphic classification (termed topo-stratigraphic) is introduced for the described sequence. The names of the Estonian stages (Aserian, Lasnamägian, Uhakuan, and Kukrusean) are used as chrono-stratigraphic references instead of the previous Swedish names of the units of stage category (*Platyurus*, *Schroeteri*, *Crassicauda*, and *Ludibundus*, respectively). New topo-stratigraphic divisions are Segerstad Limestone (of Aserian age), Skärlöv, Seby, and Folkeslunda Limestones (of Lasnamägian age), Furudal, Källa, and Persnäs Limestones (of Uhakuan age), and Dalby Limestone (of Kukrusean age in the bed-rock of Öland). The Aserian and Lasnamägian topo-stratigraphic divisions have the same lithological characteristics throughout Öland. The Uhakuan beds are developed as calcilutites (Furudal Limestone) on southern Öland continuing as a tongue (Källa Limestone) on northern Öland. The middle and upper part of the Uhakuan beds of northern Öland consist of calcarenites (Persnäs Limestone) lithologically indistiguishable from the Kukrusean Dalby Limestone which forms the bed-rock only on northern Öland.

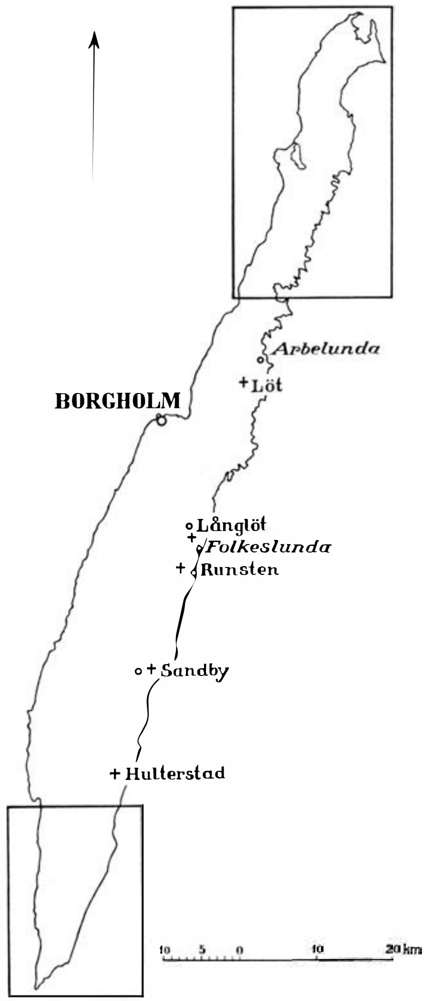
Within the Segerstad Limestone two zones are distinguished (z. of *Angelinoceras latum* and z. of *Illaenus planifrons*). Holm's zones of *Lituites discors*, *L. lituus*, and *L. perfectus* are of Lasnamägian age, and their stratigraphic position and faunal characteristics are described.

## Contents



# Introduction

This paper is the first of a series of papers by the present writer on the stratigraphy and lithology of the Viruan (Middle Ordovician) rocks of southern and central Sweden (exclusive Scania). In this series first a description of lithologic




Text-fig. 1. Map of Öland showing the areas investigated in greater detail (areas of the geological maps of Text-figs. 2 and 14) and the location of selected localities on central Öland and the northern part of southern Öland.

and faunal succession of the Viruan rocks will be given for every Cambro-Silurian district of southern and central Sweden, and later some general aspects of lithological and faunal development will be considered in separate papers.

The present paper deals with the description of the Viruan succession of the bed-rock of Öland. It is based on three drill borings (Böda Hamn of the Palaeontological Institute of Uppsala and Gammalsby and Skärlöv of the Geological Survey of Sweden) and studies in the field in the outcrop area of eastern Öland. The field work has been concentrated mainly to northern and southernmost Öland, whereas upon central Öland only some selected localities have been examined in detail. The areas which have been closely studied as well as the location of several of the examined localities of northern part of southern Öland and of central Öland are given in Text-fig. 1.

The youngest beds of the bed-rock of Öland belong to the Middle Viruan Dalby Limestone (*Ludibundus* limestone according to the previous terminology). The Upper Viruan beds (*Macrourus* calcareous siltstone) are known upon Öland only from boulders carried to their present sites by an east to west ice flow. These beds are not treated here. A recent survey of the *Macrourus* calcareous siltstone of Öland has been given by MARTNA (1955).

The main field work was carried out during parts of the summers of 1948, 1949, and 1951. In short periods of the summers of 1952, 1953, 1954, and 1958 the outcrop area has been revisited, and further collecting done, during excursions or complementary field work. During two summers Dr. J. MARTNA accompanied the present writer in the field, and his valuable help is highly appreciated.

The present writer is indebted to the successive Directors of the Palaeontological Institute of Uppsala, the late Prof. G. SÄVE-SÖDERBERGH and the late Dr. ELSA WARBURG for entrusting him with the study of the Viruan portion of the Böda Hamn core, and to Prof. PER THORSLUND (then of the Geological Survey of Sweden) for placing the cores of the Gammalsby and Skärlöv bores at his disposal. Prof. B. BOHLIN has most generously ceded his collections and diaries of his field work on eastern Öland to the writer; his cooperation in completing the geologic map of northern Öland is very much appreciated. Many thanks are due to Dr. B. COLLINI (Uppsala) for X-ray analyses of authigenic minerals. Also the help in various instances by Dr. H. MUTVEI (Riksmuseet, Stockholm) is gratefully acknowledged. The present paper has been elaborated at the Palaeontological Institute of the University of Uppsala, and the assistance of the technical staff of the Institute has been of the greatest value.

## Methods

For the study of the core sections from the Viruan (Middle Ordovician) Series of Sweden described in the present paper as well as in the coming papers a certain routine procedure has been elaborated that will be described below. The procedure applied is intended to give as exact data as possible about the vertical distribution of the fossils, the structure of the rock, and of certain aspects of the microlithology of the limestones.

The chief aim of the study of microlithology has been to supply a more detailed lithological characterization of the limestones than is possible by a merely macroscopical examination of the rock. In the present paper only a description of the microlithology is given. Certain lithogenetic problems will be treated in a concluding part of this series of papers.

In the elaboration of the microlithologic procedure two main factors had to be considered. First, the calculated data should be reasonably exact and with the smallest possible bias; they should permit a satisfactory comparison of similar data of any limestone with the original structure preserved. Secondly, the routine procedure had to be elaborated with the thought of applying it to hundreds of limestone samples, and for this reason preference was given to less time-consuming possibilities.

The general procedure in describing and studying the core sections has been as follows:

(1) The structure of the cores has been drawn in the scale 1:10, and reproduced in the scale 1:25 (cf. Text-figs. 3, 4, 18, and 22). Some simplifications, especially in the finely laminar or finely nodular portions of the core, are unavoidable, but on the whole a fairly natural picture of the sedimentational structures can be produced.

(2) The core has been split in a longitudinal direction into two halves; one half has been kept for future reference, and all work has been carried out on the other half. The necessity of keeping one half of the core untouched for future studies should be stressed as from time to time need may arise to re-study the sequence from some particular point of view.

(3) A thin section has been prepared. In the Böda Hamn core thin sections were made at each half metre of the core, in the other borings the intervals between the thin sections were chosen so as to cover different macroscopically distinguishable limestone units.

(4) The particle size of the limestone has been determined from thin sections according to the procedure described by JAANUSSON (1952). The boundary between calcilutite and calcarenite has been drawn at about twenty per cent of shell fragments longer than 0.1 mm in the thin sections. Calcilutites with more than ten per cent of shell fragments of this length are called calcarenitic calcilutites. The same procedure and terms for the particle size of the limestone have been used by JAANUSSON & MUTVEI (1953), JAANUSSON (1955), MARTINSSON (1956), and MARTNA (1955, 1957). There exists at present a large amount of data about the coarseness of different types of limestone determined by the above method, and the results enable a reasonably good comparison of the coarseness of limestones. The whole problem of determining of the particle size of limestones as well as the methods have recently been analyzed by MARTNA (1955) and need not be repeated here.

(5) When determining the particle size of the limestone the proportions of different groups of animals in the fraction larger than 0.1 mm (cf. MARTNA, 1955) was determined in many thin sections. These data will be considered in another connection.

(6) In thin section the various authigenic substances were distinguished mainly by their colour in incident light, since in this light their characteristics are considerably more distinct than in transmitted light. The following substances have been distinguished: (*a*) Haematite which causes a brownish red colour. The mineral has been determined by Dr. B. COLLINI by X-ray analysis from samples of the Gammalsby boring (at the level of 12.80 m) and Fjäcka (Segerstad Limestone). Both samples analyzed were concentrations of the reddish

brown substance, at Gammalsby boring forming a thin layer upon a bedding plane, at Fjäcka forming a crust which encloses a cephalopod. (*b*) Goethite which occurs as an alteration product around grains of chamosite and, rarely, as a pigment in some thin layers of limestone. The mineral has been determined by Dr. COLLINI by X-ray analysis from a sample of Vikarbyn (Seby Limestone), where it is associated with chamosite. The pigment with the same colour in limestone is in all probability the same mineral. In incident light goethite, or the mineral identified as such in the present paper, shows an intense yellow colour. (*c*) Chamosite. Determined by X-ray analysis from the Seby Limestone of Vikarbyn by Dr. B. COLLINI. As a rule it is of a pale green colour, and usually partly decomposed into goethite exposing all transitions from the intense yellow colour of the latter mineral into the pale green colour of the fresh chamosite. In addition an unidentified substance with a dark brown colour in transmitted as well as in incident light has been observed at some levels.

(7) The half of the core was crushed into fragments of various size, all of them being subjected to a close search for fossils, especially palaeocope ostracodes. No attention has been paid in this paper to conodonts, scolecodonts, foraminifers, chitinozoans, hystricosphaeridians, and small inarticulate brachiopods, since their study requires a special treatment. The conodont fauna of the cores will be described monographically by Dr. M. LINDSTRÖM, Lund.

(8) 20 g of crossed limestone were dissolved in diluted acetic acid, and the weight of the total insoluble residue determined. The per cent of the dissolved matter corresponds fairly closely to the contents of carbonates (in the sequence studied almost exclusively $CaCO_3$).

(9) 100 g of limestone were dissolved in diluted acetic acid, and the insoluble residue passed in wet condition through a sieve with 0.125 mm meshes. A closer study of the granulometry of the insoluble residue appeared quite unnecessary as the result would, in most cases at least, differ considerably from the original distribution of the particle size. In almost all cases the insoluble residue contained small pieces of shale or mudstone or aggregates of argillaceous matter which could not be disintegrated by dissolving in acetic acid. Further, the amount of the insoluble residue larger than 0.125 mm is comparatively very low in most samples. In the Böda Hamn core it amounts to 0.05–0.2 % of the total rock, not exceeding 0.5 %, and is at some levels as low as 0.01–0.02 %. A further fractioning of such small amounts would scarcely give any relevant results. In a previous paper (JAANUSSON & MUTVEI, 1953) we have used 0.06 mm-mesh for sieving the insoluble residue, but the fraction 0.06–0.125 mm is almost always so impure that an examination of this fraction did not contribute to the general picture of the insoluble residue. For this reason as well for saving time a coarser sieve was used in later studies. In case the insoluble residue contains large amounts of coarse particles a further fractionizing is advantageous (JAANUSSON & MUTVEI, 1953; JAANUSSON, 1955). In the borings described in this series of papers this has, however, not been found necessary.

(10) The frequency of different particles (pyrites, glauconite, non-glauconitic internal moulds) in the fraction of $>0.125$ mm of the insoluble residue of 100 g of limestone was determined by a simple counting of the number of all respective grains of this fraction. This procedure permits a good comparison of the frequency of different particles at different levels, and was chosen for taking less time than different calculations of the probable weight of the components. The number of particular grains is not exactly comparable to the total weight of these grains in different samples, in some samples small grains being abundant, whereas in other samples these grains may be large but few in number. Nevertheless, this does not seem to affect the general picture of the distribution of the insoluble particles to any considerable extent, at least not for the purpose of the general characterization of the rock.

## Classification of the Viruan Rocks of Öland

The classification of the Viruan rocks of Öland has passed through practically all the stages of the sequence of procedure of stratigraphic classification as theoretically outlined by HEDBERG (1954). The succession of rocks was first subdivided into conventional litho-stratigraphic units (Upper Red Orthoceratite Limestone, Upper Grey Orthoceratite Limestone, etc.; TÖRNQUIST, 1874; LINNARSSON in NATHORST, 1881), then a subdivision of zones was established (MOBERG, 1890). The increased knowledge of the fauna of the rocks gradually converted the zones into units which were in the practice treated as time-rock units of stage category. However, on Öland the boundaries between different divisions, whether rock units or zones, were on account of their small exposures poorly known before systematic field work had been carried out, and the sections from the borings became available. Further, in the later stages of the development of the stratigraphic classification the litho-stratigraphic units were altogether neglected, and this has necessitated the introduction of several new names of this category.

CHRONO-STRATIGRAPHIC UNITS.—The term Viruan Series (cf. KALJO, RÕÕMUSOKS, & MÄNNIL, 1958) is used here to denote the Middle Ordovician Series as defined by RAYMOND (1916). Following him the lower boundary is drawn in the limestone succession at the base of the Aserian Stage or the zone of *Asaphus platyurus* and in the graptolitic sequence at the base of the zone of *Didymograptus murchisoni* (JAANUSSON, 1960). The use of a special name for the Middle Ordovician Series so defined is necessitated by the confusion which has arisen from the existence of several, in part widely different current definitions of the Middle Ordovician.

In the current classification the Viruan sequence exposed on Öland is divided into four divisions, in ascending order the *Platyurus*, *Schroeteri*, *Crassicauda*, and *Ludibundus* Limestones. These divisions have been considered as zones or as time-stratigraphic units of stage category. The *Platyurus* Limestone may be termed the zone of *Asaphus* (*Neoasaphus*) *platyurus*, but the other three divisions, as currently defined, are not zones in the common stratigraphic sense of this term. They are units which include a wide range of different lithologies, and contain a varied fauna showing marked regional and facies differentiation. The index fossil does not play any part in their definition. They are in reality used to designate rocks formed during a specific interval of geologic time within areas, where the correlation of these rocks by faunistic evidence is, or is supposed to be, reasonably exact. Thus these divisions may best be regarded as time-stratigraphic units of stage category. However, the terms applied to them on Öland and in other districts of Sweden are not in accordance with the nomenclature of time-stratigraphic units used in most other countries, and this has already caused some misunderstandings. The *Platyurus*, *Schroeteri*, and *Crassicauda* Stages are the equivalents of the Aseri, Lasnamägi, and Uhaku Stages, respectively, of the classification of the Ordovician of Estonia, and, as long as this correlation is considered to be exact, there does not seem to exist any need for giving new names to the same units in Sweden. For this reason the corresponding Estonian terms are used here. The faunistic difference between the Lasnamägi and Uhaku Stages is frequently slight, and when the boundary region between them falls within a calcilutitic sequence, the drawing of an exact boundary between these stages is difficult. This applies to Estonia (cf. SARV, 1958) as well as to Sweden. In this case the term Tallinna Stage (BEKKER, 1922; MÄNNIL, 1958b) or Superstage is often a useful denomination for rocks formed during the Lasnamägian as well as the Uhakuan ages. It is still difficult to decide whether it would be better to consider the Tallinnan as a stage with two substages or as a superstage consisting of two stages. The latter alternative is provisionally adopted in the present paper. The correct time-stratigraphic name for the *Ludibundus* beds of Sweden is not clear yet, as in Sweden the upper part of these beds have not yet been subjected to a detailed study. In the borings of Gotland and Gotska Sandön the Kukruse and Idavere Stages can easily be distinguished, and the top of the exposed sequence of Öland certainly does not include beds younger than the Kukruse Stage. For this reason this term is used here to denote the beds of Öland previously included in the *Ludibundus* limestone. It is now quite clear that the beds of Sweden currently considered as belonging to the *Ludibundus* Limestone or Stage have to be subdivided into two divisions of stage category, but a discussion of this matter falls outside the scope of the present paper.

The correlation of the above divisions with the classification of the graptolitic succession has been discussed by JAANUSSON (1960).

LITHO-STRATIGRAPHIC UNITS.—On account of general necessity of treating the described succession in terms of objective stratigraphic units, a litho-stratigraphic classification of the Viruan sequence of Öland is proposed here. As there do not exist any nomenclatorially correct terms for the litho-stratigraphic units of the sequence in question, new names must be introduced for all lithological divisions the distinction of which have been considered useful in the description of the sequence.

In general the exposures on Öland are small, and lay bare only a fraction of the total thickness of a formation. This has made the selection of a definite type section of a formation difficult. It has been found more useful to designate type areas, where the formation is accessible for study in several small localities, whereas the actual definition of a formation is based mainly upon the section of the boring which is closest to the type area. This applies only to formations with their type area on Öland.

In the following only a short definition of each formation is given. For further details, see the descriptions and discussions of the sections.

*Segerstad Limestone.* Reddish brown, mostly thick-bedded calcarenites and calcarenitic calcilutites with or without some intercalations of finely nodular limestone. The lower boundary of the division is the boundary between the zones of *Megistaspis gigas* and *Asaphus platyurus*, the upper boundary the base of the lowermost bed of finely nodular marl of the Skärlöv Limestone. Type area is the parish of Segerstad, Öland, where the formation is accessible in several small exposures; the entire succession is known from the borings of Skärlöv and Gammalsby. On Öland the formation is overlain by the Skärlöv Formation. The Segerstad Limestone is of Aserian age.

*Skärlöv Limestone.* Reddish brown finely nodular limestones and marls with intercalations of reddish brown calcarenites. The lower boundary is the top of Segerstad Limestone as defined above, and the upper boundary is drawn in each area at the top of the uppermost division of reddish brown finely nodular limestone even if the upper portions of the division in question should be of different colour. Type area is the district east of Skärlöv railway station, where the formation is exposed in several small outcrops; the entire succession is known from the Gammalsby boring. Previously these mostly finely nodular reddish brown limestones were almost unknown, and are scarcely at all mentioned in the literature. The main part of the formation is of Lasnamägian age, whereas the time-stratigraphic attribution of the lowermost part is yet not quite clear. The formation is overlain by the Seby Limestone.

*Seby Limestone.* Mostly variegated, reddish brown grey-mottled or pale brownish red calcarenites, on southern Öland with intercalations of pale brownish red finely nodular limestone and some persistent beds of grey calcarenite. On Öland the lower boundary is the top of the Skärlöv Limestone, and the upper boundary is drawn at a level, where the colour of the rock changes from mostly pale reddish brown to grey without brownish tint. The Seby Limestone can be considered as transitional beds between the brownish red Skärlöv Limestone and the grey Folkeslunda Limestone. Its boundaries are not synchronous within Öland, the change of colour distinctive for the upper boundary of the division taking place at a considerably lower level in northern Öland than in central and southern Öland. Nevertheless until the faunal successions of these beds are known in greater detail, it has been found useful to designate these beds with a special name, and to treat them as a separate litho-stratigraphic subdivision. The Seby Limestone corresponds to the upper part of HOLM's Red *Lituites* Limestone (zone of *Lituites discors*) and his transition beds from the Red to the Grey *Lituites* Limestone. The type area is within, and east of, Seby village. The formation is of Lasnamägian age.

*Folkeslunda Limestone.* Grey calcarenites, in some districts with intercalations of beds of calcilutite. It is the division that has been called the Upper Grey Orthoceratite Limestone or the Grey Lituitid Limestone. The lower boundary is the top of the Seby Limestone as defined above. Owing to the gradual transition from calcarenite to calcilutite the exact level of the upper boundary is mostly difficult to determine; it is placed in the sections at the level, where the lithologic change is most obvious. As the type area the south-eastern part of the parish of Långlöt and the north-eastern part of the parish of Runsten of Öland are chosen, and the division is called after Folkeslunda village. The formation is exposed in the type area in several small outcrops which have yielded a rich fauna. It is overlain by the Furudal Limestone on southern Öland, and by the Källa Limestone on northern Öland. The formation is of Lasnamägian age.

*Furudal Limestone.* Grey calcilutites, in places with intercalations of grey finely nodular marls or mudstones. The lower boundary is the top of the Folkeslunda Limestone as defined above or, in Västergötland, that of an unnamed formation of grey mudstones and nodular limestones. The upper boundary is the base of the Dalby Limestone as defined below. The type locality is the quarry close to Kalkbergsbäcken at Furudal, Siljan district, but the division is better typified by the Fjäcka section described by JAANUSSON (1947) and JAANUSSON & MARTNA (1948). The Furudal Formation can be distinguished in the Siljan district, southern Öland, Östergötland, and Västergötland. It is mainly of Uhakuan age, but in some districts includes also beds of latest Lasnamägian age; the boundary between these stages is difficult to draw when it falls within calcilutitic rocks. On Öland the rocks of the Furudal Limestone interdigitate northward with a coarse calcarenite (Persnäs Limestone, *q.v.*) except for the lowermost part which is persisting as a tongue of calcilutite (Källa Limestone).

*Källa Limestone.* Tongue of the Furudal Limestone consisting of grey calcilutites with intercalations of finely nodular limestone and marl. The lower boundary is the top of the Folkeslunda Limestone, and the upper boundary the level, where the first conspicuous beds of calcarenite appear. The type area are the extensive quarries S and SW of Källa church, Öland, but the formation is better defined by the sequence in the Böda Hamn boring comprising there the beds between the levels of 10.95 and 13.15 m. The Källa Limestone is of Uhakuan age, and has been defined only in northern Öland, where it forms an easily recognisable division.

*Persnäs Limestone.* Grey calcarenites with some occasional intercalations of calcilutite or finely nodular marl. The lower boundary is the top of the Källa Limestone, and the upper boundary is drawn here at the level, where the distinctive fauna of the Dalby Limestone appears. These beds are best exposed in the vicinity of, and SW of Persnäs church, but the formation is better defined by the sequence of the Böda Hamn boring comprising there the beds between the levels of 5.80 and 10.95 m. The Persnäs Limestone is of Uhakuan age, and has been identified only on northern Öland and the northern part of central Öland. It represents a tongue of the main calcarenitic sequence of the Viruan beds as developed on Gotland.

*Dalby Limestone.* Grey calcarenites to calcarenitic calcilutites, often with a somewhat nodular texture. The lower boundary is the top of the Furudal Limestone, but on account of the gradual transition from calcilutite to calcarenite it is, as a rule, difficult exactly to determine the level of the boundary on lithological evidence. The thickness of lithologically transitional beds is in places several metres. This is inconsiderable compared with the total thickness of each the Furudal and the Dalby Limestones, but fairly great for the purposes of a reasonably exact stratigraphic classification. It has been found to be most convenient for the time being, to draw this boundary at the level, where the characteristic fauna of the Dalby Limestone (particularly the ostracode species *Euprimites locknensis* and *Steusloffia multimarginata*) makes its appearance. This level is fairly sharp faunistically in all districts of Sweden, where the Furudal Limestone can be distinguished, and also on northern Öland, where the Dalby Limestone overlies the Persnäs Limestone. Even in the field it can be determined more exactly than any boundary based on the lithologic evidence. The upper boundary of the Dalby Limestone is drawn provisionally on the top of the thickest bentonitic clay bed of the "bentonite bed group" (JAANUSSON & MARTNA, 1948). The type locality of the formation is the Fjäcka section (JAANUSSON & MARTNA, 1948) which is situated within the village of Dalby.

*General remarks.* The above classification is summarized, and correlation with the time-stratigraphic units and the graptolite zones given in Table 1.

If compared with the conventional concept (e.g. MOORE, 1947; HEDBERG, 1954) of the litho-stratigraphic units the definition of some of the (rock-)stratigraphic divisions distinguished above is somewhat unorthodox. In current usage the litho-stratigraphic units are characterized by distinctive lithology and structural relations, and should not be extended or controlled by fossils except in such few cases, where the fossil content becomes the dominant lithic feature. In the above classification, however, one of the boundaries of some divisions is defined according to faunal evidence, and thus these divisions are not real litho-stratigraphic units. The proposed classification is the result of a lengthy and careful study of the stratigraphy of the actual sequence in Sweden as well as of the general theory of stratigraphic classification, and calls for some further comments.

*Table 1*

<table>
<tr><th rowspan="2">Previous time-stratigraphic terms</th><th rowspan="2" colspan="2">Time-stratigraphic terms used in the present paper</th><th rowspan="2">Graptolite zones</th><th colspan="2">Topo-stratigraphic units</th></tr>
<tr><th>N. Öland</th><th>S. Öland</th></tr>
<tr><td>Ludibundus Limestone (lower part)</td><td colspan="2">Kukruse Stage</td><td>Zone of Nemagraptus gracilis</td><td>Dalby Limestone (lower part)</td><td rowspan="2">[Not exposed]</td></tr>
<tr><td rowspan="2">Crassicauda Limestone</td><td rowspan="5">Tallinna Superstage</td><td rowspan="2">Uhaku Stage</td><td rowspan="3">Zone of Glyptograptus teretiusculus</td><td>Persnäs Limestone</td></tr>
<tr><td>Källa L.</td><td>Furudal Limestone</td></tr>
<tr><td rowspan="3">Schroeteri Limestone</td><td rowspan="3">Lasnamägi Stage</td><td colspan="2">Folkeslunda Limestone</td></tr>
<tr><td rowspan="3">Zone of Didymograptus murchisoni</td><td colspan="2">Seby Limestone</td></tr>
<tr><td colspan="2">Skärlöv Limestone</td></tr>
<tr><td>Platyurus Limestone</td><td colspan="2">Aseri Stage</td><td colspan="2">Segerstad Limestone</td></tr>
</table>

In the present writer's opinion fossils are constituent parts of a rock, and hence their occurrence and distribution are comparable in importance to the other characteristics of a rock for the establishment of a useful regional litho-stratigraphic subdivision. Not all fossils or changes in the composition of an assemblage of fossils are equally useful for this purpose, but neither are all other different characters of a rock. The main point is that the resulting classification of a sequence of rocks is objective and of the largest possible degree of usefulness.

The faunistic boundary between the zones of *Megistaspis gigas* and *Asaphus platyurus* is extraordinarily distinct in all districts of Sweden, where these zones can be distinguished. The boundary cannot be recognized on lithologic evidence, the rock on either side of it being lithologically quite similar. The faunal break is, however, so sharp that it can easily be distinguished also in the field, and its location is therefore mappable (cf. Text-figs. 2 and 14). If the boundary had been marked by a layer of conglomerate or a discontinuity surface, no objections had been raised against its use as a boundary between two formations in the conventional litho-stratigraphic sense. However, in the writer's opinion this faunal change is comparable to a break in the succession, since it bears witness of an important change in the physical conditions, although it has not left any mark in the lithologic development.

The above boundary is regarded here as the lower boundary of the Segerstad Limestone. This division is no time-stratigraphic unit, since its upper boundary

*Table 2*

<table>
<tr><th rowspan="2">Time-stratigraphic units and certain zones</th><th colspan="2">Proposed topo-stratigraphic units</th><th colspan="3">Conventional rock units</th></tr>
<tr><th>N. Öland</th><th>S. Öland</th><th>N. Öland</th><th colspan="2">S. Öland</th></tr>
<tr><td>Kukruse Stage</td><td>Dalby Limestone (lower part)</td><td>[Not exposed]</td><td rowspan="2">"Dalby Formation"</td><td colspan="2">[Not exposed]</td></tr>
<tr><td rowspan="2">Uhaku Stage</td><td>Persnäs Limestone</td><td rowspan="2">Furudal Limestone</td><td colspan="2" rowspan="2">Furudal Formation</td></tr>
<tr><td>Källa Limestone</td><td>Källa Tongue</td></tr>
<tr><td rowspan="3">Lasnamägi Stage</td><td colspan="2">Folkeslunda Limestone</td><td colspan="3">Folkeslunda Formation</td></tr>
<tr><td colspan="2">Seby Limestone</td><td colspan="2">Seby Member</td><td rowspan="4">"Upper Red Orthoceratite Formation"</td></tr>
<tr><td colspan="2">Skärlöv Limestone</td><td colspan="2">Skärlöv Member</td></tr>
<tr><td>Aseri Stage</td><td colspan="2">Segerstad Limestone</td><td colspan="2" rowspan="2">"Lower Member"</td></tr>
<tr><td rowspan="2">Kunda Stage: Megistaspis gigas<br>M. obtusicauda<br>Asaphus raniceps<br>Asaphus expansus</td><td colspan="2" rowspan="2">[Not yet subdivided]</td></tr>
<tr><td colspan="3">"Lower Grey Orthoceratite Formation"</td></tr>
</table>

is, from necessity, drawn according to lithologic evidence and may not be contemporaneous in all districts; on the other hand it is no proper litho-stratigraphic unit either, since the lower boundary is defined in terms of local faunal succession. Further divisions of the same category are the Persnäs, Furudal, and Dalby Limestones. With the above definition all these divisions have proved to be useful terms in the classification of the local sequence of rocks. The stratigraphic divisions so defined are "litho-bio-stratigraphic" units or simply convenient regional stratigraphic units. They are termed here *topo-stratigraphic units* in order to distinguish them from the conventional litho-stratigraphic units. The term topo-stratigraphic classification can also be used when referring to a regional classification of rocks which includes topo-stratigraphical as well as conventional litho-stratigraphical subdivisions.

It must be stressed that the establishment of a combined bio- and litho-stratigraphic division is possible only if the faunal change used for defining a boundary is reasonably sharp in all districts, where the formation can be distinguished. Further, the faunal boundary must be defined in terms of an objective and local faunal change (like boundary of a zone) which occurs in all districts, where the division is developed. Experience has shown that the need for topo-stratigraphic units increases with the increase of the knowledge of the faunal succession in areas which are rich in fossils, and where the rock sequence is fairly uniform.

This discussion would not be complete without an example of what a litho-stratigraphic subdivision of the sequence treated would look like, if the conventional concept of units of this category had been followed. The red-coloured portion of the sequence corresponds to the upper part of the Upper Red Orthoceratite Limestone of TÖRNQUIST and LINNARSSON, and ought to be included together with the upper, red-coloured limestones of the Kunda Stage in one formation. At the time being the present writer cannot find any obvious use for the formation so defined. The Skärlöv and Seby Limestones would have been considered as separate members of the "Upper Red Formation". The Segerstad Limestone is quite indistinguishable lithologically from the underlying red-coloured limestones of the zones of *Megistaspis gigas*, *M. obtusicauda*, and, on central and southern Öland, from the upper part of the zone of *Asaphus raniceps*. These red-coloured calcarenites would be included in a separate member, but, again, the present writer cannot see that such a division would be of any use at the present state of our knowledge. The Persnäs Limestone, which is quite indistinguishable lithologically from the superimposed Dalby formation, would be considered as a part of the latter formation which would have its lower boundary at a much lower level on northern Öland than in the other districts of Sweden. A comparison of the conventional litho-stratigraphic subdivision with that proposed in the present paper is given in Table 2. When some or all of the conventional rock units will be found useful in some connection or other, they ought, of course, to be distinguished and properly named.

## Historical Survey

The published information about the Viruan beds of Öland is scanty. LINNARSSON (in NATHORST, 1881, p. 593) introduced the rock-stratigraphic classification of the Orthoceratite Limestone based on the colour of the rock (TÖRNQUIST, 1874) on Öland. His classification was published posthumously in the form of a short summary with only a few localities or fossils mentioned. From the colour of the rock it is, however, evident that both the Segerstad Limestone and the Skärlöv Limestone were included, together with the red-coloured upper part of the Kunda Stage in TÖRNQUIST's Upper Red Orthoceratite Limestone, and the Folkeslunda Limestone together with at least a part of the Uhakuan beds in the Upper Grey Orthoceratite Limestone. TULLBERG (1882, pp. 232–233) made the important observation that the lower part of the Upper Red Orthoceratite Limestone contains forms of the *Megalaspis* (=*Megistaspis*) *gigas* group, whereas the upper part abounds with *Asaphus platyurus*.

The well-known and widely used classification of the Orthoceratite Limestone in Sweden by MOBERG (1890) was based on the sequence of southernmost Öland. Unfortunately MOBERG's description of the different subdivisions is very brief, and only few localities and fossils are mentioned. For the upper part of the sequence MOBERG proposed the following classification:

*Strombolituites* Limestone
*Centaurus* Limestone
Transition Beds
*Platyurus* Limestone

*Table 3*

| MOBERG, 1890 | Current use prior to this paper | This paper (S.Öland) | | |
|---|---|---|---|---|
| | | Topo-stratigraphic units | Zones | Time-stratigraphic units |
| *Strombolituites [Ancistroceras]* Limestone | *Crassicauda* Limestone | Furudal Limestone | Z. of *Lituites perfectus* | Uhaku Stage |
| *Centaurus [Chiron]* Limestone | *Schroeteri* Limestone | Folkeslunda Limestone | | Lasnamägi Stage |
| | | Seby Limestone | Z. of *L. lituus* ? Z. of *L. discors* | |
| ? | | Skärlöv Limestone | ? | |
| Transition beds | *Platyurus* Limestone | Segerstad Limestone | Z. of *Illaenus planifrons* | Aseri Stage |
| *Platyurus* Limest. | | | Z. of *Angelinoceras latum* | |

The name of the *Centaurus* Limestone was changed by WIMAN (1908) into *Chiron* Limestone and, later, by WESTERGÅRD (1939) into *Schroeteri* Limestone in accordance with the changes of the name of its index fossil [*Illaenus schroeteri* (SCHLOTH.)]. *Strombolituites* is a junior synonym of *Ancistroceras*, and MOBERG's division with this name was changed by WIMAN (1902a) into *Ancistroceras* Limestone. MOBERG's description of the latter beds being very brief, and no localities being mentioned, the identification of this division and its correlation has created later investigators certain difficulties. We were able to ascertain the identity of the *Ancistroceras* Limestone first after consulting MOBERG's diaries in the Geological Survey of Sweden.

In the explanation of the geological maps of Öland the sequence in question (WIMAN, 1902a, b, 1904a, b) is treated very briefly, and the description scarcely contains anything not mentioned by MOBERG (1890) or TULLBERG (1882). MOBERG's transition beds are, however, not considered by WIMAN (1902a) as a separate unit, but are included in the *Platyurus* Limestone.

Our field work has shown that MOBERG's transition beds roughly correspond to the zone of *Illaenus planifrons* (JAANUSSON & MUTVEI, 1953) of the Segerstad Limestone. The *Strombolituites* (= *Ancistroceras*) Limestone is an equivalent to the Furudal Limestone. The correlation of MOBERG's classification with that used in the present paper is given in Table 3.

In several of his latest papers HOLM (1891, 1893, 1895) used a subdivision of his own based on cephalopods and hyolithids, of the beds of central Öland here included in the Lasnamägi Stage. No connected account of this classification was ever published, and the pertinent data are found mainly in the discussions on the vertical distribution of the species described by HOLM from these beds. A full treatment of HOLM's classification is given in the chapter on the Viruan sequence of central Öland. Nobody but HOLM has ever used this classification which the present study has shown to be based, as HOLM's work generally is, on sound evidence.

Curiously enough, apart from descriptions of separate species, no new data about the sequence in question of Öland has subsequently been published. Although much time has been spent on the study of these beds, especially by MOBERG and HOLM, the published data were extremely brief and schematical, and no fuller account ever followed. Nothing was published about the Uhakuan beds of northern Öland, and, since also the information about MOBERG's *Ancistroceras* Limestone of southernmost Öland was next to nothing, the Uhakuan beds of Öland were virtually unknown.

The knowledge of the fauna of the sequence in question of Öland was much fuller than that of the stratigraphy. In numerous papers separate species or taxonomical groups of the Aserian and Lasnamägian age have been described, the data about material from Öland being as a rule scattered among those from other districts and for different stratigraphic levels or hidden with in palaeozoological and taxonomical descriptions. Apart from several old papers the following need to be considered: trilobites by HOLM (1882), WARBURG (1939), and JAANUSSON (1953a, b, 1957a); ostracodes by JAANUSSON (1957b); graptolites by BULMAN (1932a, b) and JAANUSSON (1960); cystoids by REGNÉLL (1945); cephalopods by HOLM (1885, 1891, 1892a, b, 1895, 1896, 1897, 1898) and TROEDSSON (1931, 1932); gastropods by KOKEN (1925), hyolithids and conulariids by HOLM (1893). LINDSTRÖM (1955, p. 106) has given some information on conodonts of the Lasnamägian beds of central Öland.

Apart from some notes on asaphids by JAANUSSON (1953a, pp. 417, 420; 1953b, p. 498) the fauna of the Uhakuan beds of Öland has not been described.

The Dalby Limestone of Öland was first distinguished as a separate division, *Chasmops* Limestone, by LINNARSSON (1876). TULLBERG (1882) called it the *Echinosphaerites* Limestone. An account of these beds is given below in the description of the Böda Hamn exposure.

## Taxonomic and Nomenclatural Notes

Parts of the fauna of the sequence treated are still uncompletely described. This applies especially to molluscs, with due acknowledgement of the pioneer work done by HOLM, KOKEN, and TROEDSSON. Many species are new, others in bad need of revision. For the proper understanding of certain points of the following faunal lists some taxonomic and nomenclatural notes are given here.

(1) Two different forms, here considered as subspecies, of *Illaenus schroeteri* occur on Öland, one in beds of Lasnamägian and earliest Uhakuan (Källa Limestone) age (subsp. *schroeteri*), and the other in those of Uhakuan age (subsp. *stacyi* HOLM). The two subspecies can be distinguished only, when ephebic or gerontic specimens are available; small specimens of these forms are indistinguishable at our present state of knowledge. When in the faunal

lists only *Illaenus schroeteri* is mentioned, the available material of this species consists of small individuals only; when the subspecific name is given, the available specimens were large enough for determination also on subspecific level.

(2) Nileids, remopleuridids, and agnostids need a monographic treatment. The species from the sequence treated are mainly new, but no attempt has been made to compare the specimens found with some approximately contemporaneous, already established species from other districts. The writer feels that, even if the material from Öland might include some species already described, an identification without the basis of a monographic revision might easily result in an erroneous determination.

(3) Great care was excerted in the identification of ostracodes, the classification of the cores of borings being based largely on this group. Only specimens with clear distinctive features preserved were determined unconditionally to the species. Specimens in a less satisfactory state of preservation were identified with reservations ("cf.") at the specific level, although the writer feels certain as to the correctness of the determination. Specimens, which depart conspicuously from the usual limits of individual variability within a species, were not identified to the species, although many of them probably represent extreme individual variants within a chronodeme. Such specimens are, however, few, and none of them seems to modify the general data about the range of the species in any core.

(4) The specimens identified as "*Orthoceros*" *nilssoni* (BOLL) sp. coll. probably include a group of related species the generic attribution of which is still not clear (JAANUSSON & MUTVEI, 1953, p. 17, footnote 1). They probably belong to a new genus.

(5) A mark of interogation after a generic name in the case of brachiopods indicates that in the species concerned the internal structure is poorly known or unknown. In this case the generic reference is scarcely more than a guess. These species are small, and although serial sections have been attempted with most of them the results are still ambiguous. It is not excluded that new genera are involved.

(6) The current nomenclature and taxonomy of the Viruan species of *Echinosphaerites* are still not beyond objection. *Echinosphaerites aurantium* var. *suecica* was briefly defined but not figured by JAEKEL (1899) and is, following the decision of the second International Geological Congress, a *nomen nudum* in that paper. The species was first figured by REGNÉLL (1945, Pl. 8, fig. 5), and he ought to be regarded the nomenclatorial author of this taxon. REGNÉLL (1945, p. 149) pointed out that the form described by him under this name is very similar to, if not identical with, *E. aurantium* mut. *infra* HECKER, 1923. According to HECKER (1923, p. 7) the form described by EICHWALD (1860) as *E. ellipticus* falls within the limits of variability of *E. aurantium infra*. If he is right, the correct name of the form currently determined as *E. aurantium infra*, probably

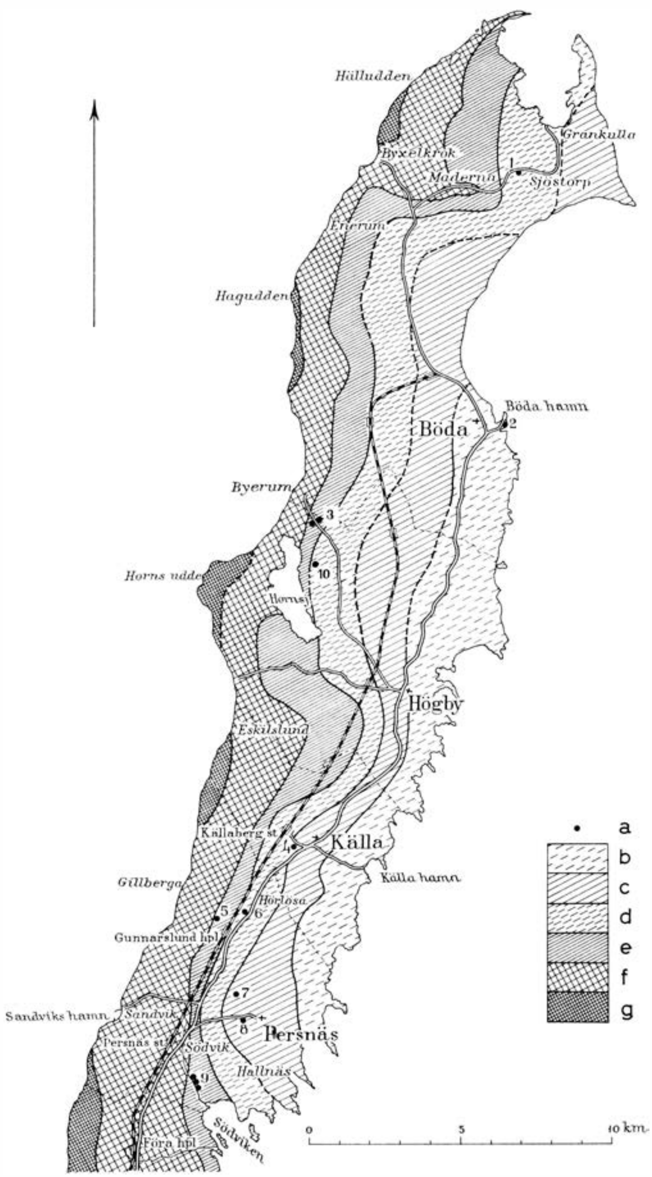
including also *E. aurantium suecicus*, is *E. ellipticus* EICHWALD, 1860. However, further, in part statistical, studies are needed in order to make possible a safely established taxonomic subdivision of the Baltoscandian representatives of this genus. Pending such studies the Swedish Lower Viruan species is in the present paper provisionally determined as *E. aurantium suecicus* REGNÉLL, 1945. ORVIKU (1927) considered the latter subspecies as a form intermediate in time and characters between *E. aurantium infra* and *E. aurantium aurantium*. According to REGNÉLL *E. aurantium suecicus* is contemporaneus with *E. aurantium infra* and morphologically very close to *E. aurantium infra*-c of ORVIKU (1927). The present study and examination of the material described by REGNÉLL has shown that *E. aurantium suecicus* has so far not been found in the zone of *Angelinoceras latum*. On Öland it appears in the zone of *Illaenus planifrons* which corresponds, according to current correlation, roughly to the Ojaküla Member (ORVIKU in MÄNNIL, 1958; *Endoceras* Limestone of earlier papers of ORVIKU) of the Aseri Stage. The species is, however, common also in the zone of *Lituites discors* of the Seby Limestone which is of Lower Lasnamägian age (the specimens from boulders at Löt mentioned by REGNÉLL, 1945, p. 149 are, for instance, with a reasonable degree of certainty from this zone). So the vertical distribution of *E. aurantium suecicus* in fact corresponds in part to that suggested by ORVIKU (1927). On the other hand, subsequent collecting has yielded rare specimens of *Echinosphaerites* also from the Lasnamägi Stage of Estonia (JAANUSSON, 1940) and the Ojaküla Member of the vicinity of Tallinn in western Estonia. These finds have yet not been closely studied.

(7) According to REGNÉLL (1945, p. 113) *Caryocystites dubia* ANGELIN, 1878 (lectotype figured by REGNÉLL, 1945, Pl. 4, fig. 6) is a senior subjective synonym of *C. angelini* HAECKEL, 1896. If this is right, the former name is the correct one for the species in question. Prof. G. REGNÉLL kindly informed the writer (*in litt.* Apr. 20th, 1952) that the immature condition of the lectotype of *C. dubia* makes the identification of this specimen as *C. angelini* not as certain as might appear from his paper of 1945, and that the problem requires further study. For this reason *C. angelini* is the name for the species used also in the present paper.

## Viruan Rocks of Northern Öland

### *Review of Exposures*

SEGERSTAD LIMESTONE.—The zone of *Angelinoceras latum* is exposed in several places but the exposures are generally small and often temporary. Pygidia of *Asaphus* (*Neoasaphus*) *platyurus* ANG. and "*Orthoceros*" *nilssoni* (BOLL) sp. coll. are met with in nearly every exposure of this zone. At Gunnarslund (locality No. 5 in Text-fig. 2) also *Illaenus excellens* HOLM and *Angelinoceras latum* (ANG.) were collected by Prof. B. BOHLIN in the surface layers of the alvar close to the quarry described by BOHLIN (1949, p. 546).




Text-fig. 2. Geological map of northern Öland compiled by B. BOHLIN (western part) and V. JAANUSSON (eastern part). Signs: *a*, locality described in the text; *b*, outcrop area of the Dalby Limestone (Kukruse Stage); *c*, Källa and Persnäs Limestones (Uhaku Stage); *d*, Folkeslunda, Seby, and Skärlöv Limestones (Lasnamägi Stage); *e*, Segerstad Limestone (Aseri Stage); *f*, Kunda Stage (*Vaginatum* Limestone); *g*, Volkhov (*Lepidurus* and "*Limbata*" Limestones) and Billingen Stages.

The best exposure of the zone of *Illaenus planifrons* is a small, old quarry on either side of the main road from Högby to Byerum immediately NNW of the village of Binnerbäck (locality No. 3 in Text-fig. 2). Here 20 cm of reddish brown, finely nodular marl is overlain by 60 cm of intensely reddish brown calcarenite. The calcarenite contains large specimens of *Asaphus* (*Neoasaphus*) *platyurus platyurus* ANG. and *Geisonoceras? centrale* (DALM.). In the finely nodular marl the following species have been found:

*Asaphus* (*Neoasaphus*) *platyurus platyurus* ANG.
*Illaenus* aff. *planifrons* JAAN.
*Pterygometopinae* n. gen., n. sp.
*Euprimites effusus* JAAN.
"*Endoceras*" sp.
*Glyptosphaerites leuchtenbergi* VOLB.

The finely nodular marl at Binnerbäck evidently corresponds to the uppermost part of that between the levels of 18.95 and 20.18 m of the Böda Hamn boring (cf. Text-fig. 24).

The calcarenites of the *Planifrons* zone are exposed also at the drainage ditch at Södvik, parish of Persnäs (locality No. 9 in Text-fig. 2). The ditch extends from the village of Södvik in south-eastern direction to the Bay of Södvik, and at places is cut down to a half of metre into the limestone. North of the main road the *Gigas* limestone is exposed, south-east of the main road the ditch continues in the calcarenites of the *Latum* zone, and farther in south-eastern direction the ditch is cut into thick-bedded, reddish brown calcarenites of the zone of *Illaenus planifrons*. Fossils could be collected almost exclusively in the heaps of debris on either side of the ditch, and great care had to be exercized in order to keep different stratigraphic horizons apart. In the calcarenite of the zone of *Illaenus planifrons* the following fossils have been found (Pal. Inst. Uppsala Nos. Öl. 19, 66, 1003–1008, 1013–1017):

*Asaphus* (*Neoasaphus*) *platyurus platyurus* ANG.
*Illaenus* aff. *planifrons* JAAN.
"*Orthoceros*" *nilssoni* (BOLL) sp. coll.
*Geisonoceras* ? *centrale* (DALM.)
*Nanno belemnitiforme belemnitiforme* HOLM
*Rhynchorthoceras* sp.

The boundary between the Segerstad and Skärlöv Limestones was not accessible in the exposures studied.

The Skärlöv Limestone is poorly exposed on northern Öland, the few available exposures being small and without determinable macrofossils.

SEBY LIMESTONE.—In a ditch at the main road about 300 m NE of the railway station of Gunnarslund (locality No. 6 in Text-fig. 2) the following section has been measured:

*Seby Limestone* 0.35 m +
*d*. 0.10 m. + Grey, reddish brown-mottled, fine-grained limestone.
*c*. 0.05 m. Nodular, reddish brown, greyish green-mottled limestone.

*b.* 0.10 m. Thick-bedded, reddish brown, greyish green-mottled limestone. *Illaenus schroeteri* (SCHLOTH.), *Euprimites effusus* JAAN., "*Conorthoceras*" *conicum* (HIS.), "*Endoceras*" cf. *barrandei* (DEW.).

*Skärlöv Limestone* 0.15 m +

*a.* 0.15 m + Intensely reddish brown, finely nodular marl.

The beds of this section are overlain by the grey Folkeslunda Calcarenite, the lowermost beds of which are exposed in the same ditch east of the main road. The division *a* of the section corresponds to the uppermost part of the finely nodular marl below 16.23 m of the Böda Hamn boring, and the divisions *b–d* to the beds between the levels 16.03 and 16.23 m of that boring.

FOLKESLUNDA LIMESTONE.—The best locality of the Folkeslunda Limestone is an extensive, old quarry close to the road from Vedby to Bäckalund, E of Hornsjön, about 1.2 km SE of Bäckalund (locality No. 10 in Text-fig. 2). A section of about half a metre is exposed in grey, thick-bedded calcarenite. During several summers Prof. B. BOHLIN has collected in this exposure which is fairly rich in fossils. The following species have been found:

*Illaenus schroeteri schroeteri* (SCHLOTH.)
*Illaenus* aff. *excellens* HOLM
*Pseudoasaphus tecticaudatus* (STEINH.)
*Pseudoasaphus aciculatus* (ANG.)
*Pseudobasilicus* ? *brachyrachis* (TÖRNQ.)
*Remopleurides* sp.
*Telephina* sp.
*Nileus* sp.
*Paraceraurus* cf. *exsul* (BEYR.)
*Chasmops* n. sp.
*Estoniops* sp.
*Uhakiella* cf. *aequigranosa* JAAN.
*Euprimites effusus* JAAN.
*Tallinnella* cf. *lata* (KRAUSE)
*Lituites* (*Lituites*) sp. indet.
"*Conorthoceras*" *conicum* (HIS.)
*Geisonoceras* ? *scabridum* (ANG.)
*Eccyliomphalus* sp.
*Alwynella* ? sp.
*Hyolithes crispatus crispissimus* HOLM

Microlithological examination of two samples of limestone furnished the following data:

| | | |
|---|---|---|
| Sample No. | Ö 258 | Ö 259 |
| Contents of fossil fragments >0.1 mm | 34% | 34% |
| Contents of total insoluble residue | 8.0% | 7.3% |

Fraction >0.125 mm of the insoluble residue contained abundant non-glauconitic internal moulds (>1000 per 100 g of limestone in the sample Ö 259). In the thin sections chamosite, goethite, and the brown substance is fairly abundant occurring as thin coatings around fossil fragments or as fillings of internal cavities of these fragments.

The fauna and the microlithological characteristics of the limestone of the above quarry quite agree with those of the Folkeslunda Limestone of the Böda Hamn boring. The section exposed in the quarry is probably somewhat below the top of this subdivision, as *Euprimites effusus* still occurs in fair abundance.

KÄLLA LIMESTONE.—Calcarenitic calcilutites of the Källa Limestone are extensively exposed in the easternmost of the large, old quarries west and south-west of the church of Källa. Most of these quarries, which cover a vast surface between the church of Källa and the railway, are now overgrown, and only heaps of weathered lichen-clad slabs of limestone show the position of former quarries. In one small quarry, immediately south of the road to the railway station of Källaberg (locality No. 4 in Text-fig. 2), quarrying has, however, been carried on until quite recently. About half a metre of calcilutites, in part finely nodular, is exposed. The rock is fairly poor in fossils; only *Nileus* can be found in almost every layer if enough time is devoted to collecting. Weathered bedding planes abound occasionally with *Leptellina ?* and other small fossils (*Christiania*, *Bolboporites*, small bryozoans). The following fossils have been found (Pal. Inst. Uppsala Nos. Öl. 70, 827, 900–923):

*Nileus* sp.
*Illaenus schroeteri schroeteri* (SCHLOTH.)
*Illaenus schroeteri stacyi* HOLM
*Illaenus* n. sp., aff. *schroeteri* (SCHLOTH.)
*Asaphus* (*Neoasaphus*) *bottnicus* JAAN.
*Pseudobasilicus* ? *brachyrachis* (TÖRNQ.)
*Remopleurides* sp.
*Leptellina* ? n. sp.
*Christiania* cf. *holtedahli* SPJELDNÆS
*Ancistroceras* sp.
*Euprimites bursellus* JAAN.
*Sigmobolbina sigmoidea* JAAN.
*Conularia* (*Plectoconularia*) n. sp., aff. *lindstroemi* HOLM
*Cryptocrinites* sp.
*Bolboporites* sp.
Undetermined, small bryozoans

Microlithological examination of two samples of limestone from the above quarry gave the following data:

| | | |
|---|---|---|
| Sample No. | Ö 252 | Ö 253 |
| Contents of fossil fragments >0.1 mm | 10% | 5% |
| Contents of total insoluble residue | 13.6% | 14.6% |

The fraction >0.125 mm of the insoluble residue contains some few badly preserved non-glauconitic internal moulds, some crystal aggregates of pyrites in Ö 252, and no glauconite. Except for a few grains of pyrites no authigenic minerals were observed in the thin sections. The limestone is thus a calcilutite almost without authigenic minerals.

The stratigraphic position and the microlithological characteristics show that the beds exposed in the quarry correspond to a part of the section between the levels of 10.9–13.15 m of the Böda Hamn boring.

PERSNÄS LIMESTONE.—Somewhat higher beds consisting of argillaceous calcarenite are exposed in an old, almost completely overgrown quarry 1.2 km north-west of the church of Persnäs (locality No. 7 in Text-fig. 2). Here too *Nileus* is the commonest species, occurring together with single specimens of *Heliocrinites*. No real section was available any more, and the exact stratigraphic position within the Persnäs Limestone of the beds once exposed in this quarry cannot be settled. The following species have been determined (Pal. Inst. Uppsala Nos. Öl. 72, 887–899):

*Nileus* sp.
*Illaenus schroeteri* (SCHLOTH.)
*Asaphus* (*Neoasaphus*) *bottnicus* JAAN.
*Pseudoasaphus tecticaudatus* (STEINH.)
*Cybelella* sp.
*Christiania* cf. *holtedahli* SPJELDNÆS
*Heliocrinites* cf. *prominens* (ANG.)
*Clathrospira* cf. *elliptica* (HIS.)

In eastern and south-eastern direction the beds of the above quarry are evidently overlain by grey, thick-bedded calcarenites which are best accessible in a small quarry 500 m W of the church of Persnäs, south of the main road from the church to Södvik (locality No. 8 in Text-fig. 2). The exposed section is 1.30 m high. The limestone in this quarry is fairly hard and rather poor in determinable fossils. Some beds are in places crowded with *Heliocrinites*, and there the limestone can be classified as coquinoid. Other species are fairly rare, and the following list is the result of an intensive collecting during short periods of several summers. The following species have been found (Pal. Inst. Uppsala Nos. Öl. 74, 862–886):

*Asaphus* (*Neoasaphus*) *lepidus* TÖRNQ.
*Pseudoasaphus tecticaudatus* (STEINH.)
*Illaenus schroeteri stacyi* HOLM
*Nileus* sp.
*Cybelella* sp.
*Remopleurides* sp.
*Laccochilina* (*Laccochilina*) sp. indet.
*Steusloffia linnarssoni* (KRAUSE)
*Leptellina* ? n. sp.
*Leptestia* sp.
*Christiania* cf. *holtedahli* SPJELDNÆS
*Alwynella* ? sp.
*Glossorthis* ? sp.
*Heliocrinites* cf. *prominens* (ANG.)
*Cryptocrinites* n. sp.
*Orthoceros regulare* (SCHLOTH.)
*Ancistroceras* sp.

Microlithological examination of two samples of limestone gave the following data:

| | | |
|---|---|---|
| Sample No. | Ö 250 | Ö 251 |
| Contents of fossil fragments >0.1 mm | 24% | 27% |
| Contents of total insoluble residue | 10.5% | 11.9% |

The fraction >0.125 mm of the insoluble residue contains abundant non-glauconitic internal moulds (300 in sample Ö 250 and >1000 in Ö 251 per 100 g of limestone). In the thin sections studied chamosite and its alteration product goethite are fairly common.

The stratigraphic position and the microlithological characteristics clearly show these beds to correspond to a part of the lithologic subdivision D of the Böda Hamn boring.

The same beds are exposed also on the northern part of central Öland in a small, partly overgrown quarry immediately NE of the road from Arbelunda to the harbour, about halfway between the village and the harbour (cf. Text-fig. 1). The rock is a grey, fairly thick-bedded calcarenite with numerous internal moulds in the insoluble residue. The following fossils have been found (Pal. Inst. Uppsala Nos. Öl. 837–850):

*Asaphus* (*Neoasaphus*) *lepidus* TÖRNQ.
*Illaenus intermedius* HOLM
*Illaenus schroeteri* (SCHLOTH.)
*Nileus* sp.
*Remopleurides* sp.
*Steusloffia linnarssoni* (KRAUSE)
*Uhakiella periacantha* JAAN.
*Heliocrinites* cf. *prominens* (ANG.)
*Ancistroceras* sp.
*Christiania* sp.
*Leptellina* ? n.sp.

This is the southernmost exposure of the Persnäs Limestone so far known upon Öland.

DALBY LIMESTONE.—The highest beds exposed on Öland belong to the Dalby Limestone. This limestone is exposed in several places along the eastern shore of the island down to Trosnäs in the parish of Persnäs, and further in some exposures on the easternmost part of the northern Öland. The best known locality is situated on the shore south of the old harbour of Böda (locality No. 2 in Text-fig. 2). From this exposure extensive collecting by several generations of palaeontologists has yielded a large material, mainly deposited in the Naturhistoriska Riksmuseet, Stockholm. The following list of fossils is based on collections in all palaeontological museums of Sweden, and gives a fairly complete picture of the fauna of a restricted portion of the Dalby Limestone of Öland. The boring of Böda Hamn was situated quite close to the shore, near the northern end of the exposure, and the beds exposed at the shore correspond to the uppermost metre or, at most, a metre and a half of the core section, at least 4.3 m above the boundary between the Persnäs and Dalby Limestones.

In studying the faunal list the following should be taken into consideration: (1) No information is available about the probably fairly rich conodont, scolecodont, and inarticulate brachiopod faunas. (2) The cephalopods, gastropods, and lamellibranchs have not been determined; none of these groups is especially common, and all are preserved as mostly scarcely determinable internal moulds. (3) No systematic description of chitinozoans has yet been carried out. (4) Bryozoa are in bad need of a modern redescription. (5) The names of articulate brachiopods are preliminary determinations by the writer, the list being neither complete nor, probably, quite correct in some details. (6) More extensive collecting will certainly increase the number of ostracode species.

*Trilobita*:

*Illaenus oblongatus* (ANG.)[1]
*Illaenus fallax* HOLM (cf. HOLM 1882, p. 88)
*Illaenus schmidti* NIESZK.
*Panderia parvula* HOLM
*Ogmasaphus costatus* JAAN.

[1] HOLM (1886, p. 117) recorded also *Illaenus kuckersianus* HOLM from this locality. This statement needs, however, further confirmation.

*Pseudoasaphus tecticaudatus* (STEINH.)
*Remopleurides* sp.
*Lonchodomas jugatus* ANG.
*Ampyx costatus* (BOECK)
*Stygina* cf. *nitens* (WIMAN)
*Paraceraurus* sp.
*Cybelella* sp. indet.
*Chasmops* cf. *odini* (EICHW.)
*Hemisphaerocoryphe sulcata* THORSLUND
*Pharostoma* sp. indet.

*Ostracoda* (JAANUSSON, 1957):
*Euprimites locknensis* (THORSL.)
*Polyceratella kuckersiana* (BONN.)
*Conchoprimitia leperditioides* THORSL.

*Cystoidea* (REGNÉLL, 1945):
*Hemicosmites oelandicus* REGNÉLL
*Caryocystites angelini* (HAECKEL)
*Heliocrinites granatum* (WAHLENBERG)
*Echinosphaerites aurantium aurantium* (GYLL.)
*Sphaeronites globulus* (ANG.)
*Cheirocrinus* sp.

*Conulariida* (HOLM, 1893):
*Conularia* (*Plectoconularia*) *telum* HOLM
*Conularia* (*Plectoconularia*) *pectinata* HOLM

*Brachiopoda Articulata:*
*Hesperorthis inostrancefi* (WYS.)
*Schizoramma* ? n.sp.
*Platystrophia dentata* (PANDER)
*Platystrophia sublimis* ÖPIK
*Platystrophia* n.sp.
*Nicolella demissa* (DALM.)
*Onniella* cf. *navis* (ÖPIK)
*Vellamo* n.sp.
*Kullervo* sp.
*Oxoplesia dorsata* (HIS.)
*Sowerbyella* (*Viruella*) cf. *minima* RÕÕM.
*Tetraodontella biseptata* JAAN., nom. nud.
*Leptestia* n.sp.
*Bilobia musca* (ÖPIK)
*Oepikina* cf. *dorsata* (BEKKER)
*Actinomena* sp.

*Bryozoa* (BASSLER, 1911):
*Pachydictya cyclostomoides* (EICHW.)
*Nematotrypa gracilis* BASSLER
*Mesotrypa milleporacea* BASSLER
*Dianulites fastigiatus* EICHW.
*Lioclemella spinea* (BASSLER)
*Orbipora distincta* (EICHW.)
*Esthoniopora curvata* BASSLER
*Hemiphragma pygmaeum* BASSLER
*Hemiphragma batheri* BASSLER
*Dittopora colliculata* (EICHW.)
*Diplotrypa bicornis* (EICHW.)
*Diplotrypa westoni* ULRICH
*Hallopora* ? *dybowskii* BASSLER

*Hystricosphaeridia* (EISENACK, 1959):
*Baltisphaeridium longispinum* (EISENACK)
*Baltisphaeridium multipilosum* (EISENACK)
*Baltisphaeridium trifurcatum nudum* EISENACK

In addition there occur some undescribed blastoids, *Bolboporites* sp., the foraminifer *Ordovicina oligostoma* EISENACK (EISENACK, 1954), *Conochitina oelandica* EISENACK (EISENACK, 1955), and fragments of graptolites (REGNÉLL, 1948).

Microlithological examination of two samples of limestone from the exposure of Böda Hamn furnished the following data:

| | | |
|---|---|---|
| Sample No. | Ö 256 | Ö 257 |
| Contents of fossil fragments >0.1 mm | 37% | 40% |
| Contents of total insoluble residue | 4.0% | 4.4% |

The fraction >0.125 mm of the insoluble residue contains abundant non-glauconitic internal moulds (500–600 per 100 g of limestone). No pyrites or glauconite was observed. In the thin sections the brown substance is fairly abundant occurring mostly as thin coatings around the fossil fragments and occasionally as fillings of internal cavities of these fragments. The latter are in places filled also by some almost colourless mineral closely associated with the above brown substance. These minerals evidently form the internal moulds of the insoluble residue. The identification of these minerals requires further study.

## *Böda Hamn Boring*

The program of the Palaeontological Institute (Uppsala) of strategically located borings for scientific purposes was initiated by the late Prof. G. SÄVE-SÖDERBERGH, and the Böda Hamn boring is the second of this series of borings. Sudden und unexpected death prevented Prof. SÄVE-SÖDERBERGH from seeing the results of his careful planning at the time when the drilling had just begun.

The boring was carried out in 1948, and was financed by a grant from the Natural Science Research Council of Sweden (Statens Naturvetenskapliga Forskningsråd). The bore hole is situated close to the beach south of the old harbour of Böda. The diameter of the core is 7 cm. The Cambrian beds and the Tremadocian shales of this boring were described by WÆRN (1952) and HESSLAND (1955), and the Lower Ordovician (Ontikan) limestones by BOHLIN (1955) and JAANUSSON (1955). This chapter can be regarded as the fourth report of the Palaeontological Institute in the series "Boring through Cambrian and Ordovician strata at Böda Hamn, Öland".

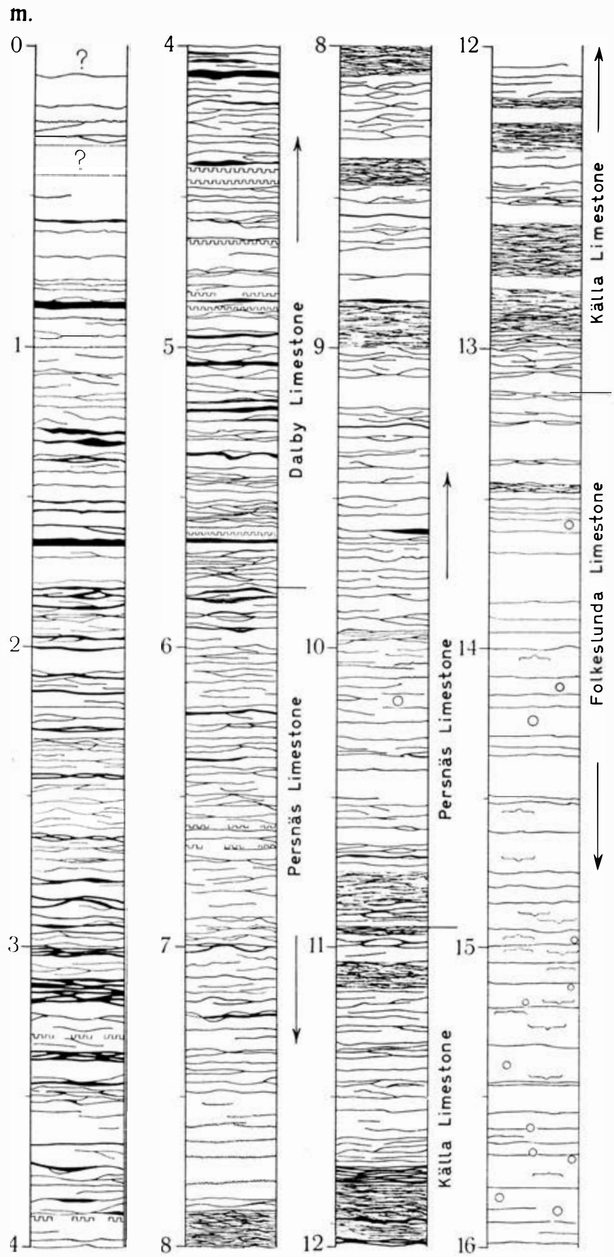
## Description of the Core

*Dalby Limestone* 5.80 m +

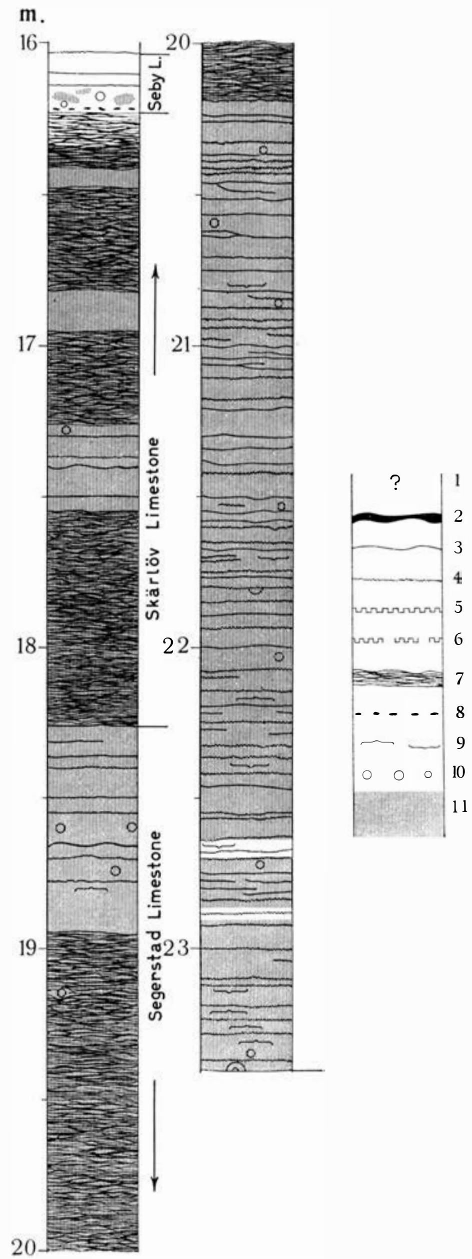
0–1.78 m. Mostly thick-bedded, grey, coarse-grained limestone with fairly even bedding planes and occasional intercalations of thin layers of marl or calcareous shale. Bedding planes occasionally with abundant pelmatozoan fragments. The boundary against the underlying beds poorly defined and the lithologic difference small.

*Panderia parvula* (HOLM).
*Stygina nitens* (WIMAN) (1.30 m).[1]
*Pseudosphaerexochus* cf. *tvaerensis* THORSLUND (1.40 m).
*Onniella* cf. *navis* (ÖPIK) (0.88 m).

[1] Here as well as in the other descriptions of the cores the numbers after the names of fossils refer to the level within the core. The range of species without these data in the description of the core is given in text-figures (Text-figs. 5 and 6 for the Böda Hamn boring).




Text.-fig. 3. Diagrammatic representation of the sedimentary structures of the Böda Hamn core (continued in Text-fig. 4). For signs, see Text-fig. 4.




Text-fig. 4. Diagrammatic representation of the Böda Hamn core (continued from Text-fig. 3). Signs: *1*, core portion destroyed during the drilling process; *2*, layer of calcareous shale, mudstone, or marl; *3*, bedding plane covered by argillaceous laminae; *4*, bedding plane formed by stylolitic structures; *5*, surface with faint black or dark grey impregnation of pyrites (? faint discontinuity surface); *6*, discontinuous surface with a faint impregnation of pyrites; *7*, finely nodular limestone; *8*, small nodules or pebbles of limestone; *9*, large trilobites; *10*, cephalopods; *11*, reddish brown rock.

Fragments of small coarsely punctate dalmanellids (0.12; 1.05 m).
*Sowerbyella* sp. (0.88 m).
*Tetraodontella biseptata* JAAN. nom. nud.
*Anisopleurella* ? n. sp. (0.88 m).
*Leptestia* n. sp. (0.50 m).
*Echinosphaerites* sp. (0.55 m).
*Orthotheca* cf. *ornatellus* HOLM (0.68 m).
*Euprimites locknensis* (THORSLUND).
*Conchoprimitia leperditioides* THORSLUND.
*Baltonotella kuckersiana* (BONNEMA).

1.78–5.80 m. Mostly thin-bedded to occasionally nodular (cf. Pl. I, fig. 4), grey, coarse- to fine-grained limestone with occasional intercalations of thin layers of marl or calcareous shale. Bedding planes of the upper 2 m occasionally with abundant pelmatozoan fragments. In the lower 2 m some fairly indistinct pyritiferous surfaces (cf. Text-fig. 3; Pl. II, fig. 3); none of them seems to be sufficiently distinct to be termed a discontinuity surface.

*Panderia parvula* (HOLM).
*Illaenus* sp. indet. (4.42 m).
*Illaenus* cf. *sphaericus* HOLM (2. 80 m).
*Remopleurides* sp. (3.10; 5.02; 5.28; 5.60 m).
*Chasmops* sp. (fragmentary pygidium) (3.43 m).
Fragments of small coarsely punctate dalmanellids (1.90; 3.10; 3.70; 3.95; 4.05; 4.56; 4.60; 4.65; 5.17; 5.40; 5.42 m).
*Tetraodontella biseptata* JAAN. nom. nud.
*Leptestia* n. sp. (2.90 m).
*Christiania* cf. *holtedahli* SPJELDNÆS (5.55; 5.62 m).
*Actinomena* sp. (3.10 m).
*Platybolbina kapteyni* (BONNEMA).
*Uhakiella* cf. *coelodesma* ÖPIK.
*Euprimites locknensis* (THORSLUND).
*Euprimites* aff. *eutropis* (ÖPIK) (3.41; 5.78 m).
*Tallinnella dimorpha* ÖPIK.
*Steusloffia multimarginata* ÖPIK.
*Steusloffia* sp. indet. (4.42; 5.65; 5.71 m).
*Sigmobolbina sigmoidea* JAAN. (4.20; ? 5.42; 5.58; 5.61 m).
*Polyceratella kuckersiana* (BONNEMA).
*Conchoprimitia leperditioides* THORSLUND.
*Conchoprimitia* sp. (2.10; 3.20; 4.02 m).
*Baltonotella kuckersiana* (BONNEMA).

No distinct lithologic boundary of any kind could be observed between this division and the underlying one, the boundary being drawn on faunistic evidence only.

## *Persnäs Limestone* 5.15 m.

5.80–7.88 m. Macroscopically indistinguishable from the overlying division.

*Illaenus intermedius* HOLM.
*Illaenus* sp. indet. (6.75 m).
*Estoniops* n. sp.
*Remopleurides* sp. (6.05; 6.24; 7.32; 7.37 m).
*Phillipsinella* n. sp.
*Trinodus* sp. (7.85 m).
*Nicolella* sp. (6.28; 7.20; 7.85 m).
*Leptestia* sp. (6.98 m).
*Bilobia* sp. (6.25 m).
*Sowerbyella* ? sp. (7.85 m).
*Anisopleurella* ? n. sp. (6.20; 6.90 m).
*Chilobolbina* aff. *dentifera* (BONN.) (7.80 m).
*Laccochilina* (*Laccochilina*) sp. indet. (6.01 m).
*Uhakiella* cf. *coelodesma* ÖPIK (7.25 m).
*Euprimites* cf. *eutropis* (ÖPIK).
*Euprimites* sp. (7.25 m).
*Levisulculus* sp. (7.80 m).
*Tallinnella dimorpha* ÖPIK.
*Steusloffia linnarssoni* (KRAUSE).

7.88–8.10 m. Grey, finely nodular limestone.
*Remopleurides* sp. (7.90 m).
*Sowerbyella* ? sp. (8.02–8.10 m).
*Leptellina* ? n. sp.
*Steusloffia linnarssoni* (KRAUSE).

8.10–8.39 m. Grey, fairly thick-bedded, coarse-grained limestone.
*Steusloffia linnarssoni* (KRAUSE).
*Remopleurides* sp. (8.12 m).

8.39–8.47 m. Grey, finely nodular limestone.
*Laccochilina* (*Laccochilina*) *paucigranosa* JAAN. (8.40 m).
*Steusloffia linnarssoni* (KRAUSE).

8.47–10.95 m. Grey, thin- to thick-bedded, mostly coarse-grained limestone.
*Trinodus* sp. (10.12 m).
*Leptellina* ? n. sp.
*Uhakiella periacantha* JAAN.
*Euprimites* cf. *eutropis* (ÖPIK).
*Euprimites* n.sp. (9.25 m).
*Steusloffia linnarssoni* (KRAUSE).
*Sigmobolbina sigmoidea* JAAN. (9.75 m).
The lower boundary is drawn at the level of conspicuous change in grain size.

*Källa Limestone* 2.20 m.

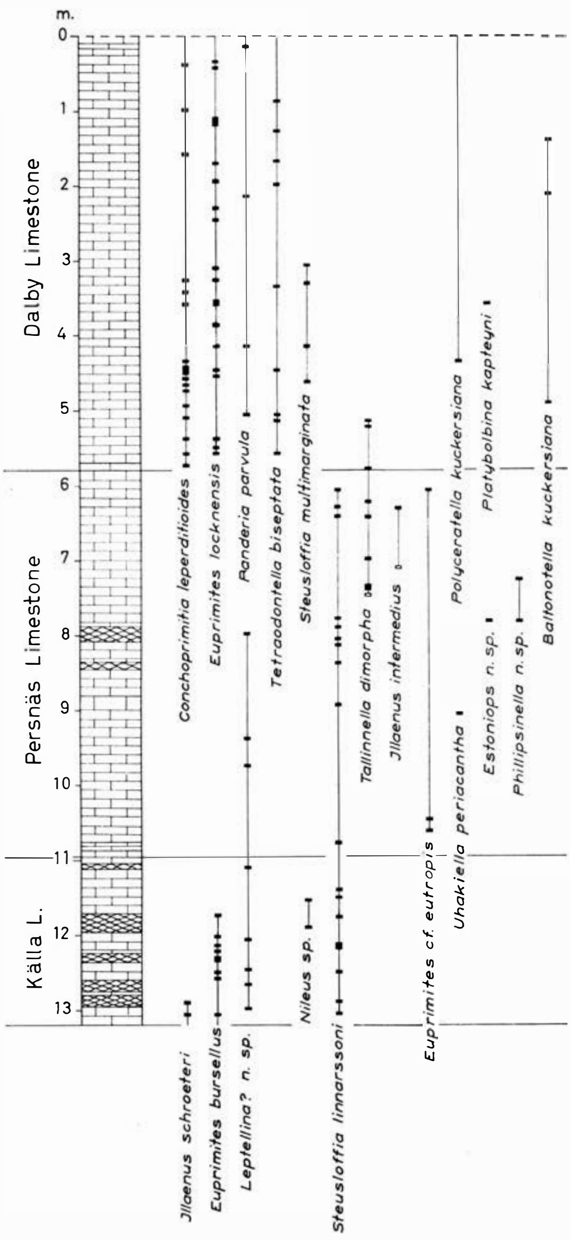
10.95–11.74 m. Grey, thin- to thick-bedded, fine-grained limestone, finely nodular between 11.05–11.15 m (Pl. I, fig. 3).
*Nileus* sp.
*Leptellina* ? n. sp.
*Bilobia* sp. (11.37 m).
*Steusloffia linnarssoni* (KRAUSE).

11.74–11.98 m. Grey, finely nodular to nodular, fine-grained limestone.
*Nileus* sp.
*Euprimites bursellus* JAAN.
*Steusloffia linnarssoni* (KRAUSE).

11.98–12.57 m. Grey, thin- to thick-bedded, fine-grained limestone, finely nodular between 12.17–12.20 m and 12.25–12.30 m.
*Leptellina* ? n.sp.
*Chilobolbina* aff. *dentifera* (BONNEMA) (12.55 m).
*Euprimites bursellus* JAAN.
*Sigmobolbina sigmoidea* JAAN. (12.05; 12.55 m).
*Steusloffia linnarssoni* (KRAUSE).

12.57–12.76 m. Grey, finely nodular limestone.
*Leptellina* ? n.sp.

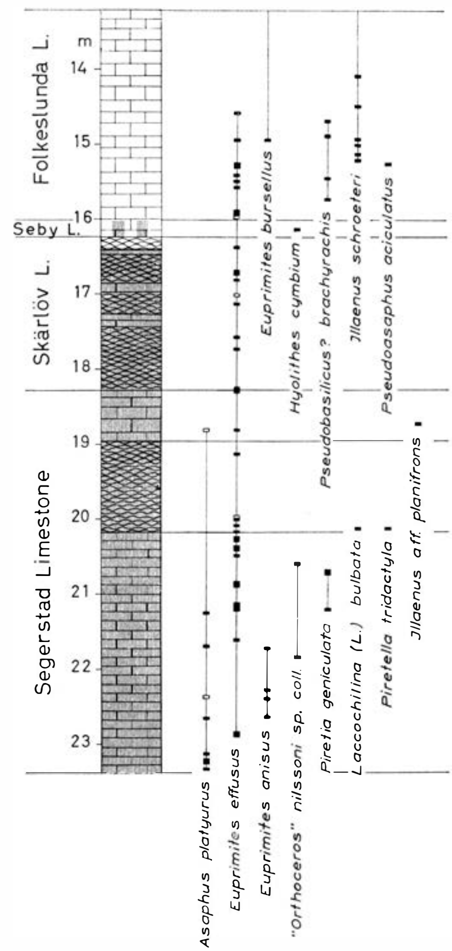
12.76–13.15 m. Thin-bedded, grey, fine-grained limestone, finely nodular between 12.88–12.94 m.
*Illaenus schroeteri* (SCHLOTH.).
*Remopleurides* sp. (12.90 m).
*Leptellina* ? n.sp.
*Euprimites bursellus* JAAN.
*Steusloffia linnarssoni* (KRAUSE).
The lower boundary is drawn at the level of conspicuous change in grain size.




Text-fig. 5. Böda Hamn core. Range of selected species within the Källa, Persnäs, and Dalby Limestones. Continued in Text-fig. 6. For signs, see Text-fig. 8.

## *Folkeslunda Limestone* 2.88 m.

13.15–16.03 m. Grey, coarse-grained, thick-bedded limestone.
*Illaenus schroeteri schroeteri* (SCHLOTH.).
*Pseudoasaphus aciculatus* (ANG.).
*Pseudoasaphus* cf. *tecticaudatus* (STEINH.) (14.42 m).
*Pseudobasilicus* ? *brachyrachis* (TÖRNQUIST).
*Asaphus* (*Neoasaphus*) sp. (14.56; 14.60 m).




Text-fig. 6. Böda Hamn core. Range of selected species within the Segerstad, Skärlöv, Seby, and Folkeslunda Limestones. Continued from Text-fig. 5. For signs, see Text-fig. 8.

*Remopleurides* sp. (14.58; 14.93 m).
*Bilobia* ? sp. (14.35 m).
*Alwynella* ? sp. (13.90 m).
*Laccochilina* sp. (15.06 m).
*Euprimites effusus* JAAN.
*Euprimites bursellus* JAAN.
*Sigmobolbina* sp. (15.87 m).
*Sigmobolbina sigmoidea* JAAN. (14.58 m).
*Baltonotella* n.sp. (15.60 m).
Undeterminable fragments of orthoceracone cephalopods.

## *Seby Limestone* 0.20 m.

16.03–16.23 m. Light brownish red, grey-mottled, fine-grained, thick-bedded limestone (Pl. II, fig. 2). The lower boundary is a distinct brownish surface with small pebbles of intensely reddish brown limestone above it.
*Hyolithes cymbium* HOLM.
"*Endoceras*" cf. *barrandei* DEW. (16.22 m).

*Skärlöv Limestone* 2.04 m.

16.23–17.26 m. In the uppermost part (16.23–16.33 m) greenish grey, otherwise brownish red, finely nodular marl (cf. Pl. I, figs. 1–2) with intercalations of fine-grained brownish red limestone between 16.41–16.48 and 16.82–16.95 m.
*Euprimites effusus* JAAN.

17.26–17.45 m. Grey, reddish brown-mottled, fine-grained thick-bedded limestone. No determinable fossils.

17.45–18.27 m. Brownish red, finely nodular marl.
*Euprimites effusus* JAAN.

*Segerstad Limestone* 5.13 m.

18.27–18.95 m. In the uppermost 23 cm and the lowermost 10 cm brownish red, in the middle grey-mottled, fine-grained, thick-bedded limestone.
*Illaenus* aff. *planifrons* JAAN.
?*Asaphus* (*Neoasaphus*) *platyurus* ANG.
*Euprimites effusus* JAAN.

18.95–20.18 m. Brownish red, finely nodular marl.
*Laccochilina* (*Laccochilina*) *bulbata* JAAN.
*Piretella tridactyla* JAAN.
*Euprimites effusus* JAAN.

20.18–23.40 m. In the middle (22.19–22.71 m) reddish brown with patches of greyish green colour, otherwise reddish brown with small greenish spots, fine-grained, mostly thick-bedded limestone. Between 22.71 and 22.79 m the limestone is in part nodular.
*Asaphus* (*Neoasaphus*) *platyurus* ANG.
*Remopleurides* sp. (21.25 m).
*Trinodus* sp. (21.75 m).
A small orthid (*Orthambonites*?) (20.69; 22.90 m).
"*Orthoceros*" *nilssoni* (BOLL) sp. coll.
*Piretia geniculata* JAAN.
*Euprimites effusus* JAAN.
*Euprimites anisus* JAAN.
*Baltonotella* n.sp. (21.60 m).

## Description of Microlithology of the Limestones

### *Particle Size and Texture of the Limestone*

Text-figs. 7 and 8.

Three main types of rock can be distinguished in the core portion studied: (1) Calcarenites, comprising the uppermost 10.95 m of the core (Persnäs and Dalby Limestones), the portion of the core between 13.15 and 16.03 m (Folkeslunda Limestone), and the reddish brown, bedded limestone of the Seby, Skärlöv, and Segerstad Formations (16.03–16.23 m, 16.82–16.95 m, 17.26–17.45 m, 18.27–18.95 m, and 20.18–23.40 m of the core; the microlithology of the thin layer of bedded limestone at the level of 16.41–16.48 m has not been studied).

(2) Calcarenitic calcilutites, comprising the portion of the core between 10.95–13.15 m (Källa Limestone).

(3) Finely nodular marl (calcarenitic calcilutite) of the Skärlöv and Segerstad Formations. The content of carbonates in this rock is usually less than 75 %.

*Calcarenites* (cf. Pl. II, fig. 1 and Pl. III). The content of fossil fragments longer than 0.1 mm in thin sections is in these limestones usually rather considerable, especially in the uppermost 2 m of the Dalby Limestone (31.3 to 41.1 %), in the Folkeslunda Limestone (25.7 to 31.4 %), and in the lowermost Segerstad Limestone (28.1 to 34.0 %). Some beds of calcilutite, though fairly rich in shell fragments, are intercalated at the levels of 8.0 m and 8.5 m.

The matrix of these calcarenites is usually fine-grained, but coarse-grained spots occur at some levels (especially at 0.5 m, 4.5 m, 6.5 m, 13.40–16.03 m, and 20.5 m). The fossil fragments usually have more or less distinct outlines, and exhibit only in the spots with coarse-grained matrix a tendency towards partial recrystallization being occasionally fused with the matrix. Shell fragments are mostly angular, without any signs of secondary rounding. Often more or less entire small shells, chiefly ostracodes, are met with. At the level of 8.0 m (a bed of calcarenitic calcilutite) the matrix is in part cryptocrystalline, and the whole rock resembles the calcilutites of the Källa Limestone (cf. below).

At the levels of 16.82–16.95 m and 18.5 m the matrix is mostly coarse-grained, the fragments are strongly recrystallized and partly fused with the matrix making determination of particle size impossible. As, however, coarse fragments are abundant, the rock can be termed a recrystallized calcarenite.

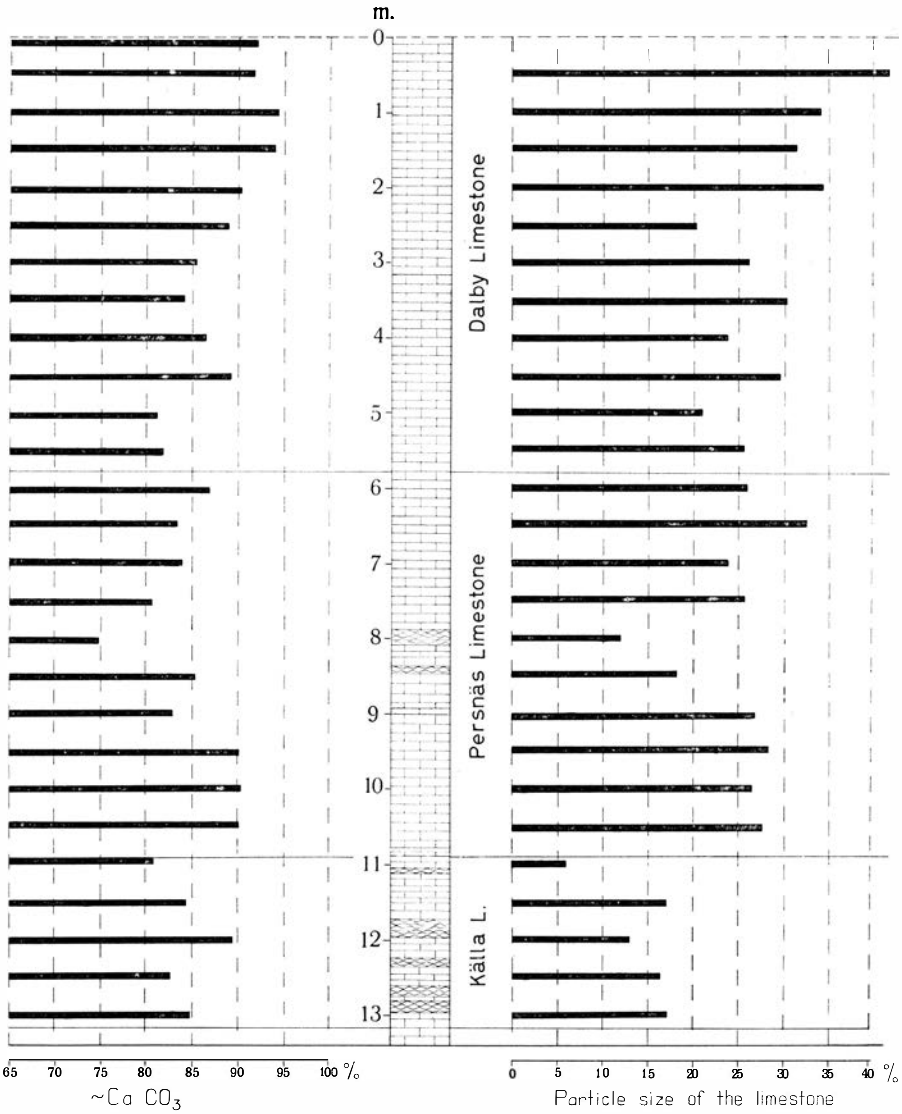
*Calcarenitic calcilutites* (cf. Pl. IV, fig. 1). The matrix is mostly cryptocrystalline with occasional fine-grained spots. The fossil fragments are usually well-preserved, and show distinct outlines. Small entire shells of ostracodes and gastropods are frequent.

*Finely nodular marl.* The microstructure corresponds to that of the above calcilutites. The matrix is more or less uniformily pigmented by haematite which usually is concentrated in laminae rich i argillaceous matter. Of interest is the occasional occurrence of small (2 to 5 mm in diameter) nodules of mostly intensely reddish brown limestone (cf. Pl. I, fig. 1) within the finely nodular rock.

## *Distribution of Authigenic Substances in Thin Sections.*

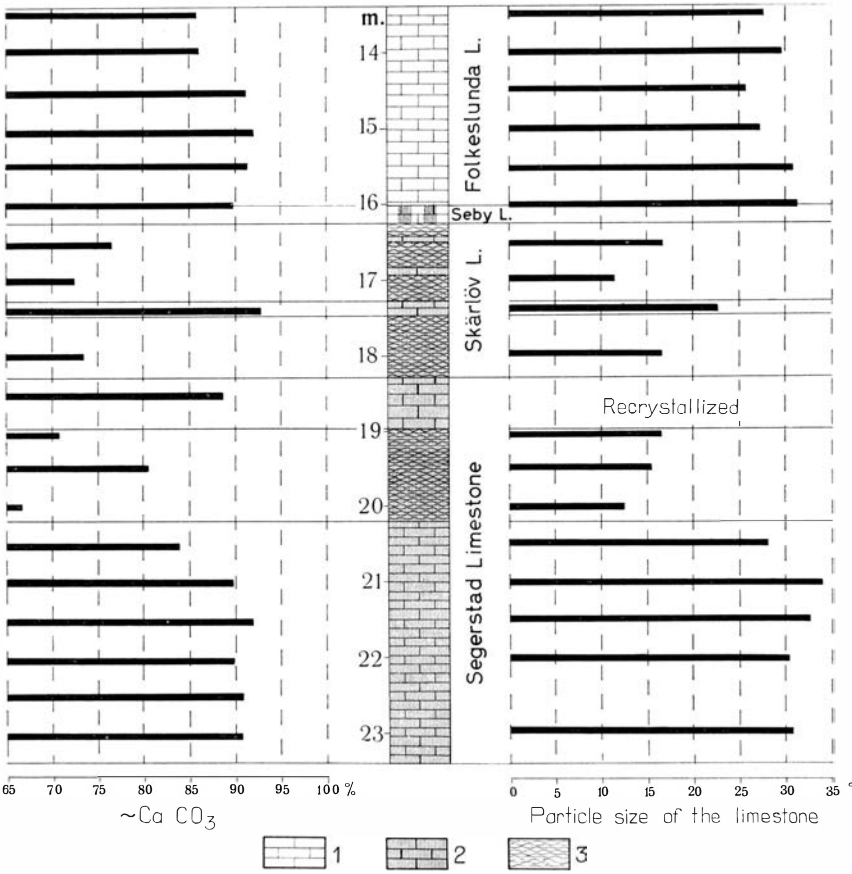
Text-figs. 9 and 10.

*Haematite* occurs only in the lowermost part of the section, viz. between 16.03 m and 23.40 m. In the finely nodular marls and at some levels of the bedded limestone the whole matrix is intensely pigmented by ferric oxide. At the other levels of the bedded limestones only a part of the matrix is brownish red, and at the level of 22.5 m only some spots of haematite occur. In these beds the thin sections are grey red-mottled, although the macroscopic appearance of the rock does not give this impression. The haematite is, especially at the




Text-fig. 7. Källa, Persnäs, and Dalby Limestones of the Böda Hamn core. To the left the material soluble in dilute acetic acid (approximately the content of $CaCO_3$), to the right particle size of the limestone according to the method of JAANUSSON (1952). Continued in Text-fig. 8. For signs, see Text-fig. 8.

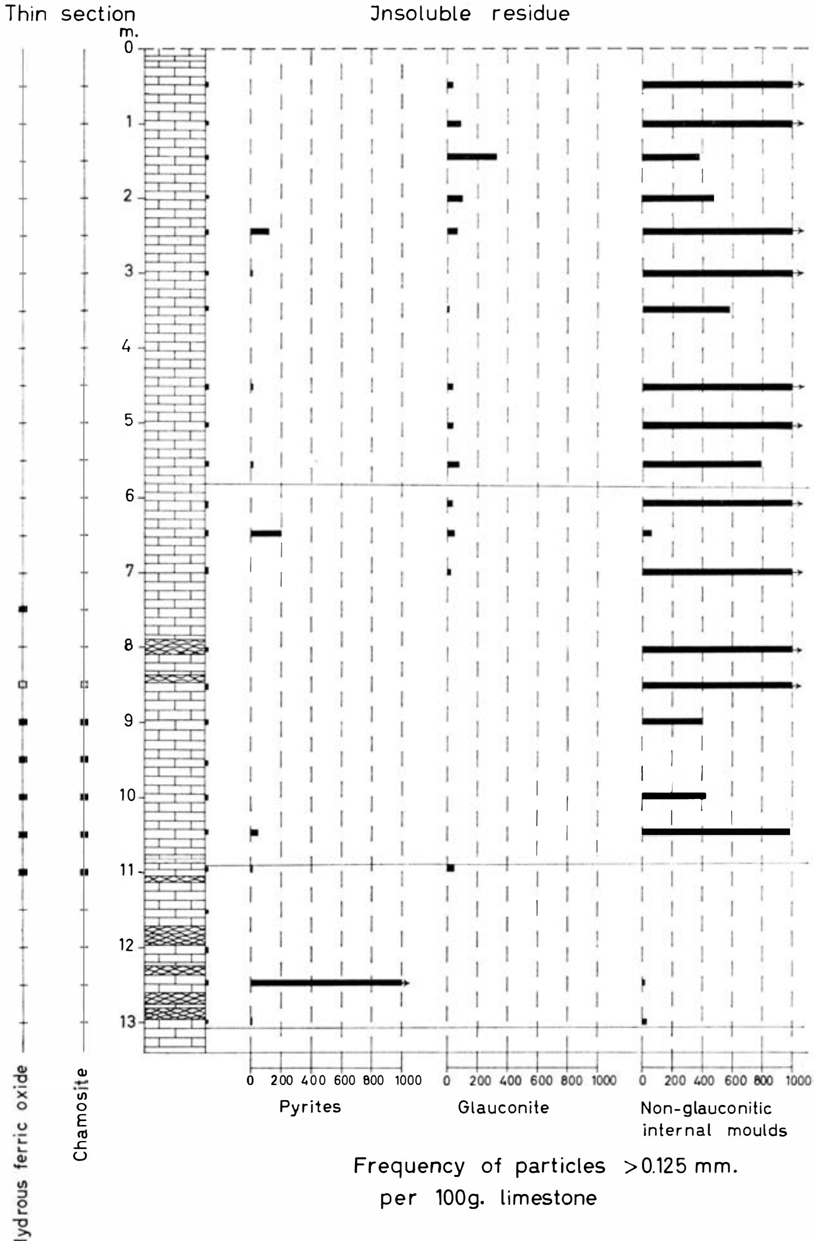
levels 20.5 m, 21.0 m, 21.5 m, and 23.0 m, partly concentrated around the fossil fragments, whereas the matrix has a varying intensity of haematite pigmentation that is even missing in some spots. At the levels of 16.82–16.95 m and 18.5 m haematite occurs mainly as thin coatings around the fossil fragments, and is concentrated within small shells of different groups and cavities of the pelmatozoan fragments.



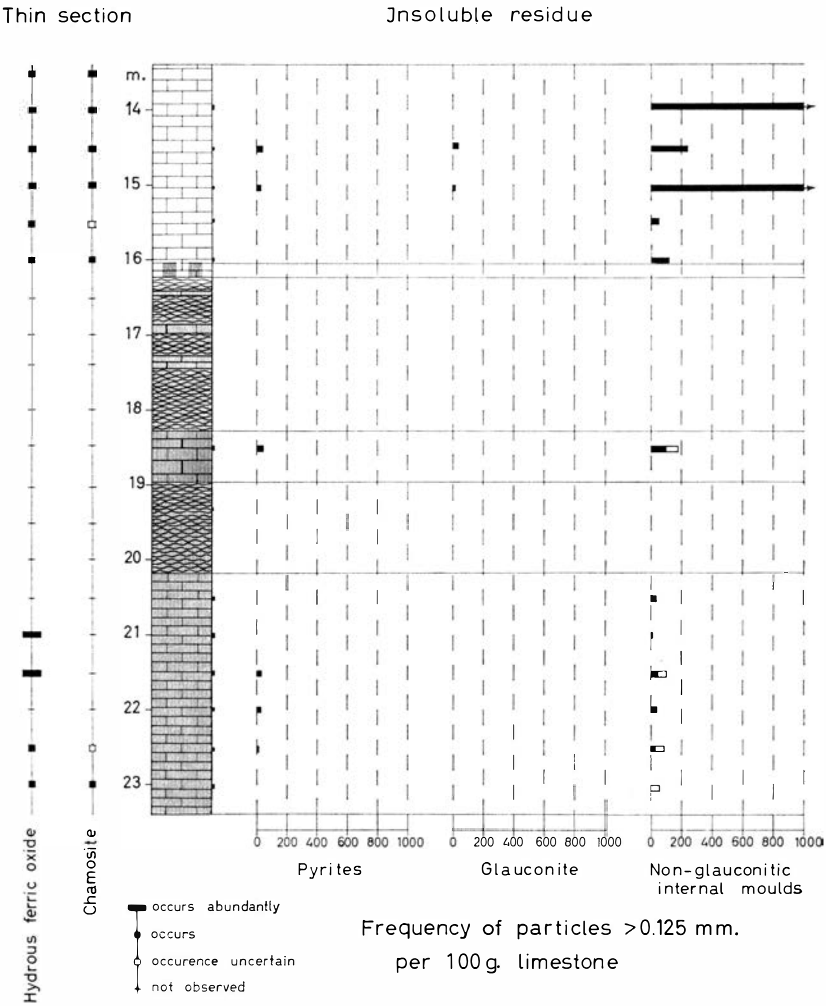

Text-fig. 8. Segerstad, Skärlöv, Seby, and Folkeslunda Limestones of the Böda Hamn core. For explanation, see Text-fig. 7. Signs: *1*, grey bedded limestone; *2*, reddish brown limestone; *3*, finely nodular limestone.

*Goethite.* At the levels of 9.0–11.0 m, 13.5–16.0 m, and 22.5–23.0 m goethite is evidently a secondary alteration product of chamosite. In these beds it occurs nearly always together with the latter, usually surrounding the grains or coatings of chamosite. In some cases goethite has probably replaced all the chamosite. Its mode of occurrence is then the same as that of the latter mineral.

At the levels of 21.0 m and 21.5 m the matrix is in part pigmented by a ferric substance with a intense yellow colour. Since the colour of this substance corresponds exactly to that of the goethite surrounding the chamosite grains, we have probably to do with the same substance. The thin sections studied suggest that in this case the hydrous ferric oxide may have been formed by a secondary hydration of haematite (cf. also HADDING, 1932, pp. 50–51). The latter still occurs within the area of goethite pigmentation as fillings of the narrow cavities of pelmatozoan fragments and in similar sheltered points, being surrounded




Text-fig. 9. Källa, Persnäs, and Dalby Limestones of the Böda Hamn core. Distribution of some authigenic minerals in thin sections and of some components of the fraction larger than 0.125 mm of the insoluble residue. Continued in Text-fig. 10. For signs, see Text-fig. 8.




Text-fig. 10. Segerstad, Skärlöv, Seby, and Folkeslunda Limestones of the Böda Hamn core. For explanation, see Text-fig. 9.

there by goethite. Such an occurrence of the haematite gives the impression that it may be a residue which has not been affected by the hydration process.

*Chamosite.* The occurrence of this mineral characterizes the Folkeslunda Calcarenite and the lower part of the Persnäs Calcarenite. It occurs furthermore in the lowermost layers of the Segerstad Limestone and in the uppermost beds of the Källa Calcilutite. In most thin sections of these beds it is, however, fairly rare. Chamosite occurs as fillings of small shells, mostly ostracodes and gastropods (cf. Pl. II, fig. 1), or of narrow cavities in echinoderm fragments. Sometimes also thin coatings of chamosite around fossil fragments have been observed. It is usually associated with, and partly decomposed into goethite (see above).

*Brown substance* (phosphorite?). A substance with a dark brown colour in incident light occurs in the uppermost part of the core (0.5–3.0 m, 4.5–7.5 m) usually as impregnation of thin laminae rich in clay or as thin coatings around the fossil fragments. The latter mode of occurrence is prevalent in the Folkeslunda calcarenite, where the brown substance occasionally also fills the narrow cavities in echinoderm fragments. The substance is often associated with small crystals or crystal aggregates of pyrites.

### *Fraction >0.125 mm of the Insoluble Residue*

Text-figs. 9 and 10.

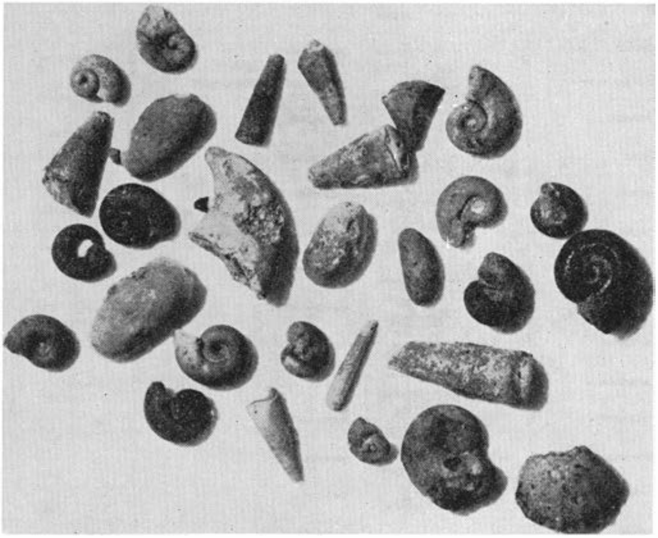
Allochthonous mineral grains, chiefly quartz, occur in the limestone in small and seemingly more or less constant quantities throughout the whole portion of the core studied.

*Pyrites.* Most pyrites observed in the thin sections has a particle size below 0.125 mm in diameter. In the insoluble residue pyrite crystals or crystal aggregates are abundant at some levels of the grey limestone, but rare or absent at other levels. In the bedded, reddish brown limestones pyrites is represented as a rule by 5–20 crystals or crystal aggregates >0.125 mm per 100 g of limestone, except at the levels of 18.50 and 23.00 m, where no pyrites was observed. Also the finely nodular marl occasionally contains some grains of pyrites. In these reddish brown limestones the pyrites is probably derived from the grey or greenish-grey spots of the rock, though no special measures have been taken for confirming this assumption.

*Glauconite.* At some levels occasional small, rounded grains of glauconite have been met with in the insoluble residue. For the most part at least they are probably allochthonous.

*Non-glauconitic internal moulds.* In the grey calcarenites of the core most of the fraction of the insoluble residue usually consists of small internal moulds of gastropods, ostracodes, rod-like fossils (in part hyolithids), and more rarely of some other groups (Text-fig. 11, Pl. V, fig. 1; see also JAANUSSON & MUTVEI, 1953 and JAANUSSON, 1955). A study of the different types of these internal moulds has not yet been accomplished. Examination of the thin sections suggests that chamosite and the brown substance (phosphorite?) are responsible for their formation.

In the uppermost 10.95 m of the core (Persnäs and Dalby Limestones) these microfossils occur in relatively considerable quantities except for the levels 6.5 and 9.5 m. In the Källa Calcilutites the internal moulds are missing except for the level of 13.0 m, where some have been encountered. In the Folkeslunda Calcarenites they occur in varying quantities, and are never missing. The reddish brown limestones and marls are for the most part devoid of internal moulds. They are represented at the levels of 18.5 m (small quantities) and



Text-fig. 11. Non-glauconitic internal moulds of the insoluble residue. Dalby Limestone, at the level of 0.5 m of the Böda Hamn core. × 15.

23.0 m (a few specimens). In the bedded limestones of the Segerstad Limestone some reddish brown, poorly preserved internal moulds, consisting of haematite, have been observed in almost every sample.

*Lithologic Subdivisions of the Lasnamägian and Uhakuan Limestones of the Core*

The general lithologic subdivision of the Lasnamägian and Uhakuan limestones of the Böda Hamn core is as follows:

*E*. Persnäs Limestone. Preponderantly coarse-grained calcarenites, mostly with abundant internal moulds in the insoluble residue. In the upper part (5.80–8.5 m of the core) chamosite absent or rare in thin sections, in the lower part present in each thin section studied.

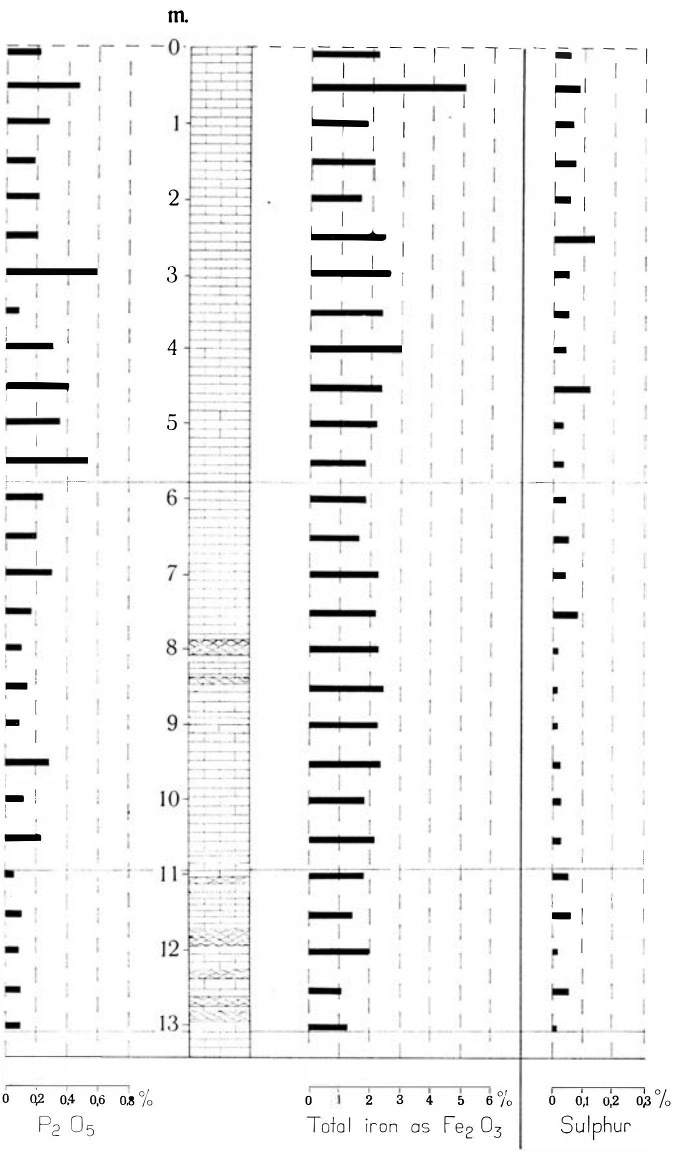
*D*. Källa Limestone. Fine-grained calcarenitic calcilutites without either internal moulds in the insoluble residue or chamosite except for the uppermost beds.

*C*. Folkeslunda Limestone. Coarse-grained, grey calcarenites with internal moulds in the insoluble residue (except in uppermost beds) and chamosite.

*B*. Seby Limestone. Brownish red grey-mottled calcarenites (microlithology not studied).

*A*. Skärlöv Limestone. Brownish red, finely nodular marls (calcarenitic calcilutites) with intercalations of thin beds of brownish red bedded limestone (mostly calcarenite without internal moulds).

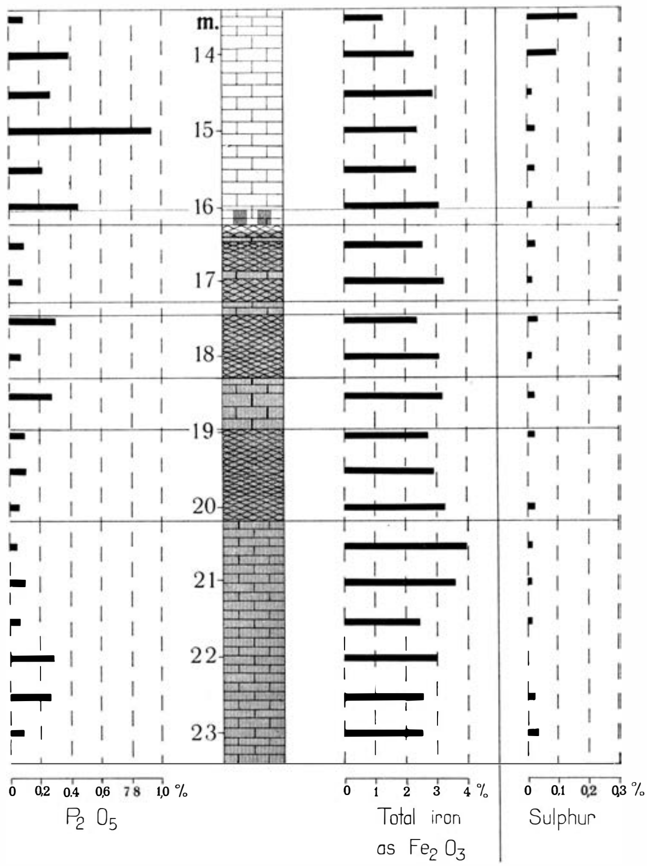
The distribution of iron and phosphorus (Text-figs. 12 and 13) will be discussed in the concluding part of this series of papers.




Text-fig. 12. Källa, Persnäs, and Dalby Limestones of the Böda Hamn core. Analyses of phosphorus, iron, and sulphur. Analyst Mr. J. LUKINS, Dipl. Ing., under supervision of Prof. I. HESSLAND. For signs, see Text-fig. 8. Continued in Text-fig. 13.

## Notes on the Viruan Sequence of Central Öland

HISTORICAL SURVEY.—In several of his latest papers HOLM used his own subdivision of the beds here included in the Lasnamägi Stage. His classification is based on cephalopods, mainly lituitids, and on hyolithids in the exposures of the northern part of southern and of central Öland. An exact correlation of his




Text-fig. 13. Segerstad, Skärlöv, Seby, and Folkeslunda Limestones of the Böda Hamn core. For explanation, see Text-fig. 12.

zones with the current classification of this part of the sequence (MOBERG, 1890) has met with difficulties, and several different attempts can be found in the literature. HOLM's zone fossils are rare or absent in southernmost and northern Öland, and almost nothing was known about the range of trilobites in relation to that of cephalopods and hyolithids. The correlation could be solved only by a re-examination of the localities in the type region of HOLM's zones. For this reason a preliminary examination of selected localities was carried out in central Öland and the northeastern part of southern Öland.

HOLM never published any connected account of his classification. The only published data are scattered notes in his various papers, mostly included in discussions on vertical distribution of species described by him from these beds. Some help in finding his localities has been obtained from HOLM's diaries preserved in the Geological Survey of Sweden.

The strata in question were distinguished by HOLM as *Lituites* Region which overlies his *Vaginatum* Region. The boundary between these regions coincides with that between the *Gigas* and *Platyurus* Limestones of the classification of MOBERG (1890). This is evident from the range of *Cyclendoceras* as well as from certain notes in HOLM's papers. In his paper of 1893 HOLM used the following subdivision of the *Lituites* Region:

*Chasmops* Region

*Lituites* Region:
- Zone of *Lituites perfectus* (Grey *Lituites* Limestone)
- Zone of *Lituites lituus* (transition beds between the Red and Grey *Lituites* Limestone)
- Zone of *Lituites discors* (Red *Lituites* Limestone)

*Vaginatum* Region

The names of these zones are found already in HOLM's paper of 1891. Later HOLM (1895, p. 618) mentiones also the zone of *Asaphus platyurus* as the lowermost subdivision of the *Lituites* Region. The name of the latter zone he evidently borrowed from the classification of MOBERG (1890). In HOLM's earlier papers these beds were referred to simply as the lowermost part of the Red *Lituites* Limestone. From various papers of HOLM the following data about his zones can be gathered:

Zone of *Asaphus platyurus* apparently coincides with the range of the index fossil, i.e. it includes the *Platyurus* Limestone and the transition beds between the *Platyurus* and *Centaurus* (= *Schroeteri*) Limestones of MOBERG (1890).

Zone of *Lituites discors* comprises (HOLM, 1893, p. 83) red-coloured beds situated immediately below the transition beds between the Red and Grey *Lituites* Limestone. These beds were also called uppermost part of the Red *Lituites* Limestone (HOLM, 1891, p. 26). Characteristic fossils: *Orthoceras* (= *Rhynchorthoceras*) *angelini* BOLL, *O.* (= "*Conorthoceras*") *conicum* HIS., *Clinoceras* sp., *Lituites discors* HOLM, *Hyolithes crispatus* mut. *crispulus* HOLM, *H. concinnus* HOLM, and *H. cymbium* HOLM.

Zone of *Lituites lituus* (HOLM, 1891, pp. 20–21; cf. also HOLM, 1893, p. 16, and 1892, p. 5) comprises the brownish-red transition beds between the Red and Grey *Lituites* Limestones, and is characterized by *Lituites lituus* MONTF., *Endoceras barrandei* DEW., and "a long form of *Orthoceras conicum*". *Endoceras barrandei* occasionally occurs in great abundance.

Zone of *Lituites perfectus* is formed by grey limestones characterized by *Lituites perfectus* (WAHLENB.), *Hyolithes acutus* EICHW., *H. crispatus* mut. *crispissimus* HOLM, and others.

FIELD OBSERVATIONS.—At present most of the localities of the beds in question of central Öland are small, and the section exposed rarely exceeds half a metre. No exposure showed a continuous section through the Lasnamägi Stage, and the succession described below is reconstructed after several small localities.

On the whole the lithologic development of the Lasnamägian sequence of central Öland is fairly similar to that of northern Öland. The sequence begins with intensely red, finely nodular marls with intercalations of bedded limestone (Skärlöv Formation). The nodular rocks are overlain by some individual beds of reddish brown grey-mottled calcarenite and somewhat more than half a metre of pale brownish red calcarenite (Seby Limestone). The top of the succession is formed by a grey calcarenite (Folkeslunda Limestone).

*Skärlöv Limestone.*—The exposures in this formation are few and temporary. The uppermost part was accessible in the drainage ditch at Långlöt described below. There the rocks of the formation are intensely brownish red finely nodular marl and limestone poor in macrofossils. Some badly preserved specimens of *Illaenus schroeteri* were the only determinable fossils found.

*Seby Limestone.*—The lowermost beds of the Seby Limestone were best accessible in the drainage ditch at Långlöt, about 700 m N of the Långlöt church and ca. 200 m W of the highway. In three places the ditch was cut into the Seby and Skärlöv Limestones, but already at the time of our visit the low section was so overgrown that details were obscure. The lowermost beds of the Seby Limestone are reddish brown calcarenites, in places grey-mottled. Fossils are commonly surrounded by a reddish brown crust-like concentration of haematite. The exact thickness could not be measured, but the sequence with this lithologic characteristics comprises scarcely more than a few individual beds of limestone. The following fossils were encountered (Pal. Inst. Uppsala, Nos. Öl. 943–949, 1028, 1030): *Illaenus schroeteri schroeteri* (SCHLOTH.), *Pseudobasilicus ? brachyrachis* (TÖRNQ.), *Echinosphaerites aurantium suecicus* REGNÉLL, *Lituites (Trilacinoceras) discors* HOLM, *Rhynchorthoceras angelini* (BOLL), "*Conorthoceras*" *conicum* (HIS.), and *Protobactrites delicatulum* TROEDSS. The ostracodes include, in addition to *Euprimites effusus*, some undescribed species.

A more complete section through most of the Seby Limestone is exposed in a quarry 400–500 m N of S Sandby village, 100–200 m west of the highway. The quarry covers a large area, but nowadays only a small part of it exposes fresh rock. This quarry was well known to HOLM, and ought evidently to be regarded as the type locality of his zone of *Lituites lituus*. The section in the quarry is as follows (Pal. Inst. Uppsala, Nos. Öl. 924–942, 1029):

*Seby Limestone* 0.66 m +

*D.* 0.18 m + Some beds of grey, thick-bedded calcarenite with pale reddish brown spots; fossils commonly surrounded by a reddish brown crust-like layer rich in haematite. The calcarenite abounds with small internal moulds of chamosite and chamositic crusts around fossil fragments.
*Illaenus schroeteri schroeteri* (SCHLOTH.).
*Pseudoasaphus aciculatus* (ANG.).
*Pseudobasilicus ? brachyrachis* (TÖRNQ.).
*Nileus* sp.
*Remopleurides* sp.
*Lituites (Lituites) lituus* MONTF. (common).
"*Endoceras*" *barrandei* DEW. (common).

*C.* 0.48 m. As above, but the brownish colour more dominating.

*Illaenus schroeteri schroeteri* (SCHLOTH.).
*Pseudobasilicus ? brachyrachis* (TÖRNQ.).
"*Conorthoceras*" *conicum* (HIS.) (common).
"*Endoceras*" *barrandei* (DEW.) (common).
*Lituites* (*Trilacinoceras*) sp. indet.
*Rhynchorthoceras angelini* (BOLL).

*B*. 0.10 m. One bed of brownish red calcarenite with occasional irregular greenish grey spots, but usually without a haematite crust around the fossils. Also the reddish brown portions of the rock are mottled owing to irregular distribution of the haematite which is occasionally concentrated in small spots (fillings of shells of small ostracodes, gastropods, etc.) or irregular laminae.
*Illaenus schroeteri schroeteri* (SCHLOTH.).
*Pseudobasilicus ? brachyrachis* (TÖRNQ.).

The boundary towards the underlying bed is formed by an almost even bedding plane with separate shallow furrows (the plane gives the impression of having been a surface like that in the Segerstad Limestone at the Segerstad lighthouse (Pl. V, fig. 2), but has subsequently undergone abrasion or erosion, or both, resulting in general levelling of the surface until only the bottom part of the deepest furrows remained upon it; however, there exists at present no real proof neither for nor against this suggestion).

*A*. 0.06 m. + As in the division *B*, but the reddish brown colour more dominating. The fossils are often surrounded by a reddish brown layer rich in haematite.
*Lituites* (*Trilacinoceras*) *discors* HOLM.
"*Conorthoceras*" *conicum* (HIS.).
"*Endoceras*" *barrandei* DEW.
*Echinosphaerites aurantium suecicus* REGNÉLL

The division *D* of the above section belongs to HOLM's zone of *Lituites lituus*, and the division *A* to that of *Lituites discors*. The attribution of the intervening divisions in terms of HOLM's zones is not yet clear.

The zone of *Lituites lituus* is exposed also at the beach straight E of Folkeslunda village, south of Skärudden. This is the old locality "Folkeslunda sjöbodar", wellknown from the extensive collections in the Riksmuseum. The collections are mainly from large boulders of the Folkeslunda Limestone on the southern side of the Skärudden, whereas the exposed section consists almost exclusively of the Seby Limestone. Unfortunately at all our visits at this locality the bedrock on the beach was too extensively covered with sand and seaweeds and the water-level too high. Under favourable conditions a detailed section can certainly be measured there. A further locality with the Seby Limestone is the old drainage ditch south of N. Kvinneby which was, on account of difficulties in obtaining sufficient and exactly dated material of macrofossils, only cursorily examined.

*Folkeslunda Limestone.*—The Folkeslunda Limestone is exposed on central Öland in several small exposures, and is in places very rich in fossils. All available sections, however, are very low. During the nineties of the last century it was available for collecting in the heaps of debris accumulated during the excavation of the drainage ditch at Brunneby. From this locality extensive collections were brought home by Prof. J. G. ANDERSSON, and are now deposited at the Riksmuseum. At present this exposure is completely overgrown. In the last ten years heaps of debris from the water-reservoir for fire extinction in the village of Lerkaka have furnished good collecting possibilities. Unfortunately at our first visit at the locality the section in the water-reservoir was already covered.

The Folkeslunda Limestone of central Öland belongs to HOLM's zone of *Lituites perfectus.* The index fossil, associated with a rich fauna, was found by us in the boulders of Folkeslunda Sjöbodar and in the debris from the water-reservoir at Lerkaka.

*Källa Limestone.*—At the beach of Runstens Hamn a grey, fine-grained, chamositiferous limestone with *Illaenus schroeteri*, *Pseudomegalaspis patagiata*, *Nileus* sp., and undeterminable cephalopods is overlain by thick-bedded, dense calcilutites very poor in fossils. The whole section comprises only a few individual beds, and it is difficult to determine their position in relation to the general section. South of Runstens Hamn and Stenboudd similar limestones are exposed in several places along the beach down to Båden, and it is probable that they belong, in part at least, to the lowermost part of the Furudal Limestone or its tongue, Källa Limestone.

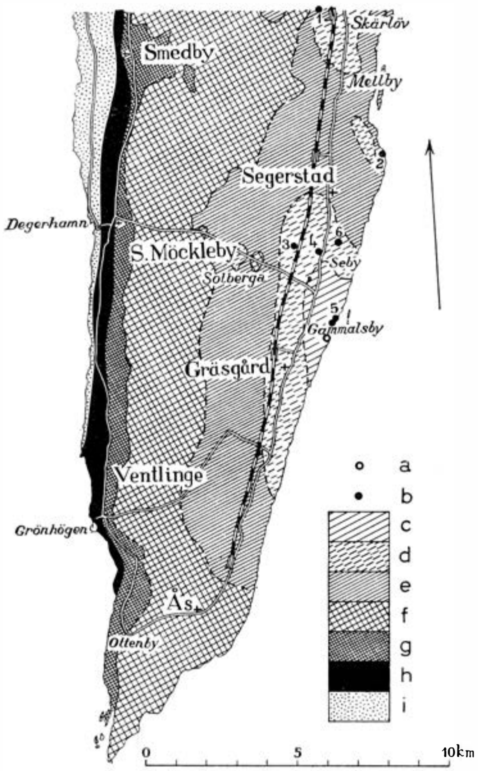
## Viruan Rocks of Southernmost Öland

### *Review of Exposures*

SEGERSTAD LIMESTONE.—The lowermost beds of the Segerstad Limestone are most easily accessible in a small quarry 300 m NW of Skärlöv railway station (locality No. 1 in Text-fig. 14). In the bottom of this shallow quarry (maximal depth 0.65 m in 1954) the intensely brownish red, fairly thick-bedded calcarenites of the zone of *Megistaspis gigas* are exposed yielding *Megistaspis* (*Megistaspidella*) *gigas* (ANG.) and *Illaenus glabriusculus* JAAN. The section continues into the Segerstad Calcarenites without any lithologic change, the boundary between these divisions being marked by a bedding surface that does not differ from most other bedding surfaces in the quarry. Faunistically the boundary is sharp, no species being common to the two divisions. Below, *Megistaspis* (*Megistaspidella*) *gigas* is a common species, above pygidia of *Asaphus* (*Neoasaphus*) *platyurus* are abundant in some beds. In the exposed beds of the Segerstad Limestone (ca. 0.40 m) the following fossils have been encountered (Pal. Inst. Uppsala, Nos. Öl. 950–958).

*Asaphus* (*Neoasaphus*) *platyurus* ANG.
*Glyptosphaerites leuchtenbergi* VOLB.
"*Orthoceros*" *nilssoni* (BOLL.) sp. coll.
*Angelinoceras latum* (ANG.).
*Euprimites effusus* JAAN.

Within the Segerstad Limestone at least two bedding planes are peculiarly sculptured, bearing shallow, anastomozing furrows (Text-fig. 15). The resemb-



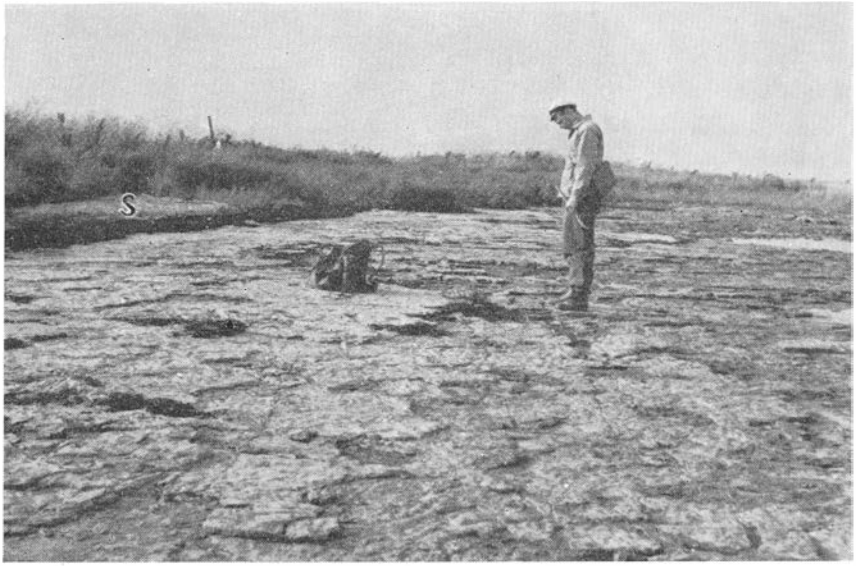

Text-fig. 14. Geological map of southernmost Öland. Western part compiled from notes and diaries (deposited at the Geological Survey of Sweden) of Prof. J. CHR. MOBERG. Eastern part according to field observations by V. JAANUSSON and J. MARTNA. Signs: *a*, boring; *b*, localities referred to in the text; *c*, Furudal Limestone (Uhaku Stage); *d*, Folkeslunda, Seby, and Skärlöv Limestones (Lasnamägi Stage); *e*, Segerstad Limestone (Aseri Stage); *f*, limestones of the Kunda Stage (*Vaginatum* Limestone); *g*, Lower Ordovician below the Kunda Stage (Volkhov and Latorp Stages and Tremadocian Subseries); *h*, Upper Cambrian beds; *i*, Middle Cambrian beds.

lance of these furrows to somewhat eroded mud cracks is suggestive, and the writer is inclined to regard them as formed by subaerial desiccation. The diameter of the polygons between the furrows varies between 2 and 5 cm, being commonly 3 to 5 cm. The depth of the furrows is from 2 to 6 mm, being commonly 3 to 5 mm. To a depth of some millimetres below the surface the rock has a more intensely red colour than deeper down, but the difference in colour is slight. It is difficult to find a plausible explanation of the origin of these furrowed surfaces other than emergence, drying, desiccation, and a subsequent submergence causing a slight re-working of the surface. The submarine cracks (STRAATEN, 1954, p. 38) have a rather different appearance, although they are indistinguishable from incomplete subaerial mud cracks (GINSBURG, 1956, p. 94) as defined by SCHROCK (1948, p. 194). Unmistakable mud cracks in the Orthoceratite Limestone have previously been figured by HÖGBOM (1920, Fig. 28) from the autochthonous sequence of Jämtland. The stratigraphic horizon of the surface figured by him within the Orthoceratite Limestone is not known, except that it ought to be younger than the zone of *Asaphus expansus*, and older than the Uhaku Stage. The polygons on HÖGBOM's photograph are larger than those in the Lower Segerstad Limestone of Skärlöv, and resemble those of the Upper Segerstad Limestone of Segerstad figured and discussed below.

Text-fig. 15. Furrows, resembling mud cracks, on a bedding plane of the lowermost Segerstad Limestone in the quarry 300 m NW of Skärlöv railway station. $\frac{2}{3}$ of natural size. Photo N. HJORTH.

The beds of the Segerstad Limestone exposed in the above quarry belong to the zone of *Angelinoceras latum.* The index fossil of this zone was encountered by Dr. J. MARTNA also in a small quarry 700 m ENE of Segerstad church in the lowermost beds of the Segerstad Limestone, where it is associated with *Asaphus* (*Neoasaphus*) *platyurus.*

Reddish brown calcarenites of the zone of *Illaenus planifrons* are exposed between the above quarry of Skärlöv and Skärlöv railway station, 150 m NW of




Text-fig. 16. Exposure of the uppermost Segerstad Limestone N of Segerstad lighthouse. *S* denotes the white to pale red thick-bedded limestone on the top of the Segerstad Limestone. Photo J. MARTNA, 1951.

the latter. Only some few individual beds are accessible, containing *Illaenus* aff. *planifrons* JAAN., *Geisonoceras ? centrale* (DALM.), "*Orthoceros*" *nilssoni* (BOLL) sp. coll., and *Glyptosphaerites leuchtenbergi* VOLB. (Pal. Inst. Uppsala, No. Öl. 959).

The best exposure of the zone of *Illaenus planifrons* on southernmost Öland is the beach N of Segerstad lighthouse (Text-fig. 16; locality No. 2 in Text-fig. 14). There the accessible section comprised only about 40 cm (much less now, the bedrock on the beach having subsequently been to a large extent covered by sand and seaweeds). The highest exposed beds consisted of a hard, thick-bedded, white to pale brownish red calcarenite (*S* in Text-fig. 16), poor in macrofossils. Only some large pygidia of *Asaphus* (*Neoasaphus*) *platyurus platyurus* (Pal. Inst. Uppsala, No. Öl. 1001) have been found in this calcarenite which, on lithological reasons, is to be correlated with a similar limestone at the top of the Segerstad Limestone of the borings of Gammalsby (10.90–11.15 m) and Skärlöv (3.27–3.51 m). At Segerstad lighthouse the white calcarenite overlies intensely brownish red limestone, in places with intercalations of thin layers of reddish brown nodular limestone occasionally abounding in poorly preserved specimens of *Echinosphaerites*. The reddish brown limestone has yielded the following fossils (Pal. Inst. Uppsala, Nos. Öl. 997–1000, 1002, 1027):

*Asaphus* (*Neoasaphus*) *platyurus platyurus* ANG.
*Pseudoasaphus tecticaudatus* (STEINH.)
*Illaenus* aff. *planifrons* JAAN.
*Echinosphaerites aurantium suecicus* REGNÉLL
"*Orthoceros*" *nilssoni* (BOLL) sp. coll.

About 10 cm below the white calcarenite lies a peculiarly sculptured bedding surface with large and fairly deep anastomozing furrows (Pl. V, fig. 2). This surface probably corresponds to that at the level of 11.23 m of the Gammalsby boring. The resemblance of the furrows to the mud cracks in the Orthoceratite Limestone of Jämtland (HÖGBOM, 1920, Fig. 28) is suggestive. On account of the lack of a more plausible explanation the writer is inclined to consider also this surface to be formed by subaerial desiccation. The polygons have a diameter from 5 to 15 cm, and are thus considerably larger than those in the Lower Segerstad Limestone of Skärlöv. The morphology of the surface resembles closely that at the boundary between the zones of *Angelinoceras latum* and *Illaenus planifrons* of Vikarbyn, Siljan district (JAANUSSON & MUTVEI, 1953, pp. 25–26, Pl. I), and also the latter surface may be taken as formed by subaerial desiccation. In this case the pebbles above the surface (JAANUSSON & MUTVEI, 1953, Pl. I, fig. 1) may be derived from subsequent abrasion of the edges of the polygons. Some factors influencing the size of the polygons in recent carbonate sediments have been discussed by GINSBURG (1956), but it is uncertain, whether or not they are unconditionally applicable also to sediments of the type of red calcarenites of the Segerstad Limestone.

SKÄRLÖV LIMESTONE.—All exposures of the Skärlöv Limestone on southernmost Öland are small or temporary, and nowhere a complete section has been exposed. It is probable that these beds were not accessible to MOBERG (1890). The limestone is poor in fossils. These are as a rule poorly preserved and mostly undeterminable. In heaps of debris from the water-reservoir for fire extinction in the villages of Mellby and Skärlöv *Illaenus schroeteri* (SCHLOTH.) and *Pseudobasilicus ? brachyrachis* (TÖRNQ.) were found in an intensely brownish red, finely nodular limestone of the Skärlöv Formation.

SEBY AND FOLKESLUNDA LIMESTONES.—In a temporary exposure, made in 1951 for a water-reservoir for fire extinction in the village of Seby (locality No. 4 in Text-fig. 14) the following section was measured by Dr. J. MARTNA and the present writer (cf. Text-fig. 17):

*Folkeslunda Limestone* 1.46 m +

$C_2$. 0.13 m + Fairly thin-bedded (individual beds 4–8 cm), fine-grained, grey limestone.

$C_1$. 0.08 Light grey, finely nodular limestone.

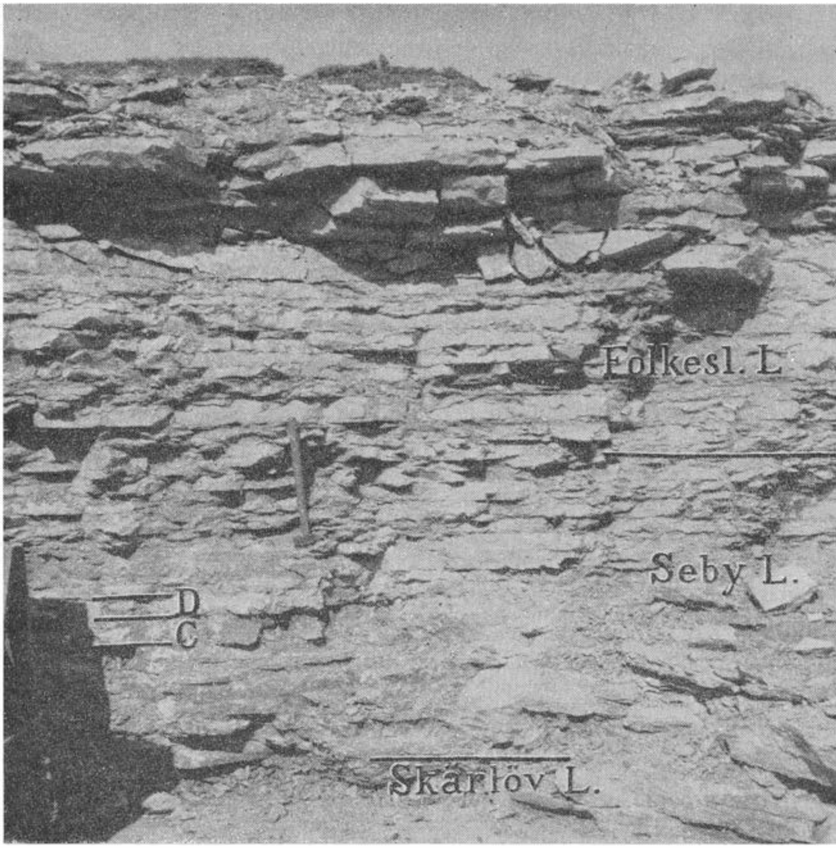
*B*. 0.55 Grey, thick-bedded (individual beds 4–10 cm), coarse-grained limestone with numerous dark grains.
*Illaenus schroeteri schroeteri* (SCHLOTH.).
*Pseudoasaphus aciculatus* (ANG.).
*Pseudobasilicus ? brachyrachis* (TÖRNQ.).

*A*. 0.70 Light grey, fairly thin-bedded (individual beds 4–10 cm), fine-grained limestone.

*Seby Limestone* 0.98 m.

*G*. 0.06 One bed of pale brownish red, grey-mottled, fine-grained limestone.

*F*. 0.18 Pale red, finely nodular limestone.




Text-fig. 17. The section in the water-reservoir for fire extinction of the village of Seby. *C* and *D* denote the beds of grey calcarenite in the Seby Limestone (cf. Text-fig. 25). Photo J. MARTNA, 1951.

*Nileus* sp. (Pal. Inst. Uppsala, No. Öl. 960).
*Illaenus schroeteri* (SCHLOTH.) (No. Öl. 961).

*E*. 0.17 Brownish red grey-mottled, fine-grained, fairly thick-bedded limestone.
*D*. 0.08 One bed of grey, fine-grained limestone.
*C*. 0.10 One bed of dark grey, coarse-grained limestone.
*B*. 0.09 Grey, fine-grained, thin-bedded (individual beds 3–5 cm) limestone.
*A*. 0.30 Brownish red, fine-grained limestone with grey spots (individual beds about 8 cm).

*Skärlöv Limestone* 0.15 m. +

*E*. 0.15 + Brownish red, finely nodular limestone.

The section was exposed along a vertical wall, and only a few determinable fossils could be obtained. In the waste from this excavation *Illaenus schroeteri* (SCHLOTH.) and "*Conorthoceras*" *conicum* (HIS.) were encountered in a brownish red, grey-mottled, fine-grained limestone.

In general the Seby section corresponds fairly well to the section of the

Gammalsby boring, though some details are different. The latter circumstance may depend in part on the different appearance of the limestones in a core and in an exposure. The following rough correlation seems to be plausible (the numbers refer to the corresponding portion of the Gammalsby core):

*Folkeslunda Limestone.*

$C_1 + C_2$. 7.00–7.20 m (no finely nodular rock was, however, observed in the core at this level).
*B*. 7.20–7.74 m (good correspondance).
*A*. 7.74–8.40 m (no finely nodular rock observed in the Seby section).

*Seby Limestone.*

*G*. 8.40–8.47 m.
*F*. 8.47–8.74 m (this finely nodular limestone has a considerably greater thickness in the Gammalsby core).
*E*. 8.74–8.80 m (this division is much thinner in the Gammalsby core).
*D*. 8.80–8.84 m.
*C*. 8.84–8.93 m.
*B*. 8.93–9.03 m.
*A*. 9.03–9.48 m (no finely nodular rock in this division of the Seby section).

The main differences between these two sections lie in the development of certain finely nodular beds and in the thickness of some divisions.

On account of the rich graptolite fauna a section measured by Dr. B. BOHLIN in 1941 in a small exposure (watering hole for animals) ca. 500 m E of the northernmost house of the village of Seby (locality No. 6 in Text-fig. 14; No. 19 in BOHLIN's diary of 1941) is of special interest. The section is in descending order (Pal. Inst. Uppsala, Nos. Öl. 962–988):

*Seby Limestone* 0.51 m. +

*D*. 0.05 + Dark grey, coarse-grained limestone.
*C*. 0.10 Grey, coarse-grained limestone.
*Didymograptus* cf. *murchisoni murchisoni* (BECK).
*Pseudoclimacograptus angulatus sebyensis* JAAN.
*Climacograptus pauperatus* BULMAN.
*Climacograptus distichus* (EICHWALD).
*Glyptograptus* cf. *teretiusculus* (HIS.).
*Abrograptus* n. sp.
*Pseudoasaphus* sp.
*Ampyx* (*Cnemidopyge*) n. sp.
*Nileus* sp.
*Euprimites effusus* JAAN.
*Euprimites bursellus* JAAN.
*Conorthoceras conicum* (HIS.).
*B*. 0.06 Thin-bedded, grey limestone with brownish tint.
*Conorthoceras conicum* (HIS.).
*A*. 0.30 Thick-bedded (4 individual beds), reddish brown limestone with grey spots.
*Euprimites effusus* JAAN.

*Skärlöv Limestone* 0.25 m. +

0.25 m + Finely nodular reddish brown limestone with grey spots.

The section agrees in detail with the corresponding portion of the section in Seby village (cf. Text-fig. 25).

Dark grey, thick-bedded, coarse-grained calcarenites of the Folkeslunda Limestone are exposed in a watering hole for animals about 1 km N of Torngård railway station close to the track (locality No. 3 in Text-fig. 14). Here the following species have been found in heaps of debris accumulated during the excavation of the watering hole:

*Illaenus schroeteri schroeteri* (SCHLOTH.).
*Pseudoasaphus aciculatus* ANG.
*Pseudobasilicus ? brachyrachis* (TÖRNQ.).
*Remopleurides* sp.
*Lituites* (*Lituites*) sp. indet.
*Glyptograptus* sp.

In a light grey, partly nodular limestone in the same exposure *Nileus* sp. is abundant.

HOLM (1891, p. 755) mentions the occurrence of his zone of *Lituites lituus* in "transition beds between the Red and Grey *Lituites* Limestone". This exposure is now almost completely overgrown and unavailable for collecting of more than isolated specimens. The exact position of the beds with *Lituites* (*Lituites*) *lituus* within the Seby Limestone of southernmost Öland could not be ascertained.

FURUDAL LIMESTONE.—The only extensive locality of the Furudal Limestone of southernmost Öland is a natural exposure on the beach N of the harbour of Gräsgård (locality No. 5 in Text-fig. 14). According to his diary this locality was well-known to MOBERG as an exposure of his *Strombolituites* (= *Ancistroceras*) Limestone, and it can be regarded as the type locality of this division. The rock along the beach is a dense, light grey, fairly thick-bedded calcilutite with thin intercalations of grey calcareous mudstone and marl. It is in general very poor in fossils, and *Nileus* is by far the commonest among them. The following species have been collected by us (Pal. Inst. Uppsala, Nos. Öl. 851–861):

*Illaenus schroeteri stacyi* HOLM.
*Pseudobasilicus ? brachyrachis* (TÖRNQ.).
*Nileus* sp.
*Remopleurides* sp.
*Lonchodomas* sp.
*Alwynella* ? sp.
*Ancistroceras* sp. indet.
Indeterminable orthoceracone cephalopods.

The boring of Gammalsby was carried out quite close to this locality, and the uppermost beds of the core represent those exposed along the beach.

## *Gammalsby boring*

The boring of Gammalsby was carried out by the Geological Survey of Sweden in 1943, and is situated on the beach of the Baltic 275 m N of Gräsgårds Hamn. The diameter of the core is 7 cm. The Cambrian beds and the

Tremadocian shales of this boring were described by WESTERGÅRD (1944). The Ontikan limestones are still undescribed. The topmost beds of the boring are evidently the highest levels that are exposed on southernmost Öland.

## Description of the Core

*Furudal Limestone* 5.64 m. +

0–0.66 m. Grey, dense limestone, thick-bedded in the upper and thin-bedded in the lower part.
*Nileus* sp.
*Remopleurides* sp. (0.07 m.)
*Laccochilina* (*Laccochilina*) sp. indet. (0.57 m).
*Steusloffia linnarssoni* (KRAUSE).

0.66–0.93 m. Grey, finely nodular to nodular limestone.
*Nileus* sp.
*Remopleurides* sp. (0.75 m).
*Laccochilina* (*Laccochilina*) sp. indet. (0.68 m).
*Sigmobolbina* cf. *sigmoidea* JAAN. (0.68 m).

0.93–1.64 m. Grey, thick- to thin-bedded, dense to fine-grained limestone, coarse-grained between 1.13 and 1.24 m.
*Nileus* sp.
*Steusloffia linnarssoni* (KRAUSE).
*Sigmobolbina sigmoidea* JAAN. (0.98; 1.40 m).

1.64–1.82 m. Grey, finely nodular to nodular limestone.

1.82–3.61 m. Grey, dense, mostly thick-bedded limestone, finely nodular between 2.00 and 2.04 m.
*Nileus* sp.
*Euprimites bursellus* JAAN.
*Euprimites* sp.
*Sigmobolbina sigmoidea* JAAN. (3.10; 3.40; 4.45 m).

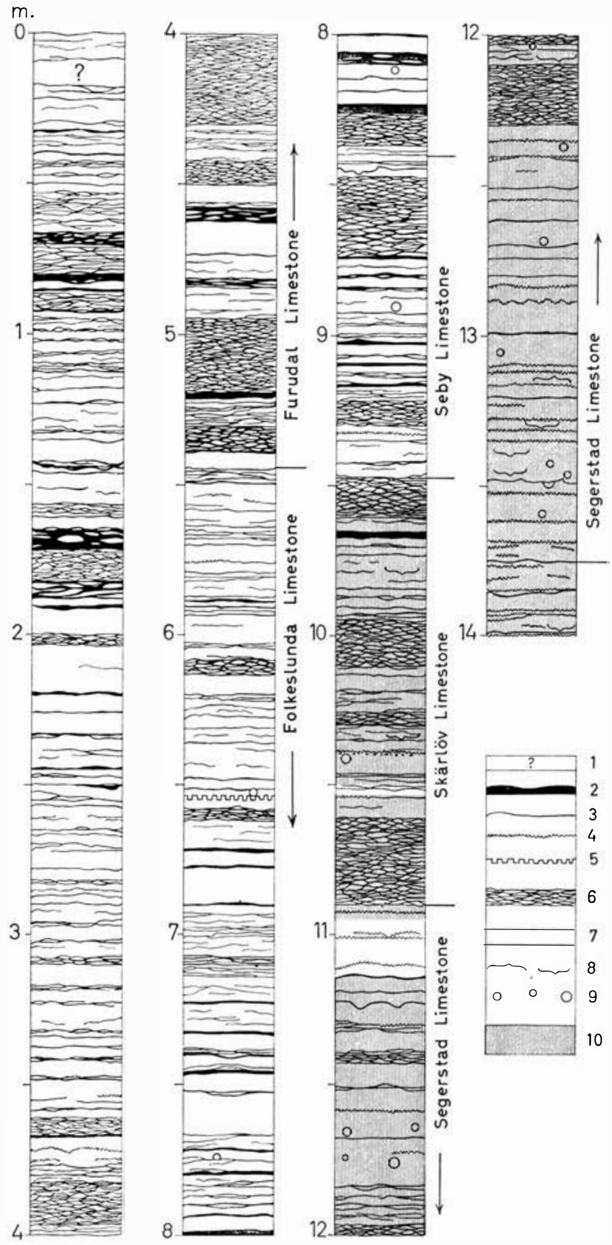
3.61–3.67 m. Grey, finely nodular limestone.
*Nileus* sp.
*Sigmobolbina* cf. *sigmoidea* JAAN. (3.64 m).

3.67–3.83 m. Two beds of grey, dense limestone.
*Sigmobolbina sigmoidea* JAAN. (3.78 m).

3.83–4.30 m. Grey, finely nodular limestone with thin-bedded, dense limestone between 3.97 and 4.04 m.
*Illaenus schroeteri* (SCHLOTH.).
*Remopleurides* sp. (3.99 m).
*Trinodus* sp. (4.00 m).
*Euprimites* sp. indet. (4.15 m).
*Steusloffia linnarssoni* (KRAUSE).
*Steusloffia* sp. indet. (3.85; 4.27 m).
*Sigmoopsis* sp. indet. (4.15 m).
*Sigmobolbina sigmoidea* JAAN. (3.99 m).

4.30–4.43 m. Grey, thin-bedded, fairly dense limestone.
*Illaenus schroeteri* (SCHLOTH.).
*Nileus* sp.

4.43–4.50 m. Grey, finely nodular limestone.




Text-fig. 18. Diagrammatic representation of the uppermost part of the Gammalsby core. Signs: *1*, core portion destroyed during the drilling procedure; *2*, layer of calcareous shale, mudstone, or marl; *3*, bedding plane covered by argillaceous laminae; *4*, bedding plane formed by stylolitic structures; *5*, surface with a faint black or dark grey impregnation of pyrites (? faint discontinuity surface); *6*, finely nodular limestone; *8*, large trilobites; *9*, cephalopods; *10*, reddish brown rock.

4.50–4.95 m. Grey, dense limestone, occasionally fairly thick-bedded. Intercalations of calcareous mudstone and marl between 4.58–4.64 and 4.82–4.85 m.
*Nileus* sp.
*Uhakiella* cf. *aequigranosa* JAAN. (4.53 m).
*Euprimites bursellus* JAAN.
*Euprimites* sp. (4.90 m).
*Tallinnella* sp. indet. (aff. *sebyensis* JAAN.) (4.53 m).
*Steusloffia* sp. indet. (4.53 m).

4.95–5.48 m. Grey, finely nodular to nodular limestone.
*Illaenus schroeteri* (SCHLOTH.).
*Pseudomegalaspis* cf. *patagiata* (TÖRNQ.) (5.09 m).
*Nileus* sp.
*Euprimites bursellus* JAAN.
*Euprimites* sp. indet. (5.02 m).
*Steusloffia linnarssoni* (KRAUSE).

5.48–5.64 m. Grey, dense, fairly thick-bedded limestone. The lower boundary is drawn at the level, where dense limestone changes into coarse-grained.
*Nileus* sp.
*Uhakiella aequigranosa* JAAN. (5.60 m).
*Euprimites bursellus* JAAN.

## *Folkeslunda Limestone* 2.76 m.

*H*. 5.64–6.07 m. Grey, in the upper 32 cm fairly coarse-grained, in the lower 11 cm fine-grained, thin-bedded limestone.
*Laccochilina* (*Laccochilina*) sp. indet. (6.06 m).
*Uhakiella* cf. *aequigranosa* JAAN. (6.03 m).
*Euprimites bursellus* JAAN.
*Steusloffia linnarssoni* (KRAUSE).

*G*. 6.07–6.14 m. Grey, finely nodular limestone.
*Euprimites effusus* JAAN.

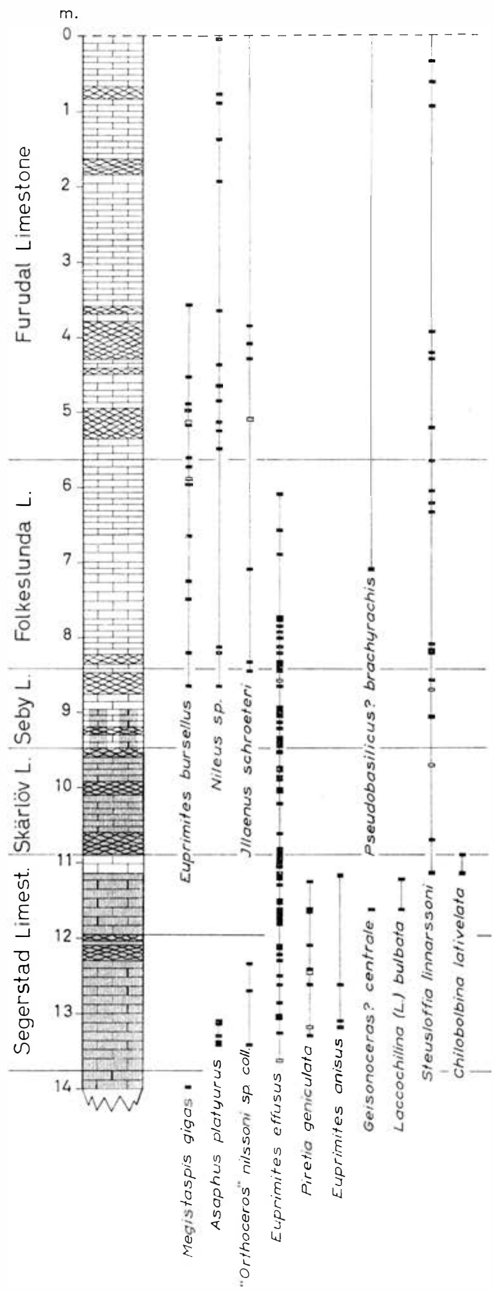
*F*. 6.14–6.47 m. Grey, fairly coarse-grained, thick-bedded limestone.
*Tallinnella* cf. *angustata* (KRAUSE) (6.30 m).
*Steusloffia linnarssoni* (KRAUSE).

*E*. 6.57–6.62 m. Grey, finely nodular limestone.
*Uhakiella aequigranosa* JAAN. (6.58 m).
*Euprimites effusus* JAAN.

*D*. 6.62–6.93 m. Grey, thick-bedded, in the lower 17 cm fairly coarse-grained limestone.
*Uhakiella* cf. *aequigranosa* JAAN. (6.65 m).
*Euprimites effusus* JAAN.
*Euprimites bursellus* JAAN.
*Sigmobolbina* cf. *sigmoidea* JAAN. (6.70 m).
*Conchoprimitia* n.sp. B (6.62 m).

*C*. 6.93–7.20 m. Grey, thin-bedded limestone.
*Illaenus schroeteri* (SCHLOTH.).
*Pseudobasilicus* ? *brachyrachis* (TÖRNQ.).
*Ampyx* (*Cnemidopyge*) n.sp. (6.85 m).

*B*. 7.20–7.74 m. Grey, coarse-grained, thick-bedded limestone with numerous dark grains in the lower 7 cm and the upper 20 cm.
*Remopleurides* sp. (7.55 m).
*Chilobolbina* aff. *dentifera* (BONNEMA) (7.55 m).




Text-fig. 19. Range of selected species in the uppermost part of the Gammalsby core. For signs, see Text-fig. 8.

*Euprimites bursellus* JAAN.
*Haploprimitia* ? n. sp. (7.50 m).

$A_2$. 7.74–8.06 m. Grey, fine-grained limestone with thin to moderately thick individual beds.
*Uhakiella aequigranosa* JAAN. (7.82 m).

*Euprimites effusus* JAAN.
*Sigmobolbina* sp. indet. (7.82 m).

$A_1$. 8.06–8.40 m. Grey, finely nodular limestone intercalated with fine-grained to dense, grey bedded limestone between 8.16–8.23 and 8.37–8.40 m. The lower boundary is drawn at the level, where the first signs of reddish colour appear.
*Illaenus schroeteri* (SCHLOTH.).
*Nileus* sp.
*Piretella* sp. indet. (8.10 m).
*Euprimites effusus* JAAN.
*Euprimites bursellus* JAAN.
*Steusloffia linnarssoni* (KRAUSE).
*Steusloffia* sp. indet. (8.22; 8.38 m).
*Sigmobolbina* sp. indet. (8.10 m).

## *Seby Limestone* 1.08 m.

*G*. 8.40–8.47 m. Two beds of fine-grained limestone, the upper bed pale reddish brown, the lower bed grey and with only a faint reddish tint.
*Illaenus schroeteri* (SCHLOTH.).
*Piretella* sp. indet. (8.41 m).
*Euprimites effusus* JAAN.

*F*. 8.47–8.74 m. Pale reddish finely nodular limestone.
*Nileus* sp.
*Piretella* sp. indet. (8.58 m).
*Euprimites effusus* JAAN.
*Euprimites bursellus* JAAN.
*Steusloffia linnarssoni* (KRAUSE).

*E*. 8.74–8.80 m. Two beds of pale reddish brown, fine-grained limestone.

*D*. 8.80–8.84 m. One bed of grey fairly coarse-grained limestone.

*C*. 8.84–8.93 m. One bed of grey, coarse-grained limestone.
*Euprimites effusus* JAAN.

*B*. 8.93–9.03 m. Grey, fine-grained, thin-bedded limestone.
*Euprimites effusus* JAAN.

*A*. 9.03–9.48 m. Pale reddish brown grey-mottled, fine-grained limestone, in the upper part thick-bedded, in the middle (9.22–9.30 m) finely nodular, in the lower part fairly thick-bedded.
*Euprimites effusus* JAAN.
*Steusloffia linnarssoni* (KRAUSE).

## *Skärlöv Limestone* 1.42 m.

*E*. 9.48–9.61 m. Finely nodular limestone, in the upper part pale reddish brown grey-mottled, in the lower part intensely reddish brown. The change of the colour takes place at 9.52 m.
*Euprimites effusus* JAAN.

*D*. 9.61–9.94 m. Reddish brown, fairly thick-bedded limestone.
*Illaenus* sp. (9.80 m).
*Piretella* sp. indet. (9.76 m).
*Euprimites effusus* JAAN.
*Steusloffia* cf. *linnarssoni* (KRAUSE).

*C*. 9.94–10.10 m. Finely nodular, reddish brown limestone.
*Euprimites effusus* JAAN.

*B*. 10.10–10.62 m. Reddish brown, thick-bedded, fine-grained limestone with a layer

of finely nodular limestone between 10.26–10.28 m and a layer of greyish limestone between 10.50–10.53 m.
*Illaenus* sp. (? *schroeteri*) (10.33 m).
*Euprimites effusus* JAAN.

*A*. 10.62–10.90 m. Finely nodular, reddish brown limestone.
*Euprimites effusus* JAAN.
*Steusloffia linnarssoni* (KRAUSE).

*Segerstad Limestone* 2.86 m.

10.90–11.15 m. White to pale brownish red, thick-bedded, fine-grained limestone, in the uppermost 4 cm of a somewhat darker colour.
*Chilobolbina lativelata* JAAN.
*Euprimites effusus* JAAN.
*Steusloffia linnarssoni* (KRAUSE).

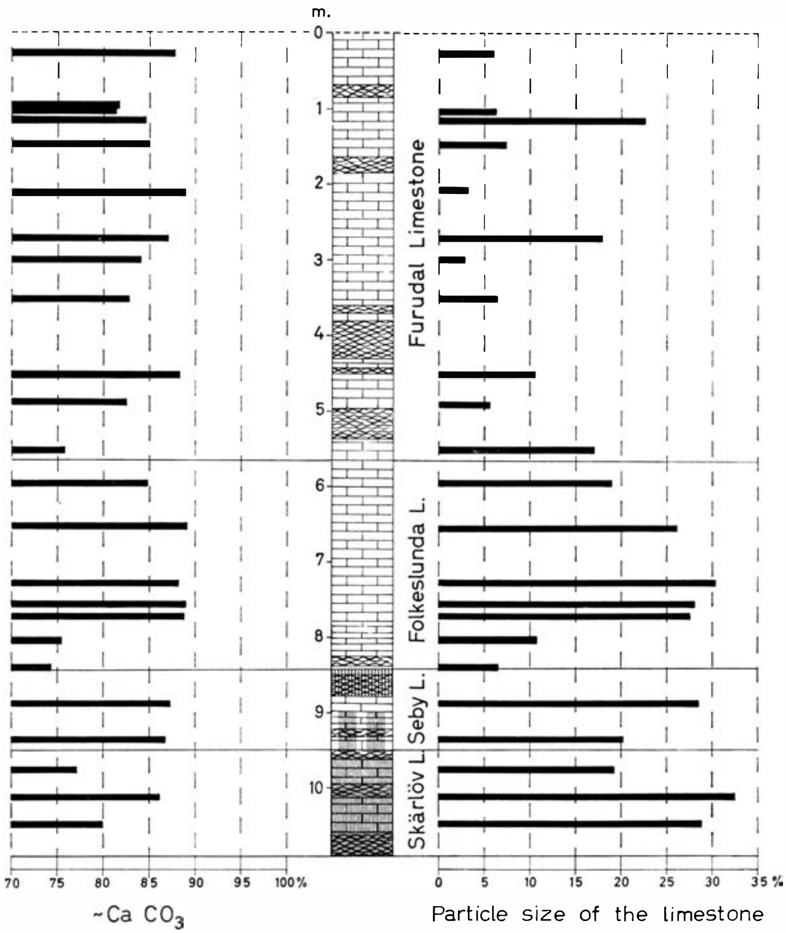
11.15–11.96 m. Reddish brown, thick-bedded, fine-grained limestone, finely nodular between 11.40 and 11.43 m, thin-bedded in the lowermost 10 cm. Between 11.60 and 11.80 m larger fossils are surrounded by a layer rich in haematite. At the level of 11.23 m a bedding surface with deep furrows.
*Geisonoceras* ? *centrale* (DALMAN).
*Laccochilina* (*Laccochilina*) *bulbata* JAAN.
*Piretia geniculata* JAAN.
*Euprimites effusus* JAAN.
*Euprimites anisus* JAAN.
*Conchoprimitia* n. sp. A (11.20 m).

11.96–12.30 m. Finely nodular reddish brown limestone with a bed of limestone between 12.03 and 12.10 m.
*Piretia geniculata* JAAN.
*Euprimites effusus* JAAN.

12.30–13.75 m. Reddish brown, fine-grained, fairly thick-bedded limestone. The lower boundary is drawn on the basis of palaeontological data. At the level of 13.48 m bedding surface with deep furrows.
*Asaphus* (*Neoasaphus*) *platyurus* ANG.
"*Orthoceros*" *nilssoni* (BOLL) sp. coll.
*Piretia geniculata* JAAN.
*Euprimites effusus* JAAN.
*Euprimites anisus* JAAN.
*Sigmobolbina* ? n. sp.

## Description of the Microlithology of the Limestones

In the Segerstad Limestone only the uppermost white to pale red calcarenites have been studied as regards their microlithology. During the deposition of the Skärlöv and Seby Limestones the sedimentation has undergone numerous small changes causing a repeated alternation of beds with different structure or particle size, or both. It has not been possible to undertake a detailed microlithological examination of each macroscopically distinguishable lithologic unit. This is the case also for certain portions of the Folkeslunda and Furudal Limestones.




Text-fig. 20. Skärlöv, Seby, Folkeslunda, and Furudal Limestones of the Gammalsby boring. To the left the material soluble in dilute acetic acid (approximately the content of $CaCO_3$), to the right particle size of the limestone according to the method of JAANUSSON (1952). The sparsely vertically striated portion of the section denotes pale reddish brown rock. For other signs, see Text-fig. 8.

## *Particle Size and Texture of the Limestone*

Text-fig. 20.

The uppermost white limestones of the Segerstad Formation consist of coarse calcarenites which are so extensively re-crystallized that the determination of the particle size is not possible in the thin sections studied. The fossil fragments are to a large extent re-crystallized and fused with the coarsely crystalline matrix. The amount of the limestone soluble in diluted acetic acid is large (92.2% in the Gammalsby bore and 95.4% in the Skärlöv bore).

The Skärlöv Formation consists of intensely reddish brown calcarenites intercalated by finely nodular marls or limestones (the microlithology of latter has not been studied). Also in the Seby Formation the bedded limestones are mostly calcarenites, the grey beds having a particularly coarse grain. The lowermost part of the Folkeslunda Formation consists of fine-grained calcilutites, but higher up in the section the grain size increases considerably, the main part of the formation being formed by calcarenites. Towards the top of the Folkeslunda Formation the grain size decreases again, and the boundary towards the Furudal Limestone is poorly defined lithologically. It is drawn here according to macroscopic characteristics, but the determinations of the particle size in thin sections suggest that the change from calcarenite to calcilutite takes place at a lower level.

The Furudal Limestone is mostly a fairly dense calcilutite with small contents of shell fragments (cf. Pl. IV, fig. 2).[1] Some portions of the section consist of calcarenitic calcilutites, and in the upper part of the section a 11 cm thick bed of calcarenite is intercalated. The finely nodular limestones have not been studied microlithologically, but according to their macroscopic appearance their contents of shell fragments longer than 0.1 mm is small.

The texture of the calcarenites agrees with that of the Böda Hamn core. At some levels the matrix exhibits coarsely crystalline spots, and there the shell fragments are partly fused with the matrix. Such re-crystallized spots within otherwise well-preserved calcarenites occur almost in all thin sections. The matrix of the calcilutite is mostly cryptocrystalline and denser than in the calcarenitic calcilutite of the Böda Hamn core. Otherwise no distinct differences could be observed.

### *Distribution of Authigenic Substances in Thin Sections*

Text-fig. 21.

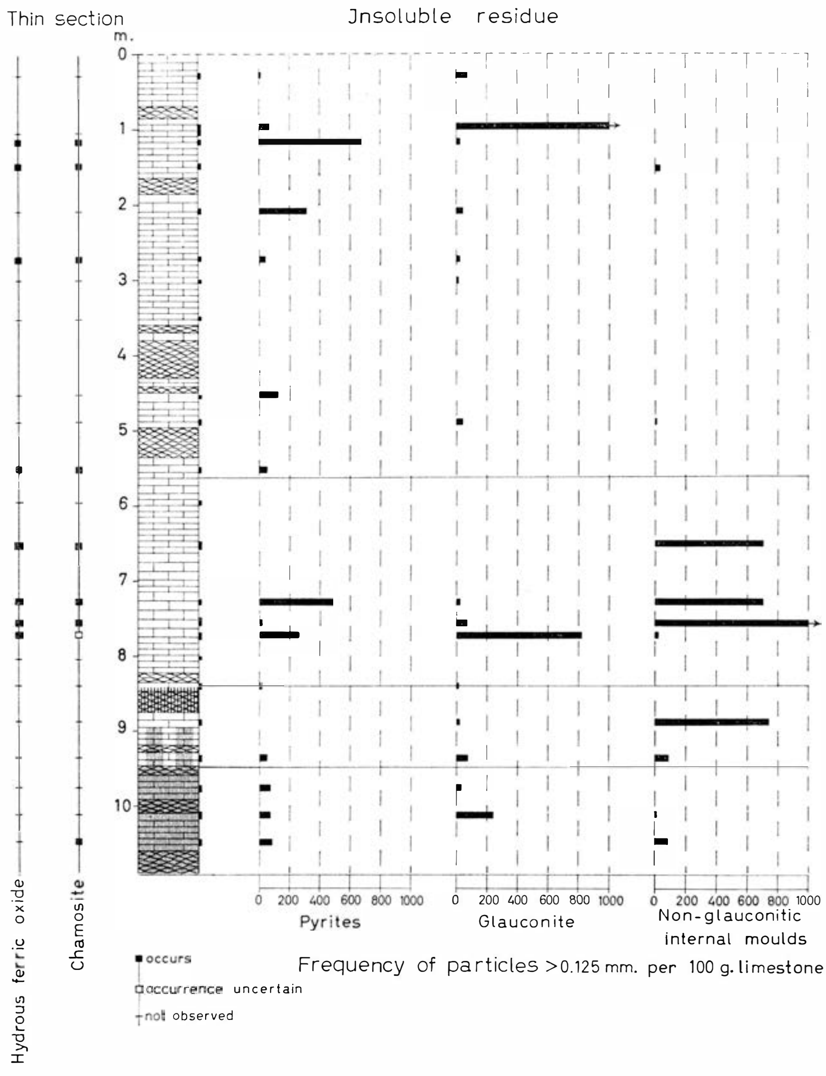
*Haematite.* The matrix of the Skärlöv Limestone is strongly pigmented by haematite. The latter is quite unevenly distributed, producing a speckled appearance of the rock in the thin section. The haematite is concentrated in thin, irregular layers or spots that have a dark brownish red colour. The groundmass between these spots is light reddish brown or occasionally even grey and without haematite pigment. Macroscopically this limestone has, however, an intensely brownish red colour.

At the level of 9.36–9.39 m a part of the calcarenite is in thin section more or less uniformily but very weakly pigmented by haematite, the limestone showing there a light pink colour. The concentration of the haematite is so weak that it can scarcely be distinguished in the thin section. Some small spots with a more intense brownish red colour occur, however.

*Goethite.* In the Gammalsby core this substance always occurs as a secondary alteration product of chamosite. For its range in the core, see Text-fig. 21.

*Chamosite.* The mode of occurrence of chamosite in the Gammalsby core corresponds to that in the Böda Hamn core. The substance is rare at the levels

[1] It should be noted that the calcarenite with goethite (and chamosite?) figured by HADDING (1958, Fig. 159) is not from *Crassicauda* beds, but from the Folkeslunda Limestone.




Text-fig. 21. Skärlöv, Seby, Folkeslunda, and Furudal Limestones of the Gammalsby core. Distribution of some authigenic minerals in thin sections and of some components of the fraction larger than 0.125 mm of the insoluble residue. For signs, see Text-fig. 8.

of 10.47–10.51 m and 1.49–1.52 m. At the other levels with chamosite the latter is fairly abundant, a large percentage of the cavities within small shells being filled by it or its alteration product goethite.

*Brown substance* (phosphorite or pyrites?) is abundant in the middle part of the Folkeslunda Limestone forming there thin coatings around the fossil fragments or filling their interior. Occasionally it occurs also as pigmentation of thin laminae rich in argillaceous matter.

### *Fraction larger than 0.125 mm of the Insoluble Residue*

Text-fig. 21.

As in the Böda Hamn section the amount of allochthonous mineral grains, chiefly or exclusively quarz, is very low. No distinct fluctuations of their frequency could be observed except that these particles are especially few in pure calcilutites.

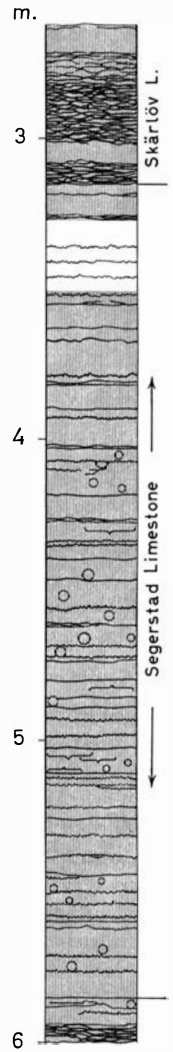
*Pyrites.* Small quantities of pyrites occur in most samples studied; only at some levels, viz. 5.93–6.00 m and 3.49–3.58 m no pyrites was observed in the insoluble residue. At four levels pyrites is fairly abundant (cf. Text-fig. 21). In the bed 0.93–1.00 m it occurs as small crystal aggregates, cubes, and some pyritohedra. Pyrites is abundant also in the white calcarenite at the top of the Segerstad Limestone (>1000 per 100 g of limestone in the Gammalsby core).

*Glauconite.* Minute grains of glauconite occur in all samples except for the levels of 4.51–4.56 m, 10.45–10.52 m, and 11.04–11.13 m. In three beds the glauconite is fairly abundant in the insoluble residue though on account of the minuteness of its grains its absolute quantities are very small. The grains are most numerous at the level of 0.95–1.00 m (about 1800 grains >0.125 mm per 100 g of limestone), but they form only about 0.005% of the whole rock. The largest grains have a diameter of 0.3 mm, but the majority of glauconite is at the limit of the mesh size of the sieve (0.125 mm). The grains are subangular to rounded, dark, mostly with a smooth, shining surface. They are probably allochthonous. In the bed 7.67–7.74 m the glauconite grains have the same size as above but are fairly angular, partly light green, partly dark. Their appearance might suggest an autochthonous origin. At the level of 10.08–10.17 m the glauconite has the same grain size and appearance as at the level of 1.0 m. No glauconitic internal moulds have been met with in the whole section.

*Non-glauconitic internal moulds* occur in all samples studied, except for the levels of 3.49–3.51 m and 8.37–8.46 m. They are usually represented only by 1 to 5 specimens per 100 g of limestone. In five samples the internal moulds occur in abundance. In the beds 7.23–7.34 m and 6.47–6.57 m they are mostly poorly preserved, between 7.53–7.61 m the moulds are especially abundant and as a rule excellently preserved, and at the level of 8.84–8.94 m they are less numerous than at 7.6 m, but equally well preserved. They are abundant also in the white calcarenite of the Segerstad Limestone (about 500 in 100 g of limestone in the Gammalsby core, >1000 in the Skärlöv core). The general appearance of the internal moulds agrees with that in the Böda Hamn core.

## *Skärlöv Boring*

The boring of Skärlöv was carried out by the Geological Survey of Sweden in 1946, and is situated close to the beach of Skärlövs Hamn. The diameter of




Text-fig. 22. Diagrammatic representation of the sedimentary structures of the uppermost part of the Skärlöv core. For signs, see Text-fig. 18.

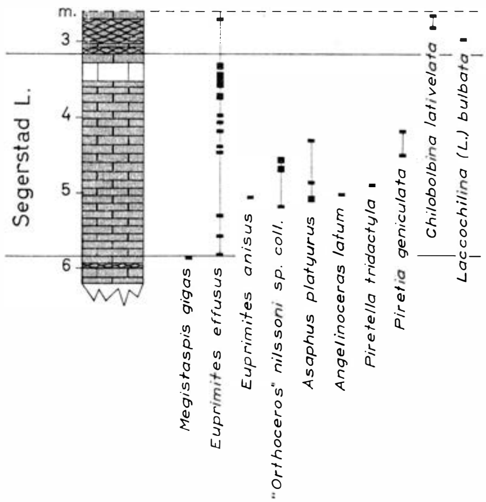
the core is 7 cm. The Cambrian beds and the Tremadocian shales have been described by WESTERGÅRD (1947), whereas the Ontikan limestones have still not been studied.

## Description of the Core

0–2.62 m. Quaternary deposits.

*Skärlöv Limestone* 0.53 m. +

2.62–2.72 m. Reddish brown, thick-bedded, fine-grained limestone.
*Euprimites effusus* JAAN.
*Chilobolbina lativelata* JAAN.




Text-fig. 23. Range of selected species in the Segerstad and Skärlöv Limestones of the Skärlöv boring. For signs, see Text-fig. 8.

2.72–3.15 m. Finely nodular reddish brown limestone with a bed of reddish brown fine-grained limestone between 3.02–3.07 m.
*Chilobolbina lativelata* JAAN.
*Laccochilina* (*Laccochilina*) *bulbata* JAAN.

*Segerstad Limestone* 2.70 m.

3.15–3.27 m. Reddish brown, fine-grained limestone.

3.27–3.51 m. White to pale reddish, thick-bedded, coarse-grained limestone, between 3.37–3.41 m reddish brown with greyish green spots.
*Euprimites effusus* JAAN.

3.51–5.85 m. Reddish brown, fine-grained, fairly thick-bedded limestone. The lower boundary is formed by a bedding plane and is drawn on palaeontological evidence.
*Asaphus* (*Neoasaphus*) *platyurus* ANG.
*Trinodus* sp. (4.78 m).
"*Orthoceros*" *nilssoni* (BOLL) sp. coll.
*Angelinoceras latum* (ANG.).
*Piretia geniculata* JAAN.
*Piretia clypeolaria* JAAN. (5.35 m).
*Piretella tridactyla* JAAN.
*Euprimites effusus* JAAN.
*Euprimites anisus* JAAN.
*Tallinnella pachydactyla* JAAN. (4.90; ? 5.40 m).
*Steusloffia* sp. indet. (3.60 m).
*Sigmobolbina* ? sp. (4.99 m).
*Sigmobolbina* n. sp. (3.53 m).

## Comparison between the Gammalsby and Skärlöv Borings

The distance between Gammalsby and Skärlöv borings is 12 km in N–S direction. The comparable portions of the section are fairly similar, but show also some notable differences (cf. Text-fig. 24). In the Skärlöv bore the white calcarenite is some centimeters thicker. This limestone is easily identified by its colour, and has been observed also in the exposure at the beach of Segerstad lighthouse halfway between these borings (see the description of that locality). In the Skärlöv bore the white calcarenite is overlain by some beds of similar limestone but with intensely brownish red colour. The thickness of these brownish red beds is considerably larger in the Skärlöv boring (12 cm) than in the Gammalsby boring (4 cm). The Segerstad Limestone of the Skärlöv bore differs from that of the Gammalsby bore also by its 16 cm lesser thickness and by the complete absence of finely nodular beds. The latter are 27 cm thick in the Gammalsby bore, and the differences in the thickness may thus depend in part on the wedging out of the finely nodular beds.

## Stratigraphy and Fauna of the Viruan Sequence of Öland

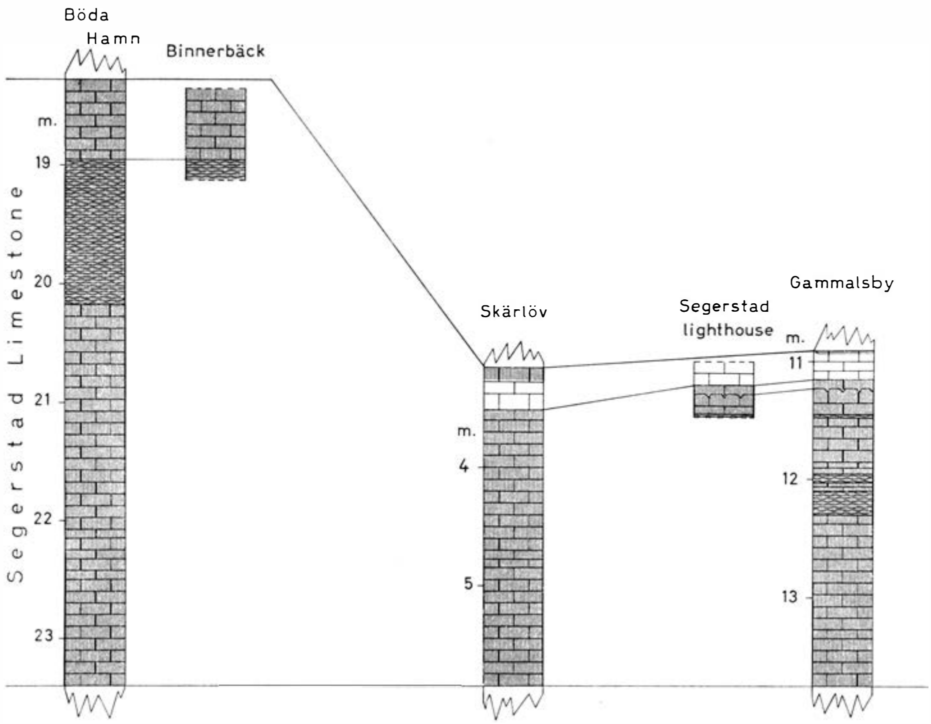
ASERI STAGE.—The Aseri Stage is represented on Öland by the Segerstad Limestone. The latter seems to correspond to the zone of *Asaphus* (*Neoasaphus*) *platyurus*. It is yet not known with certainty, whether the upper boundary of the Aseri Stage, or of the zone of *Asaphus platyurus*, coincides exactly with that of the Segerstad Limestone, or lies within the lowermost part of the Skärlöv Limestone. The latter formation has yielded but few determinable macrofossils, and the faunistic change from the Aseri to the Lasnamägi Stage is in Sweden not abrupt in the ostracode faunas. However, the assumption that the boundary between these stages is comparable to that between the Segerstad and Skärlöv Limestones seems to be a reasonably close approximation.

The Segerstad Limestone has an essentially uniform development throughout the whole of Öland. It consists of intensely reddish brown calcarenites, in the upper part with occasional intercalations of a bed or beds of finely nodular limestone or marl. The lower boundary is a bedding plane that cannot be distinguished from other similar bedding planes, but marks an abrupt faunal change. No species common to both the zones of *Megistaspis gigas* and *Asaphus platyurus* is known at present on Öland. The abruptness of the faunal change suggests a hiatus, possibly in form of a gap in sedimentation, but no lithologic evidence in support of this suggestion is known.

The thickness of the Segerstad Limestone in the borings of Öland is as follows:

| | |
|---|---|
| Böda Hamn | 5.13 m. |
| Skärlöv | 2.70 m. |
| Gammalsby | 2.86 m. |

The limestone is thus considerably thinner on southern Öland than on northern Öland (cf. Text-fig. 24). Several peculiarly sculptured bedding planes upon at least three different levels of the limestone of southernmost Öland bear furrows which remind of mud cracks, whereas on northern Öland structures resembling mud cracks have so far not been observed.




Text-fig. 24. Sections of the Segerstad Limestone of Öland. For signs, see Text-fig. 8.

The two zones, described by JAANUSSON & MUTVEI (1953) in the Segerstad Limestone of the Siljan district, are well distinguishable also on Öland. The zone of *Angelinoceras latum* is characterized on Öland by its index fossil, and the zone of *Illaenus planifrons* by *Illaenus* aff. *planifrons* JAAN. and *Geisonoceras* ? *centrale* (DALM.). According to the present material these species are restricted to the respective zones. It is possible that further study of cephalopods will increase the number of species characteristic for each zone. The determination of the level of the boundary between the zones is difficult in the cores and in existing exposures, and for this reason no direct comparison of the thicknesses of the zones in different cores can be made. The sequence of the lower zone seems, however, to be considerably thicker than that of the zone of *Illaenus planifrons*.

LASNAMÄGI STAGE.—The sequence of the Lasnamägi Stage is subdivided in the present paper into three litho-stratigraphic units, in descending order the Folkeslunda, Seby, and Skärlöv Limestones. These subdivisions are conventional rock units, and the boundaries between them are demonstrably metachronous. The classification is admittedly provisional.

The thickness of the Lasnamägi Stage and of its litho-stratigraphic subdivisions is given in Table 4 (cf. also Text-fig. 25).

*Table 4*

| | Lasnamägi Stage (total) | Skärlöv Limest. | Seby Limest. | Folkeslunda Limest. |
|---|---|---|---|---|
| Böda Hamn | 5.12 m | 2.04 m | 0.20 m | 2.88 m |
| Seby (branddamm) | 2.59 m + | 0.15 m + | 0.98 m | 1.46 m + |
| Gammalsby | 5.26 m | 1.42 m | 1.08 m | 2.76 m |

*Skärlöv Limestone.*—Throughout the whole of Öland the Segerstad Limestone is overlain by intensely reddish brown, finely nodular marls intercalated by bedded calcarenites of the same colour. These beds are included here in the Skärlöv Formation. In northern Öland finely nodular marls, and in southern Öland bedded limestones preponderate (cf. Text-fig. 25). These beds are generally very poor in macrofossils, and most specimens are badly preserved. Cephalopods are comparatively rare and mostly indeterminable.

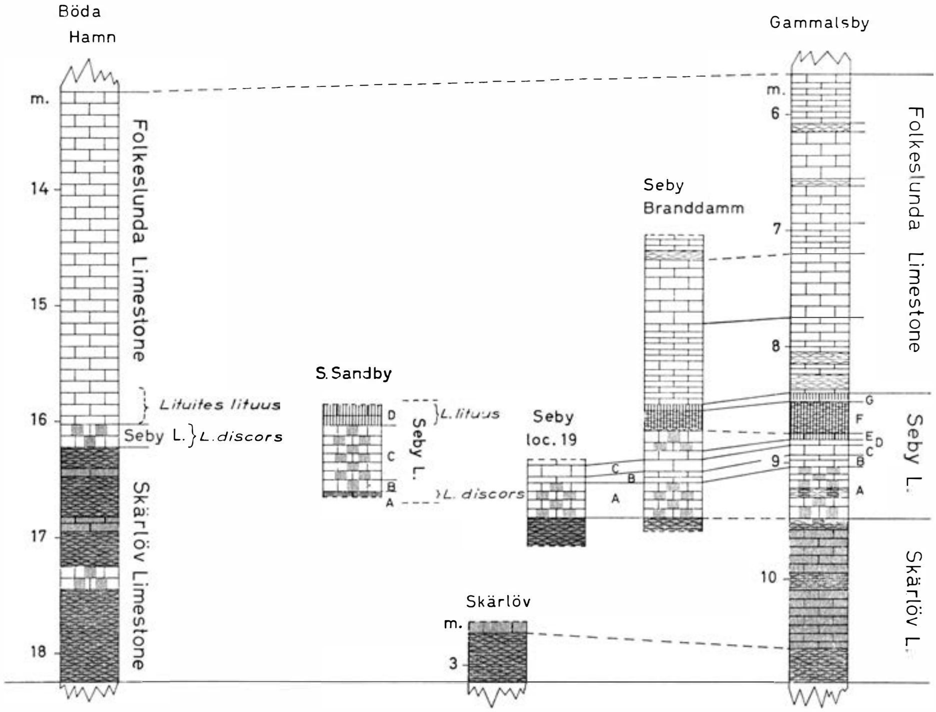
*Seby Limestone.*—The Skärlöv Limestone is overlain by reddish brown grey-mottled or pale reddish brown bedded limestones (mostly calcarenites), on southernmost Öland intercalated by pale brownish red, finely nodular limestone and some persisting beds of grey calcarenite. All these beds are included here in the Seby Limestone. On southernmost Öland the upper part of the formation has a considerably smaller grain size than on central and northern Öland.

*Folkeslunda Limestone.*—The upper part of the Lasnamägian sequence of Öland is formed by grey calcarenites (the Upper Grey Orthoceratite Limestone), on southernmost Öland with intercalations of finely nodular marl. The uppermost and lowermost portions of the Folkeslunda Limestone have a conspicuously smaller grain size on southernmost Öland than in central and northern Öland. Chamosite, which is of a general occurrence in the Folkeslunda Limestone of northern Öland, is restricted in the Gammalsby boring to the middle part of the formation.

The level of the upper boundary of the Folkeslunda Limestone is fairly distinct on northern Öland, but somewhat diffuse on the southernmost part of the island, owing to the more or less gradual transition of the grain size of the limestone from a calcarenite to a calcilutite. It is not certain, whether the proposed level of the boundary in the Gammalsby boring is exactly comparable with that of the Böda Hamn boring. The difference, if present, does, however, probably not exceed half of metre.

*Faunal succession within the Lasnamägi Stage.* The few determinable fossils hitherto found in the Skärlöv Limestone indicate a Lasnamägian age of these beds, but have no bearing on a detailed zonal subdivision.

The lowermost beds of the Seby Limestone of central and the northern part of southern Öland contain a distinctive cephalopod and hyolithid fauna characterized by *Lituites* (*Trilacinoceras*) *discors* HOLM, *Protobactrites delicatulum*




Text-fig. 25. Sections of the Skärlöv, Seby, and Folkeslunda Limestones of Öland. The sparsely vertically striated parts of the sections denote pale reddish brown rock. For other signs, see Text-fig. 8.

TROEDSSON, *Bactroceras avus* HOLM, *Hyolithes cymbium* HOLM, and *H. crispatus crispulus* HOLM, all of which are according to the present material restricted to these beds. The number of such species will probably increase, when the cephalopod fauna is properly described. These beds correspond to the zone of *Lituites discors* of HOLM. The find of *Hyolithes cymbium* in the Seby Limestone of the Böda Hamn bore indicates that there the whole Seby Limestone belongs to the same zone. The fauna characteristic for the zone of *Lituites discors* occurs at the same general level also in some localities of the Siljan district. In southernmost Öland none of the above species has been encountered, the probably corresponding portion of the section has a somewhat different colour, and seems to be poor in fossils. As also an exact lithologic correlation of the relevant portions of the sections of southern Öland with the sections farther north is uncertain, the zone of *L. discors* cannot at present be distinguished on southernmost Öland.

In the section at Södra Sandby the uppermost part of the Seby Limestone contains *Lituites* (*Lituites*) *lituus*, and belongs to HOLM's zone of *L. lituus*. The exact level of the boundary between this and the underlying zone of *L. discors* cannot be determined even at this locality, as the beds with index fossils are separated by beds without distinctive fossils. On southernmost Öland the beds with *Lituites* (*Lituites*) *lituus* (HOLM, 1891, p. 755) belong to the Seby Limestone, but the range of the species within the formation is unknown. On northern Öland HOLM has found the index species at Stora Mossen in a boulder of a grey calcarenite belonging to the Folkeslunda Limestone and probably corresponding to the lowermost part of this formation. The position of the horizon with *Lituites lituus* in the sections of northern Öland studied by the present writer could, however, not be determined.

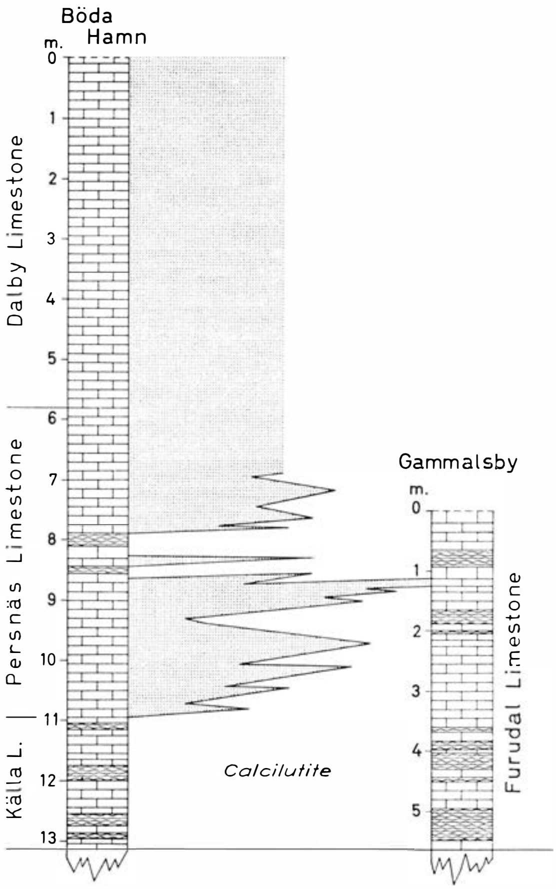
The known fauna of the beds with *Lituites* (*Lituites*) *lituus* is poor in species, and the zone fossil and *Hyolithes dispar crassus* HOLM are the only species that seem to be restricted to this zone. "*Endoceras*" *barrandei* DEW. occurs also in the beds with *Lituites discors*, but is rare or possibly absent in beds higher than HOLM's zone of *Lituites lituus*. Outside Öland *Lituites* (*Lituites*) *lituus* has not been identified with certainty, and hence the corresponding beds cannot be distinguished.

The main part of the Folkeslunda Limestone corresponds to HOLM's zone of *Lituites perfectus*, but the exact range of this species within the formation is still unknown. Determinable specimens of the index species are only rarely met with in measurable sections. Additional characteristic species for this zone are *Cyclolituites applanatus* REM., *Geisonoceras* ? *scabridum* (ANG.), *Hyolithes acutus* (EICHW.), *H. crispatus crispissimus* HOLM, and *H. innotatus* HOLM.

The faunal differences between the beds with *Lituites* (*Trilacinoceras*) *discors*, *L.* (*Lituites*) *lituus*, and *L.* (*L.*) *perfectus* find their expression only in the cephalopod and hyolithid faunas. The trilobite and ostracode faunas do not show any conspicuous change from one cephalopod and hyolithid zone to the other, and are, in fact, fairly uniform throughout the whole Lasnamägi Stage. There appear, however, many new, but mostly rare species in the beds above the zone of *Lituites lituus*, but this difference may depend, in part at least, on the larger exposures with better collecting facilities in the Folkeslunda Limestone.

A grey calcarenite of the Seby Limestone of southernmost Öland (division C of the sections) has yielded a fairly rich graptolite fauna of the zone of *Didymograptus murchisoni* (JAANUSSON, 1960). The exact attribution of these beds in terms of the lituitid zones is unknown, but they belong either to the zone of *Lituites discors* or that of *L. lituus*. The Folkeslunda Limestone of northern and central Öland has yielded a different assemblage of graptoloids that may be comparable to that of the lowermost part of the zone of *Glyptograptus teretiusculus* (JAANUSSON, 1960).

UHAKUAN STAGE.—The lithologic development of the Uhakuan beds of southernmost Öland is almost indistinguishable from that of several other districts of Sweden (Siljan district, Östergötland, Västergötland), and the term Furudal Limestone is applied to these beds. The rock is mainly calcilutite, mostly dense and with a very small content of shell fragments of sand size.




Text-fig. 26. Comparison of Uhakuan beds of Böda Hamn and Gammalby borings to show the possible interdigitation of calcarenitic (dotted area) and calcilutitic (white area) facies. For signs, see Text-fig. 8.

It is intercalated with finely nodular limestone and marl of the same general grain size. In the lower part of the stage the calcilutitic development of the Uhakuan beds extends throughout the whole Öland. The tongue of the Furudal calcilutite that overlies the Folkeslunda calcarenite on northern Öland is termed here the Källa Limestone. The facies of the middle and upper Uhakuan beds of northern Öland differs considerably from that of southernmost Öland, being formed by coarse calcarenites which are here included in the Persnäs Limestone. The Furudal Limestone of southernmost Öland contains one thin bed of calcarenite, and some beds of the Persnäs Limestone are calcilutitic. The possible interdigitation of the Uhakuan calcilutitic and calcarenitic facies is diagrammatically represented in Text-fig. 26. The difference in the fauna between the Persnäs calcarenites and the Furudal calcilutites obviously reflect the differences in the bottom condition. So large sessile forms, such as cystids and large brachiopods are not rare in calcarenites but almost completely missing in calcilutites.

No zonal subdivision of the Uhakuan beds is possible at present.

KUKRUSE STAGE.—The Kukrusean beds, represented by the Dalby Limestone, form the bedrock of Öland only on the northern part of the island. The sequence is lithologically fairly uniform, and consists of coarse calcarenites. The fauna is rich, and abounds in sedentary organisms. Two faunal divisions can be distinguished. The lower two to three meters of the Dalby Limestone contain several species otherwise distinctive for the Uhakuan beds, such as *Tallinnella dimorpha* ÖPIK, *Sigmobolbina sigmoidea* JAAN., *Uhakiella* cf. *coelodesma* ÖPIK, and *Christiania* cf. *holtedahli* SPJELDNÆS which occur here together with distinctive species of the Dalby Limestone, such as *Euprimites locknensis* (THORSL.), *Conchoprimitia leperditioides* THORSL., and *Panderia parvula* (HOLM). A fairly common species possibly confined to this division is *Steusloffia multimarginata* ÖPIK. The middle and upper part of the Dalby limestone lack the above species of Uhakuan aspect.

REMARKS ON THE TABLE OF VERTICAL DISTRIBUTION OF SPECIES.—In Table 5 the known range of species in Aserian, Lasnamägian, and Uhakuan beds of Öland is summarized. The species of the Kukruse Stage are not included, since the lists of species from the Böda Hamn exposure and the Böda Hamn core are together sufficiently representative for this division on Öland. The list of fossils is only provisional, since large parts of the fauna are still undescribed or in bad need of revision. It is published mainly for the reason that the previous information on the range of many species, often referred to also in the modern literature, needed to be expressed and visualized in terms of the modern classification of these beds.

The list is by no means complete. All published references known to the writer are included, and most of them checked by examination of the actual material. In addition there is a considerable amount of undescribed species, especially of cephalopods and gastropods. In some cases even no proper generic name exists. Only part of such information, particularly that on trilobites, has been included in the list. Most of the data about cephalopods have been taken from HOLM's determinations in the collections of Riksmuseum. LINDSTRÖM's (1955) information about certain conodonts is not included on account of the difficulty in assigning the exact stratigraphic horizon.

"*l*" and "*u*" denote that the species has been found in the lower or upper part of the division, respectively.

*Table 5*

| | Aserian | | Lasnamägian | | | | | Uhakuan | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Segerstad Limestone | | Skärlöv Limest. | Seby Limestone | | | Folkeslunda L. | Furudal L. | Källa Limest. | Persnäs Limest. |
| | *Latum* zone | *Planifrons* z. | | *Discors* zone | *Lituus* zone | S. Öland | | | | |
| TRILOBITA.— | | | | | | | | | | |
| *Asaphus* (*Neoasaphus*) *platyurus platyurus* ANG. | + | + | | | | | | | | |
| aff. *ornatus* POMP. | | | | | | | + | | | |
| *bottnicus* JAAN.[1] | | | | | | | | | + | + |
| *lepidus* TÖRNQ. | | | | | | | | | | + |
| *Ogmasaphus* cf. *praetextus* (TÖRNQ.) | | | + | | | | | | | |
| *Pseudoasaphus tecticaudatus* (STEINH.) | | + | | | | | + | | | + |
| *aciculatus* (ANG.) | | | | | + | ? | + | | | |
| *Pseudobasilicus* ? *brachyrachis* (TÖRNQ.) | | | + | + | + | | + | + | + | |
| *Plectasaphus plicicostis* (TÖRNQ.) | | | | | | | + | | | |
| *Pseudomegalaspis patagiata* (TÖRNQ.) | | | | | | | + | cf. | | |
| *Ogygiocaris sarsi* ANG. | | | | | | | + | | | |
| *Nileus* sp. | | | | | + | + | + | + | + | + |
| *Illaenus excellens* HOLM | + | | | | | | | | | |
| aff. *excellens* HOLM | | | | | | | + | | | |
| aff. *planifrons* JAAN. | | + | | | | | | | | |
| *schroeteri schroeteri* (SCHLOTH.) | | | + | + | + | + | + | | + | |
| *schroeteri stacyi* HOLM | | | | | | | | + | + | + |
| aff. *schroeteri* (SCHLOTH.) | | | | | | | | | + | |
| *intermedius* HOLM | | | | | | | | | | + |
| *Phillipsinella* n. sp. | | | | | | | | | | + |
| *Ampyx* (*Cnemidopyge*) n. sp. | | | | | | + | + | | | |
| *Lonchodomas* cf. *rostratus* (SARS) | | | | | | | + | + | | |
| *Remopleurides* sp. sp. | + | | | | + | | + | + | + | + |
| *Telephina* sp. | | | | | | | + | | | |
| *Paraceraurus* cf. *exsul* (BEYR.) | | | | | | | + | | | |
| *Nieszkowskia* n. sp. | | | | | | | + | | | |
| *Cybelella* sp. sp. | | | | | | | + | | | + |
| *Chasmops* n. sp. | | | | | | | + | | | |
| *Estoniops* aff. *panderi* (FR. SCHM.) | | | | | | | + | | | |

[1] The species has been found only in beds which are here considered to be of Uhakuan age. JAANUSSON (1953 b, p. 498) regarded the Källa Limestone as the top of the "*Schroeteri* Limestone". Further studies have shown these beds to belong to the "*Crassicauda* ( = Uhaku) Stage". He (loc. cit.) recorded the species also from Hadeland, Norway, but a close comparison of the actual specimen with all available material of *A. (Neoasaphus) bottnicus* has shown the Norwegian specimen to belong to a different species though the similarity in the ornamentation of the pygidium and thoracic rachis is remarkable.

*Table 5 (cont.)*

| | Aserian | | Lasnamägian | | | | | Uhakuna | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Segerstad Limestone | | | Seby Limestone | | | | | | |
| | *Latum* zone | *Planifrons* z. | Skärlöv Limest. | *Discors* zone | *Lituus* zone | S. Öland | Folkeslunda L. | Furudal L. | Källa Limest. | Persnäs Limest. |
| *Estoniops* n. sp. | | | | | | | | | | + |
| *Pterygometopinae* n. gen., n. sp. | | + | | | | | | | | |
| *Hoplolichas dissidens* (BEYR.) | | | | | | | + | | | |
| *Trinodus* sp. sp. | + | | | | | | | + | | + |
| OSTRACODA.— | | | | | | | | | | |
| *Chilobolbina* aff. *dentifera* (BONN.) | | | | | | | + | | + | + |
| *lativelata* JAAN. | | u | + | | | | | | | |
| *Laccochilina* (*Laccochilina*) *bulbata* JAAN. | | + | + | | | | | | | |
| *paucigranosa* JAAN. | | | | | | | | | | + |
| *Piretella tridactyla* JAAN. | + | + | | | | | | | | |
| *Piretia geniculata* JAAN. | + | + | | | | | | | | |
| *clypeolaria* JAAN. | + | | | | | | | | | |
| *Uhakiella aequigranosa* JAAN. | | | | | | | + | + | | |
| *periacantha* JAAN. | | | | | | | | | | + |
| cf. *coelodesma* ÖPIK | | | | | | | | | | + |
| *Euprimites effusus* JAAN. | + | + | + | + | | + | + | | | |
| *anisus* JAAN. | + | + | | | | | | | | |
| *bursellus* JAAN. | | | | | | + | + | + | + | |
| cf. *eutropis* ÖPIK | | | | | | | | | | + |
| n. sp. | | | | | | | | | | + |
| *Tallinnella dimorpha* ÖPIK | | | | | | | | | | + |
| cf. *angustata* (KRAUSE) | | | | | | | + | | | |
| *pachydactyla* JAAN. | + | | | | | | | | | |
| *sebyensis* JAAN. | | | | | | + | | | | |
| cf. *lata* (KRAUSE) | | | | | | | + | | | |
| *Steusloffia linnarssoni* (KRAUSE) | | u | + | | | + | + | + | + | + |
| *Sigmobolbina sigmoidea* JAAN. | | | | | | | + | + | + | |
| *Sigmobolbina* sp. | | | | | | | + | | | |
| *Sigmobolbina* ? n. sp. | + | | | | | | | | | |
| *Conchoprimitia* n. sp. A | | + | | | | | | | | |
| *Conchoprimitia* n. sp. B | | | | | | | + | | | |
| *Baltonotella* n. sp. | + | | | | | | + | | | |
| CEPHALOPODA.— | | | | | | | | | | |
| *Orthoceros regulare* (SCHLOTH.) | | | | | | | + | | | + |
| *bifoveatum* (NOETL.) | | | | | | | + | | | |
| "*Orthoceros*" *nilssoni* (BOLL) sp. coll. | + | + | | | | | | | | |

*Table 5 (cont.)*

| | Aserian | | Lasnamägian | | | | | Uhakuan | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Segerstad Limestone | | | Seby Limestone | | | | | | |
| | *Latum* zone | *Planifrons* z. | Skärlöv Limest. | *Discors* zone | *Lituus* zone | S. Öland | Folkeslunda L. | Furudal L. | Källa Limest. | Persnäs Limest. |
| *Polygrammoceras*[1] *strictum* (ANG.) | | | | | | | + | | | |
| *oelandicum* TROEDSS. | | | | | | | + | | | |
| *lineatum* (HIS.) | | | | | | | + | | | |
| *densestriatum* TROEDSS. | | | | | | | + | | | |
| *simplex* TROEDSS. | | | | | | | + | | | |
| *fontis* TROEDSS. | | | | | | | + | | | |
| *Troedssonella endoceroides* (TROEDSS.) | | | | | | | + | | | |
| *Geisonoceras ? centrale* (HIS.) | | + | | | | | | | | |
| *scabridum* (ANG.) | | | | | | | + | | | |
| "*Conorthoceras*" *conicum* (HIS.) | | | | + | + | + | + | | | |
| *Protobactrites delicatulum* TROEDSS. | | | | + | | | | | | |
| *Clinoceras* sp. | | | | + | | | + | | | |
| *Ctenoceras* sp. | | ? | | | | | | | | |
| *Bactroceras avus* HOLM | | | | + | | | | | | |
| *Trocholites teres* (EICHW.) | | | | + | | | + | | | |
| *hospes* REM. | | | | | | | + | | | |
| *Rhynchorthoceras angelini* (BOLL) | | | | + | ? | | | | | |
| sp. | | + | | | | | | | | |
| *Ancistroceras undulatum* (BOLL) | | | | | | | + | ? | ? | ? |
| sp. | | | | | | | | + | + | + |
| *Angelinoceras latum* (ANG.) | + | | | | | | | | | |
| *Lituites* (*Trilacinoceras*) *discors* HOLM | | | | + | | | | | | |
| (*Lituites*) *lituus* (MONTF.) | | | | | + | + | 1 | | | |
| (*Lituites*) *perfectus* (WAHLENB.) | | | | | | | + | | | |
| *Cyclolituites applanatus* (REM.) | | | | | | | + | | | |
| *lynceus* HOLM | | | | | | | + | | | |
| *Cochlioceras burchardi* (DEW.) | | | | + | | | + | | | |
| *Cyrtendoceras hircus* HOLM | | | | | | | + | | | |
| "*Endoceras*" *barrandei* DEW. | | | | + | + | | ? | | | |
| *recurvum* HOLM | + | | | | | | | | | |
| *papilla* HOLM | | | | | | | + | | | |
| *Nanno belemnitiforme belemnitiforme* HOLM | + | + | | | | | | | | |
| *belemnitiforme elata* HOLM | | | | | | | + | | | |
| HYOLITHIDA.— | | | | | | | | | | |
| *Hyolithes cymbium cymbium* HOLM | | | | + | | | | | | |
| *cymbium fallax* HOLM | | | | + | | | | | | |

[1] Cf. SWEET, 1958, pp. 61–62.

*Table 5 (cont.)*

| | Aserian | | Lasnamägian | | | | | Uhakuan | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Segerstad Limestone | | Skärlöv Limest. | Seby Limestone | | | Folkeslunda L. | Furudal L. | Källa Limest. | Persnäs Limest. |
| | *Latum* zone | *Planifrons* z. | | *Discors* zone | *Lituus* zone | S. Öland | | | | |
| *crispatus crispulus* HOLM | | | | + | | | | | | |
| *crispatus crispissimus* HOLM | | | | | | | + | | | |
| *acutus* EICHW. | | | | | | | + | | | |
| *concinnus* HOLM | | | | + | | | | | | |
| *innotatus* HOLM | | | | | | | + | | | |
| *hospes* HOLM | | | | | | | + | | | |
| *dispar crassus* HOLM | | | | | + | | | | | |
| CONULARIIDA.— | | | | | | | | | | |
| *Conularia* (*Plectoconularia*) *lindstroemi* HOLM | | | | | | | + | | | |
| aff. *lindstroemi* HOLM | | | | | | | | | + | |
| BRACHIOPODA.— | | | | | | | | | | |
| *Nicolella* sp. | | | | | | | | | | + |
| *Leptestia* sp. | | | | | | | | | | + |
| *Leptellina* ? n. sp. | | | | | | | | | + | + |
| *Bilobia* sp. | | | | | | | ? | | + | + |
| *Sowerbyella* ? sp. | | | | | | | | | | + |
| *Anisopleurella* ? n. sp. | | | | | | | | | | + |
| *Alwynella* ? sp. sp. | | | | | | | + | + | | + |
| *Christiania* cf. *holtedahli* SPJELD. | | | | | | | | | + | + |
| GRAPTOLITHINA.— | | | | | | | | | | |
| *Pseudoclimacograptus angulatus sebyensis* JAAN. | | | | | | + | 1 | | | |
| *eurystoma* JAAN. | | | | | | | + | | | |
| *luperus* JAAN. | | | | | | | + | | | |
| *Climacograptus pauperatus* BULMAN | | | | | | + | | | | |
| *distichus* (EICHW.) | | | | | | + | + | | | |
| *Glyptograptus* cf. *teretiusculus* (HIS.) | | | | | | + | + | | | |
| *Lasiograptus haplus* JAAN. | | | | | | | + | | | |
| *Hallograptus* ? *hystrix* (BULMAN) | | | | | | | + | | | |
| *Dicellograptus geniculatus* BULMAN | | | | | | | + | | | |
| *Abrograptus* n. sp. | | | | | | + | | | | |
| *Didymograptus* cf. *murchisoni murchisoni* (BECK) | | | | | | + | | | | |
| ECHINODERMATA.— | | | | | | | | | | |
| *Heliocrinites* cf. *prominens* (ANG.) | | | | | | | | | | + |
| *Echinosphaerites aurantium suecicum* REGNÉLL | | + | | + | | | | | | |
| *Glyptosphaerites leuchtenbergi* VOLB. | + | + | | | | | | | | |
| *Cryptocrinites* n. sp. | | | | | | | | | + | + |
| *Bolboporites* sp. | | | | | | | | | + | |

## *Appendix*

*Table 6.* Approximative $CaCO_3$-content and particle size of the limestone in the Böda Hamn core

| Horizon (in m) | Material soluble in dilute acetic acid ($\approx CaCO_3$) % | Horizon (in m) | Percentage of fossil fragments longer than 0.1 mm in thin sections |
|---|---|---|---|
| 0.43– 0.54 | 91.9 | 0.50– 0.53 | ~41 |
| 0.96– 1.02 | 94.3 | 0.96– 1.02 | 34 |
| 1.43– 1.48 | 93.9 | 1.50– 1.53 | 31 |
| 2.00– 2.07 | 90.2 | 1.97– 2.00 | 34 |
| 2.49– 2.56 | 89.0 | 2.49– 2.56 | 20 |
| 2.99– 3.02 | 85.6 | 2.99– 3.02 | 26 |
| 3.44– 3.51 | 84.0 | 3.50– 3.53 | 30 |
| 3.95– 4.01 | 86.4 | 3.98– 4.00 | 24 |
| 4.49– 4.55 | 89.3 | 4.49– 4.52 | ~30 |
| 5.00– 5.06 | 81.1 | 4.97– 5.00 | 22 |
| 5.53– 5.56 | 81.6 | 5.47– 5.50 | 26 |
| 6.06– 6.17 | 86.8 | 5.97– 6.00 | 26 |
| 6.45– 6.52 | 83.1 | 6.48– 6.51 | 33 |
| 6.94– 7.02 | 83.7 | 7.01– 7.04 | 24 |
| 7.48– 7.55 | 80.2 | 7.48– 7.50 | 26 |
| 8.02– 8.06 | 73.7 | 7.97– 8.02 | 12 |
| 8.50– 8.57 | 85.2 | 8.48– 8.50 | 18 |
| 8.98– 9.03 | 82.7 | 8.97– 9.00 | 27 |
| 9.51– 9.58 | 90.0 | 9.50– 9.53 | 28 |
| 9.98–10.05 | 90.1 | 10.00–10.03 | 26 |
| 10.44–10.50 | 89.9 | 10.50–10.53 | 27 |
| 10.94–11.00 | 80.8 | 10.98–11.01 | 7 |
| 11.51–11.55 | 84.3 | 11.49–11.52 | 17 |
| 12.00–12.08 | 89.3 | 11.97–12.00 | 13 |
| 12.44–12.49 | 82.6 | 12.48–12.50 | 16 |
| 12.98–13.00 | 84.7 | 13.00–13.03 | 17 |
| 13.44–13.50 | 85.9 | 13.47–13.50 | 28 |
| 13.94–14.00 | 86.1 | 13.97–14.00 | 30 |
| 14.50–14.55 | 91.1 | 14.47–14.50 | 26 |
| 15.02–15.05 | 91.9 | 14.99–15.02 | 27 |
| 15.45–15.50 | 91.3 | 15.50–15.53 | 31 |
| 15.98–16.03 | 89.9 | 16.00–16.03 | 31 |
| 16.48–16.55 | 76.3 | 16.41–16.48 | 17 |
| 17.00–17.05 | 72.3 | 16.98–17.01 | 12 |
| 17.47–17.52 | 92.9 | 17.57–17.50 | 23 |
| 18.00–18.08 | 73.3 | 17.98–18.01 | 10 |
| 18.48–18.54 | 88.6 | 18.48–18.50 | Recrystallized |
| 19.00–19.04 | 70.7 | 18.97–19.00 | 17 |
| 19.47–19.50 | 80.3 | 19.50–19.53 | 15 |
| 19.93–20.04 | 66.5 | 19.99–20.01 | 12 |
| 20.45–20.50 | 83.7 | 20.47–20.50 | 28 |
| 20.98–21.05 | 89.9 | 20.98–21.00 | 34 |
| 21.48–21.53 | 91.9 | 21.45–21.50 | 33 |
| 21.99–22.04 | 89.8 | 21.99–22.04 | 30 |
| 22.51–22.55 | 90.8 | | |
| 23.00–23.05 | 90.6 | 22.95–23.00 | 31 |

*Table 7.* Approximative $CaCO_3$-content and particle size of the limestone in the Gammalsby core

| Horizon (in m) | Material soluble in dilute acetic acid ($\approx CaCO_3$) % | Horizon (in m) | Percentage of fossil fragments longer than 0.1 mm in thin sections |
|---|---|---|---|
| 0.24– 0.33 | 87.7 | 0.24– 0.27 | 6 |
| 0.93– 1.00 | 81.6 | | |
| 1.00– 1.07 | 81.2 | 1.02– 1.05 | 6 |
| 1.14– 1.19 | 84.5 | 1.15– 1.18 | 23 |
| 1.45– 1.53 | 84.9 | 1.49– 1.52 | 7 |
| 2.05– 2.16 | 88.9 | 2.05– 2.08 | 3 |
| 2.65– 2.74 | 86.9 | 1.71– 2.75 | 18 |
| 2.99– 3.05 | 83.9 | 2.99– 3.05 | 3 |
| 3.49– 3.54 | 82.7 | 3.49– 3.54 | 6 |
| 4.51– 4.56 | 88.2 | 4.51– 4.56 | 12 |
| 4.84– 4.94 | 82.2 | 4.90– 4.93 | 6 |
| 5.49– 5.58 | 75.6 | 5.54– 5.57 | 17 |
| 5.93– 6.00 | 84.4 | 5.95– 5.98 | 19 |
| 6.47– 6.57 | 89.1 | 6.52– 6.57 | 26 |
| 7.23– 7.34 | 88.1 | 7.30– 7.33 | 30 |
| 7.53– 7.61 | 88.8 | 7.54– 7.57 | 28 |
| 7.67– 7.74 | 88.6 | 7.66– 7.70 | 27 |
| 8.00– 8.05 | 75.3 | 8.00– 8.03 | 11 |
| 8.37– 8.46 | 74.2 | 8.37– 8.42 | 7 |
| 8.84– 8.94 | 87.1 | 8.84– 8.87 | 29 |
| 9.31– 9.40 | 86.6 | 9.36– 9.39 | 20 |
| 9.73– 9.82 | 77.1 | 9.78– 9.81 | 19 |
| 10.08–10.17 | 86.0 | 10.14–10.17 | 33 |
| 10.45–10.52 | 79.7 | 10.47–10.51 | 29 |
| 11.04–11.13 | 92.2 | 11.04–11.10 | Recrystallized |

*Table 8*. Böda Hamn core. Analyses of total iron as $Fe_2O_3$, total phosphorus as $P_2O_5$, and sulphur. Analyst J. Lukins

| Horizon (in m) | $Fe_2O_3$ | $P_2O_5$ | S | Horizon (in m) | $Fe_2O_3$ | $P_2O_5$ | S |
|---|---|---|---|---|---|---|---|
| 0.0 | 2.16 | 0.21 | 0.05 | 12.0 | 1.98 | 0.08 | 0.02 |
| 0.5 | 5.04 | 0.47 | 0.08 | 12.5 | 1.08 | 0.09 | 0.05 |
| 1.0 | 1.80 | 0.27 | 0.06 | 13.0 | 1.26 | 0.09 | 0.01 |
| 1.5 | 1.98 | 0.18 | 0.07 | 13.5 | 1.26 | 0.09 | 0.16 |
| 2.0 | 1.62 | 0.21 | 0.05 | 14.0 | 2.25 | 0.39 | 0.09 |
| 2.5 | 2.43 | 0.20 | 0.13 | 14.5 | 2.88 | 0.27 | 0.01 |
| 3.0 | 2.61 | 0.59 | 0.05 | 15.0 | 2.34 | 0.93 | 0.02 |
| 3.5 | 2.34 | 0.08 | 0.05 | 15.5 | 2.34 | 0.21 | 0.02 |
| 4.0 | 2.97 | 0.30 | 0.04 | 16.0 | 3.06 | 0.45 | 0.01 |
| 4.5 | 2.34 | 0.41 | 0.12 | 16.5 | 2.52 | 0.09 | 0.02 |
| 5.0 | 2.16 | 0.35 | 0.03 | 17.0 | 3.24 | 0.08 | 0.01 |
| 5.5 | 1.80 | 0.53 | 0.03 | 17.5 | 2.34 | 0.30 | 0.03 |
| 6.0 | 1.80 | 0.24 | 0.04 | 18.0 | 3.06 | 0.06 | 0.01 |
| 6.5 | 1.62 | 0.20 | 0.05 | 18.5 | 3.15 | 0.27 | 0.02 |
| 7.0 | 2.25 | 0.25 | 0.04 | 19.0 | 2.70 | 0.08 | 0.02 |
| 7.5 | 2.16 | 0.17 | 0.08 | 19.5 | 2.97 | 0.10 | tr. |
| 8.0 | 2.25 | 0.10 | 0.01 | 20.0 | 3.24 | 0.05 | 0.02 |
| 8.5 | 2.43 | 0.14 | 0.01 | 20.5 | 3.96 | 0.04 | 0.01 |
| 9.0 | 2.25 | 0.08 | 0.01 | 21.0 | 3.60 | 0.09 | 0.01 |
| 9.5 | 2.34 | 0.28 | 0.02 | 21.5 | 2.43 | 0.06 | 0.01 |
| 10.0 | 1.80 | 0.12 | 0.02 | 22.0 | 2.97 | 0.28 | tr. |
| 10.5 | 2.16 | 0.23 | 0.02 | 22.5 | 2.52 | 0.26 | 0.02 |
| 11.0 | 1.80 | 0.05 | 0.05 | 23.0 | 2.52 | 0.08 | 0.03 |
| 11.5 | 1.44 | 0.10 | 0.06 | | | | |

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## Plate I

All figures two thirds of natural size.

1–2. Finely nodular, reddish brown limestone of the Skärlöv Formation. Böda Hamn boring, between the levels of 17.02–17.14 m. Fig. 1, polished surface; Fig. 2, external view of the core. The white spots on Fig. 1 have a pale green colour in the rock. Notice the small nodules (*N*) of limestone with a more intensely reddish brown colour than the rest of the rock.

3. Polished surface of a finely nodular grey limestone of the Källa Formation. Böda Hamn boring, between the levels of 11.03–11.13 m. *T*, calcite filling of a tube of an endobiontic animal.

4. Somewhat nodular calcarenite of the Dalby Limestone. Böda Hamn boring between the levels of 3.06–3.18 m.

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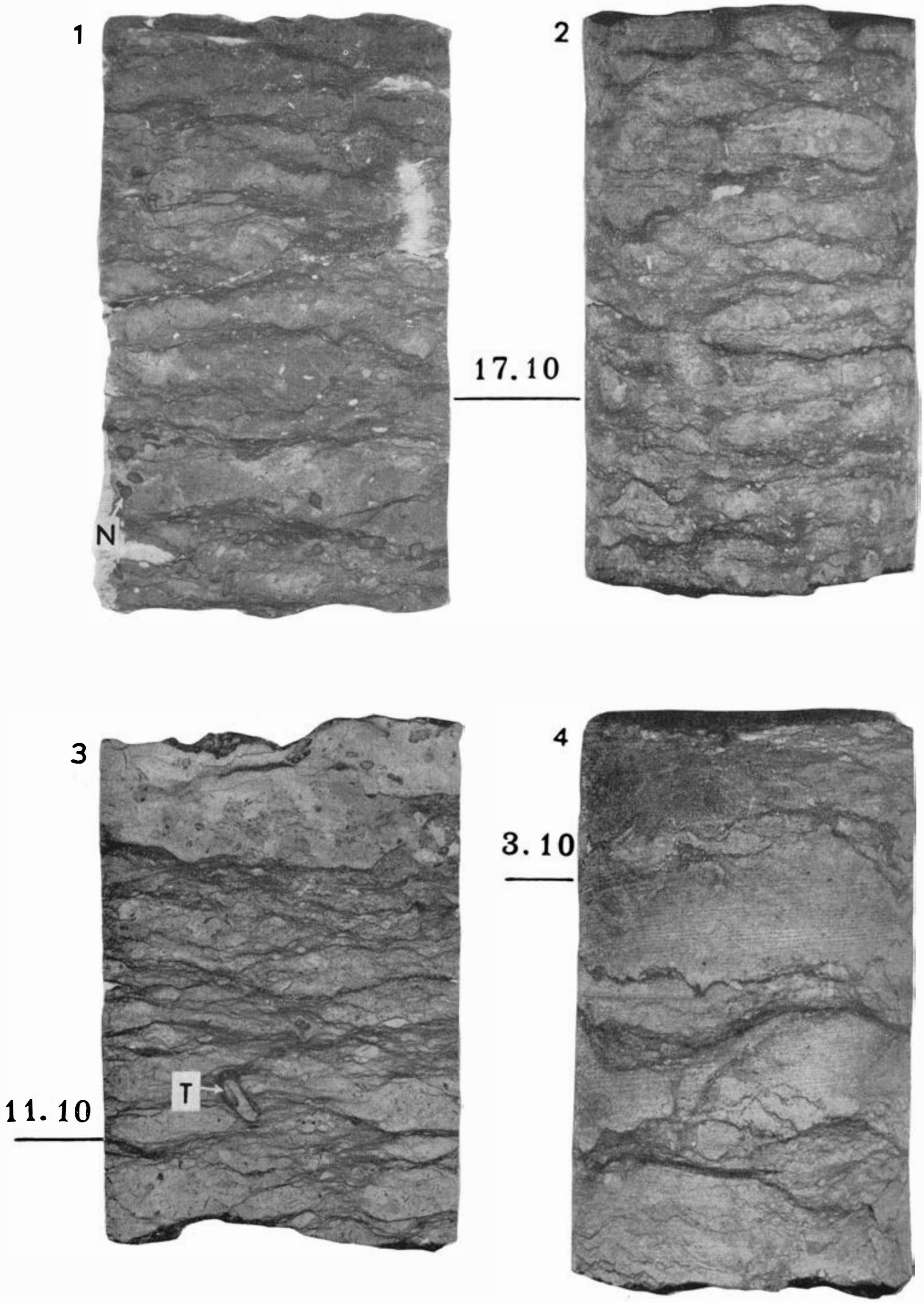
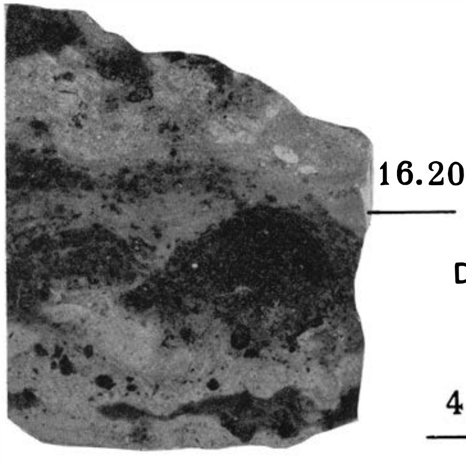
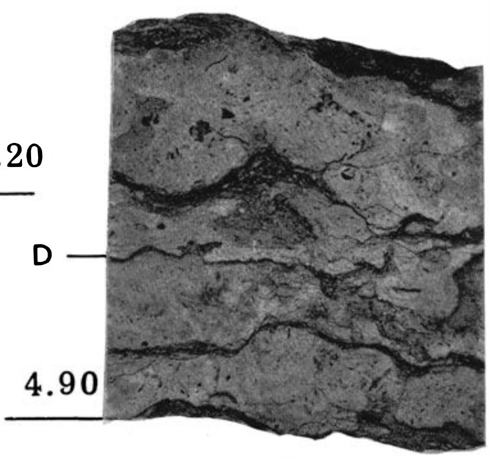

1
2
17.10
N
3
4
3.10
T
11.10


1. Thin section of the Folkeslunda calcarenite. Böda Hamn boring, between the levels of 13.47–13.50 m. 27.8 % of fossil fragments longer than 0.1 mm in the thin section. *C*, chamosite filling a small gastropod shell. ×40.

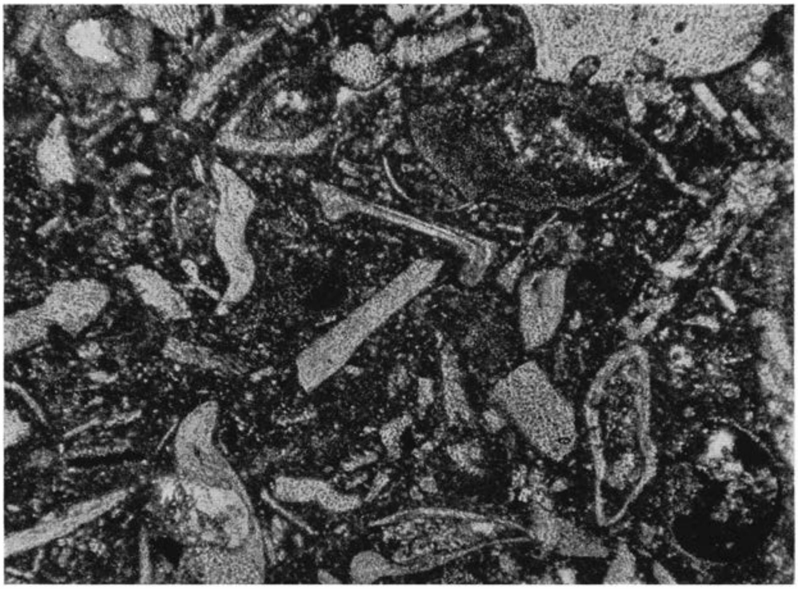


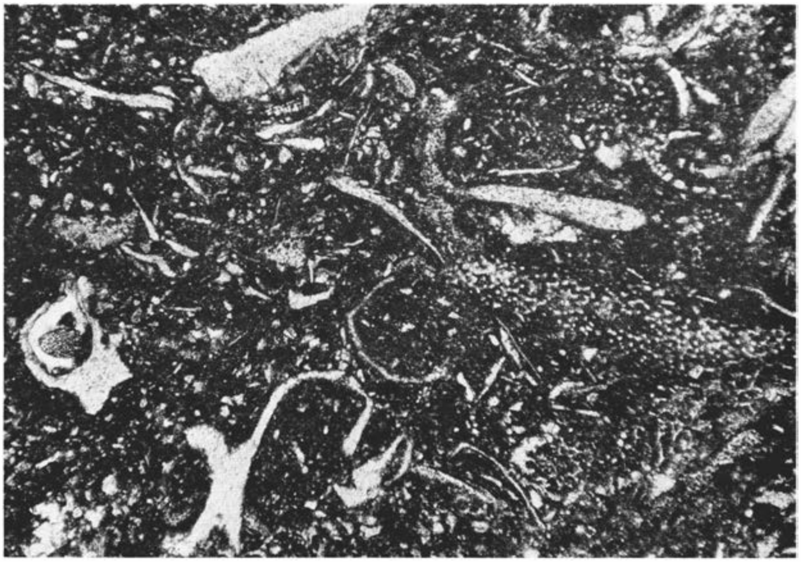

2 3

2. Grey calcarenite with reddish brown spots (dark on the photograph). Seby Limestone, Böda Hamn boring, between the levels of 16.17 and 16.23 m. Notice the numerous small dark (intensely reddish brown) nodules of limestone in the lower part of the figure. Two thirds of natural size.
3. Grey calcarenite of the Dalby Formation. Böda Hamn boring, between the levels of 4.83 and 4.90 m. *D*, faint, discontinuous surface pigmented by pyrites. Two thirds of natural size.

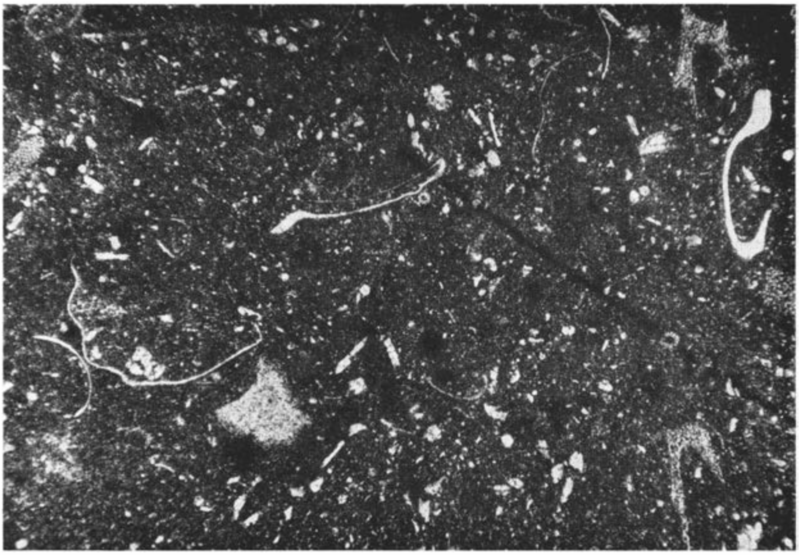
1. Thin section of the Dalby calcarenite. 34.2 % of fossil fragments longer than 0.1 mm in the thin section. Böda Hamn boring, between the levels of 1.97–2.00 m. × 40.



2. Thin section of the Persnäs calcarenite. 26.4 % of fossil fragments longer than 0.1 mm in the thin section. Böda Hamn boring, between the levels of 10.00–10.03 m. The black colour within a gastropod shell in the lower right corner as well as the other black spots are caused by chamosite filling the cavities of shell fragments. × 40.

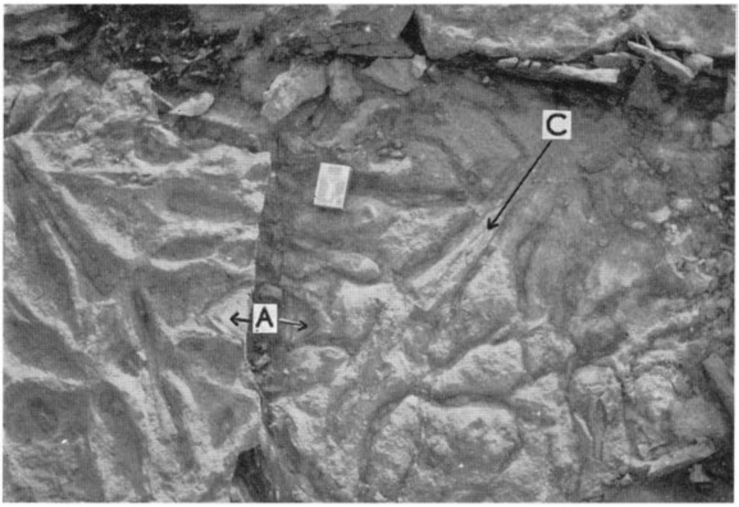


1. Thin section of the Källa calcarenitic calcilutite. 12.9 % of fossil fragments longer than **0.1 mm** in the thin section. Böda Hamn boring, between the levels of 11.97–12.00 m. × 40.



2. Thin section of calcilutite of the Furudal Formation. 5.9 % of fossil fragments longer than 0.1 mm in the thin section. Gammalsby boring, between the levels of 0.24–0.27 m. × 40.

1. Internal moulds from the insoluble residue of the Folkeslunda calcarenite. Böda Hamn boring, between the levels of 13.94—14.00 m. $\times 15$.




2. Furrows resembling mud cracks in the uppermost part of the Segerstad Limestone, ca. 10 cm below the white calcarenite. Beach N of Segerstad Lighthouse. Photo J. MARTNA 1951. Length of the match-box 5 cm. On the left the overturned slab removed from the right. *A*, a large pygidium of *Asaphus* (*Neoasaphus*) *platyurus*; *C*, a cephalopod causing irregularity in the shape of the polygons.