Danmarks geologiske Undersøgelse
II. Række. Nr. 23

Scandinavian Indicator-Boulders

in the

Quaternary Deposits

Extension and Distribution

By

V. Milthers

With 4 plates and dansk Resumé

Kjøbenhavn
I Kommission hos C. A. Reitzel
Andelsbogtrykkeriet i Odense
1909

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Introduction.

By the word »Indicator-boulder« is meant the stones in the Quaternary layers the characteristics of which are so peculiar and distinct that it can be determined exactly from what spot or rather limited area of the region once covered by the ice they came. Knowledge of the fact that loose stones were to be found outside Scandinavia which bore a resemblance to the permanent rocks in Scandinavia had already been obtained long before any clear conception could be formed of the significance of this resemblance. It was only gradually as the theory on the Scandinavian inland ice advanced that a clear understanding on the matter was arrived at.

The actual study of the occurrence and distribution outside Scandinavia of the Scandinavian, crystalline indicator-boulders has been carried on for nearly a generation with excellent results for the Quaternary geology. The rich development of these studies had its beginning in the discovery by G. DE GEER of the value of the Åland rocks as indicator-boulders (1881).[1] The geological importance of these studies was strongly emphasized by the same author's theory on »the second Baltic Ice-Stream« (1884) and by NATHORST and LUNDBOHM'S discovery (1885 and 1888) of the »older« Baltic Ice-Stream, which like the »younger« stream had moved over Scania from the east and south-east.

The stimulating influence of these works has displayed itself mainly in the western part of the glaciated region, Denmark, North-West Germany and Holland. A considerable literature directly concerned with the indicator-boulders, their distribution and the geological results to be drawn therefrom regarding the Quaternary period, has arisen on the basis of investigations in these countries. We find further in descriptions to geological maps and other geological works more or less detailed information regarding the discovery of indicator-boulders in the Quaternary layers. Another reason however, why these

[1] The numbers in parentheses refer to the list of literature.

investigations have been carried on with such energy and great success in the western parts of the glaciated region, is that we find there an extremely varied boulder material, the indicator-boulders of Norwegian origin occurring together with boulders carried down through the Baltic. Boulders from the north appear side by side with boulders which have come from the east and south-east.

In the more eastern parts of the Scandinavian glaciated region, thus in North-East Germany, the study of the indicator-boulders has not been cultivated so constantly nor so extensively. And in Russia the Scandinavian, crystalline indicator-boulders have remained practically unstudied. As to some extent a contributory cause of this it may be mentioned that in the eastern Baltic region the directions of the ice-flow have not apparently been so variable nor so much almost directly opposed as in the western Baltic. We find certainly that in North-East Germany and in the Russian Baltic provinces the boulders have been carried in such contrary directions as from N. W. to S. E. and from N. E. to S. W., but it is not believed as in the Western Baltic region that the contents of the Quaternary layers in indicator-boulders can be used as a basis for stratigraphical division. One result of this has been that investigations on the indicator-boulders have remained on the whole disregarded.

In the western and south-western glaciated region the horizontal distribution of the different kinds of indicator-boulders is fairly well known. In the eastern Baltic region on the other hand one of the principal tasks will be to study and to know even the distribution in a horizontal direction. This task is further in Russia of importance from a Quaternary geological point of view for the reason, that we may there find the most easterly boundaries of the distribution of several of the principal Swedish and Northern Baltic indicator-boulders, which belong to the commonest forms and are to be found everywhere in the Quaternary layers of the Western Baltic, namely boulders from Åland, Baltic quartz porphyries and boulders from Dalarne.

In the south-western part of the Scandinavian glaciated region the tasks for the student of indicator-boulders are different. It has been believed here at various times that certain horizons might be characterised by means of their contents, presence of some types of boulders and complete absence of others. Such a qualitative classification has however been found unmaintainable in most cases as knowledge was gradually obtained on the occurrence of the boulders and the complicated modes of formation of the Quaternary layers. Boulders of northern and boulders of eastern (Baltic) origin can for example be found almost everywhere in Denmark side by side in the same depos-

its. On the other hand there is the possibility that by including quantitative methods in the study of the boulders, by information on the varying quantitative distribution of the various kinds of boulders in the Quaternary layers, we may come upon lines which may yield new contributions towards the solution of the often difficult glacial-geological problems.

The investigations, the results of which are incorporated in the present work, have had as main object so far as the East Baltic region is concerned to increase our knowledge of the extension of Scandinavian boulders and especially to determine how far to the east and north-east the principal Swedish and North Baltic boulders have been carried by the Scandinavian inland ice. The journeys rendered necessary by this object were undertaken in the summer of 1901 and 1902. I have already reported on the 1901 journey (Foreløbig Beretning om en geologisk Rejse i det nordøstlige Tyskland og russisk Polen. D. G. U. III R. Nr. 3, 1902). I am indebted to the Directorate of the Carlsberg Fund for providing the funds which enabled me to undertake these investigations in the field, as also to the Commission for the Geological Survey of Denmark, which with great kindness placed the necessary time at my disposal.

The other quantitative investigations in the field were undertaken in the years 1904—07 partly occasionally, partly on special journeys which I undertook within the boundaries of Denmark on behalf of the Danish Geological Survey. In 1905 by the aid of the Carlsberg Fund a journey was made to the collections of the Swedish Geological Survey in Stockholm and the University in Upsala in order to search for materials for comparison with several series of boulders, which were supposed to come from Dalarne but which hitherto had been somewhat disregarded as indicator-boulders.[1]

[1] I take this opportunity to express my thanks to Prof. A. E. Törnebohm and Prof. A. G. Högbom for the willingness and kindness with which the collections in question were made accessible to me.

Origin and nature of the boulders investigated.

1. Boulders from the Christiania district.

In the environs of Christiania Fjord there is an extensive district of characteristic postsilurian eruptive rocks. Part of these form the origin of a great number of indicator-boulders in the Quaternary layers of North and West Jutland and of the Frisian Islands. In certain parts of Jutland where boulders from the Christiania district are found in specially great numbers, the multitudinous varieties of these rocks are often richly represented. Rhomb-porphyry especially and the rocks Laurvikite, Laurdalite and other which are of almost the same origin as the former are constantly to be found in great quantities here.

In a work intended to give an exact description of the occurrence of Norwegian rocks in Denmark's Quaternary layers, it would be necessary to consider all the varieties comprised in this large eruption-series. It is to be hoped that there will be an opportunity to do so later on. In the present paper, the object of which as regards Norwegian boulders is only to illustrate the main features of their distribution compared with that of Swedish and Baltic boulders, it has been considered more to the purpose to exclude the numberless varieties and only to deal with some few of the rocks of the Christiania district. The distribution of these boulders is so large that they are found not only in places where Norwegian indicator-boulders are on the whole numerous but also in districts where otherwise the Swedish and Baltic indicator-boulders are in the majority. There are two types of boulders of which this may be said especially to be the case, viz.: rhomb-porphyry and rhomb-porphyry conglomerate.

Rhomb-porphyry appears in the Christiania district partly in fissures partly as lava-sheet. It is found over a very extensive area filling up the fissures in primitive rocks, in palæozoic sedimen-

tary layers and in the oldest eruptive rocks round Christiania Fjord. Still greater however are the quantities spread as lava-sheet over vast areas, especially west and northwest of Christiania Fjord. The true rhomb-porphyry as surface rock exactly corresponds to Laurvikite as deep-rock. The rhombic-shaped felspar-crystals of the stone in transverse section make it easily identified; the typical form of the crystals however is often changed and effaced.

There are also other series of postsilurian eruptive rocks in the Christiania district which correspond to different kinds of rhomb-porphyry. Thus BRÖGGER[1] states that:

Gabbrosyenite corresponds to Plagioclase rhomb-porphyry,
Laurvikite to Rhomb-porphyry,
Laurdalite to Nefeline rhomb-porphyry and
Nordmarkite to Quartz rhomb-porphyry.

In the present investigation the separate varieties of rhomb-porphyry are taken as one in spite of their great differences as regards colour, structure and composition.

According to BRÖGGER,[2] time was when the rhomb-porphyry as a coherent layer was spread over the whole of the Christiania district and extended beyond its bounds. BRÖGGER estimates the territory once covered as ca. 22000 square kilometers, i. e. an area only a little smaller than Jutland (25000 sq. km.). At the end of the postsilurian eruption-period the rhomb-porphyry lavas were however broken through over large areas and covered by later eruptive rocks and are only preserved either on sunken territories or as fragments in later eruptive rocks.

Rhomb-porphyry conglomerate[2] is found in the original fixed rock on a number of islands and islets in the extreme southeast of Christiania Fjord, namely, on the 35 km. long distance from »Revlingen« southwest of Mos to »The Sisters« southwest of Frederikstad. It is exclusively composed of edged fragments of rhomb-porphyry not much rolled but mingled with finer sediment; it contains a greater number of varieties of rhomb-porphyry rocks than found anywhere else in the Christiania district, in fact, it even contains varieties found in no other part of the whole rhomb-porphyry territory. On the other hand the conglomerate contains no other eruptive rocks of the Christiania district nor any palæozoic or primi-

[1] W. C. BRÖGGER: Die Eruptivgesteine des Christianiagebietes. I. Kra. 1894, p. 180.

[2] W. C. BRÖGGER: Konglomerater i Kristianiafeltet. Nyt Mag. for Naturvid. Bind 38, 1900.

tive rocks. This brown conglomerate of which small fragments often look as if they were volcanic tuff is, according to BRÖGGER, far from being of volcanic origin; on the contrary, it is an ordinary stratified coast-deposit composed of material produced by erosion of the oldest rhomb-porphyry lavas. After their eruption these lavas as already stated formed a coherent layer of vast extent. The conglomerate contains no rocks of later origin than rhomb-porphyry and may be considered as having been deposited earlier than the volcanic eruptions in the Christiania district, which immediately succeeded the formation of the rhomb-porphyry lavas.

This characteristic rock forms a very considerable number of boulders which in all probability may be considered as originating from the above mentioned parts of Christiania Fjord. If an enumeration is made on the basis of the lists of indicator-boulders given at the end, for the purpose of ascertaining the number of boulders of rhomb-porphyry as compared with the conglomerate, we find that for 8 boulders of rhomb-porphyry there occurs one boulder of conglomerate. Taking into consideration how comparatively seldom boulders of other postsilurian eruptive rocks of the Christiania district are found outside northern and western Jutland as compared with boulders of rhomb-porphyry, it may be said that conglomerate boulders are among the most frequent and important of indicator-boulders from the Christiania Fjord region.

The fact that the territory, from which the boulders of conglomerate originate, is situated more to the east than the eruptive rocks of the Christiania district, which have provided the greatest quantity of Norwegian indicator-boulders to the Danish Quaternary layers, has increased the importance of the first-named. Rhomb-porphyry is well-known from districts further to the south-east but only as a porphyry-dyke extending along the Swedish fringe of islands from Strömstad to Lysekil. Still the fact, that conglomerate boulders on Sealand are found comparatively often just as far to the east as boulders of rhomb-porphyry, indicates, that the fixed rock which formed the origin of the boulders also had a distinctly easterly position compared with the rocks from which the boulders of rhomb-porphyry came. On a contrary supposition the conglomerate boulders on approaching the limits of their easterly distribution would occur more seldom than rhomb-porphyry, in the same proportion as in Jutland, where the main distribution is found. This is not the case, near Roskilde they were even found in almost as great numbers as rhomb-porphyry.

Boulders of this kind have been already mentioned in Danish geological papers, namely, in the two explanations of the sheets of

Vendsyssel,[1] the explanation of geological sheets of Northwest Sealand[2] and in a paper on Norwegian boulders in Sealand.[3] In all these papers they are considered to be porphyry-tuff and in the last it is stated that they are spread over the same area in Sealand as the boulders of rhomb-porphyry. Later, some boulders of the same rock were found along the shores of Stevns.[4]

2. Boulders from Dalarne.

It has been known for many years that in the drift deposits in Northern Germany and Denmark stones of the same nature as porphyry from Dalarne are found. These facts were already mentioned in geological papers from the first half of the 19th century. The beautiful stone ornaments of porphyry made at Elfdal porphyry-works were spread far and wide, making these rocks well-known far outside Scandinavia, though this knowledge has had no subsequent geological importance. This is principally due to the fact that the porphyry rocks of Dalarne have not been subjected to any continuous investigation which might serve as basis for the study of boulders. Investigations of special rock varieties have certainly been carried out, as also of special districts of Dalarne, each forming a valuable commencement, but a summary of the conditions on which the study of boulders depends is still lacking. It is evident that until this want has been met the study of boulders from Dalarne will only be inadequate. The present work does not claim to be more than such an inadequate and provisional attempt to point out the importance of part of the porphyries of Dalarne as boulders.

As regards the identification of boulders with the related rock-types in Dalarne this preliminary study has had to take its starting-point from the boulders themselves. By placing these in special groups and comparing them with specimens of the solid rock, it has been possible in spite of the defective information regarding the porphyry territory of Dalarne as a whole to gain somewhat increased knowledge of the porphyry types that may have importance for the study of the boulders.

[1] A. JESSEN: Kortbladene Skagen, Hirshals, Frederikshavn, Hjøring og Løkken. Danmarks geol. Undersøgelse. I. R., Nr. 3, 1899. — A. JESSEN: Kortbladene Aalborg og Nibe (nordlige Del). Danmarks geol. Undersøgelse. I. R., Nr. 10, 1905.

[2] K. RØRDAM og V. MILTHERS: Kortbladene Sejrø, Nykjøbing, Kalundborg og Holbæk. Danmarks geol. Undersøgelse. I. R., Nr. 8, 1900.

[3] V. MILTHERS: Norske Blokke paa Sjælland. Medd. fra Dansk geologisk Forening. Nr. 5, 1899.

[4] V. MILTHERS: Kortbladene Faxe og Stevns Klint. Danmarks geologiske Undersøgelse. I. R., Nr. 11, 1908.

A short summary of the geology of the porphyry territory of Dalarne is obtained from »Upplysningar till geologisk öfversigtskarta öfver Sveriges berggrund«.[1] »The true porphyries in Dalarne may be divided into three main-classes. Undermost lie red porphyries, then come beds of greenish porphyrites and above these are scattered porphyries irregular in distribution and of a very compact ground-mass, hence called »hornstone porphyries«.

»The Red porphyries are partly brick-coloured partly more reddish brown. The first named are principally found in the Elfdal territory proper and are represented there on the one hand by the well-known Bredvad porphyry and on the other by Garberg granite porphyry which is but a coarse variety of the former. Seen under the microscope the small-grained ground-mass of Bredvad porphyry consists of very red-coloured felspar and quartz. The porphyritic crystals which are neither large nor numerous, are generally composed exclusively of red felspar in spite of the abundance of quartz contained in the ground-mass. The crystals of Garberg porphyry are larger and more numerous whereas the ground substance generally has a very distinctly micropegmatitic structure. — Towards the borders of the porphyry territory reddish-brown porphyries with variable appearance are predominant. Part of them are distinctly quartz-porphyries; this is especially the case at and west of Särna.

»The main distribution of the following porphyrites is found in the Elfdal territory and south of this. They consist of extensive layers of rather dark dirty-green rocks which may be considered as more or less transformed augite porphyrites. Closely connected with these is the so-called Venjan porphyrite of which the main distribution is in the country east of the Lake Venjan. This rock is much lighter than the porphyrites named but like them contains crystals of plagioclase and more or less transformed green augite sometimes bronzite and besides quantities of brown mica. In the microscopic small-grained ground-mass, quartz is often found in quantities.

»Hornstone porphyries, Dalarnes youngest porphyry, appear as already stated in large and small isolated hillocks above the porphyry layers, each of them usually containing a special porphyry variety. They generally have a compact brown or dark-brown, often flow-structured ground-mass in which small light white or reddish felspar-crystals, orthoclase and partly also plagioclase are sometimes sparingly, sometimes abundantly interspersed. As a rule they contain no crystals of quartz. In spite of the dark colour of the rocks they contain a relatively large amount of silica«.[2]

[1] Sveriges geologiska undersökning. Ser. Ba. Nr. 6. 1901. Page 14—15.

[2] Translated from the Swedish.

Red porphyries.

Bredvad porphyry. This is the most frequent of all Dala porphyries and the one that has the largest distribution as boulders in the Quaternary layers. This depends on the fact that its distribution in fixed rock is greater than that of any other Dala porphyry. A. E. Törnebohm gives the following description of Bredvad porphyry:[1]

> »Er besteht aus einer beinahe dichten, unter dem Mikroskope doch deutlich körnigen, braunrothen, felsitischen Grundmasse mit spärlichen Einsprenglingen von gleichfals braunrothem Orthoklas und grünen Punkten, wahrscheinlich von Chlorit. Hin und wieder, obgleich ziemlich selten, bemerkt man auch einzelne Körner von gelblichweisen Oligoklas; deutlich erkennbare Quarzkörner finden sich aber nicht. Diese Porphyrart hat eine nicht unbedeutende Verbreitung, indem sie allgemein um die östliche Dal-Elf nordwestlich von Elfdal-Kirche vorkommt und sich von dort gegen Norden bis nach Lillherrdal in Herjeådalen erstreckt«.

This extensive distribution in fixed rock leads to a corresponding frequency and wide distribution as boulder. In all places where boulders from Dalarne are at all found, Bredvad porphyry is seldom wanting. This is the case in all Denmark from the north point of Jutland to the south-eastern Sealand; in certain parts of West Jutland it is on the whole the most common of all crystalline indicator-boulders found there. It is quite superfluous however to name the places in Denmark where boulders of Bredvad porphyry are to be found as they occur almost everywhere. We shall also return to this later. I need only mention here that, e. g. in gravel-pits at Roskilde and near Farum N. W. of Copenhagen, it is found in much greater quantities than the commonest types of Baltic boulders from the Åland Islands and the northernmost part of the Baltic.

To the south through Sleswig and Holstein Bredvad porphyry is also of frequent occurrence, and on counting the indicator-boulders in a gravel-pit near Vastorf east of Lüneburg (as will be further mentioned later) I found Bredvad porphyries as numerous as Hedström's Baltic quartz-porphyries. As to the occurrence of Bredvad porphyry in Northwestern Germany J. Martin[2] states that:

[1] Ueber die Geognosie der schwedischen Hochgebirge. Bih. till K. Svenska Vet. Akad. Handl. Bd. 1. Nr. 12. 1873.

[2] Diluvialstudien II. Das Haupteis ein baltischer Strom. Sep. der X. Jahresber. Naturw. Ver. zu Osnabrück 1894.

»in der That wird man nach meinen bisherigen Erfahrungen zum wenigsten im westlichen Theil der norddeutschen Tiefebene in einer grösseren Steinansammlung selten vergeblich nach ihm suchen«.

As to the occurrence of Bredvad porphyry in the Netherlands the literature contains no decisive statements. SCHROEDER VAN DER KOLK (1891) states that several boulders of Dala porphyry have been found, and investigations have also been carried out by J. MARTIN and v. CALKER. From these investigations it is evident that boulders from Dalarne are frequently found in the Netherlands and that Bredvad porphyry is the commonest. As far as I have been able to ascertain from the geological collection belonging to the University at Utrecht no Bredvad porphyry however is found in the southern part of Holland. This is presumably in connection with the extreme scarcity with which boulders of rocks from the district round Christiania Fjord appear in this part of Holland.

In certain districts of the provinces of Hanover and Brunswick, where boulders from Dalarne are on the whole numerous, Bredvad porphyry is the most frequently found of all indicator-boulders; this is seen from two enumerations of boulders I made at the villages Horst and Wipshausen 15—17 km. N. W. of Brunswick. I obtained the same result in the neighbourhood of Halle and near the town Schraplau 23 km. W. by S. of Halle. In both places Bredvad porphyry occurred in rich quantities in fluvio-glacial gravels.[1]

In Mecklenburg O. MATZ (1903) states that this porphyry is very common between the Mecklenburg boulders. According to COHEN and DEECKE Bredvad porphyry also occurs in Pommerania though not very frequently. Turning to West and East Prussia, boulders of Bredvad porphyry are comparatively often found in the glacial gravels. In fact this porphyry is hardly absent anywhere in East Prussia where any large number of crystalline boulders are found. In 1901 I visited many places and found Bredvad porphyry in nearly all of them. The list given later gives further particulars of this. The fact that this Dala porphyry is a very common boulder in East Prussia is quite natural if one takes into consideration that it is found far to the north and east in the Russian Baltic provinces and adjacent countries. For further details on this subject I may refer to the section on the boulder-studies in Russia. I need only mention here that Bredvad porphyry was found as far eastward as near Minsk; near Swenziany N.

[1] In Westphalia W. MEYER has lately stated (1907) that boulders from Dalarne are on the whole scarce but that Bredvad porphyry is the kind most frequently found.

of Vilna specimens were obtained; it was also found near Glubokoi 100 km. further to the east. Finally, it was found, though only in small quantities, in the åsar Rullekaln south of Mitau and Kruschkaln west of Mitau as also at Galgenberg near Tukkum west of Riga. On the whole it seems here to approach the outermost limit of its north-eastern distribution; 2 boulders of Bredvad porphyry were found however in a gravel-pit N. E. of Wolmar between Riga and Dorpat.

This distribution in Russia is quite in agreement with the easterly distribution of Bredvad porphyry in Sweden; at Södertelge it frequently occurs in the ås-gravel, whereas near Stockholm, only a few miles further to the east, it is not found. G. Aminoff (1904) has investigated the limit of its eastern distribution in Sweden. The eastern limit of Bredvad porphyry here generally represents the eastern limit of Dala porphyries as a whole.

It has already been mentioned that of all Dala porphyries Bredvad porphyry has the widest distribution as boulder, and that this may be considered as standing in connection with its wide distribution in fixed rock. This distribution however by no means reduces the importance of the Bredvad porphyry as indicator-boulder in the Quaternary layers outside the Baltic. And for this purpose it is in many respects excellently suited just on account of its frequency, whereas many of the other characteristic rocks from Dalarne appear as boulders in too small numbers to be extensively used for the study of boulders. It is of importance indeed that the rocks which are in future to be used as indicator-boulders with advantage for Quaternary geology, besides possessing characteristic petrographic qualities, are also of such frequent and regular occurrence in the drift deposits, that conclusions regarding Quaternary geology may be based upon their varying frequency. The special interest of a minute petrographic investigation and description of boulders, which only appear as rarities everywhere in the Quaternary layers, or of boulders the characteristics of which are only traced by means of the microscope, is of far less importance to Quaternary geology than the work in the field, the object of which is a systematic enumeration of indicator-boulders easily defined and absolutely trustworthy. Such enumerations are especially of importance in places where a rich number of available boulders renders it possible to effect a comparison of the different types of boulders. A work of this kind ought not to be neglected as in fact it is now. And Bredvad porphyry is better suited to this purpose than most of the other rocks from Dalarne, however characteristic and well-defined in occurrence they may be.

Heden porphyry. A series of boulders of a colour varying from more or less dark brown to reddish brown form the transition

to Bredvad porphyry. The grained, granitic, ground-mass contains quantities of lighter crystals of plagioclase up to 1 cm. in length and orthoclase crystals of the same colour as the ground substance. It also contains a number of green grains (chloritic) which however, in the coarse varieties, are not very conspicuous. The light felspar-crystals in the small-grained ground substance give these small-grained varieties a more distinctly porphyritic appearance; the crystals are generally quite light, faintly pink or a little greenish. The small, irregular green patches of basic minerals are rather conspicuous in the light brown ground-mass. Through these small-grained varieties we come to the true Bredvad porphyry.

As to the coarse variety, the collection of the Geological Survey of Sweden contains a specimen of the corresponding solid rock from the district west of H e d e n in the southerly part of Lima parish in the South-West Dalarne. In Sweden's Quaternary layers boulders of an exactly corresponding rock were found at the following places:

Ås by Katrineholm (2 boulders) (MILTHERS).
N. of Redberga, Marka parish, Skaraborg län (2 boulders) (MUNTHE).
W. of Sköttning, Luttra parish (MUNTHE).
Persberg railway-station, Vermland (v. SCHMALENSEE).
Fogelsång in Scania (v. SCHMALENSEE).

A boulder from Heilsberg in East Prussia, No. 2243 in the collection from East Prussia determined by HJ. LUNDBOHM in the year 1886, has some similarity to this group.

As to the small-grained variety of this series of boulders, I have seen no exactly corresponding specimen from the solid rock. As boulder it was however found in several places in the Quaternary layers of Sweden:

Döderhult parish, Kalmar (SVEDMARK) (detrm. by A. E. TÖRNEBOHM).
Great Karlsö, Gothland (2 boulders) (G. HOLM).
Nettraby parish, Blekinge (HJ. LUNDBOHM).
Husby parish, East Gothland (HJ. LUNDBOHM).
Ås by Södertelge, W. of Stockholm (2 boulders) (MILTHERS).
Ås by Katrineholm (several boulders) (MILTHERS).

Outside Sweden it was found as boulder near:

Gammelrød, Borup parish, Sealand (A. CLÉMENT).
Sonnerup wood, Højby parish, Sealand (MILTHERS).
Neighbourhood of Faxe, Sealand (MILTHERS).
Vargaarde, Jutland (A. JESSEN).
Skansebakken, N. Sundby, Jutland (A. JESSEN).
Beach north of the Skaw, Jutland (MILTHERS).

A couple of boulders from Hoch Redlau, N. of Dantzic, and from Vastorf, E. of Lüneburg, are more like the ordinary Bredvad porphyry.

None of the boulders used by G. AMINOFF for determining the limit of the easterly distribution of Dala boulders in Sweden correspond either to the solid type-rock from Heden in Lima parish or to the boulders mentioned here. So there is reason to believe that we must look for the home of these boulders chiefly in the South-West Dalarne.

Closely related to this group of boulders — and partly also the following — are the quartzless orthoclase porphyries described by A. E. TÖRNEBOHM,[1] of which he says that they

> »zeichnen sich im Allgemeinen durch die Grösse und Menge der ausgeschiedenen Feldspathkrystalle aus. Sie bestehen aus einer braunen oder rothbraunen Grundmasse, die mit 4''' bis 5''' langen Orthoklaskrystallen gespickt ist; ausserdem kommen gewöhnlich auch matte Körner von gelbweissen oder grünweissen Oligoklas und kleine grüne Punkte (Chlorite) vor. Zu dieser Gruppe gehören unter anderen der Porphyr des Ås-Berges nordöstlich von Wenjan, der von Bergåsen westlich von Malung und der in den Bergen westlich von Heden in Lima. An letztgenanntem Orte tritt neben den quarzfreien auch ein quarzführender Porphyr auf«.

Brown porphyry. A number of boulders of a distinctly brown porphyry-type correspond to rocks found round Kallberget south of Tandsjön, north of Tisjön in the northwesterly part of Lima parish near the Norwegian frontier. — Through transitions this type is related to the above-mentioned porphyry-type, especially to its coarse variety known from Heden in Lima parish. The special characteristics of the brown porphyries are the brown felspar-crystals 1—3 mm. long, which are evenly interspersed in the gritty ground-mass. TÖRNEBOHM states (see below) that varieties containing crystals of quartz are also to be found. To the north in Idre parish in the neighbourhood of Drefdagen there occur porphyries of a similar dark appearance; but I know no boulders exactly corresponding to these porphyries.

A boulder of the brown Tandsjø porphyry-type was found by H. MUNTHE near Tidaholm, Agnetorp parish, near Skara; in the ås by Södertelge and at Katrineholm I have seen no boulders of this type, though boulders from Dalarne are of frequent occurrence especially at Katrineholm. It is not mentioned in G. AMINOFF's collection.

[1] Die Geognosie der schwedischen Hochgebirge. pp. 9—10.

As boulder outside Sweden this porphyry was besides those stated in the list found at:

Vadumtorp in Vendsyssel (A. Jessen).
Bölling in West Jutland (Milthers).
Gniben, Sealand's Odde (Milthers).

The quartz-containing rocks which correspond to these boulders are characterized by Törnebohm under the name of quartz-containing orthoclase porphyries. In »Die Geognosie der schwedischen Hochgebirge« he says:

»Die quarzführenden Orthoklasporphyre haben in der Regel eine braune oder braunviolette, bisweilen eine graue, dichte Grundmasse, worin Körner von Quarz nebst Krystallen von blassrothen oder fleischrothen Orthoklas und mitunter auch von gelbweissen Oligoklas mehr oder weniger dicht eingestreut liegen. Hierher gehören z. B. die Porphyre um Särna, um Drefdagen, östlich von Herjehogna, im Enars-Berge westlich von Lillherrdal und um Glöte im Kirchspiele Linsäll. Ferner mag hierher gezählt werden der an seiner braunvioletten Grundmasse und seinen kleinen braunen Orthoklaskrystallen erkenntliche Porphyr nördlich des Tisjö im Kirchspiele Lima, obgleich derselbe nur spärlich deutlich erkennbare Quarzkörner enthält«.

In this characterization of the fixed rocks we see that the abovementioned group of brown porphyry is related to the following group, the home of which is round Särna.

Brown-violet Särna porphyry. The way in which Törnebohm as above cited has characterized Särna porphyry will also apply to a specimen of the rock from the village of Nordomsjön, N. of Särna church, which is in the collection of the Swedish Geological Survey. The collections contain several boulders of exactly the same character from the district round Särna. A boulder from Nasser Garten, Königsberg in East Prussia, determined by Hj. Lundbohm, closely resembles the rock from Nordomsjön. Lundbohm describes it as follows:[1]

»Porphyr mit dunkelbraun violette Grundmasse, in welcher zahlreiche weisse und röthliche, oft rechtanguläre, 0,5 bis 3 mm. lange Krystalle von Orthoklas, spärliche grünweisse, etwas grössere von Plagioklas und viele runde farblose Quarzkörner mit 0,5 bis 2 mm. Durchschnitt eingestreut sind. Dieser Porphyr ähnelt sogar vollständig einen nördlich von Särna in N. W. Dalarne an-

[1] Geschiebe aus der Umgegend von Königsberg in Ostpreussen. Phys. ök. Gesell. zu Königsberg 1888.

stehenden. Von dem bekannten Porphyr in Blyberg (Elfdalen, Dalarne), mit welchem dieser bei flüchtiger Betrachtung leicht verwechselt werden kann, ist er durch die Quarzkörner, welche in jener sich nicht finden, streng verschieden«.

Besides those stated in the list boulders corresponding to this porphyry-type were found at the following places:

Lundbjerg in Vendsyssel (K. J. V. STEENSTRUP),
Ørsø in Vendsyssel (A. JESSEN)

and in Sweden:

Ås by Katrineholm (2 boulders) (MILTHERS).

Red Särna porphyry. Boulders of another porphyry which may also be considered as originating from Särna are found in somewhat larger quantities, very homogeneous and typical in appearance. I have had no opportunity to see specimens of this type from solid rocks; in Sweden it was found as boulder at the following places:

Hulegård, Hornborga parish, Skaraborg län (H. MUNTHE).
Habansgård, Borgunda parish, Sköfde (MUNTHE).
Ås by Hallsberg station (E. ERDMANN).
Moraine N. E. of Orsa in Dalarne (G. AMINOFF).
Särna (O. TORELL and HJ. LUNDBOHM).
Ås at Katrineholm (3 boulders) (MILTHERS).
Ås at Södertelge (MILTHERS).

Outside Sweden boulders of this porphyry were found at many places as stated in the list.

In the small-grained, red ground-mass crystals of quartz and oligoclase are very conspicuous. Large quantities of quartz-crystals, the transverse section of which does not exceed 2—3 mm., are evenly interspersed throughout the ground substance. The felspar is generally yellowish white and occurs as crystals not exceeding 5 mm. in length; they are as a rule as numerous and as large as the quartz-crystals. Besides these plainly visible crystals of plagioclase, this porphyry contains also felspar-crystals of the same colour as the ground-mass.

While the brown porphyries from the district between Tandsjön and Tisjön in Lima parish possibly have no very large distribution as boulders, because they occur in solid rocks so far to the south-west, circumstances indicate on the other hand, that the red quartz-containing porphyry from Särna has quite a wide distribution. In this respect I need only point out that it was found comparatively often not only in Denmark, especially in Vendsyssel as might be supposed from the westerly position of Särna, but also scattered in rich

quantities in a south-easterly direction from its home place. From the list we note that 3 boulders were found at Katrineholm and 1 at Södertelge only a few kilometers west of the easterly limit of Dala boulders in Sweden. Red Särna porphyry is no doubt fairly common in the south-east Baltic Quaternary layers. That I am unable to state other discoveries of boulders than that made at Dantzic, this may partly be due to the fact that it was only after having compared some discoveries made in the year 1904 with discoveries from former years that I understood the importance of this type as indicator-boulder.

Garberg porphyry. Garberg granite porphyry, already mentioned on page 9 as a »coarse variety« of the Bredvad porphyry-type, falls under a division of Dalarne's red porphyries of which a few boulders have been found. In »Minerographic notes on porphyry rocks in the Elfdal parish«[1] Peter Jakob Hjelm says regarding the Garberg porphyry that it is »a red felspar-rock containing a small quantity of white vitreous quartz, still less of green soapstone and small patches of dark talc«.[2] The two largest porphyry blocks cut from the old Elfdal porphyry works are made of this rock, namely, the enormous vase at Rosendal Castle near Stockholm and Charles the 14th's sarcophagus in the Riddarholm's church in Stockholm. A. E. Törnebohm states[3] that »both works are made of a red, rather coarse granitic kind of porphyry, which is not so inclined to break as the finer porphyries. The material used for Charles the 14th's sarcophagus was obtained from a large boulder found a little south of Elfdal church. The work took 12 years, and when it was at last completed the question arose how the heavy thing was to be brought all the long way from Elfdal to Stockholm. The conveyance took place in winter by sledging. The sarcophagus was placed on a sledge drawn by hundreds of peasants who were animated by a fiddler sitting on the top of the load«.[4]

The porphyry-type from which this gigantic boulder originated has its home in the neighbourhood of the village of Garberg near East Dal River, S. E. of the village of Elfdal. Stones of the same kind have also in olden times been cut at the Elfdal porphyry works under the name of »Gåshvarf«, so called from the village bearing this name a little to the south-east of the village of Elfdal.

When I collected boulders in the Ås at Katrineholm in the year 1905, I found 4 boulders of Garberg porphyry.

[1] Minerograph. Anteckningar om porphyrbergen i Elfdals Socken. K. Vet. Akad. Handl. Sthlm. 1805.

[2] Translated from the Swedish.

[3] Grunddragen af Sveriges Geologi. Sthlm. 2. edit. 1894. p. 35—36.

[4] Translated from the Swedish.

Kåtilla. Ornaments made of boulders found in the neighbourhood of the village of Kåtilla due west of Elfdal church, have from olden times been cut at the Elfdal porphyry works under the above name. A considerable number of boulders found in and outside Sweden correspond to this porphyry-type. The stationary rock of this porphyry-type is however apparently not to be found near the place where the boulders occurred and which have given the porphyry its name. On the other hand a rock is found in the porphyry-hill Tobinopp and probably also in other places which corresponds exactly to the porphyry cut under the name of Kåtilla and to the boulders which are of the same kind as this rock. In his paper on »Orsa Finmark's geology«[1] E. SVEDMARK gives the following description of the porphyry from Tobinopp on the north-eastern side of Sundsjön:[2] »The ground-mass of this porphyry is light brown with abundant interspersion of felspar-crystals. These are of two kinds, some are of the ordinary reddish-brown colour and do not exceed 5 mm. in length, others are partly light grayish partly greenish grey, rectangular, increasing to 10 mm. by 5 mm., sometimes they are even still larger. The porphyry also contains small needles of hornblend not exceeding 1—2 mm. in length. Under the microscope small grains of a distinctly titanium-rich ore are visible, as also titanite and apatite. Epidote is also richly represented«.

Boulders of this porphyry were found in Sweden outside Dalarne in:

Ås at Kulsta, N. of Nynäshamn (G. AMINOFF).
Ås at Tumba, S. W. of Stockholm (not typical) (G. AMINOFF).
Ås at Katrineholm (2 boulders) (MILTHERS).

Outside Sweden this porphyry was for the first time pointed out as boulder by H. LUNDBOHM in his determination of East Prussian boulders (1886). A very characteristic boulder from »der Kurischer Nehrung« of a »rothe Grundmasse mit gelben und rothen Feldspath-Krystallen« is determined here as »Dala-Porphyr »Kåtilla««. — The list gives the frequent occurrence of this boulder-type, which was also taken at the following places:

Rügen (V. HINTZE).
Vargaarde, Jutland (A. JESSEN).
Skansebakken, N. Sundby, Jutland (A. JESSEN).
Vilsted, N. of Sorø, Sealand (MILTHERS).
Tokkerup near Faxe, Sealand (MILTHERS).
Bjerge Klint, N. of Korsør, Sealand (MILTHERS).

[1] Geol. Fören. Förh. Bd. 17, 1895, p. 162; S. G. U. Ser. C. No. 147.
[2] Translated from the Swedish.

Differing a little from the above-mentioned type are boulders from:

Freerslev Hegn, S. W. of Hillerød, Sealand (MILTHERS).
Roskilde (MILTHERS).
Møens Klint (V. HINTZE).
Hirshals in Vendsyssel (A. JESSEN).
Vastorf, E. of Lüneborg (2 boulders) (MILTHERS).
Schwarzwasser in West Prussia (MILTHERS).

The wide distribution of this porphyry-type as boulder together with its distinct character makes it of great importance as indicator-boulder. The fact that 3 boulders of this type were collected in the short distance along the shore from Warnicken to Rauschen in Samland, though attention was not specially directed to it, indicates that it must be a common boulder in the south-eastern Baltic region. This is not astonishing if one takes into consideration that it occurs in solid rock in the north-eastern part of Dalarne's porphyry district close to its north-eastern limit; we may therefore probably find it as boulder still further to the north-east than in Samland, this being the case with Bredvad porphyry and other Dala porphyries. Moreover, the occurrence of boulders at Kåtilla in Dalarne justifies the supposition that this porphyry may also be found in solid rock to the north-west of Elfdal, i. e. in the direction of Särna; and in all probability it is from such a district in the western Dalarne that the boulders originate, which have been found so frequently in Denmark.

Red, small-grained porphyry. The collections which the author and others have been able to make present a series of boulders so homogeneous in character that we are justified in taking them as a special type. The ground-mass is red, sugar-grained and has some similarity to a few small-grained varieties of granite from Åland. The phenocrysts consist of yellowish white felspar-crystals, partly edged, partly more or less rounded; they do not generally exceed 5 or 6 mm. in length; small, irregular patches of a dark mineral (hornblend) are also found in the ground-mass, the patches are almost of the same size as the yellow felspar-crystals but occur in somewhat smaller quantities. In the character and frequency of the crystals this group corresponds exactly to the small-grained variety of the porphyry group mentioned on page 13 together with the porphyry from Heden in Lima parish. It differs however from the latter in the character of the ground-mass which in the group described here is coarser and distinctly granitic even when seen with the naked eye.

I have not seen this form from solid rocks, but in Sweden several boulders were found which together with those occurring outside the

Baltic point to Dalarne as the home place of the boulders. At Rötved, Fjelkestad parish, Christianstad (sheet: Bäckaskog) G. DE GEER in 1886 found 2 boulders of Bredvad porphyry in moraine-gravel and 1 boulder of »another typical Elfdal porphyry«.[1] This boulder in fact belongs to the granitic porphyry-type described here. A boulder exactly corresponding to the type was found at Bispberg's large mine in South-East Dalarne.

A boulder of a closely related type was taken by G. AMINOFF in a moraine N. W. of Wimo station in Dalarne.

Moreover, in 1905 I found boulders of the red, grained porphyry in the Ås at Katrineholm as well as near Södertelge.

Outside Sweden boulders of this type were found at many places (see the list).

A boulder (No. 6540) from Thorn in West Prussia determined by HJ. LUNDBOHM in 1886 as »vielleicht von Dalarne« obviously also belongs to this group. The dark mineral usually occurring as grains is however almost lacking in the small boulder from Thorn kept in the collections of the Swedish Geological Survey.

Porphyrites.

Grönklitt porphyrite. The group of Dalarne's porphyritic rocks which lies above the red porphyries is like these richly represented among the crystalline boulders of the Quaternary layers. It is these which are mentioned in the text to the »Geological map of Swedish rocks« (see page 9) under the name of greenish porphyrites and are considered to be more or less transformed augite porphyrites. The rock from which most of the boulders seem to originate is of a partly reddish brown, partly dark reddish violet or sometimes grayish violet ground-mass, containing porphyritic crystals of plagioclase and augite.

The crystals of plagioclase are most richly represented; they are also in themselves the most conspicuous crystals on the disintegrated surface of the boulders and give these a very characteristic appearance. They are edged and do not generally exceed 5 mm. in length; they are of a yellowish green colour, not very conspicuous in fresh fractures but give the dark coloured ground an evenly spotted appearance. On disintegration the crystals assume a lighter colour and generally stand out sharply outlined as small rectangular, yellowish spots against the reddish violet background. The only kind of indicator-boulder outside Dalarne which may be said to have a somewhat similar appearance is

[1] Sveriges Geol. Undersökning. Ser. Aa. Nr. 13. 1889. pag. 63.

brown Baltic quartz-porphyry (see page 30), but on the one hand it never fully possesses the characteristic violet hue of the porphyrite, on the other it always contains porphyritic, separated quartz crystals, so that confusion is excluded.

The crystals of augite are green, somewhat darker than the groundmass; they are irregular and almost of the same size as the felspar-crystals but not very conspicuous either on disintegrated surfaces or on fresh fractures. The greenish appearance of the stones as a whole is most often due to the colour of the augite.

It seems as if the main distribution of these diabasic porphyrites in fixed rock is to be found in the district round Orsa and Elfdal, but their nature and distribution have not been further described.

G. AMINOFF has found boulders of this characteristic porphyrite near Rysjön, a station on the railway-line Norrsundet-Linghed, and near Tumba, south-west of Stockholm. Near Södertelge which lies a little further to the west I found a large number of boulders, as also near Katrineholm in Sudermania. Boulders of this rock were also found in Gothland and Scania, and HJ. LUNDBOHM[1] has mentioned several from Halland.

Outside Sweden this porphyrite is, next to Bredvad porphyry, more frequently found as boulder than all other porphyritic rocks of Dalarne. This is illustrated by the list given later. Boulders of this type are also on many earlier occasions mentioned in the literature. Thus, 2 boulders from East Prussia already determined by HJ. LUNDBOHM in 1886 as Dala porphyries,[2] viz. No. 5708 from Thorn and No. 7854 from Heilsberg, belong to this kind of porphyrite. From Oldenburg J. MARTIN[3] states the occurrence of a number of boulders of »Orsa porphyry«, also belonging to this kind of porphyrite. The explanations to the Danish geological maps often mention the occurrence of »Grönklitt porphyry«, by which is understood the porphyrite described here. The name is derived from one of the places where it was found in fixed rock, namely Grönklitt, N. E. of Orsa church. The boulders are very common in Denmark and may be met with all over the country.

Venjan porphyrite. It has been set down by Swedish geologists that the porphyrite group just mentioned is closely related to another porphyrite rock occurring east and south of the Lake Venjan;

[1] Om den äldre baltiska isströmmen i Södra Sverige. Geol. Fören. Stockh. Förh. 10. 1888, p. 173.

[2] Verzeichniss einer Sammlung Ost- und Westpreussische Geschiebe. Schriften der phys.-ökon. Gesellschaft in Königsberg 1886, p. 89.

[3] J. MARTIN: Das Haupteis ein baltischer Strom. Diluvialstudien II. Jahresber. Naturwiss. Ver. zu Osnabrück. 1894.

TÖRNEBOHM[1] has called it Venjan porphyrite and characterized it as a mica porphyrite. It consists of a partly grayish and partly brownish ground-mass containing numerous large and small crystals of plagioclase of a pale yellowish green colour without any sharp delimitation. It also contains crystals of augite and of brown mica formed as six-sided plates. These different components are often found in such quantities that the ground-mass is scarcely discernible by the naked eye, and the rock gets a granite-like rather than a porphyritic appearance. The microscopic investigation however shows that there is a ground-mass, even in the apparently fully grained varieties, consisting of a grained aggregate of quartz and felspar. In spite of the abundance of quartz contained in the ground-mass, separate quartz-crystals are however very seldom found.

The boulders of Venjan porphyrite do not like several others occur in great quantities. In Sweden they were found in the region south of the Lake Wener; near Katrineholm I found a single boulder of Venjan porphyrite among a great number of Dala boulders; H. HEDSTRÖM (1894) found 1 boulder in Gothland. In Holstein and in the Frisian Islands a number of boulders of this rock[2] were found, and also in Denmark it occurs at several places where Dala porphyries are richly represented. From Warsaw the occurrence of a single boulder is noted.

Dalarnes youngest porphyries (Elfdal porphyry).

Above the layers of the older red porphyries and porphyrites appear as already stated isolated hillocks of younger quartz-porphyries, »Hornstone porphyries«. They are the porphyry varieties generally mentioned under the name of »Elfdal porphyries«. They are rocks of a compact brown or dark brown ground substance often showing flow-structure. The porphyritic crystals mainly consist of felspar partly striped partly unstriped. The felspar-crystals do not generally exceed 3—4 mm. in length and are lighter than the ground substance. Quartz is not found macroscopically nor is it very predominant in the ground-mass. The ground-mass generally contains patches which are not separable from the surrounding ground-mass when examined under the

[1] Ueber die Geogn. d. schwed. Hochgebirge l. c. Beskrifning till blad no. 1 af Geologisk öfversigtskarta öfver mellemsta Sveriges Bergslag.

[2] HJ. SJÖGREN: Om skandinaviska block och diluviala bildningar på Helgoland. Geol. Fören. Förh. 6. 1883.

JOHS. PETERSEN: Geschiebestudien II. Geogr. Gesellsch. in Hamburg. 16. 1900. — Ueber die krystallinen Geschiebe der Insel Sylt. Neues Jahrb. 1901. — Untersuchungen über die krystallinen Geschiebe von Sylt, Amrum und Helgoland. Neues Jahrb. 1903.

microscope by ordinary light, but which become visible by polarized light. They then appear as an aggregate of irregularly interspersed microlites and needles showing simultaneous extinction in each individual patch.

The rocks in the different massives of Dalarne's later quartz-porphyries are often of a rather heterogeneous form and appearance. This is why the various types have gone under different names such as: Blyberg porphyry, Klittberg porphyry, »Rännåsarne«, »Mjågen«, according to the places where they were found. The differences seem to be mostly in form only, but the same form, characters and dissimilarities as those displayed by the solid rocks may be found among the boulders.

Boulders of these Elfdal porphyries are quite conspicuous but do not occur in great numbers. In the present investigation no distinction has been made between the different types, as this is of scarcely any importance.

Other Dala porphyries.

Among the porphyry boulders which may with certainty be said to originate from Dalarne, there are some which were only found in quite small numbers and others the solid type-rock of which it has been impossible to determine exactly. Some of these boulders resemble a kind of porphyry which has been cut at the Elfdal porphyry works under the name of »Orrlock«; some boulders are very much like a kind of porphyry found near »Orrlockstjärn«; some resemble a variety occurring near Suggboda north of Elfdal church. Other boulders resemble a porphyry named Enå porphyry from Stenberget, Orsa parish. — Most of these boulders are reddish porphyries with small felspar-crystals; some of them seem to be related to the porphyrites.

3. Boulders from Scania.

Basalt. In Northern Scania, north and east of Ringsjön, there is a district of considerable extent, where the basalt has burst up through the gneiss of the primitive rock. Some 70 places are known, where basalt-massives are visible mostly as hillocks of small size.[1] The rock is for the most part bluish black, compact and often contains olivine, which is to be seen without microscope. On the

[1] Fr. Eichstedt: Skånes basalter. S. G. U. Ser. C. Nr. 51. 1882. — S. G. U. Ser. A_1, a. 1 & 2. 1904.

other hand augite and felspar are only seldom discernible without the microscope. In Eastern Scania basalt is also found.[1]

Basalt boulders from Scania are of a very considerable distribution in the Quaternary layers of Denmark, North-Western Germany and Holland, and are in certain places to be found in very large numbers. The position of the place from which they originate, far from the home places of the other crystalline indicator-boulders and in the extreme south of Sweden, has given the occurrence of the basalt boulders a special interest. It has also been found that among the boulders there are types of Scanian basalt which are not known in the solid rock. Thus EICHSTEDT (1883) has shown that glass-basalt, of which no equivalent is known in solid rock, occurs among the boulders. And J. PETERSEN (1899) and J. MARTIN (1903 and 1906) have pointed out some other basalt-types hitherto unknown from the localities of stationary basalt. They may possibly be met with in Scania proper but are covered by Quaternary deposits; they are possibly stationary in the Baltic near Scania. — The basalt known in solid rocks and as boulders from the district of Scania are: Felspar-basalt, Nefeline-basanite and -basalt, Leucite-basanite and -basalt and Glass-basalt.

The main distribution of the basalt boulders is found to the west and to the south-west. Near Jutland they occur as far to the north as in Læsø. In the southern part of Jutland they occur in large quantities in patches; in the head moraine in Red Cliff on Sylt they are common. In the principality of Lübeck J. MARTIN found great numbers in patches and states that basalt boulders are very common in the duchy of Oldenburg. In the northern part of Holland quite a considerable number were found also in patches. From Brunswick some boulders were obtained, from Saxony a comparatively large number. In Mecklenburg they were very common to the west, scarce to the east, but here also they were found in large quantities in patches. No boulders were obtained from Rügen, but near Eberswalde and Heegermühle in Brandenburg and near Rüdersdorf some basalt-boulders were found. These places lie like those in Saxony due south of the basalt districts of Scania. J. KORN (1904) has however found basalt boulders still further to the east, viz. at Drossen and Massin near Landsberg, i. e. ca. 80 km. further to the east than Eberswalde, following the direction of a line which points S. 15° E. from Scania. Thus the spreading-angle of the basalt boulders is ca. 150°, which is far greater than that of the boulders from other parts of Scandinavia.

[1] G. DE GEER: Kartbladet Vidtsköfle. S. G. U. Ser. Aa. Nr. 105. 1889.

This wide spreading-angle is of great importance, for it must be remembered that all the North Baltic material which has come to North-Western Germany and Denmark has been brought thither through the Baltic valley south of Scania or in part across this part of the country itself. It is thus probable that the same wide spreading, to which the basalt boulders have been subject, has also in part affected the North Baltic material at this one spot on its way.

4. Boulders from Eastern Småland.

Påskallavik porphyry. In certain parts of the granite and porphyry district of Kalmar län in Småland there is a large number of porphyry-dykes of a characteristic appearance, the boulders of which deserve the name of indicator-boulders. Their importance in this respect was already pointed out by L. Holmström (1867) who named the porphyry Påskallavik porphyry because of its occurrence near the seaside town Påskallavik between Oskarshamn and Kalmar. The geological and petrographical qualities of the Småland Gang-porphyries[1] have later been subjected to comprehensive investigations by O. Nordenskjöld,[2] who has separated the porphyries into various groups and types of which in particular the discrimination between Påskallavik porphyry with microgranitic ground-mass and Sjögelö porphyry with micropegmatitic ground-mass must be noted. It is virtually only the first-named which occurs in great numbers as boulder. In the region west of Påskallavik and Mönsterås especially, it is found in dykes; the Sjögelö porphyry type in its most distinct form occurs further inland to the west. Nordenskjöld indicates however that even these two groups intermerge and according to H. Hedström[3] both structures may occur in the very same dyke. When to this is added that the superficial character or form of the rocks offers no good basis for making a distinction between the groups, I see no special reason for discriminating the boulders. The original name of Påskallavik porphyry is therefore continually used here.

Påskallavik porphyry is of a grayish sometimes faintly reddish colour. It is remarkable for its conspicuous porphyritic felspar-crystals, which are much lighter than the ground-mass and often faintly pink. They are generally 0,5—1 cm. long, exceptionally reaching 2 cm.

[1] Gang-porphyry = porphyry found in a dyke.

[2] Om de porfyriska gångbergarterna i Östra Småland. S. G. U. Ser. C. Nr. 133. Geol. Fören. Förh., Stockh. 14. 1903, and other publications.

[3] Kartbladet Mönsterås med Högby. S. G. U. Ser. Ac. Nr. 8. 1904.

The felspar-crystals are sometimes edged and oblong, but they are often round and may have a ring of plagioclase outermost, so that the appearance of Påskallavik porphyry resembles that of Rapakivi. Quartz-crystals are sometimes also to be found. They are generally round, almost as large as a pea and of a sapphire colour. Macroscopically separated quartz is however often completely lacking.

One of the dykes of Påskallavik porphyry first discovered lies 2 km. west of Påskallavik and may be traced ca. 2 km. in a northerly direction. As to two neighbouring dykes the easterly one is 40 m. broad, the other half as broad. The main Gang-porphyry district is in the region south of Långamåla 12—24 km. west of Mönsterås; another district is found north of Fliseryd, but single porphyry dykes are often found in the district extending from the region west of Oscarshamn to the region north-west of Kalmar.

The boulders of Påskallavik porphyry are spread far and wide but generally only occur in small numbers. Outside the Baltic they are found so far away as in Vendsyssel, West Jutland, Holland, Saxony, Silesia and East Prussia. But from the various places to which the Baltic ice-currents have carried even large numbers of other boulders, only a few of these have in general been obtained. Some exceptional cases will be mentioned later.

The small quantity of Påskallavik porphyry boulders may be considered as a natural consequence of the fact that they originate from eruptive dykes which have only offered surfaces of small extent as fields of activity for the ice-streams. It may possibly also have been of some importance, that the place from which they originated was a little outside the territory which may be considered as the true highway of the Baltic ice-streams, the Baltic-valley itself, in which the strongest erosion by the land-ice took place. Påskallavik porphyries have passed into the Baltic ice-stream solely by a movement across or obliquely to the direction of the true Baltic stream.

5. Boulders from the North Baltic district.

The Åland Islands.

Of the rocks which have been of importance as indicator-boulders the Rapakivi rocks are among those which have attracted the greatest attention. After TORELL had noticed their importance as indicator-boulders and G. DE GEER (1881) had given a description of their most characteristic qualities, they rapidly became of importance to the Quaternary studies outside the Baltic. Some more exact descriptions

of their petrographic character have afterwards often been given, by FROSTERUS and SEDERHOLM[1] and by COHEN and DEECKE.[2]

The varieties of Rapakivi rocks occurring as boulders are closely related to the varieties known in the Åland Islands in fixed rock, especially to the following: Rapakivi, granite, Rapakivi-like granite, quartz porphyry and Rapakivi-like quartz porphyry.

Åland Rapakivi is a reddish brown porphyritic granite, the small-grained ground-mass of which contains numerous round grains of orthoclase surrounded by plagioclase. The grains of orthoclase, the transverse section of which is generally 0,5—2 cm., are almost of the same colour as the ground substance; the light green plagioclase, which is inclined to disintegrate, assumes a white colour which gives the surface of disintegrated stones a very characteristic appearance, as the plagioclase is seen as distinct light rings encircling the round orthoclase grains (»Rapakivi-eyes«). Quartz and plagioclase often enter into the composition of the orthoclase grains, which therefore on disintegration assume a lighter hue than ordinarily.

The ground-mass mainly consists of brown orthoclase and quartz, which are micropegmatitically coalesced so that there is a difference between the Åland and the South Finnish Rapakivi. The other minerals principally contained in the ground-mass are plagioclase, hornblend and biotite, which however is often transformed to chlorite. On disintegration the hornblend on the surface of the stone often wholly disappears, leaving small cavities.

While the South Finnish Rapakivi on disintegration easily turns to gravel (Rapakivi means: rotten stone), the Åland Rapakivi is not worn by exposure to atmospheric influence and consequently it is easily preserved as boulder. It does not however belong to the kind of Åland boulders which are of the most frequent occurrence. For further illustration of this fact I may refer to the last pages of this paper, which contain the list of the boulders that have been found. As compared with other indicator-boulders large boulders of Åland Rapakivi are much more frequent than small. The characteristic qualities of the former are also very distinctly seen macroscopically.

The richest occurrence of Rapakivi in fixed rock, as yet known, is found in the northern and eastern parts of Åland, but it is also scattered over a large area north of Mariehamn in the southern part.

[1] BENJ. FROSTERUS och J. J. SEDERHOLM: Beskrifning till kartbladet No. 17 Finström. Finlands Geol. Undersökning. Helsingfors 1890. — BENJ. FROSTERUS: Beskrifning till kartbladet No. 21 Mariehamn. Finlands Geol. Undersökning. Helsingfors 1892.

[2] C. COHEN und W. DEECKE: Ueber Geschiebe aus Neu-Vorpommern und Rügen. Berlin 1892.

Åland granite is small-grained and of a somewhat lighter colour than Rapakivi. The graphic, granitic coalescence of felspar and quartz is sometimes discernible by the naked eye. Cavities surrounded by crystal-points of quartz and felspar are often found in this rock. It does not contain so many dark minerals as Rapakivi, but transitional forms to this rock are found therein in great numbers.

Åland granite occurs partly in dykes partly scattered over large and small districts of the Åland Islands. It is generally of a more frequent occurrence as boulder than Rapakivi, especially the boulders as large as a fist and below this size.

Rapakivi-like granite. A rock of a special character which occurs as boulder as well as fixed rock, may be mentioned as forming the transition from Rapakivi to granite, sometimes resembling the former, sometimes the latter. In its typical form it differs from granite by its porphyritic structure; in contrast to Rapakivi the porphyritic felspar-crystals are not round but rectangular and form no »Rapakivi-eyes« as is the case with Rapakivi, because the orthoclase is not surrounded by plagioclase. On the other hand the crystals often consist of plagioclase, so that on disintegrated surfaces they appear as white rectangular patches. Like Rapakivi its ground-mass generally contains some hornblend, which gives it a darker appearance than Åland granite.

Rapakivi and the Rapakivi-like granite are spread over the greater part of Åland; the two rocks are gradually and insensibly merged, so that sometimes it is impossible to determine for certain to which of them the boulders belong. The boulders of Rapakivi-like granite are not of such frequent occurrence as those of Åland granite and Åland Rapakivi.

In their paper »Ueber Geschiebe aus Neu-Vorpommern und Rügen« Cohen and Deecke have taken this group and Åland granite as one. Its special marks are however so characteristic that in the determination of boulders there is every reason for taking it as a special type, even though in many cases it may be difficult to discriminate between them.

Quartz porphyry. The ground-mass is reddish brown, a little darker than that of the other Rapakivi-rocks. Firmly embedded in the small-grained, compact and tough ground-mass are numerous rounded quartz-crystals as large as peas; it also contains rectangular crystals of orthoclase. On disintegrated surfaces the porphyry may therefore have a beautifully spotted appearance.

The ground-mass like that of the other rocks is of a micropegmatitic structure. Seen under the microscope dark minerals are

less conspicuous than in the varieties which are closely related to Rapakivi, but they are however constantly to be found.

This typical quartz-porphyry now only occurs in a small district in Jomala parish north of Mariehamn and as dykes in other Rapakivi rocks. As boulder it is however of very frequent occurrence compared with Rapakivi and the granites. This fact justifies the supposition, that previous to the Quaternary ice-scouring of Åland it had a far more considerable distribution, or that it is also present in fixed rock and has been open to the land-ice in the sea-territory bordering upon Åland. There is at any rate every reason for believing the latter supposition to be correct.

Rapakivi-like quartz porphyry. The colour of this rock varies from chocolate brown to reddish brown. The small-grained ground-mass contains a number of porphyritic crystals partly of quartz partly of orthoclase and plagioclase. The rock stands as a transition-form between quartz porphyry and Rapakivi. The quartz-crystals are rounded and generally like those of quartz porphyry as large as peas, but they differ from these by being nearly always surrounded by a thin cover of hornblend, which is to be seen on the surfaces as a dark ring encircling the rounded quartz-crystals. As the hornblend is inclined to disintegrate, the round quartz grains stand out in relief from the surface or the quartz falls out leaving a cup-shaped depression. The orthoclase crystals are generally edged and have no cover of plagioclase. Where the felspar-crystals chiefly consist of plagioclase they are on disintegrated surfaces like those of Rapakivi-like granite of a lighter colour than the ground-mass.

At many places we find in fixed rock transitions between this type and the kinds to which it forms a transition. As boulder the rock is however nearly always easily determinable. In its typical form it only occurs in Åland in a district east of Mariehamn. The great number of boulders which have been found prove however that, like quartz porphyry, it had before the Glacial Period or still has a far greater distribution than that known in Åland. This is the Åland rock which is most frequently found as boulder in the deposits of the Glacial Period.

Bottom of the Baltic south of Åland.

As previously mentioned the sea-territories round Åland have probably provided a considerable number of the boulders of which Åland may be said to be the home place, viz. Åland quartz porphyry and Rapakivi-like quartz porphyry. Two other Baltic quartz porphyries of which no equivalents in fixed rock are known originate, as far as

it has been possible indirectly to determine, from the bottom of the Baltic south of the Åland Islands and north by north-east of Gotska Sandön. The two kinds of porphyry are here named: Brown Baltic quartz porphyry and Red Baltic quartz porphyry.

Brown Baltic quartz porphyry is thoroughly described partly by H. HEDSTRÖM[1] partly by COHEN and DEECKE.[2] In the very compact ground-mass lie numerous crystals of quartz and felspar and dark green chloritic patches. The ground-mass varies in colour, sometimes it is almost reddish, sometimes dark grayish brown. The size of the crystals therefore is of greater importance. The quartz crystals are gray or of a darker colour, rounded and the transverse section is generally less than 2 mm.; in some stones the crystals may reach a length of 3—4 mm. They are sometimes very small and not very conspicuous, but they are always present and are visible under a magnifying glass. The felspar-crystals are somewhat larger; their transverse section is usually 2—3 mm. or it may be a little greater. They are edged in form and in fresh fractures of almost the same colour as the ground-mass but on disintegrated surfaces they are always of a lighter colour.

The felspar-crystals partly consist of orthoclase partly of plagioclase, as is easily seen from the colour of the disintegrated rock. The quartz-crystals are generally magmatically corroded and often have a sunken surface. They are nearly always surrounded by a characteristic marginal zone of the same character as the ground-mass, but which is opaque to polarized light at the same time as the quartz.

The boulders of brown Baltic quartz porphyry were originally considered as originating from Dalarne and were for a time known as »Enitri porphyry«, a name derived from a place in Öland where they were found. But in 1894[3] and in 1895[4] H. HEDSTRÖM came to the conclusion that the boulders originate from a territory in the bottom of the Baltic extending between Åland, Gotska Sandön and the Swedish fringe of islands south-east of Stockholm.

The boulders of brown Baltic quartz porphyry are scattered over almost the same districts as the boulders from Åland. In the central districts of occurrence this however does not hold true, the Baltic quartz porphyry occurring here more to the west (Gothland and Got-

[1] Studier öfver bergarter från morän vid Visby. Geol. Fören. Förh. Stockh. 16. band. 1894. S. G. U. Ser. C. 139.

[2] Ueber Geschiebe aus Neu-Vorpommern und Rügen. Erste Fortsetzung. 1896.

[3] Studier öfver bergarter från morän vid Visby. l. c.

[4] Om block of postarkäiska eruptiva Östersjöbergarter från Gotska Sandön. Geol. Fören. Förh. Stockh. 17. 1895.

ska Sandön), Åland boulders to the east (the region round Riga Bay and Ösel). As to the quantity of boulders, the number of brown Baltic quartz porphyry-boulders generally exceeds the number of Åland boulders in the greater part of the district of occurrence, when the different varieties of the latter are taken separately, but in this respect there may in certain places be large and peculiar differences. The boulders are generally as large as the fist or below this size; but boulders of the size of the head and still larger are frequently found even as far from the origin as in West Jutland. Often the boulders form broad plates of some centimeters in thickness.

Red Baltic quartz porphyry. In the red ground-mass, which macroscopically is of a very fine-grained, almost compact appearance, lie numerous crystals of quartz and felspar. The transverse section of the quartz-crystals does not exceed 3 mm.; on worn surfaces they appear as white, somewhat rounded, but irregular dots, but are in fresh fractures of a dark, smoky-gray or black colour. The felspar-crystals are edged, 1—4 mm. long and brick-coloured like the ground-mass, so they are not very conspicuous.

It is sometimes found that the felspar as well as the quartz becomes strongly magmatically corroded after crystallisation. The ground substance is of a micropegmatitic or microgranitic structure. In many boulders we find patches of a dark-green rock which has not yet been subjected to exact investigation. It seems almost to be an old basic rock, of which fragments have entered into the magma of the quartz porphyry. These patches are sometimes as large as hazel nuts but as a rule considerably smaller.

Until the middle of the eighties the boulders of this rock were supposed to originate from Dalarne. The collections of the Swedish Geological Survey at that time contained a small number of boulders but collected from a very large district. About this time the Rapakivi rocks in the Sundsvall district were discovered. On a 15 m. broad porphyry-dyke at Rödön a quartz porphyry apparently related to the Rapakivi rocks[1] was found. The prevailing view therefore was that these boulders originated from Rödön and adjacent parts of the Gulf of Bothnia. And for many years they were mentioned in the literature as boulders of »Rödö quartz porphyry«. The investigations on the occurrence of these boulders in 1905 gave the result that, like brown Baltic quartz porphyry, they originate from the bottom of the Baltic south of Åland.[2] As far as it is possible to ascertain from what is

[1] Hj. Lundbohm: Om den äldra baltiska isströmmen i södra Sverige. Geol. Fören. Förh. Stockh. 10 p. 174. 1888.

[2] V. Milthers: Woher stammen die sogenannten »Rödö«-Quartz-porphyrgeschiebe im baltischen Diluvium? Medd. fra Dansk geol. Foren. 12. 1906.

known of their distribution up to the present time we shall have to look for the district of the solid rock of red Baltic quartz porphyry in a south-easterly direction from Åland, whereas the source of the brown Baltic quartz porphyry is to be sought further to the west and nearer to the Swedish coast.

Like brown Baltic quartz porphyry, red Baltic quartz porphyry is one of the commonest of indicator-boulders in the Baltic glaciated territory. A comparison of the quantities shows that they generally occur in about equal amounts. In some regions there are however certain constant variations, the true cause of which it has not yet been possible to decide. In the part of the district of occurrence which lies nearest to their source, the two kinds of boulders differ greatly in their distribution. In the Russian Baltic provinces red Baltic quartz porphyry has a far greater distribution to the east and to the north-east than brown Baltic quartz porphyry, but as a set-off it seems to occur comparatively seldom in Gothland compared with the latter.

As to the size of the boulders, it must be noted that they are often very small, generally less than a fist. Sometimes however boulders as large as the head may be found. Even as very small stones this indicator-boulder is easily determinable on account of its shape and pure red colour, which is uninfluenced by disintegration and is the same throughout the rock.

Distribution of the indicator-boulders.

Statistical enumeration of indicator-boulders.

As we have seen from the foregoing section, boulders from Dalarne and the Åland district are scattered over the glaciated territory right from the Skaw to Saxony and from Holland to the Russian Baltic provinces. Their wide distribution was already years ago a matter of fact. From certain quarters it has however been contested that typical Dala porphyries were to be found so far to the east as in West and East Prussia, but the doubt which was expressed has only been based upon suppositions and not upon investigations.

But while the horizontal distribution of the boulders owing to the many investigations has constantly become more and more known, little attention has been paid on most occasions to the proportionate quantity in which the boulders from different origins occur in the Quaternary layers. This is however what ought especially to be taken into consideration by Quaternary geological studies. In places where boulders from different sources are to be found, it only very seldom happens that boulders of one origin (e. g. Norwegian) occur in a special geological horizon, and that boulders of another origin (e. g. Ålandish) lie in another separate horizon. The literature is certainly able to state the occurrence of such deposits, e. g. in Sylt (STOLLEY), Vendsyssel (A. JESSEN) and North Sealand (RØRDAM), but these statements are few or on renewed investigations proved to be incorrect. In almost every place where the Quaternary deposits contain boulders from different sources this heterogeneous material lies intermingled; thus in Denmark we almost without exception find northern and Baltic material lying side by side in the Quaternary layers. This is also the case not only in Denmark but in all the south-western Scandinavian glaciated territory, if by »northern« material, as is the case here, is understood not only the boulders from the Christiania district, but

also boulders from Dalarne, which have been carried off by the land-ice directly from Dalarne and not through the Baltic valley. Such radially distributed boulders and boulders of Baltic origin (tangential distribution) appear indiscriminately in the layers. This being so, it will not suffice to carry out the investigations of the quality of the boulders, the question as to their quantity is just as important. Indeed it is not sufficient to ascertain that boulders from a certain source are to be found in a certain district. An investigation of the proportionate number of boulders from different sources in one particular deposit is also required. One is thus necessarily led into making enumerations of the indicator-boulders.

The stone-enumerations already made by FORCHHAMMER form a kind of model for such enumerations. For this purpose he used stones as large as a fist which lay in stone-heaps and gravel-pits, dividing them into three groups: 1) granite and gneiss, 2) transition-rocks and 3) Cretaceous rocks (flint etc.). From his numerous enumerations he came to a clear and full recognition of the great difference between the boulders in the various parts of Denmark. This is distinctly seen by his pointing out that the boulders in the western part of Jutland mainly consist of »transition-sandstone« which corresponds to the rocks in Norway, and that the stones in northernmost Jutland chiefly consist of porphyry, syenite and »transition-sandstone« corresponding to »den Uebergangsgesteinen des nördlich davon gelegenen Christianiasystems«. From later times the literature only mentions enumerations of boulders made by O. MATZ (1903) in eastern Mecklenburg, by J. PETERSEN (1905) on Sylt and later by SCHROEDER and STOLLER (1907) in Holstein. Even though many of the other works, in which the occurrence of indicator-boulders is discussed, contain several explicit statements of the proportionate frequency of the boulders, these determinations have been founded on an estimate only; a direct enumeration has generally not been made.

If we are about to make an enumeration of indicator-boulders in a heap of stones, a field or a gravel-pit, and for practical reasons are prevented from counting all the stones that occur, we are obliged to choose the manner of procedure we want to use. I may first mention the method used by O. MATZ. In the gravel-pit in Stavenhagen wood, where the enumeration was made, the largest stones had been removed for building purposes.

> »Das zurückgebliebene Material, in seinen grössten Partien Blocke von ungefähr Kopfgrösse darstellend, war zusammengelesen und aufgehäuft zu bestimmt abgemessenen parallelepipedischen Gebilden von $^1/_2$ m. Höhe. Da die so untergebrachten Geschiebe

weder mit Kalkkrusten noch mit Eisenoxydhydrat oberflächlich verunreinigt waren, so eigneten sie sich vorzüglich zu einer genauen Auszählung des Gesamtmaterials sowie zu einer Bestimmung des darin inbezug auf seine Heimat Bekannten. Zu dem Zweck habe ich bei fünf der beregten Haufen die Anzahl der auf 1 qm. obere Grundfläche entfallenden Gesteine durch Zählen ermittelt und daraus die Summe sämtlicher der Beobachtung sich darbietenden Gesteine auf dieser ganzen Fläche berechnet. Wenn trotz der nicht unbedeutenden Grösse mancher Gerölle durchschnittlich 120 auf den qm. kommen, so erklärt sich das daraus, dass auch die auf den Lücken der oberen Schicht sichtbaren Gesteine mitgezählt sind«.

The number of stones found in the area of 88 sq. m. subjected to the enumeration, represented altogether 8258 crystalline boulders. Among these 91 were indicator-boulders, the source of which could with certainty be macroscopically determined. These were:

1 »Ångermanland Rapakivi«,
2 Red Baltic quartz porphyry,
22 Brown Baltic quartz porphyry,
17 Åland Rapakivi,
23 Åland granite,
9 Åland quartz porphyry,
4 Påskallavik porphyry,
8 Bredvad porphyry,
1 Scanian basalt and
4 Coarse-grained (Åsby-?) diabase.

It is however a rare exception that the boulders are found thus regularly accumulated in heaps of stones, so that we are able to make even an approximately trustworthy estimate of the aggregate amount of boulders occurring therein. We must generally make enumerations of indicator-boulders under less favourable circumstances than on the above-described occasion. Boulders of the same size as those among which MATZ made his enumeration, are even more rarely available in sufficiently large numbers. As it is of the greatest importance however to make as many enumerations as possible, we are obliged to give up counting the grand total of the stones. This would often take so much time, that we should not succeed in collecting a sufficient number of indicator-boulders of the various types.

In the enumerations of indicator-boulders I have made, the results of which I shall set forth in the following pages, I have therefore only taken into consideration the certain types of boulders I wanted

to enumerate, and which were easily determinable macroscopically, while I have considered it unnecessary to enumerate the rest of the stone-material. I have collected all the indicator-boulders which I was able to find in the course of 1 or 2 hours in an area as small in extent as possible, e. g. a gravel-pit. After having collected all the material required for the purpose, I have made the enumeration. We may raise the objection to this method of collecting the material, that it is not absolutely objective. This difficulty will however be considerably reduced by the collector getting accustomed to scrutinize the various types of boulders he wants to collect and directing his attention principally to these. The influence of the subjectivity will also be greatly reduced if one and the same district is searched several times.

There is another circumstance which may cause some difficulty in the comparison of the various enumerations, namely, the size of the boulders. The main point is to make a certain size of stone the base of the enumerations. It is found that the size of the stones may influence the frequency of the various types of indicator-boulders. Thus the various porphyries from Dalarne and red Baltic quartz porphyry most frequently occur as boulders less than the size of a fist, while stones of these rocks as large for example as the head are only exceptionally found. On the other hand, large stones of rocks from the Åland Islands will be relatively more abundant. As the stones which are smaller than a clenched fist are in several respects better fitted for collection than the stones above this size, I have principally used these for the enumerations. They are also better suited to the purpose on account of their richer occurrence and smaller weight, which facilitates the collection and the housing of the material which has been collected. The fact is that I consider it most important that we do not confine ourselves to making an enumeration on the spot, but that specimens of the material which has been subjected to the enumeration are if possible taken home, especially specimens of kinds the presence of which is a matter of doubt. In this way only do we get an absolutely reliable basis for later critical examination. In investigations of the kind mentioned it is generally much easier to take home specimens of the boulders which have been collected, than to start on another journey to the original place of discovery.

Sealand (and Hven).

From the collections of indicator-boulders made by the Danish Geological Survey it has been found that there is no place in Sealand where Baltic boulders are completely lacking. But it is also seen,

that Norwegian boulders are to be found over the whole of Sealand. Boulders of Norwegian origin principally occur in the northern parts of the island and are very scarce in the southern parts. In the explanation of the sheets Hillerød and Elsinore, K. RØRDAM[1] has thought himself justified in characterizing the »older« moraine-clay in North-East Sealand by its number of Norwegian rocks and its lack of Baltic rocks. Later authors especially in foreign countries have often referred to RØRDAM's characterization. We must however point out, that its correctness has not been proved. Norwegian and Baltic boulders lie side by side in the deposits, but in different quantities.[2]

In the North-Eastern Sealand a comparatively small number of indicator-boulders is found. The character of the boulders may however be of great interest, even though the number is so small that it is of no importance as basis for the proper enumeration.

Hornbæk. Past Horneby south of Hornbæk runs a row of gravel-ridges marked in the geological maps as an ås. In the explanation of the sheet (p. 55—56) RØRDAM pictures a transverse section of the ridge south of Horneby and says that, »above the layers of sand which make the true ridge, there is a more or less extensive cap of coarse, reddish, often clayey moraine-gravel which lacks all indication of stratification and contains boulders of subangular forms and often several meters in diameter«. In 1906 a section in such moraine-gravel was visible south of Horneby. A large quantity of boulders was found, but only a few the source of which could be determined.

Among strand-stones found east of Hornbæk the following indicator-boulders were stated: 5 from Norway, 9 from Dalarne, 9 from the North Baltic territory, and 1 from Småland. It is impossible to determine from which diluvial layers they originate.

Havreholm. Past Havreholm, ca. 4 km. S. W. of Hornbæk there is another ridge, which according to RØRDAM's map is connected with the Hornbæk ås, as the one branch of a horse-shoe arch. It also contains in places many large boulders on the surface. In the explanation RØRDAM says (p. 56, in connection with the above cited): »As it is impossible to get at the interior of the Hornbæk-Havreholm ås, one might be tempted to consider the ås as a real terminal moraine on account of its arched form and the number of large boulders which are embedded in and scattered upon its surface«. At several places in the ridge only normally stratified gravel is seen; north of Havreholm the gravel is somewhat sandy. I have

[1] De geologiske Forhold i det nordøstlige Sjælland. D. G. U. I R. Nr. 1. 1893, p. 16.

[2] V. MILTHERS: Norske Blokke paa Sjælland. Medd. fra Dansk geologisk Foren. 5. 1899.

found several Baltic boulders in various smaller sections, which on the other hand only contained a single Dala porphyry and 1 boulder of rhomb-porphyry conglomerate.

Strødam 2½ km. N. W. of Hillerød. There is a wide hillocky landscape extending east of Hillerød and from there further to the north-north-west; as I have mentioned on a former occasion,[1] it has arisen along a stationary ice-border. Part of the outer bounds of this range of hills is formed by the region near Strødam and by the Gadevang brick-works north of Hillerød, where also the stoneless strata of clay have been displaced by the pressure exercised by the ice. In a gravel-pit near Strødam, where a number of stones, especially small ones, lay unearthed and sorted, I found 5 rhomb-porphyry and conglomerate boulders, 3 Dala, 3 North Baltic and 5 Scanian basalt boulders.

In gravel-layers near Gadevang brick-works 2 rhomb-porphyry conglomerate boulders were found as also 1 boulder of brown Baltic quartz porphyry. In a gravel-pit N. of Lake Grib Sø 1 rhomb-porphyry and 1 conglomerate boulder, but no Baltic boulders.

Hven. In connection with what has been stated as to boulders found in North-East Sealand I may mention a collection and enumeration of indicator-boulders among strand-stones in Hven. Above an extensive sediment-series of stratified clay and sand with so-called »coal-amber-pinlayers« there is a moraine-cover formed by an upper and lower moraine as pointed out by L. Holmström.[2] In the paper referred to it is stated that the lower »grayish black« moraine-clay found in Hven completely lacks boulders belonging to the cretaceous system. This is not the case with the upper moraine-layer. Among 100 strand-stones ca. 2—3 cm. in length, which came from the upper moraine, Holmström found the following number of various rocks:

27 pCt. Crystalline rocks.
13 - Sandstone (among which none belonging to the Lias?).
6 - Lime-stone (from »the Silurian system«?).
19 - Lime-stone from the cretaceous system.
35 - Flint.

And in a collection of stones of double the size he found:

34 pCt. Crystalline rocks.
11 - Sandstone (no Lias«?).

[1] N. Hartz og V. Milthers: Arktisk Ferskvandsler i Allerød Teglværksgrav. Medd. fra Dansk geol. Foren. 8. 1901.

[2] Bidrag till kännedomen af moränbildningarne på Hven och närliggande skånska kust. Geol. Fören. Förh. Stockh. 2. 1874.

2 pCt. »Silurian«(?) lime-stone.
13 - Lime-stone from the cretaceous system.
40 - Flint.

From the absence of lias-rocks and the rich quantity of stones from the cretaceous system HOLMSTRÖM draws the conclusion that this upper moraine has come from the south-east. As to the lower clay-horizon it is »most probable that it has come from the north or north-east«.

The crystalline indicator-boulders which formed the basis of my enumeration were collected in front of the cliffs north of St. Ibb's Church on the north-west corner of the island. We find here extensive layers of stratified sand of the same layer-series which forms the main mass of the island and which at its north-east corner is said to reach 85 M. below the level of the sea, where it rests upon the cretaceous lime-stone. These sand-layers contain no stones. In the north-west coast-cliff they are covered by moraine-clay, which as far as can be seen is completely or mostly composed of the same material as the upper Baltic moraine. The clay contains a number of large and small boulders which form the origin of the strand-stones. Among the 108 boulders which were subjected to enumeration were found: 93 North Baltic, 1 Påskallavik porphyry, 10 Dala porphyries and 4 rhomb-porphyry conglomerate boulders. 5 boulders of Scanian basalt were also found, but these were far more richly represented than the other kinds; they were collected to a much less extent. Finally, a large number of Kinnediabase boulders were found; this kind of boulder is also generally of frequent occurrence in North-East Sealand.

The above-named group of stones, of which more than 7/8ths are of Baltic origin, and HOLMSTRÖM'S enumeration of stones prove that the upper moraine is distinctly Baltic. The older moraine which HOLMSTRÖM mentions has however also marked the character of the boulders. Besides the remarkable occurrence of Norwegian porphyry conglomerates, some Dala boulders which are of a special interest — apart from those mentioned in the enumeration — were found. 7 boulders in all were found of the rock-type from Dalarne, which has been mentioned under the name of Heden porphyry, viz. 2 of the small-grained variety and 5 of the coarse characteristic Heden porphyry. Of these 5 there is one however which has some similarity to the brown felspar porphyry to the nørth in Lima parish. On the other hand the usually very common boulders of Bredvad porphyry and Grönklitt porphyrite were only scarcely represented. One boulder of »Kåtilla« was found besides the one mentioned in the enumeration.

There is reason here to notice the comparatively large quantity of »Heden porphyry« from Western Dalarne. It is a rock which is not frequently found in the form of boulders. Together with the Norwegian conglomerate boulders and the Kinnediabase boulders, they show that an extensive transference has taken place along the west coast of Sweden, and there is reason to believe that they originate from the lower moraine which is poor in flint and lime-stone.

We may now return to North-East Sealand.

Freerslev S. W. of Hillerød. As soon as we get a little west of the ridge of hills near Hillerød and outside the territory of the glacial invasion, in which the ridge lies, the form of the ground varies and a collection of boulders near Freerslev railway station shows that there is also a difference in the composition of the various boulder-groups. In a gravel-pit here 2 rhomb-porphyry, 5 Dala, 12 North Baltic and 2 Scanian basalt boulders were found. Thus, the Baltic element is in the majority, but here as well as in the previously mentioned places in North-East Sealand the number of indicator-boulders was comparatively small.

Strø Bjerge by Ølsted. From the village Ølsted which lies between Frederiksværk and Frederikssund a very prominent ridge called Strø Bjerge extends in a south-easterly direction. Near Ølsted railway station there is a deep cut in the ridge which has provided gravel for the construction of the Hillerød—Frederiksværk railway. Flint boulders are richly represented; 4 Norwegian, 23 Dala, 21 Baltic and 2 Scanian basalt boulders were also found among the numerous stones in the gravel-pit.

The strand-cliffs south of Frederiksværk. The strand-stones found along the high cliffs south of Frederiksværk (west of Kregome) have originated from various layers, which are to be seen in the cliffs. These layers are formed by three horizons: 1) lower moraine-clay which is generally very poor in stone and for the most part rubble-clay; in all probability only a comparatively small number of the strand-stones originate from this clay; 2) sand- and gravel-layers which may most probably be considered as having been deposited at the same time as the last ice there, washed out partly from the moraine material of this ice, partly from the underlying layers. They generally consist of sand and do not contain large gravel-layers; in all probability most of the strand-stones however originate from them; 3) upper moraine-clay which is only of any great thickness at a few places, nevertheless several of the strand-stones probably originate from it.

The three horizons lie fairly normally above each other. While Rørdam as a matter of course considers that the »lower« moraine-clay

in North-East Sealand has been deposited by a north-to-south-going ice-current, N. V. Ussing in his textbook of Denmark's geology says,[1] that in the region south of Frederiksværk the two moraines which are laid bare in the cliffs facing Roskilde Fjord seem to originate from the Baltic ice-current.

Among the strand-stones which have come from the moraines and the interjacent fluvio-glacial horizon I collected the following boulders: 96 Baltic (Åland and Northern Baltic) porphyry, 4 Påskallavik porphyry, 3 Scanian basalt, 28 Dala and 6 Norwegian boulders. The large quantity of Baltic boulders found here is principally due to the rich abundance of a certain rock, namely the brown Baltic quartz porphyry. Among the 96 boulders from the North Baltic district and Åland, 49 consisted of brown Baltic quartz porphyry; on the other hand, only 4 boulders of red Baltic quartz porphyry were found, the same number as I obtained among 21 Baltic boulders in the gravel-pit near Ølsted. The preponderance of Baltic boulders is however remarkable, and nothing supports the supposition that one of the two moraines has been of a distinctly northerly origin. The preponderance of the Baltic character is conspicuous along all the 8 km. long, steep cliff and must be considered as correctly representing the character of the separate horizons.

Farum. Near Farum lime- and crushed-stone-works there are large gravel-pits where a collection of indicator-boulders may be made with advantage. A very large number of the boulders are however of sedimentary origin. In a collection made here 19 Baltic, 32 Dala and 1 rhomb-porphyry conglomerate boulder were found; thus only a little more than a third of all the indicator-boulders were of Baltic origin. The fact that Dala boulders are in the majority is seen not only from their comparatively large number but also from the presence of the various types: of all the 11 main-types of Dala boulders, 8 were found again by Farum.

Roskilde. Near Roskilde there are extensive gravel-deposits which are normally covered by the moraine-clay of the last ice-sheet, as is also the case near Farum. The gravel contains a large number of boulders of the Danian and Paleocene stages from the underground east and south-east of Roskilde. A collection gave the result that the following indicator-boulders were found: 21 Baltic, 9 Scanian basalt, 34 from Dalarne, 11 rhomb-porphyry and conglomerate. It is thus seen that Norwegian and North Swedish material is in still greater preponderance at Roskilde compared with the Baltic than was the case by Farum. Not even a third of the indicator-boulders is purely North

[1] Danmarks Geologi. D. G. U. III R. Nr. 2. 1899, p. 196.

Baltic. In the gravel-pit near Hedehusene railway station, where an exact enumeration however has not been made, the various boulders occur in approximately the same proportion as at Roskilde. Striated boulders[1] at Hedehusene show that the last ice-cover has here been moving in the direction from S. E. to N. W., a fact which is in full agreement with other well-known conditions here. The many sedimentary boulders in the gravel-layers from the prequaternary underground east of Roskilde indicate that the gravel has also been deposited in connection with an ice moving in a westerly direction (Baltic ice). But all the more remarkable therefore is the large quantity of Norwegian and Dala boulders found in the gravel-layers. They show that previous to the invasion of the Baltic ice-current there has been a quantity of northern, Norwegian and West Swedish material, from which the water appearing in connection with the succeeding ice-cover could separate the gravel-layers. Now it may have been a similar foundation of northern material which formed the origin of the large number of Dala boulders found near Farum gravel-pit.

Vangede-Gentofte. In a gravel-pit of large extent near Vangede west of Gentofte I have collected the following boulders: 32 Baltic (Åland and Northern Baltic), 1 Påskallavik porphyry, 2 Scanian basalt and 13 Dala boulders. Three-fourths of the whole number or thereabout are Baltic and only a little more than one-fourth Dala boulders. The great preponderance of Baltic boulders is wholly due to the two kinds of Baltic quartz porphyry, of which 11 boulders of the red and 19 of the brown were found, while the Åland boulders were only represented by 2 quartz porphyries. Taking into consideration that a great number of boulders of the same kind may locally appear by the breaking of a single or a few large boulders, it is possible that the apparently great preponderance of Baltic boulders does not mean an exactly corresponding preponderance of Baltic material compared with northerly material. It is however certain that the moraine-clay deposited upon the gravel-layers at Vangede is fully Baltic, as is also the moraine-clay at Roskilde. In stratigraphical respect the gravel-layers at Vangede and Roskilde are of almost the same age; this is also the case with the covering moraine-layers at the two places. They have arisen in connection with one and the same glacier-border.

If we bring together the impressions obtained from the above enumerations, it will be difficult to get from these a fundamental and clear idea of the way in which the various gravel-layers have been

[1] G. F. L. Sarauw: En Belægning af isskurede Blokke i Nymølle Grusgrav ved Hedehusene. Medd. fra Dansk geol. Foren. 10. 1904.

formed. This is principally due to the fact that the places in Sealand at which the enumerations were made, have been greatly cut across by ice-currents from different sides. Instead of assuming that the conditions in the northernmost Sealand so far as the drift deposits are concerned are specially »clear« — the opinion expressed by K. Rørdam[1] — there is reason to point out that these deposits display a richness of variations much greater than is usually found in such a small territory. The occurrence of boulders here cannot be explained by means of the investigations of indicator-boulders alone, but together with the study of other conditions these contribute to the solution of this question. The changing in the directions of the ice-currents, which has taken place during the time when the ice-cover was melting away from North-East Sealand, has caused the many separate variations which are represented by the varying occurrence of boulders, even at places which lie near each other. These changing ice-currents have also influenced the surface and the general contents in the moraine-clay, as is shown by stone-enumerations. To enter into further discussion of this subject would however be too much outside the purpose of the present investigation. The object of the work has only been to emphasize, that the great variation in the occurrence of the boulders and other conditions indicate that North Sealand at the end of the Glacial Period has arisen as the product of ice-currents which advanced at different times from the north-east, the south-east and the south respectively.

Before ending the special discussion of North-East Sealand I may call attention to the occurrence of basalt boulders. As might be supposed they are fairly common, because the transport of the North Baltic boulders has partly taken place by way of Scania. The basalt boulders have thus been carried down either directly or by radiating ice-currents, first carrying them southward from their source to be afterwards received in the Baltic ice-currents. In the mapping of North Sealand a comparatively large number of boulders were collected but they are not specially noted in the explanation of the geological sheets (by Rørdam).[2]

Southern Sealand. Ice-currents of Baltic origin have almost exclusively marked the character of the boulders in this part of the island. A few Norwegian boulders hawe been found as strand-stones near Stevns.[3] The group of crystalline indicator-boulders is mainly

[1] Oversigt over de af Danmarks geologiske Undersøgelse indtil Foraaret 1895 udførte Arbejder. D. G. U. III R. Nr. 1. 1896, p. 16.

[2] See J. Petersen: Geschiebestudien II. Mitth. d. Geogr. Ges. in Hamburg. 16. 1900, p. 133.

[3] V. Milthers: Kortbladene Faxe og Stevns Klint. D. G. U. I R. Nr. 11. 1908.

Baltic. The brown Baltic quartz porphyry is again by far the commonest of the Baltic boulders. Of frequent occurrence are also the red Baltic quartz porphyry and the various Rapakivi rocks from Åland. Påskallavik porphyry is not richly represented, and boulders of Scanian basalt are scarce in South Sealand. Boulders from Dalarne are not infrequent, especially Bredvad porphyry and Grønklitt porphyrite, but they are far from being as numerous as the Baltic boulders.

An exact enumeration of boulders in a single deposit has only been made in fluvio-glacial layers near Vordingborg railway station. The following boulders were found: 10 Dala, 25 North Baltic, 1 Påskallavik porphyry and 3 Scanian basalt boulders. The number of Dala boulders found here is hardly so great that they may not have been brought down by the Baltic ice-currents across the middle part of Sweden and through the Baltic valley.

North-Western Sealand. The coasts of North-West Sealand facing the Kattegat like the Kattegat coasts of North-East Sealand show many boulders from the Christiania district. From the moraine-mass in which they were originally embedded they have passed into the gravel and moraine-clay which also contain Baltic material. Inland we find Baltic boulders in all the gravel-layers we know, but in certain districts they are in the minority compared with material of northern origin. The mass of northern Quaternary material, the presence of which is proved by the collections near Farum and Roskilde, may be traced further to the west in Sealand. Even though the later ice-currents were for the most part of Baltic origin, the older material of northern origin already deposited was able to mark the character of the rocks found in the deposits..

Stenlille. Past the village of Stenlille runs a long ås containing large sections. The material consists of sand and large or small gravel-layers. The ridge goes from south to north. The following boulders were collected there: 1 rhomb-porphyry conglomerate, 39 from Dalarne, 22 North Baltic, 4 Påskallavik porphyry and 1 basalt boulder. It is seen from this that north-eastern material is in great preponderance. I have formerly stated the occurrence of rhomb-porphyry in a gravel deposit near Vilsted 5 km. S. E. of Stenlille.[1]

Blæsinge Bakker. 6 km. north of Slagelse a rising ground projects from the surrounding level. This is the Blæsinge ridges which mainly consist of fluvio-glacial sand with small gravel-layers partly covered by a moraine-cap. In the gravel-layers I found the following boulders: 1 Norwegian porphyry conglomerate, 11 from Dalarne, 9

[1] V. Milthers: Norske Blokke paa Sjælland. Medd. fra Dansk geologisk Forening. 5. 1899.

North Baltic and 1 Scanian basalt boulder. The small number of indicator-boulders found here thus show a slight preponderance of stones of northern origin.

The comparatively large quantity of northern material found in the gravel-layers at Stenlille and in the Blæsinge ridges is probably due to the older deposits coming from the north, from which later ice- and water-currents have carried the boulders. Even the upper moraine has a Baltic character just as further to the north.

Bjergby near Mørkøv. The landscape just south of Lamme Fjord is formed by a distinct moraine-level above which rise a number of large and small conical hillocks, the interior of which consists of gravel-layers generally of a sloping and irregular stratification. A cap of moraine-clay composed of almost the same material as the surrounding moraine-clay is deposited upon the gravel-layers. South of this level, between it and the large Aamose (river-bog), lies a high, hillocky landscape frequently containing gravel-layers of the same character as that of the conical hillocks. In both places the gravel-layers hardly contain any Baltic boulders, a condition rare in Sealand.

In a gravel-pit in Kirkebjerg 1,5 km. N. E. of Bjergby containing a large number of stones, especially small ones, I made an enumeration of indicator-boulders which were only sparsely represented compared with the quantity of other boulders. Altogether, the following were found: 3 North Baltic, 6 Dala, 8 Norwegian boulders (4 rhomb-porphyry and 4 conglomerates [and 3 possibly Norwegian]), 4 Scanian basalt and some boulders of Kinnediabase. Several boulders of the variegated flint from Christiansstad in Scania were found in the same kind of layers, both in these conical hillocks and in the hilly landscape further to the south.

The rocks in the gravel-layers of Kirkebjerg are thus of a distinctly northern character. Baltic boulders are scarce in these gravel-layers as also in the gravel-layers of the prominent ridges scattered over the moraine-level south of Lamme Fjord. It has also been found that Baltic boulders are scarce in the gravel-layers in the hilly ridge south of the railway-line Mørkøv—Jyderup. Gravel-layers of a similar kind as those near Kirkebjerg are often to be met with. At both places the character of the boulders indicates a considerable inflow of material from northern regions.

Odsherred. The moraine-deposits and gravel-layers in Odsherred between Sejrø Bugt and Isefjord contain boulders of northern as well as of south-eastern origin. Along the Kattegat shore Norwegian boulders are fairly common, but boulders of Baltic origin are also to be found in great numbers. Through Odsherred ex-

tends a distinct tract of curving marginal moraines.[1] Near Lyng-huse at Grevinge, where two moraine-curves meet, a gravel-pit was opened for the purpose of providing material for the construction of the Odsherred railway; it contained a large number of small and large boulders. An investigation shows that indicator-boulders are however almost completely lacking. A single Rapakivi-like quartz porphyry from Åland, a few Scanian basalts, a couple of porphyries from Dalarne were found, but the number of the ordinary indicator-boulders is extraordinarily small compared with the number usually found in places where crystalline boulders are in abundance. Elsewhere in the gravel-layers of Odsherred, along the marginal moraines, there is the same comparatively sparse occurrence of indicator-boulders. Between Højby and Svinninge some boulders of rhomb-porphyry and conglomerate were found, but boulders from Dalarne and from the district round Åland are generally of a strangely infrequent occurrence.

The comparatively small number of the usual indicator-boulders shows that the moraines, from which the boulders originate, have received no considerable inflow of material from the sources of the indicator-boulders, not even from Dalarne and the Baltic district, which generally either jointly or separately are richly represented by indicator-boulders. There is reason to believe that the sparse occurrence of these boulders in Odsherred is due to the fact, that the main-inflow of material there has come from Scandinavian districts which lie nearer than the above mentioned, namely e. g. from the western part of South Sweden.

The curved marginal moraines extending through Odsherred show that for a time the melting of the retreating inland-ice stopped altogether. From Poul Harder's investigation of »an East Jutland ice-edge line«[2] we also learn that, when the ice covered all Sealand and the ice-border was found in South-East Jutland, the retreat of the inland-ice was marked by stoppages or advances. The ice-current, in front of which this ice-edge line has left its marks, has brought a great quantity of Baltic material to the Grenaa peninsula, as will be mentioned later. Harder also points out that the ice-lobes, the outer boundary of which was the ice-edge line discovered by him, have been supplied with material from an ice-current through the Baltic. As the ice gradually melted away in the territory between the Grenaa peninsula and Odsherred, we may suppose that the inflow of Baltic ice has decreased, whilst there was an increasing inflow from

[1] See D. G. U. I R. Nr. 8. 1900. p. 69 ff.

[2] En østjydsk Israndslinje. D. G. U. II R. Nr. 19. 1908.

the western part of South Sweden, from Halland and the western parts of Småland. Only in this way can we explain why the gravel-layers which are in close connection with the deposits near the ice-border are almost destitute of indicator-boulders of Baltic origin. And in this way also we may explain the absence of Dala boulders. From the older Quaternary layers containing large numbers of these boulders they might have passed into the later deposits irrespective of the directions of the ice-currents. The non-occurrence of Dala boulders in the later deposits proves however that these boulders were not found in the older layers from which the marginal-gravel may have received material, and that the glacier which deposited the gravel-layers did not contain material from Dalarne. The kind of boulders found near Lynghuse and elsewhere in Odsherred and those occurring in the gravel-layers south of Lamme Fjord show that there has been a change in the directions of the ice-currents; West Swedish and northern masses of ice displaced the Baltic. While the ice later gradually melted away, North-East Sealand was also invaded by changing ice-currents alternately coming from Western Sweden and from the Baltic as already mentioned before.

Agnsøgaard. The curved marginal moraines extending through Odsherred end near Vejrhøj. But west of Følleslev and Jyderup we find a continuation of the same, traceable southward to Bjergsted Bakker west of Skarrid Lake. But further to the southwest we see no trace of the »Isefjord-glacier« which has deposited the moraine-curves of Odsherred. Here and further to the south along the Storebelt, we find however the traces of a »Storebelt glacier« which has advanced from the south. A stone-enumeration made in gravel-pits near the railway-line east of Agnsøgaard shows that the influence of the Baltic currents has been greater here than in Odsherred. 1 rhomb-porphyry, 14 Dala, 15 North Baltic and 1 Påskallavik porphyry boulder were found. The Dala boulders which were found have probably come from older deposits, afterwards passing into the younger layers in which they were found. At many places we find evidence that such older layers with northern materials have been present from an earlier period of the Glacial Age. I need only mention here the boulders found at Stenlille and Roskilde, where there is no doubt that the last ice-cover has come from the Baltic district, while the northern material has been taken up from older drift-deposits.

From other investigations we come to the conclusion that the varying direction of the movement of the ice-currents during the time when the melting of the ice took place has strongly marked the character of the Quaternary layers and the boulders of Sealand. Lying between the Kattegat and the Baltic the island was subjected alternately

to invasion from the north and north-east and from the south and south-east during the whole time when the melting was going on. The study of the occurrence of the indicator-boulders is in agreement with the results we come to from the form of the country and the character of the deposits.

Funen and Langeland.

On Funen and Langeland — just as on Sealand — there is no spot where Baltic boulders are lacking. From what we have learnt in the preceding of the conditions on Sealand, it is clear, that there is here also the possibility of everywhere finding boulders of Norwegian origin. Discoveries of rhomb-porphyry at Ristinge Klint on Langeland have been known for a long time. Explanations to the geological sheets of Funen prove, that Norwegian boulders are very rare in North Funen, but more common in the country south of Odense—Kjerteminde and boulders of this origin have been found at several places on the surface. The character of the surface moraines is however chiefly Baltic. In 1906 I made some enumerations in gravel-pits on Langeland and Funen.

Rudkøbing. In the neighbourhood of Rudkøbing several gravel-pits are found in the numerous and pointed hillocks. The position of the gravel-layers in the hills is almost always very inclined often quite vertical, the same as is the case in the hills south of Lamme Fjord on Sealand. But the composition of the stones in the gravel at these two places is very different. Whilst the character of the stones in the hills between Bjergby and Kundby is chiefly West Scandinavian the nature of the stones in the hillocks surrounding Rudkøbing is preeminently Baltic. In two gravel-pits south-east of Rudkøbing I found 30 North Baltic boulders (of which 19 were brown Baltic quartz porphyry, but no red Baltic quartz porphyry), 7 porphyries from Småland (Påskallavik porphyry). 27 porphyries from Dalarne were found belonging to 9 different varieties. I only found 1 Norwegian boulder which possibly may be an amygdaloidal stone from the rhomb-porphyry region. Later I shall speak about the result of this collection of stones when the discoveries from Funen have been mentioned.

In the neighbourhood of Svendborg there is a lot of large deposits of gravel containing many sections. I have collected boulders in the gravel-pits at Hømark south-west of Troldmose wood, in the northern part of Langebakke and in a large gravel-pit north of Christiansminde; an enumeration has also been made in a gravel-pit at Høje Bøge. As the result with regard to the crystalline boulders was everywhere quite similar, they can be mentioned together.

The character of the moraine which covered the gravel layers east of Svendborg is distinctly Baltic, many North Baltic boulders being for example seen on the surface. The condition is different however in the gravel-pits. 21 North Baltic boulders were collected here, and 71 boulders from Dalarne (of almost all the varieties known as boulders), 14 boulders from the neighbourhood of Christiania (of which one Syenite) but no Gang-porphyry from Småland. 1 basalt boulder was found and many boulders of Kinnediabase. The result of the enumeration made in the gravel-pit at Høje Bøge west of the town was: 2 rhomb-porphyries, 18 porphyries from Dalarne (8 varieties), 7 North Baltic boulders (all from Åland) and 1 basalt boulder.

The difference between the stones in the gravel-layers at Svendborg and at Rudkjøbing is thus striking. The Baltic character, which is preeminent on Langeland, is much less distinct in the gravel-layers at Svendborg. The majority of the indicator-boulders have come down over West Sweden. The country further to the north shows the same character, namely, at

Kirkeby Station. An extensive gravel-pit in moraine gravel belonging to the surface layers is found here. It contained 9 North Baltic boulders, 1 Gang-porphyry (without quartz grains) from Småland, 1 basalt, 24 Dala porphyries and several boulders of Kinnediabase.

Vantinge ås. South-west of Ringe some extensive, distinct ridges of gravel are found, cutting across each other north-west of Espe Station almost at a right angle. The ridge in the direction N.—S. is Vantinge ås and has been described by V. MADSEN in the explanation of Nyborg sheet.[1] Whilst the layers in many of the other åses on Funen are inclined or vertical, the situation of the layers in Vantinge ås is everywhere undisturbed. It cannot be seen from this explanation, how this row of hills has been situated in relation to the margin of the melting ice-cover. The stones show a transition from the conditions at Svendborg and at Kirkeby Station to a more Baltic character, which grows still more distinct in the åses farther northwards. Several extensive sections, containing however essentially fine-grained, sandy material, are found in Vantinge ås. The following boulders were found in three gravel-pits in the neighbourhood of Tillebro 2 km. N. W. of Espe station: 55 North Baltic, 1 Påskallavik porphyry, 3 basalt, 74 Dala porphyries, 12 rhomb-porphyries and porphyry conglomerates and several boulders of Kinnediabase.

Højby ås extends south-west—north-eastwards past Højby Station between Odense and Ringe. It has the perpendicular layers characteristic of many of the åses on Funen and also known in

[1] D. G. U. I R. Nr. 9.

similar formations on Sealand. In gravel-pits north of Højby Station the following boulders were found: 29 North Baltic, 1 Gang-porphyry (Påskallavik porphyry) from Småland, 5 basalt, 31 Dala porphyries (only some few varieties) and 5 Norwegian.

Grindløse ås like Højby ås consists of a long row of ridges, more or less high, which begin at Guldbjerg Station south-east of Bogense, pass Grindløse north-eastwards and end at the southernmost part of Klinte beach. Perpendicular layers are also found in this ås. Gravel-pits in different parts of the ås contained the following boulders: 24 North Baltic, 2 Påskallavik porphyries, 2 basalt, 29 Dala porphyries (many varieties) and 2 Norwegian boulders. The proportion between indicator-boulders of Baltic and northern origin is per cent almost the same as at Højby ås.

The result of these enumerations of indicator-boulders shows, with regard to East Funen, that on approaching Svendborg the relative number of the northern boulders is constantly increasing. At this town — and possibly everywhere in the highly situated parts of South Funen — it is evident that the material of the gravel-layers has essentially been brought from the north during a part of the Glacial Period which was a little earlier than the final part. As is the case in the interior part of Sealand, a glacial kernel of northern origin is also noticed here, from which the later Baltic invasion of ice has taken the northern elements of the boulders in the moraines. As stated, the explanations of the geological sheets also mention the preponderance of Norwegian boulders in South Funen in proportion to those in North Funen. With regard to the southernmost districts of Funen and the neighbouring islets V. Madsen[1] mentions, that Norwegian boulders are »not so rare but that there is the possibility of finding some few specimens after careful search on every excursion to the coast«. As we have seen, 1 stone of Norwegian origin can be found in the gravel deposits at Svendborg for every 2 North Baltic indicator-boulders. The northerly character is still more distinctly perceptible from the extreme richness of Dala porphyries, as regards both the number and occurrence of different varieties. The result is, that we can state with certainty the direct transport of material over West Sweden to these parts of Denmark and farther to the south-west. It is evident, that only a small minority of the Dala porphyries have been brought by the Baltic route.

As has been indicated before, the character of the moraine-covering of these gravel-layers is more distinctly Baltic and possibly more related to the preeminently Baltic deposits in the northern part of Funen than to the subjacent gravel deposits. The Baltic character,

[1] D. G. U. II R. Nr. 15.

which is seen in the åses in North Funen with their diminishing number of Norwegian kinds of stones, is, as the explanations of the sheets show[1], still more distinct at Hindsholm and in the neighbourhood, where Norwegian boulders are very seldom. An exact statistical investigation of the stones has however not been made here, but enumerations of stones in the moraine-clay show a decided contrast to the localities in Central and South Funen, the moraines at Hindsholm being relatively poor in rocks from the cretaceons formation whilst such rocks are found abundantly in the rest of Funen in comparison with those brought down from the far-off parts of the Baltic or from the Swedish continent (palæozoic limestone, sandstones, eruptives and crystalline slates) a contrast, which may well be connected here with the absence of Norwegian boulders.

As mentioned there is a decided difference between the boulders from the gravel-pits at Rudkjøbing and those at Svendborg, a difference which shows itself in different ways. Besides the distinctly Baltic character of the layers at Rudkjøbing in contrast to those at Svendborg, I may specially draw attention to the great number of porphyries from Småland in the gravel-layers at Rudkjøbing. If this relatively large number of boulders from Småland may be considered a picture of the stones of this kind in the Langeland hills, it is evident, that material from the eastern Småland and the adjacent parts of Sweden and the Baltic, has been carried down to a more than usual extent to these gravel-layers on Langeland. In connection with this the investigation which has been made by K. A. Grönwall[2] of fossil-bearing boulders from Langeland, South Funen and Ærø is interesting. The result of this investigation is, that the boulders on Langeland »which originated from south-eastern Scania, Bornholm and the surrounding parts of the Baltic, are absolutely predominant in comparison with the boulders carried a farther road, for instance, from Gothland and the East Baltic; whilst boulders from the East Baltic are in the majority and boulders from south-eastern Scania and Bornholm are very rare in South Funen.«

As I have only made collections of boulders at Svendborg, the present studies of the crystalline boulders do not offer any means of understanding the fact, that the localities along the coasts of South Funen and the neighbouring islands, where Norwegian boulders especially are found, are at the same time the places where Baltic boulders of distinctly eastern origin occur. In the neigbourhood of Svendborg I have however not found any porphyry from Småland, but on the contrary basalt boulders from Scania.

[1] D. G. U. I R. Nr. 2, 7 and 9.
[2] D. G. U. II R. Nr. 15.

With regard to Langeland the result of GRÖNWALL's investigation is confirmed by the great number of porphyries from Småland at Rudkjøbing. GRÖNWALL has determined south-eastern Scania, Bornholm and the adjacent parts of the Baltic as the native place of a great number of Langeland's sedimentary boulders. From this native place the boulders have no doubt been carried first in a south-westerly direction and thereafter to the west, passing the neighbourhood of Laaland to the place where they have been deposited. The glacier-stream which carried these boulders away from their home has then — passing the surroundings of Bornholm — been in the direction N. E. to S. W., that is: according to the direction of Bornholm's earlier »striæ«. — In other words, the glacier-stream, which picked up the boulders from south-eastern Scania and the surrounding parts of the Baltic, came from the South Swedish highlands, from Småland and Blekinge. Not before the glacier-stream had arrived into the Baltic basin was it taken up in the true Baltic stream and carried off westwards. In this way may naturally be explained both that the deposits on Langeland contain numerous sedimentary boulders from the region mentioned and that the number of the Påskallavik porphyries is so great. But whilst GRÖNWALL finds in the material mentioned evidence that the Langeland moraine material »has only been carried a proportionally short distance«, many boulders, especially brown Baltic quartz porphyry, have been found in the gravel-layers investigated, which prove a transport from far off. The great number of this kind of boulders together with the absence of red Baltic quartz porphyry in the gravel-layers at Rudkjøbing is quite according to GRÖNWALL's statement, that East Baltic sedimentary boulders are lacking on Langeland.

Wherever the Dala boulders appear in large quantities and in many varieties we are also certain of finding boulders of Kinnediabase. It is quite natural that these have been included in the ice-masses which moved down from Dalarne in a direct line over West Sweden and Central Denmark.

Another kind of stone, found at almost all the places investigated, is basalt from Scania. It is not probable, that these boulders have been carried quite straight from their native places to where they have been deposited. It may be supposed, either that they have been brought by a glacier-stream passing radially from the source into the Baltic basin and from there with Baltic ice to their resting places (consequently like the boulders from Småland) and this is the most probable, or they have been carried by a Baltic ice-stream from Scania north-westwards passing Sealand and then south-westwards to the places where they have been deposited.

Jutland.

However great the contrasts may be in the distribution of the boulders on the Danish islands, they are much surpassed by the contrasts found in this respect among the different parts of Jutland. To facilitate the general view, the parts of Jutland treated here are divided into three regions: 1) North Jutland, north of the outwash-plains (Hedesletter) and Randers Fjord, 2) East Jutland (mainly east of the great outwash-plains) and 3) the West Jutland hilly regions (Bakkeøer).

North Jutland north of the outwash-plains and Randers Fjord. Only Vendsyssel has been more exactly investigated in this part of Jutland. From the works of Forchhammer, Deichmann-Branth and Johnstrup it is known that boulders from the Christiania neighbourhood here constitute the majority of the stones. Systematic investigations made later have partly confirmed this, partly shown that boulders of Baltic origin also appear in the Vendsyssel deposits. A. Jessen has given complete information on this in the explanations of the sheets.[1] Besides the Christiania boulders many boulders of Dala porphyries have been found; they »are more common than the Baltic rocks, but their number is less than that of the stones from Christiania Fjord«. The boulders from these different native places are found beside each other in the diluvial gravel, the origin of which is fluvio-glacial. On the other hand, there have not yet been found any Baltic rocks in the stony Yoldia clay, by Jessen called »the lower Diluvium«.

I have only made enumerations and collections of boulders at a few places in Vendsyssel.

Flamsbakke S. S. W. of Aasted Church ca. 9 km. W. S. W. of Frederikshavn. Stratified gravel containing shell-fragments is found here covered by moraine-like gravel. Among the large number of boulders in the gravel-pit 190 Norwegian rhomb-porphyries and porphyry conglomerates, 17 Dala porphyries (most of the known varieties) and 10 North Baltic boulders were found.

Skansebakke (redoubt hill) N. of Nørre-Sundby contains large profiles of diluvial stratified gravel and extensive gravel-pits with a lot of small stones. The result of the investigation was: 220 Norwegian rhomb-porphyries and conglomerate boulders, 32 Dala porphyries (as at Flamsbakke almost all the known varieties) but only 6 North Baltic boulders.

The North Baltic boulders found on these occasions have mostly been from Åland (at Flamsbakke also a boulder of red Baltic quartz

[1] D. G. U. I R. Nr. 3 and 10.

porphyry). JESSEN however has at many places discovered both brown and red Baltic quartz porphyry (Rödö quartz porphyry) and I have also at other places been able to find boulders of these kinds. In addition to this JESSEN has made discoveries of Påskallavik porphyries from diluvial gravel in Vendsyssel.

Svinkløv. Among strand-stones here the following indicator-boulders were collected: 60 rhomb-porphyries and conglomerates, 19 from Dalarne and 4 North Baltic.

Hanstholm. Among the stones on the beach the following were noted: 56 of rhomb-porphyry and conglomerate, 28 from Dalarne and 3 North Baltic.

Bislev 4 km. S. of Nibe. In some small gravel heaps from the hills west of the village of Bislev I have found the following boulders: 69 Norwegian, 11 Dala boulders and 9 North Baltic. All the boulders were but small generally a hen's egg in size and they originated evidently from fluvio-glacial gravel.

Ræbild W. of Skjørping Station. West of Skjørping Station a very beautifully developed row of marginal moraine-ridges extends in the direction S. S. E. to N. N. W. Westernmost in this region, where the separate ridges are more isolated than in the central parts of the area, I have collected several indicator-boulders in a gravel-pit. The deposit consisted of stones a hen's egg in size, packed close together, intermixed with a finer yellow material, moraine gravel formed by fluvio-glacial material. The result was: 150 Norwegian rhomb-porphyries and conglomerates (besides other Norwegian rocks) 20 Dala porphyries, 11 North Baltic boulders and 1 Påskallavik porphyry.

Langaa. At Langaa station in the Gudenaa valley's river basin, which originates from a late-glacial epoch, a large gravel-pit occurs, of which the public railway has the use. Easternmost in the long section we find uppermost a pebble bed with almost unsorted gravel above sandy, stratified material; westernmost very stony layers appear in the lower parts of the section, but the material is well sorted and much rolled. The stones, which form the basis of the enumeration, were usually larger than a fist. 114 Norwegian indicator-boulders, 16 Dala boulders, 15 North Baltic boulders, 1 basalt and 16 boulders of Kinnediabase were found.

Møldrup—Hvam, North of Viborg. In 1905 I was a member of an excursion to the country between Møldrup station and Hvam station, on which occasion 13 Dala boulders and 5 North Baltic boulders were collected. The number of Norwegian indicator-boulders, especially rhomb-porphyries, observed in the same district in stone heaps or on fields, where the boulders named were collected, amounted to almost one hundred.

Bovbjerg. In the northern part of the Bovbjerg cliff, from the lighthouse to Ferring, moraine clay is observed in the whole height of the cliff. In the southern part of the cliff, from Trans to the lighthouse, where indicator-boulders were collected and counted, two horizons of moraine clay occur, separated by enormous layers of gravel and sand, the position of which is almost horizontal and undisturbed. The characteristic of the gravel is its large quantities of white flint. The moraines contain many limestones. Among the stones on the beach the following indicator-boulders were collected: 410 rhomb-porphyries and conglomerates from the Christiania neighbourhood, 26 Dala boulders, 4 North Baltic boulders and some few boulders of Kinnediabase. The result of a collection made at another part of the beach, where the numerous Norwegian kinds of stones were not counted, but only the Swedish and Baltic boulders, was: 38 Dala porphyries, 13 North Baltic boulders, 1 Påskallavik porphyry and 3 boulders of basalt from Scania. As the boulders were collected among the stones of the beach, they may have been washed out from all the different layers visible in the cliff, both from the upper and lower moraine clay as from the interjacent gravel-layers.

A gravel-pit 1 km. east of Lomborg Church south of Lemvig. The high road from Ramme station to Rom Church south of Lemvig passes the northernmost part of Kronhede. This is an outwash-plain, which as N. V. Ussing has stated was formed in front of an ice-margin, which was situated along the northern boundary of the plain. Behind — north of — the plain we find a characteristic moraine-landscape with small hillocks with quite the same character as on the Danish islands. In the explanations of the Aalborg and Nibe sheets A. Jessen[1] states, that »the formation of the ground and the whole landscape in south-eastern Jutland and on the Danish islands is quite different from that in West and North Jutland«. But this is only the case to a small extent in the country north of Kronhede. The country between Lemvig and Dybe Church is especially characteristic in that respect: a landscape with low ridges of moraine clay, with steep slopes and kettle-formed or irregular small lakes and peat bogs. The outwash-plain south of this country consists of gravel and sand; in the gravel-pit near the high road east of Lomborg Church stratified gravel containing a large quantity of white flint appeared in the section, $1^1/_2$ m. in height. The indicator-boulders found here were: 171 rhomb-porphyries and Norwegian conglomerates, 13 Dala porphyries, 2 North Baltic boulders and some few boulders of Kinnediabase.

[1] D. G. U. I R. Nr. 10. p. 82.

All the discoveries from Northern Jutland mentioned here have in common, partly, that the Baltic kinds of stones appear very rarely and partly, that the Norwegian material is found in much greater quantity than the material brought from Dalarne which passed over West Sweden and the Kattegat before arriving to North Jutland. A. JESSEN mentions, that the conditions of the ground at Vendsyssel indicate that, »the land-ice at the last while melting was moving in a direction from N. E., the direction of the ice-margin having been essentially N. W.—S. E.« The direction of the tract of marginal moraines at Skjørping is N. N. W.—S. S. E. During the melting from the North Jutland districts on the Kattegat the margin of the land-ice has thus essentially conformed to the Swedish Kattegat coast.

According to the Swedish investigations the recessional moraines in Halland and the adjacent countries have quite a similar direction. It is not until farther north in Sweden, in Dalsland, where the large marginal moraines, well-known from DE GEER'S investigations, are found, that the direction has changed more to the east into Sweden. From these large moraines through the Swedish districts on the Kattegat to Northern Jutland the recessional moraines thus show a fairly similar course.

At the time when the land-ice covered great parts of Northern Jutland, it was on the whole moving from north to south. With regard to Vendsyssel JESSEN[1] supposes, that the direction turned more and more from N. N. E.—S. S. W. to E. N. E.—W. S. W., at the same time as the ice was melting. The direction of the marginal moraines farther into the country agrees with this. The direction of the large characteristic marginal moraine, pointed out by USSING[2] between Troelstrup and Snæbum on the Viborg—Aalestrup railway, is thus quite west—east corresponding to a movement of the ice from north to south. This is most finely seen on the area Bovbjerg—Holstebro—Hald, where the hillocky moraine landscape meets with the outwash-plains and marks the line of the stagnating margin — as has been shown by USSING. Apart from the curves, more or less great, made by this line, its direction is on the whole from west to east. The great predominance of the Norwegian boulders compared with boulders from the Swedish region of transportation also indicates a transport corresponding to this direction of the glacial margin, a transport from north to south. The ice-stream, which last covered the northernmost part of Jutland, shows itself distinctly to have been Skagerak ice.

JESSEN considers, that the Baltic material has been carried to Vendsyssel during the first part of that period of the distribution of

[1] D. G. U. I R. Nr. 10. p. 81.
[2] D. G. U. III R. Nr. 2.

the ice, when Northern Jutland was for the last time covered by the land-ice. JESSEN also supposes, that the material has been brought by the land-ice and not by rivers or the floating ice. If we — with USSING — suppose, that North Jutland's uppermost glacial layers and South-East Jutland's upper glacial layers have been formed at periods equally far from the period when the West Jutland hilly regions were created, the supposition of JESSEN, regarding the time when the Baltic boulders were carried to Vendsyssel and the rest of North Jutland, is however not satisfactory. It is namely a fact, that Baltic boulders are also found in the diluvium of the West Jutland hilly regions even in its most western parts; the material must thus have been transported before this diluvium was formed. On the supposition that the period of formation of these parts of the West Jutland drift-deposits is separated from the period of formation of the East Jutland and North Jutland upper diluvium by a long interval without ice, an inter-glacial epoch, the Baltic boulders must have been brought down in connection with a distribution of ice before this inter-glacial epoch.

The layers in Vendsyssel, which according to JESSEN have been deposited in connection with the last ice-cover in this part of Denmark, are »diluvial sand, diluvial gravel, moraine sand and stony sand«. Baltic boulders have been found in the fluvioglacial gravel and in their local moraines (moraine gravel), as also in the stony sand of the hills. No Baltic boulders have been found in the moraine sand.

No Baltic boulders have been found in the older Yoldia clay which is considered by JESSEN to have been deposited during an earlier part of the Glacial Period, separated from the last part by an inter-glacial epoch. But this does not show, that they may not be present, as they have not been found in the moraine sand either which however can have taken them from the diluvial gravel. In the older Yoldia clay the Dala porphyries are only represented by a single Bredvad porphyry. As the Dala porphyries are for the rest much more common in Vendsyssel than the Baltic boulders, it must be considered as a mere accident, that the latter are not found in situ in the older Yoldia clay. The absence of Baltic boulders in this Yoldia clay cannot therefore be considered evidence of its period of formation having been essentially earlier than the period of formation of Vendsyssel's upper glacial layers, or that they have been separated by an inter-glacial epoch.

East Jutland. Whilst the great transport of Norwegian material of stones is characteristic of Northern Jutland as a whole, it is only in some single parts of south-eastern Jutland, that the character of the stones in the gravel-pits and on the ground's surface is so pre-

dominantly Norwegian. This is perhaps however the case over the greater part of the region west of a line Randers—Skanderborg, north of the Himmelbjerg lakes and east of the Karup outwash-plain. No real enumerations have been made in this region, but Dr. P. HARDER has been so kind as to communicate to me some observations he has made at a few places. In the country between Hadsten and Mundelstrup it has thus been observed, that rhomb-porphyries are common or appear more often than Baltic boulders. Norwegian boulders are quite predominant at Linaa east of Silkeborg. It may reasonably be supposed, that the same is the case in the region more to the north of this and west of Hadsten—Mundelstrup.

On the Grenaa peninsula collections and enumerations have been made of indicator-boulders in the large gravel-pits at Rosmus Station. The result from the different places was: 60 North Baltic, 42 from Dalarne, 16 rhomb-porphyries with accompanying conglomerates, and 12 boulders of Kinnediabase. The same characteristic Baltic ice transport, indicated by the conditions of the ground here and by the direction of the striæ on the Saltholmskalk at Grenaa, also shows itself distinctly in the large number of Baltic boulders contained in these gravel-layers at Rosmus.

The character of a gravel deposit at Løsning Station between Horsens and Vejle is still more distinctly Baltic; 35 North Baltic boulders, 6 porphyries from Småland, 4 basalts from Scania, 32 Dala boulders, 2 rhomb-porphyries and only a single Kinnediabase were found here.

In the country west and north-west of Horsens Baltic boulders are also predominant according to information kindly given me by Dr. P. HARDER. It is worth remarking that the brown Baltic quartz porphyry is quite common here; on the other hand the red Baltic quartz porphyry seems to be very rare in the same regions. In the same area between Uldum and Mos Lake Norwegian boulders are seldom in such gravel-layers, which here belong to the latest glacial deposits.

At W. Hornstrup south of Jelling the following boulders were found in fluvio-glacial layers: 19 North Baltic boulders, 9 Dala boulders, 10 rhomb-porphyries and 1 basalt boulder. It is striking, that the number of the rhomb-porphyries should be so great here and the Dala boulders so few.

The mixture of Scandinavian (Norwegian and West Swedish) and Baltic material, found at the last mentioned place, is also characteristic of the contents of the gravel-layers to the south towards Kolding and Vamdrup.

On Nordbæk field 6½ km. W. of Egtved many indicator-boulders have been found in a gravel-pit containing a large number of boulders as large as a fist. The gravel-layers are found in an irregular, hummocky area of marginal moraines, situated immediately behind the large Grindsted outwash-plain. The Baltic character is on the whole very distinct; 24 North Baltic boulders, 11 basalt, 23 Dala boulders, 9 Norwegian boulders and some few Kinnediabase were found here.

At Bølling in Egtved parish N. W. of Kolding the result of an enumeration in fluvio-glacial gravel-layers was: 40 North Baltic, 73 Dala boulders, 24 rhomb-porphyries and conglomerates; no Kinnediabase.

The following boulders were found in gravel-layers N. W. of Verst Church: 37 North Baltic, 1 Påskallavik porphyry, 3 basalt, 40 Dala boulders, 9 rhomb-porphyries and quite a few boulders of Kinnediabase.

In fluvio-glacial layers at Gamst poor-house N. W. of Anst the result was: 6 North Baltic boulders, 13 Dala boulders, 2 rhomb-porphyries.

Near the railway at Dollerup S. W. of Lunderskov in some gravel heaps, originating from gravel-layers just beneath the ground's surface, there were: 40 North Baltic boulders, 1 Påskallavik porphyry, 80 Dala boulders, 32 rhomb-porphyries with accompanying conglomerates and some few Kinnediabase.

In fluvio-glacial layers without any separate moraine cover at Rolsmølle N. E. of Lunderskov the result was: 14 North Baltic boulders, 24 Dala porphyries, 8 rhomb-porphyries and some few Kinnediabase.

In a gravel deposit south of Ødis-Bramdrup mill S. E. of Vamdrup there were: 21 North Baltic boulders, 40 Dala porphyries, 13 rhomb-porphyries and conglomerates and some few boulders of Kinnediabase.

At all the places mentioned here, from Løsning Station to Ødis-Bramdrup mill the gravel-layers from which the boulders came have no moraine cover; they are thus themselves the uppermost glacial deposit at the place.

At Kolding (towards Sest) gravel-layers are found covered by moraine clay, but for the rest they are like the gravel-layers round Lunderskov. The conformity visible in the stratigraphic conditions also appears in the contents of indicator-boulders; 41 North Baltic boulders, 2 porphyries from Småland, 4 basalts, 66 Dala boulders, 22 rhomb-porphyries and conglomerate boulders were found.

All the gravel-layers between Egtved, Anst, Vamdrup and Kolding which have been investigated, have in common, that the North Baltic

boulders are everywhere in greater number than the boulders from the Christiania neighbourhood. The boulders from Dalarne are however the most predominant. The contents of the gravel-layers investigated in this part of the country thus show quite a homogeneous composition, which cannot be considered accidental. It proves, that the moraine deposits, from which the gravel-layers originate, have had a homogeneous composition in regard to the stones.

West of the line Egtved—Verst—Anst a district is found, which may also in this connection be referred to the East Jutland region. It extends from Vejen—Brørup both southwards and northwards. In the fluvio-glacial deposits of this region some collections of boulders have been made. The number of the stones has however been small at every place.

In Harebjerg S. of Brørup Station there is a section, 15 m. high, in fluvio-glacial and very regular gravel-layers, the material of which is employed for the making of lime sand-stone (mortar). Many small boulders are found here but relatively few indicator-boulders; after careful search all I found was: 7 North Baltic, 29 from Dalarne, 3 boulders of rhomb-porphyry and some few Kinnediabase. Not far to the west of this place there is an interglacial peat bog with layers probably overlying the gravel-layers in Harebjerg; these are also older than the interglacial.

East of Vittrup in Lindknud parish N. of Brørup small sections are found in fluvio-glacial gravel, the layers of which are perpendicular and therefore deposited before the surrounding moraine layers. In some gravel heaps from these places 6 North Baltic boulders, 8 Dala boulders and 5 rhomb-porphyries were found.

Between Lindknud and Læborg several places are found where similar vertical or very sloping gravel-layers appear, but the number of boulders has here been so small, that no enumeration of the indicator-boulders was made.

North-west of Læborg. A small hill with a section occurs among the many hills here rising over the surroundings. On account of the sliding of the ground and its becoming overgrown the conditions of bedding have however not made any investigation possible. The discoveries in the old gravel-pits here were: 4 North Baltic boulders, 3 basalts, 12 Dala boulders, 7 rhomb-porphyries and conglomerates.

At the bottom of the drained Sandsø Lake ca. 2 km. N. E. of Vorbasse a considerable number of indicator-boulders was found in the stony sand. Their character is by contrast strikingly Baltic; 54 North Baltic, 1 Påskallavik porphyry, 4 basalts, 50 Dala boulders and 8 Norwegian boulders were found. Of the North Baltic boulders 39 were brown Baltic quartz porphyry, but of different types, and of

the boulders from Dalarne 36 were Bredvad porphyry; the Baltic character was however very predominant.

The Baltic (East Jutland) character on the stretch Vorbasse—Bække—Lindknud—Læborg—Vejen—Skibelund is however much more distinct in the indicator-boulders of the ground's surface and of the surface moraines. The fact is, that boulders of rocks from the Christiania neigbourhood are very rare on this stretch. North Baltic boulders are on the contrary very common. But one kind of stone must be mentioned as specially characteristic of a wide area of this country, namely, basalt from Scania. In the area from Thorsted (between Egtved and Bække) to Skibelund near Vejen railway station boulders of basalt are found very commonly on the fields and in the stony sand covering the moraine clay. They are found without exception in any stone heap from the fields, and they are often present in great numbers even if other indicator-boulders are rare or quite lacking.

A little more to the west, in Lindknud, Vorbasse and Hejnsvig parishes, where the basalt boulders are not so numerous, the indicator-boulders are on the whole very rare, whilst for the rest a great number of crystalline boulders appear frequently. In Rostbanke between Hejnsvig and Vorbasse only the following indicator-boulders were found among a lot of stones from moraine gravel: 1 Åland Rapakivi, 1 Åland granite, 1 basalt, 1 Bredvad porphyry, 1 brown Dala porphyry, 1 Heden porphyry and even 1 brown porphyry from Dalarne and besides 2 rhomb-porphyries; no Kinnediabase. A little more westerly, the Norwegian character of the indicator-boulders gradually becomes more predominant.

In some gravel-layers which appeared on making a road $1^1/_2$ km. N. W. of Hejnsvig almost equally many boulders from the three most important native places were found. The gravel is considered to be fluvio-glacial containing almost exclusively small stones among sand and is not covered by a later glacial deposit. The following indicator-boulders were found: 6 North Baltic, 1 Påskallavik porphyry, 8 Dala boulders and 7 Norwegian. As there were not many boulders on the whole, the number of the indicator-boulders found was proportionally great compared with what apparently was present among the field stones in this neighbourhood. The character is here quite similar to that in the gravel-layers under the surface moraine in the country between Brørup and Lindknud.

North of Grindsted outwash-plain there are regions where the conditions are much like those in the country south of the plain.

In Stilbjerg marl-pit the marl is covered by a stratum of fluvio-glacial sandy gravel with some few, mostly small stones. The

gravel is covered by blown sand but is at some spots almost quite wanting and is substituted by a zone of larger stones much sand-worn and lying on the surface of the marl. In the stratified gravel the following indicator-boulders were found: 3 North Baltic, 6 Dala and 7 Norwegian boulders. In quite a similar, thick gravel-layer covering marl on the margin of the hilly region south of Stilbjerg I found during a short stay one basalt boulder but for the rest no indicator-boulders.

The gravel-layer at Stilbjerg thus contains a group of boulders, the character of which is much like the character of the fluvio-glacial gravel-layers between Brørup and Lindknud. As was the case there, the number of the Baltic boulders among the field stones is however very much larger. In a little stone heap of field stones at Bankehøje S. W. of Uhe (and east of Stilbjerg) there were thus found of rocks from Åland: 3 quartz porphyries, 4 Rapakivi-like quartz porphyries, 1 granite and 2 Rapakivi-like granites, 1 basalt, 2 Bredvad porphyries and 1 Laurvikite (but no rhomb-porphyries or conglomerates). For the rest boulders of sandstone and quartz appeared abundantly. All the boulders were as large as the fist.

A little more to the east some enumerations of indicator-boulders have been made, namely, between Lindballe and Farre. Though the distance between the localities is but small their boulders are very different. One enumeration was made in a gravel-pit in Toppelund hill 1 km N. E. of Lindballe. At the very top of the pointed hill rolled but indistinctly stratified gravel was found, mostly as large as eggs, with only a little fine material; 4 North Baltic boulders, 27 Dala boulders and 33 Norwegian were found, consequently a group of boulders with a strikingly northern character.

At Krogvad bridge 1600 m. S. S. E. of Farre only 1400 m. N. N. E. of Toppelund hill a group of boulders of quite a different composition was found in a gravel-pit, the depth of which was but small; viz. 16 North Baltic boulders, 11 Dala boulders and 7 rhomb-porphyries. Possibly the distinctly Baltic character here may be explained by the fact, that the place is on a plain over which the glacier-river from the east may have transported material of a more Baltic character than that of the stones of the earlier gravel hills. The water passing Krogvad bridge is Omme river, but the ground is for the rest a part of the East Jutland hilly landscape, which is extremely distinct in the neighbourhood of Lindballe.

A considerable row of hills, a region of marginal moraines originating from the retreat of the extensive Baltic ice-cover, extends northwards from the country between Farre and Givskud over Kollemorten and East Nykirke. North of Rørbæk Lake the

hills continue from Nørre Snede farther northwards. The Baltic boulders in the gravel-layers are however very few. In some small gravel heaps between Kollemorten and E. Nykirke (the exact native place of which is however not known) 4 rhomb-porphyries, 5 Bredvad porphyries and 1 Grønklitt porphyrite, but only a single North Baltic boulder, namely an Åland quartz porphyry, were found. The character of the group of boulders here has thus probably been marked by boulders from earlier moraine deposits brought from more northerly directions, as was the case in Toppelund hill.

In the district farther to the west, Give and Thyregod parishes, some enumerations show conditions of quite a similar character.

At Klavrbjerg on the road from Give to Ringive the following indicator-boulders were found in a road-cutting and in a little gravel-pit: 6 North Baltic, 12 Dala boulders and 11 rhomb-porphyries.

In the hilly surroundings N.W. of Give (e. g. at Ubberup and at Bøllund), where to the west many sand-worn stones occur here and there, of indicator-boulders several rhomb-porphyries were found, but also Baltic boulders and basalt on the surface. In a surface-layer of moraine-like gravel at Gadebanke, Bregnehoved S.W. of Give, 8 rhomb-porphyries, 1 Åland quartz porphyry and 1 basalt were found.

A collection of stones was made in a little gravel-pit of fluvioglacial gravel 1400 m. S.E. of Thyregod, where the sand is used for cement stones. Their size was mostly that of an egg. The result was: 3 North Baltic, 7 Bredvad porphyries and 12 rhomb-porphyries.

West Jutland. This part of Jutland consists of the West Jutland hilly regions lying west of and between the great central and West Jutland outwash-plains; some parts of the hilly regions are however reckoned to East Jutland. Even with this modification we may not beforehand take it for granted, that the other, more westerly parts of these hilly regions can be considered as a unity in regard to the period of their deposits and the direction of the ice-stream during the deposition. Concerning the first, the period of deposition, the boulders cannot here, as little as at other places, decide whether the deposits were formed during a single continuous period or during spaces of time separated by interglacial periods. It is only when connected with other conditions that the boulders here can give significant information. But with regard to the directions of the glacier-streams the indicator-boulders and their relative numbers have a more important significance.

In a region like South-Western Jutland, where all detailed investigation of the drift is lacking, scattered investigations of the numbers

of the indicator-boulders, like the present, can only give hints and indications. A rather common opinion among geologists has been that the boulders of the moraine in South-West Jutland were like those of Vendsyssel. This is directly stated by JESSEN: »the characteristic kinds of stones in the moraines and the relative numbers of these kinds of stones (Norwegian and Baltic) are . . . . the same«.[1] This is perhaps the case at many places, but not however — as we shall see — at every place. If we consider it as a fact — as JESSEN does — that »the earlier hilly regions« to the east extend to »the moraine line Vamdrup—Randbøl«, the stones indicate that there are extensive parts of the country west of this line, which are essentially different from Northern Jutland. This has already been proved. But there are also localities far to the west in Jutland, where the boulders have a character very different from that which is known in Vendsyssel.

In gravel-pits in the hills on the road S. E. of Raasted Church (S.W. of Holstebro) we find moraine-like gravel with boulders reaching the size of the head. Whilst in the gravel-layers of Lomborg, where an enumeration of stones was made, there is much flint, the gravel at Raasted is far less rich in flint. Of crystalline indicator-boulders were found: 3 North Baltic, 1 basalt, 20 Dala boulders, 130 rhomb-porphyries and conglomerates. On the other hand no Kinnediabase were seen.

Near the Holstebro—Herning highroad West of Aulum extensive sections are found in fluvio-glacial layers. The result of the search here was: 1 North Baltic boulder, 11 Dala porphyries, 175 rhomb-porphyries and conglomerates; no Kinnediabase. Quite a similar grouping of stones was found in the gravel heaps along the highroad from Holstebro to Aulum. Among the stones here, which originate from gravel deposits in Tvis and Aulum parishes, 1 North Baltic boulder, 7 Dala porphyries, 233 rhomb-porphyries and conglomerates were found, but no Kinnediabase.

The stones in some very extensive but not very deep (1—2 m.) gravel-pits West of Herning are of a still more distinctly Norwegian origin; 518 rhomb-porphyries and conglomerates and 6 Dala porphyries were found here, but no Kinnediabase and no North Baltic boulders. Among field-stones brought from Snejbjerg west of Herning, 2 Åland boulders were however found and 1 basalt. V. MADSEN[2] has indicated discoveries of 2 boulders of red Baltic quartz porphyry among material from the gravel-pits west of Herning. As the stones

[1] D. G. U. I R. Nr. 10. p. 84.

[2] V. MADSEN: Om inddelingen af de danske kvartærdannelser. Medd. fra Dansk Geol. Foren. Nr. 5, 1899, p. 10.

were taken from the place where they were stored, they did not originate probably from the gravel-pits, but were field-stones; the same is the case with a discovery of Kinnediabase noted from the same place.

In stone-heaps at Vildbjerg and at Trehøje in the high hills west of Vildbjerg VICTOR MADSEN[1] states that he sought in vain for Baltic boulders. Not even Dala porphyries seem to have been discovered on that occasion. According to MADSEN'S statements Norwegian kinds of stones seem to be the only ones found here even among the field-stones.

At Frifeld on the highroad 13 km. west of Herning the discoveries in a heap of field-stones gathered from the nearest field were: 39 rhomb-porphyries and 1 basalt from Scania but no other indicator-boulders.

The whole region now dealt with from Holstebro south-eastwards to Herning and a little more to the west seems essentially to be characterised by the absence of boulders originating from the south-east. The gravel-layers show an almost complete absence of Baltic boulders, and they are also seldom among the surface moraine boulders. This is emphasised so much because a different condition is predominant at some places farther to the south-west with regard to the field-stones, i. e. the surface moraine stones.

In some not very deep gravel-pits in the hills near the highroad south of Ølstrup Church (ca. 12 km. E. of Ringkjøbing) 61 rhomb-porphyries and conglomerates and 1 Dala porphyry were found among the stones, which were not very numerous.

In a small and not very deep gravel-pit at Dalager ca. 1½ km. N. of Borris Station the result was: 20 rhomb-porphyries and conglomerates, 6 Dala porphyries and a single North Baltic boulder.

A strikingly large number of stones of Baltic origin was found however in some small gravel-pits south-east of Vennergaarde in Velling parish south-east of Ringkjøbing. The profiles are situated partly in glacial unstratified gravel in a hill, partly in a low mound at the coast directly at the foot of the hill, and the material originates from the glacial gravel-layers higher up; 10 North Baltic boulders, 20 Dala porphyries, 51 rhomb-porphyries and conglomerates were found here.

The relatively large number of Baltic boulders found in these gravel-layers indicates a more considerable transport of Baltic material, than that which is seen in the gravel-layers northwards and eastwards to Holstebro and Herning.

Of much more distinctly Baltic origin are however the field-stones investigated along the road from Dalager in Borris to

[1] loc. cit., p. 10.

Fasterkjær in Faster and gathered from the fields adjacent to the road; 12 North Baltic boulders, 6 Påskallavik porphyries and 13 Dala porphyries were collected here, but no rhomb-porphyries.

In the surrounding country rhomb-porphyries seem on the whole to be rare as field-stones. In a stone heap at Fiskbæk in N. Vium parish there were for example found of indicator-boulders: 10 Bredvad porphyries and only 1 boulder of rhomb-porphyry.

In a small stone heap at a farm a little to the south-east of Velling Station 2 boulders of basalt were found in addition to some few boulders of rhomb-porphyry and Dala porphyry.

Among the ruins of the burned farm Aldershvile at Ringkjøbing MADSEN[1] found »in a stone heap, which for the most part consisted of the stones of the yard, besides Norwegian boulders and quartz, several red granites with blue quartz (from Småland), two Gang-granite porphyries from Småland, three Baltic granite porphyries, one Åland quartz porphyry, two Bredvad porphyries«. The statement of MADSEN at another part (p. 11) of the same treatise about the boulders at Ringkjøbing that »Baltic boulders (and also Småland) appear, but are very seldom« is scarcely right. His own data on the discoveries of boulders from Småland are also evidence against this, because the porphyries from Småland (Påskallavik porphyry) are on the whole so rare as boulders, that their appearance in relatively small numbers indicate a not inconsiderable transport of Baltic material. Further, among the stones on the coast of the Fjord between Ringkjøbing and Hugborg Kjær ($3^1/_2$ km. S. E. of Ringkjøbing) MADSEN found »a Gang-granite porphyry and a red, very granular granite with blue quartz from Småland«, besides 6 North Baltic boulders.

The great number of Baltic kinds of stones and the small number of Norwegian, which were thus found in places as field-stones in the countries N. E. of Skjerne (and perhaps at Ringkjøbing), speak in favour of the probability, that N. E. of this region there is a boundary for the extension of an ice from the north which reached a little beyond a line from Holstebro—Herning, but did not reach the line Ringkjøbing—Borris. The origin of the last ice-cover east of Ringkjøbing Fjord has on the contrary been distinctly Baltic.

With regard to the region south of that mentioned, only a few observations have been made.

In Svollibjerg 2—3 km. N. of Sønder Omme there are fluvioglacial gravel-layers without further moraine cover. A large number of small stones appear in the gravel; 49 Norwegian boulders and 6 Dala porphyries were found among these, but no Baltic boulders.

[1] loc. cit., p. 13.

In Krusbjerg in Ølgod parish, 5½ km. S. E. of Ølgod Station, there are large gravel-pits, which yield gravel to the roads far around. In one of the profiles the sloping layers of gravel rest on sand. The stones, of which many are rather large, are well rolled, but at the lower, hardly sloping boundary of the gravel-layers, directly upon the sand underlayers, there is a horizon with sand-worn stones, many of which are as large as the head or more. Among the boulders in the gravel there are several rhomb-porphyries, but no Baltic boulders.

In the country soutwards, past Tistrup and Varde, the origin of the field-stones also seems to have been almost exclusively Norwegian. On the road 1½ km. N. E. of Tistrup, in a large heap of field-stones, the only indicator-boulders found were rhomb-porphyries. For the rest the boulders were predominantly quartz and sand-stone, of which many were nicely sand-worn. South of Tistrup, in some heaps of field-stones, some single rhomb-porphyries and many of the other eruptive rocks from the Christiania neighbourhood were also found, whilst the main number of the boulders was for the rest almost entirely quartzites.

South of Nørholm several boulders of rhomb-porphyry were found in fluvio-glacial gravel-layers without moraine cover. The main ingredients of the boulders are however flint and quartzites.

In some extensive but not very deep gravel-pits on the highroad 1 km. E. of Korskro between Varde and Bramminge an enumeration of indicator-boulders was made. The character of the deposit where the stones occur is rather peculiar. The stones are seldom larger than an egg, mostly the size of a nut; they are often packed close together, but at other places there is yellow sand among the stones and at some places they are as if strewn about in the sand. The stones are well rolled, but the deposits are not at all stratified; nor is there any even transition in the size of the grains between the stones and the sand in which they lie. The layer may be considered as a moraine of pure sand, into which the rubble-stones from a very uniform layer without sand have been mingled. That this explanation is right is shown by some gravel-pits at Tinghøje 700 m. N. E. of Korskro. Brown moraine-sand is found uppermost here varying in height, at most 3 m. It contains some few small rubble-stones, but beneath the sand layer there is ca. 1½ m. gravel (pebbles) packed close together and distinctly stratified; they are a little larger than the stones in the gravel-pits near the highroad, but, however, seldom exceed the size of an egg. Beneath the gravel-layer there is sand again. The sand covering the gravel-layer is only moulded as moraine in the uppermost meter; underneath, the sand lies in disordered layers of fluvio-glacial sand. The moraine-

sand is thus evidently a sort of local moraine of fluvio-glacial, pure sand, into which rubble-stones from the subjacent gravel-layers are mingled. The stones consist mostly of flint and quartzite; of indicator-boulders there were found: 1 Åland quartz porphyry, 8 Dala boulders and 42 rhomb-porphyries and conglomerates from the Christiania neighbourhood.

North of Tjæreborg Station there are many gravel-pits in fluvio-glacial gravel-layers without moraine cover. The gravel is much rolled, containing both fine and coarse material, but seldom larger than a fist. The following boulders were found: 1 Påskallavik porphyry, 4 boulders possibly basalt, 37 Dala boulders and 156 boulders of rhomb-porphyry and conglomerates, besides many other eruptives from the Christiania neighbourhood. Lastly, numberless boulders of quartzite occurred.

The character of the surface moraine's group of boulders in the surroundings of Korskro and Tjæreborg as represented by the indicator-boulders among the field-stones has not been investigated. But eastwards from Korskro Baltic boulders are not rare among the field-stones compared with Norwegian boulders. Thus, in stoneheaps of field-stones at Grimstrup there were found: Åland quartz porphyries and Bredvad porphyries but no rhomb-porphyries. In stone heaps in the surroundings of Vejrup some few boulders from Åland have been found whilst no rhomb-porphyries were seen. Still farther to the east boulders from Åland are rather common among the field-stones. Thus in a stone heap at Lintrup $4^1/_2$ km. N. of Holsted there were: a boulder of Åland quartz porphyry 1 cubic foot in size, a boulder of Rapakivi of the size of the head, 2 Rapakivi-like quartz porphyries and 1 Bredvad porphyry but no rhomb-porphyries of other Norwegian indicator-boulders from the Christiania region; numerous quartzites were however found. The conditions here are thus — with regard to the indicator-boulders — much like those in Lindknud and Vorbasse parishes.

At Klelund $4^1/_2$ km. N. of Lintrup Åland quartz porphyry was also found among the field-stones but no rhomb-porphyry. With regard to gravel-layers here, gravel from a road crossing N. of Lintrup has been investigated. Among a large number of small stones only some few (4—5) boulders of Bredvad porphyry were found, but no other indicator-boulders.

As we have seen, there is on the whole some difference between the indicator-boulders of the fluvio-glacial gravel-layers and on the surface of the fields (surface moraines), a difference which should engage the attention on future investigations in these localites.

Sleswig and Holstein.

The same dissimilarity in the stones of the gravel-layers and the moraines in the eastern and western districts of North Jutland is also traceable southwards from the Danish boundary. The distinct contrast found in North Jutland is however far from being so predominant in Sleswig, and farther southwards it disappears probably completely. Some few enumerations have been made in Sleswig.

At Rødekro West of Aabenraa there are some extensive but not very deep gravel-pits, where the gravel is at the surface without moraine-cover; 63 North Baltic boulders, 1 Påskallavik porphyry, 73 Dala porphyries, 12 rhomb-porphyries and conglomerates were found here. On the whole the character of this group of boulders is of the same kind as that of the gravel-layers in the district of Lunderskov—Kolding, even if the Baltic is a little more predominant at Rødekro.

The Baltic character is still more distinct at Flensborg in the gravel-layers, here covered by an upper moraine. The discoveries here in some gravel-pits partly south partly east of the town, were: 28 North Baltic boulders, 3 boulders of basalt, 32 Dala porphyries and 4 rhomb-porphyries. Though the number of the Dala porphyries was so large, only some few boulders of Kinnediabase were found.

On the coast near Stensigmose S. E. of Broager Dr. MADSEN has collected some boulders which he has kindly placed at my disposal. The collection was: 24 North Baltic, 2 Påskallavik porphyries, 8 Dala porphyries (probably several more varieties of porphyries are present than those which were collected), 4 rhomb-porphyries and conglomerates (1 Norwegian syenite) and 2 Kinnediabase.

On the coast at Emmerlev cliff N. W. of Højer lock a collection was made of boulders washed out from the cliff, here of moraine clay. The result was: 35 North Baltic boulders, 2 Påskallavik porphyries, 6 basalts from Scania, 62 Dala porphyries, 8 rhomb-porphyries and porphyry conglomerates and 22 Kinnediabase. The stones of the moraine in Emmerlev cliff are thus very much like those of the gravel-layers at Rødekro and at Flensborg. The same relative number of Norwegian kinds is present; only the Dalarne and the other West Swedish rocks appear proportionally somewhat more abundant. In comparison with the gravel-layers in the neighbourhood of Lunderskov (which — like the gravel-layers at Rødekro — are the latest glacial layers at the place) the moraine at Emmerlev cliff turns out to be relatively more Baltic and especially proportionally poorer in the Norwegian rocks than is the case in the gravel-

layers. ZEISE (1889), who gives the moraine-clay in Emmerlev cliff the name of »Unterer Geschiebemergel«, also mentions several discoveries of Åland and Finnish (?) boulders from this place.

The character of the boulders grows gradually more Baltic southwards, and gradually fewer Norwegian boulders are found. J. PETERSEN (1900) says »In Schleswig-Holstein gehören Geschiebe aus dem Christianiagebiet zwar nicht zu den häufigsten, so doch zu den ganz charakteristischen Erscheinungen, die nicht übersehen werden können. Man kann ziemlich sicher sein, z. B. am Schulauer Ufer oder in den Bahrenfelder Kiesgruben, auf jeder Exkursion ein oder mehrere Geschiebe aus dem Christianiagebiet zu finden«. The result is thus, that Norwegian boulders are rather rare in the Hamburg neighbourhood especially compared with the Baltic kinds of stones. Norwegian boulders are however found over the whole of Holstein; ZEISE indicates discoveries of 4 rhomb-porphyries on the east coast of Femahrn. But south of Holstein, only some few Norwegian boulders have been found.

By an investigation on diluvial, marine and freshwater beds at Ütersen—Schulau in the southern part of Holstein SCHROEDER and STOLLER (1907) have found the following boulders in moraine-clay at two places in the neighbourhood (the boulders were investigated by J. KORN).

		Glinde Upper moraine.	Wedel Lower moraine.
Norway.	Rhomb-porphyry	2	1
—	Syenite porphyry	2	»
—	Laurvikite	1	»
—	Pulaskite	1	»
Dalarne.	Bredvad porphyry	12	3
—	Grönklitt porphyrite (»Siljan porphyry«)	5	»
—	Venjan porphyrite	3	1
—	Quartz porphyry	4	2
—	Elfdal porphyry	2	»
Scania.	Basalt	6	1
Småland.	Påskallavik porphyry	3	2
Åland.	Granite	2	4
—	Rapakivi	16	15
—	Rapakivi granite	»	4
—	Porphyritic granite	1	2
—	Rapakivi granite porphyry	»	3
—	Granite porphyry	1	1
—	Quartz porphyry	7	2
Brown Baltic quartz porphyry		4	3
Red Baltic quartz porphyry		2	3

The lower moraine is thus here of a much more Baltic character than the upper moraine, a relation of great interest.

At Heligoland the Norwegian and West Swedish materials seem to appear more richly, which is naturally according to the situation of this island in relation to the Danish countries, where the same boulders appear abundantly. At Heligoland the boulders have been investigated by SJÖGREN (1883) and J. PETERSEN (1903).

PETERSEN states that the following relative numbers of boulders occur at Heligoland: North Baltic boulders 5, Påskallavik porphyries 3, basalt 5, Dala boulders 8, boulders from the Christiania neighbourhood 10 and several Kinnediabase. The stones occur on the beach at a part of the cliff washed by the sea during the flood-tide. It is PETERSEN'S opinion, that the reason why no more Norwegian boulders (rhomb-porphyries) have been found is, that the boulders at Heligoland are very much exposed to weather and wind, and that the rhomb-porphyries have not had so much power of resistance against this influence as the quartz porphyries. »Rhombenporphyre sind nicht sehr hart; wenn eine relativ so grosse Zahl, die sich auf kleinem Raum vorfand, der Zerstörung entging, so muss jedenfalls ursprünglich ein grosser Reichtum an norwegischem Material vorhanden gewesen sein«.

On Amrum J. PETERSEN has investigated the indicator-boulders of the Quaternary layers. He states that the composition of the diluvium on Amrum is apparently very simple. Moraine-clay is lacking, only gravel and sand are found. Ordinarily the predominant layers are »stony sand« (Geschiebedecksand) characterised by the irregular mixture of the stones in the sand. Sometimes layers are seen of stratified sand and gravel without larger stones; the stony sand rich in boulders also seems to lie over a similar layer. PETERSEN states about the boulders: »Als besonders auffallendes Merkmal ist der enorme Reichthum an Christianiagesteinen hervorzuheben, der den Sylts noch weit übertrifft. An der ca. 300 m. langen, ca. 20 m. breiten Strandstrecke von Ualani fand ich in ganz kurzer Zeit nicht weniger als 13 Laurvikite und einige zwanzig Rhombenporphyre, ferner Nordmarkit und Foyait, sowie Ägiringranit. Am Strande von Wittdün, wo die Geschiebe nicht so zahlreich sind, eine ganze Anzahl Rhombenporphyre, in den Kiesgruben des Geschiebedecksandes Laurdalit, Laurvikit, Rhombenporphyr«. »Neben den genannten Geschieben fanden sich auf Amrum Venjanporphyrit, Bredvadporphyr, Påskallavikporphyr, Rödönrapakiwi, Ålandsrapakiwi und -Granitporphyr, Ostseequartzporphyr, Öjediabasporphyrit von dem bekannten Habitus mit grossen Feldspatheinsprenglingen, zahlreiche Diabasporphyrite mit schmal leistenförmigen Feldspathen (wegen ihrer relativ grossen Zahl auf das Gebiet nördlich Christiania hinweisend), Åsbydiabas, Kinnediabas, Basalt. Also dieselben Gesteine, die von Sylt her bekannt sind. Und

dennoch verschieden in ihren Mengenverhältnissen. Wenn man auch nicht sagen kann, dass die Christianiagesteine absolut vorherrschen — hier wie überall ist die grosse Mehrzahl der Geschiebe wenig charakteristisch oder nicht mit Sicherheit auf ein bestimmtes Gebiet zurückführbar — aber gegenüber den Ålandsgesteinen und Basalten, mit denen sie ihrer Zahl nach auf Sylt verglichen wurden, herrschen sie stark vor. Während man auf keinem der Geschiebehaufen, die aus den Kiesgruben zum Zweck des Strassenbaus gewonnen und neben ihnen aufgeschüttet sind, vergeblich nach norwegischen Gesteinen sucht, ja sicher sein kann, sie in mindestens einem, meistens mehreren Exemplaren zu finden, wird man vielfach vergeblich nach Ålandsgesteinen und Basalten suchen. Ich hatte ca. 30 norwegische Geschiebe gefunden, ehe ich den ersten Basalt auffand«.

On Sylt Stolley (1901) divides the Quaternary into three parts: The old sand diluvium, the main moraine and the upper sand. The old sand diluvium, the lowest horizon, which is considered by Stolley to have originated from the earliest glaciation, consists of transformed miocene sand, with which Scandinavian material has mingled. The stones from this place have been investigated by J. Petersen (1905). The following were found among 880 boulders:

Gneiss	355	Elfdal porphyries	3
Mica-slate	10	Other quartz porphyries	19
Laurvikite	3	Nordmarkite porphyries	2
Nordmarkite	9	Rhomb-porphyries	69
Granite	366	Grorudite (?)	1
Åland Rapakivi	3	Diabase and diabase porphyrite	10
Påskallavik porphyry	1	Venjan porphyrite	1
Other granite porphyries	5	Helleflint	16
Bredvad porphyries	6	Felspar sand-stone	1

Among the indicator-boulders those from the Christiania neighbourhood are predominant here. Comparing the conditions with those at other places they are evidently most like those in South-West Jutland, where the Norwegian indicator-boulders are also predominant often in a far higher degree than here, but where the Baltic indicator-boulders are however also found and the Dala boulders are seldom lacking. With regard to the composition of the indicator-boulders, we may consequently compare »the old sand diluvium« on Sylt with the fluvio-glacial layers in South-West Jutland.

Stolley has shown that this sand diluvium, which at Rødeklev also appears as a sandy moraine containing many boulders, lies under the North Frisian »Tuul«, an interglacial peat layer, 1,5—2 m. in thickness; its contents show that it is related to the interglacial peat layers at Brørup in Jutland.

Above the old sand diluvium and the interglacial Tuul at Rødeklev lies again the »main moraine«; this has a rather considerable thickness, and its composition is sandy and poor in lime, because it is a sort of local moraine from the sandy underground: miocene Kaoline sand and the sand diluvium. It is quite probable that the main moraine has also obtained from this underground a relatively large number of stones from the Christiania neighbourhood, of which »the old sand diluvium« also contains a great deal. We are however not sufficiently informed of the stones of the main moraine in comparison with the other glacial horizons in Rødeklev. As it has been stated that the old sand diluvium under the »Tuul« not only contains boulders originating from the Christiania neighbourhood and West Sweden, but also Baltic boulders, a valuation of the relative numbers of the indicator-boulders cannot be made with the stones as basis, which are washed out of the Quaternary layers and are found at the coast. J. PETERSEN says on this (1905) that in his earliest investigations he considered »dass die am Strande liegenden Gerölle in ihrer prozentualen Zusammensetzung ein treues Bild von der Zusammensetzung der Haupmoräne geben. Diese Annahme ist, nachdem ich die Mächtigkeit und den Geschiebereichtum des untersten Diluviums in den neuen Aufschlüssen kennen gelernt habe, nicht mehr haltbar. Es steht noch unverändert fest, dass die Hauptmoräne Sylts verhältnismässig reich an norwegischen Geschieben ist, diese Tatsache ist durch die grosse Zahl von norwegischen Geschieben, die ich in den letzten sechs Jahren in dem Hauptgeschiebemergel und den zugehörigen Geschiebesanden beobachtet habe, festgestellt, sie ergibt sich auch aus der Häufigkeit faustgrosser und grösserer Stücke von Rhombenporphyr, Nordmarkit und Laurvikit unter den Strandgeröllen — faustgrosse Geschiebe sind in der untersten Moräne sehr selten«.

In the same treatise PETERSEN says: »In der Sylterhauptmoräne ist . . . das aus dem Norden stammende Geschiebematerial verhältnismässig sehr reichlich vertreten, so reichlich, dass die Annahme, es befinde sich auf sekundärer glacialer Lagerstätte, ausserordentlich unwahrscheinlich ist«. Concerning this the following question may be asked; does the Baltic material then lie at a secondary place? In the subjacent sand diluvium Baltic material is only found in very small quantity. In the main moraine Baltic material appears however not very seldom; this is seen from PETERSEN's own statements, based on dicoveries which have been made partly among the stones at the coast, partly in the moraine itself. One kind of boulder may especially be mentioned, namely basalt. STOLLEY (1901) speaks about the »in der Moräne der Hauptvereisung häufigen Gesteine, vor allem der Basalte«. PETERSEN says (1901) that basalt boulders appear very

abundantly in the gravel of the beach. In a later treatise (1903) the same author speaks of »Hunderten von dichten Basaltgeschieben auf Sylt, die ich beobachtet habe«. Are then these hundreds of basalt boulders in Rødeklev's main moraine at a secondary place: i. e. carried down by a north—south or a north-east—south-west glacier-stream? or in what manner have they arrived here?

Instead of considering the Norwegian material to be secondary in the moraine, PETERSEN considers it more probable, »dass während der Hauptvereisung eine Verlegung des Zentrums und der Richtungen der Vereisung im Sinne einer Verschiebung des Nährgebiets von Westen nach Osten und der Transportrichtungen von Nord—Süd bis Nordost—Südwest stattgefunden hat. Gestützt wird diese Annahme durch den Umstand, dass, wie bereits früher (STOLLEY, Sylt III) gesagt und weiter unten noch gezeigt wird, die Ablagerungen der dem Haupteis vorangehenden Vereisung auf fast rein nördliche bis nordöstliche Ursprungsgebeite hinweisen«.

It seems to me that these conditions speak in quite the contrary direction to what PETERSEN himself says. It is in reality rather the Norwegian boulders and not those from Scania and the Baltic, which we are to consider as secondary in the main moraine at Rødeklev. The transport of these boulders to Sylt is plainly enough quite impossible without a Baltic glacier-stream assisting, but the supposition of PETERSEN excludes the latter. If we accept his view, the appearance of the Baltic boulders and the basalts from Scania is a complete riddle. It is much more reasonable to consider the main moraine itself to be of Baltic origin. It is perhaps probable that it is of the same age as the moraine in Emmerlev cliff[1]; but whilst the latter, the character of which is distinctly Baltic, is quite a normal moraine without appearing specially local, the moraine at Sylt has, as STOLLEY states, much local material from the under-ground. If the Norwegian and West Swedish stones are in striking degree more predominant in the moraine at Rødeklev than at Emmerlev cliff, this may naturally be explained by the local influence of the stones of the underlying glacial horizons.

That the main moraine at Rødeklev has been carried down by a glacier-stream from the east is made still more probable by the contents in the upper stony sand. This »Geschiebesand« on Sylt, which covers the main moraine but cannot be distinctly distinguished from the latter (PETERSEN), corresponds to the main moraine, as the surface moraine of the ice corresponds to its bottom moraine. PETERSEN

[1] See against this: C. GAGEL: Ueber einem Grenzpunkt der letzten Vereisung (des Oberen Geschiebemergel) in Schleswig-Holstein. Jahrb. Kgl. Pr. geol. Landesanstalt für 1907.

(1905) says himself, that »die oberflächlichen Geschiebesande von Sylt, denen die norwegischen Geschiebe zwar nicht fehlen, sie aber doch in geringerer Menge einschliessen and bedeutend vorherrschend baltisches Material führen«. It is then not sufficient, when PETERSEN in his »Zusammenfassung« states that »die Geschiebe der Hauptmoräne weisen auf verschiedene Nährgebeite des Haupteises hin, es hat eine Verlegung der Transportrichtungen von der Nordsüdrichtung bis in die Ostnordost—Westsüdwestrichtung stattgefunden«. He is nearer the right conditions when he says: »Die aus dem östlichen Skandinavien herkommende Bewegung hat vorgeherrscht, insbesondere am Schluss der zweiten Eiszeit«. The condition is very probably this, that the main moraine on Sylt is a Baltic moraine. This appears from the Baltic stones of its surface moraine, from its containing large quantities of Scanian basalt and of Baltic boulders and from analogy with the Baltic moraine at Emmerlev cliff.

North-West Germany between Lüneburg and the Oder.

In some parts of this region very detailed investigations have been made of the crystalline indicator-boulders. The boulders in Neu-Vorpomerania and at Rügen have been closely studied by E. COHEN and W. DEECKE, especially petrographically, and they have here found boulders from several native places in Sweden and the Baltic region. With regard to Mecklenburg the question of the boulders has often been dealt with by E. GEINITZ and most recently by O. MATZ (1903). F. WIEGERS has made investigations in the neighbourhood of Lüneburg (1899).

The boulders, which appear most commonly in Neu-Vorpomerania, at Rügen and in Mecklenburg are those originating from Åland and the northern parts of the bottom of the Baltic. Next to the boulders from Åland, the boulders of Påskallavik porphyry according to COHEN and DEECKE are the most common in Neu-Vorpomerania. They are here even indicated as »ausserordentlich häufig«. If this is right, this region is certainly also the only one in the whole glaciated region outside Scandinavia, where it is the case. In Hinter Pomerania they are at any rate not common; from Brandenburg only some single discoveries of Påskallavik porphyries have been noted; and westwards the frequency diminishes greatly in comparison with the boulders from the northern Baltic region.

From Mecklenburg O. MATZ notes a considerable number of discoveries of Påskallavik porphyries, saying that »Geschiebe dieser Art

sind im mecklenburgischen Diluvium häufig, meist Gerölle von Faust- bis Kopfgrösse«. An enumeration of indicator-boulders at Stavenhagen far to the east in Mecklenburg by MATZ gave however only 4 boulders of Påskallavik porphyry, whilst at the same place 49 boulders from Åland and 22 of brown Baltic quartz porphyry were found.

The result of O. MATZ's enumeration of boulders at Stavenhagen has however already been mentioned. The stones were of the size of the head. The following indicator-boulders were found:

1 Ångermanland Rapakivi,
2 Red Baltic quartz porphyries,
22 Brown Baltic quartz porphyries,
9 Åland quartz porphyries,
23 Åland granites,
17 Åland Rapakivi,
4 Påskallavik porphyries,
8 Bredvad porphyries,
1 Basalt from Scania,
4 Coarse-grained (Åsby?) diabase.

I think that the reason why so few boulders of red Baltic quartz porphyry were found in this deposit, which for the rest is so distinctly Baltic, is that the boulders chosen have been of a size, which the boulders of red Baltic quartz porphyry seldom reach. The same is partly the case with the boulders of Bredvad porphyry and several others of the Dala porphyries. But at all events the enumeration is evidence that the North Baltic material is present in great preponderance compared with the Swedish material which has been carried down by a glacier-stream passing more from north to south. With regard to Mecklenburg it may further be mentioned that single boulders of Norwegian origin have been found, namely, rhomb-porphyries.

Lüneburg. The boulder material which forms the basis of the paper by F. WIEGERS came from a gravel-pit at Vastorf E. of Lüneburg; »Es wurden 35 Handstücke als typische Vertreter ausgewählt« of the porphyry boulders collected here by WIEGERS. Of these the following could be classified:

2 Red Baltic quartz porphyries,
3 Brown Baltic quartz porphyries,
3 Felsite porphyries } Dalarne,
3 Cancrinitsyenite }
8 Helleflints } Småland.
10 Påskallavik porphyries }

It is evident that WIEGERS has considered the numbers given as at any rate to some extent characteristic of the relative numbers of the boulders at that place, because he connects the following remark with the enumeration: »Die Heimath ist bei allen Gesteinen Schweden und ihre Zahl nimmt, wie natürlich, von Norden nach Süden zu«.

This relatively large number of Småland porphyries and especially of Påskallavik porphyries in addition to the absence of Åland quartz porphyry was the cause of my visiting this locality (in 1904).

In the extensive gravel-pits with fluvio-glacial gravel situated directly by the railway, an extremely rich material was found for the collection of indicator-boulders and I had a specially good opportunity for making an enumeration to elucidate the relative numbers of the different indicator-boulders. But it was soon quite clearly seen — even from superficial inspection — that the Påskallavik porphyries were not present in such relatively large numbers as might have been supposed from F. WIEGERS' statement; quite the contrary.

The enumeration was made as follows; during one hour I collected all the indicator-boulders of the types dealt with here which I was able to find within a well-examined part of the gravel-pit and in the heaps of stones there. There were just such heaps, easily investigated and washed clean by the rain, where the stones had a size between a fist and a nut. The result of the collection and the enumeration was:

38 Red Baltic quartz porphyries,
23 Brown Baltic quartz porphyries,
26 Åland quartz porphyries and Rapakivi-like quartz porphyries,
14 Åland granite and Rapakivi,
1 Påskallavik porphyry,
23 Bredvad porphyries,
14 Grönklitt porphyrite,
4 other Dala porphyries,
1 basalt,
1 rhomb-porphyry.

In addition, a single boulder of Kinnediabase was found.

With regard to the nature of the boulders, it may also be mentioned that if larger stones, of which many were present at other places in the gravel-pit, had been included, the number of the Åland boulders would no doubt have been a good deal larger. Of the indicator-boulders it was namely almost entirely the boulders from Åland which appeared as large specimens, and there were rather many of them. The size of the other stones was seldom more than

that of a fist; the red Baltic quartz porphyry especially appeared relatively abundantly as small stones; boulders of red Baltic quartz porphyry of a size of up to a child's head were however also present. Boulders of Småland porphyry were on the other hand very seldom. The statistical enumeration gave only one Påskallavik porphyry, and during the whole investigation of the gravel-pits and of their boulders, i. e. during the course of several hours, the whole result was 3 boulders of Småland Gang-porphyry (Påskallavik porphyry) and about 10 boulders of Helleflint and granite possibly originating from Småland. The investigation thus shows that, with regard to the indicator-boulders, the main contribution came from the North Baltic region, and that the number of the Småland porphyries is much less in comparison with this. At Vastorf the condition is almost the same in this regard as in the Quaternary deposits in Denmark.

The only countries from which we have statements of a remarkably common occurrence of Påskallavik porphyry, but where no statistical enumeration has been made, are those investigated by COHEN and DEECKE: Neu-Vorpomerania and Rügen. An enumeration here will probably show, that the relative frequency in proportion to the North Baltic boulders and to the Dala boulders is not so »ausserordentlich« great as is stated by the authors, but that their number is much less, just as is the case at Stavenhagen in East Mecklenburg.

In addition to the boulder of rhomb-porphyry found in the Vastorf gravel-pit, there were two others both larger than a fist.

Boulders of basalt appeared apparently only seldom, the only one found was that mentioned under the results of the enumeration. As the indications in the literature state, that this kind of stone is otherwise common in the Quaternary of North-West Germany, it may be supposed, that several boulders of basalt are to be found at Vastorf.

With regard to the occurrence of boulders of basalt in this part of Germany, it may also be mentioned, that according to statements in the literature a boulder from Demmin (PETERSEN 1903) is known from Neu-Vorpomerania and Rügen. They are seldom in the eastern part of Mecklenburg. MATZ mentions one boulder from his enumeration of the stones at Stavenhagen. He also says that in the eastern parts of Mecklenburg, whoever »mit Vorliebe gerade nach Basalten gesucht hat, kann aus dieser Gegend nur zwei Funde, nämlich Vielist und Jürgensdorf anführen«. STEUSLOFF however has found (MARTIN: Basalte 1903) in the neighbourhood of New Brandenburg in »unterdiluvialen« gravel-layers a large quantity of basalt boulders. MARTIN mentions discoveries of 54 basalt boulders from this country. Special conditions for deposition have thus been present here.

The greater part of the basalt discoveries from Mecklenburg, mentioned by MATZ, originate from its western part (10 boulders originate from Sternburg) and such boulders are probably rather common there. They appear very often in the surroundings of Lübeck. It is thus mentioned by MARTIN (1903), that »in der Moräne am Nordufer des Kellersees und in dem Strandgeröll der Neustädter Bucht bei Haffkrug« he obtained 51 basalts. At another place (»Zur Frage der Stromrichtungen« 1901) the same author says that »während ich am Nordufer des Kellersees in den Kiesgruben bei Malente, der Holsteinischen Schweiz und Siebek innerhalb 3 Tage 40 Basalte sammelte, welche ich in Begleitung zahlreicher weissgeflekter Feuersteine, Scolithussandsteine, Hälleflinten, Rapakiwis und ungezählten Mengen von Porphyren schwedischer und baltischer Abstammung antraf, bestand meine ganze Ausbeute an norwegischen Gesteinen aus nur 2 Rhombenporphyren«.

It may be added regarding the basalt boulders, that discoveries of these boulders have been made at many localities in Holstein; J. PETERSEN in his »Geschiebestudien I (1899)« made a complete list of these. J. PETERSEN mentions a single discovery from Lüneburg. Their number is abundant in Oldenburg according to MARTIN.

North-East Germany and Poland.

As boulders, originating from the Åland islands, from the bottom of the Baltic south of these islands and from Dalarne in Sweden, appear far into Russia, it is natural, that such boulders are also common in the countries westwards, in East and West Prussia, Russian Poland, Posen and Hinter Pomerania. This has also been already partly known from the literature which has dealt with the distribution of the crystalline indicator-boulders in these provinces.

LIEBISCH already in 1874 noted discoveries of Elfdal porphyry at Lyck in East Prussia. The first, who expressly mentioned the occurrence of Åland rocks as boulders in East Prussia, was G. DE GEER, who in his treatise »on the second distribution of the Scandinavian land-ice« in 1884, speaks of finding Åland quartz porphyry at Lyck and of Rapakivi and quartz porphyry at Königsberg. In the same year SEECK (1884) states, with regard to East and West Prussia, that »Ålandsgesteine sind sehr häufig« in these provinces. Discoveries of both Åland granite and Rapakivi and quartz porphyry are mentioned. LUNDBOHM (1886 and 1888) and J. KORN (1895) also state expressly the common appearance of Åland boulders in East Prussia and they both mention discoveries of boulders from Dalarne.

Of Dala boulders LUNDBOHM in 1888 determined a violet Särna porphyry (No. 204 from Nasser Garten) and a Blyberg porphyry (No. 231 from Craussenhof at Königsberg). In 1886 he mentions discoveries of Cancrinitsyenite in Samland. J. KORN mentions (following LUNDBOHM's determinations of the native places) discoveries of Bredvad porphyry and other Dala boulders the nature of which is not exactly indicated. COHEN and DEECKE (1896) have made a revision of the determinations of the porphyries, which according to J. KORN have come to East Prussia from Finland. The result has turned out to be, that at any rate some of these porphyries originate probably from Dalarne and are Bredvad porphyry. It may also be mentioned, that ZIRKEL in his Petrographi (II vol. p. 414, 2nd edition), speaks about the discovery of a boulder of Cancrinitsyenite from Dalarne at Langenau south of Dantzig.

The literature mentioned here does not note any discoveries of the Baltic quartz porphyries. As mentioned on an earlier occasion[1] there was however, among the material classified by LUNDBOHM in 1886, several boulders of brown Baltic quartz porphyry. Boulders of red Baltic quartz porphyry were also found in this collection. LUNDBOHM put them together into one group, about which is said (p. 89) »No. 2025 und 5646 von Lyck, No. 5762 und 5786 von Rauschen, No. 7300 von Wormditt und No. 8887 von Königsberg. Rother Quartz-Porphyr. Grundmasse dicht mit kleinen, runden oder eckigen dunkeln Quarzen und sehr kleinen spärlichen hellrothen Feldspath-Krystallen«. I have seen these specimens in the East Prussian Province Museum except No. 5646. In the collection obtained for determination by LUNDBOHM in 1888 there were no boulders of this rock, the worth of which as indicator-boulder is, however, emphasized in the text accompanying the list of the boulders. But discoveries of such boulders in East Prussia are mentioned in the treatise on »the earlier Baltic ice-stream in South Sweden from the same year (and there called: Rödöquartzporphyry).

The investigation I made in 1901, with regard to the occurrence of indicator-boulders in North-East Germany, further confirmed the earlier discoveries of the kinds of boulders mentioned. With regard to Dalarne some kinds of indicator-boulders were also found, which had not been known from there before. On this it is sufficient to refer partly to the section on the origin and nature of the indicator-boulders investigated, partly to the list of the indicator-boulders.

At several of the places where the collections were made, the number of the boulders was not very great. This is an essential

[1] MILTHERS (1902).

reason for the list not containing more than it does. In large collections of boulders from these provinces the indicator-boulders from Åland, the bottom of the Baltic and Dalarne may ordinarily be found well-represented. This has been contested by some few authors, especially by JOHS. PETERSEN but without sufficient reasons, and even without considering the existing evidence. When COHEN and DEECKE for some more westerly countries lay stress on the absence of such »besonders typischen Gesteine wie die fluidalstructuirten Elfdalener Felsitporphyre und Cancrinitsyenit«, this is not very good evidence of the absence of Dala boulders, as the boulders mentioned are on the whole to be considered as proportionately rare. There is no doubt however, that Bredvad porphyry and Grönklitt porphyrite are present, because they are quite common as boulders in the more eastern parts of Germany. Probably the other kinds of Dala porphyries may also be found when searched for, as was the case in the north-eastern provinces. A real determination of the contrary would be extremely interesting.

Dala boulders are however not so common in East and West Prussia as boulders from Åland and the bottom of the Baltic south of Åland. This is a natural result of its being only a part of the boulders from Dalarne which were carried so much in a south-easterly direction past Sweden, that they could be taken up by the Baltic ice-stream and spread about in the north-east German provinces, whilst others of the Dala porphyries were scattered in south-westerly directions. Only the Dala boulders, which in Sweden were carried through the northern part of the provinces Södermanland and Östergötland, furnished any essential contribution to the boulders found in North-East Germany. When it is also considered how extensive the region of distribution of the North Baltic boulders is, it is intelligible that the relative number of the Dala boulders is not very great at every single place of the region of distribution, even if it is extremely large quantities which have been brought to the Baltic ice-stream over the Swedish provinces mentioned.

The eastern boundary for the distribution of the boulders brought from the Småland coasts in the surroundings of Öland into the Baltic ice-stream, lies in North-East and East Germany. This is the case with the Påskallavik porphyry and the other Småland Gang-porphyries which are like this. In the report above mentioned, on collections of boulders in North-East Germany, it is specially noted, that Påskallavik porphyry is quite certainly known as far to the east as at Schlawe in Pommerania and at Glogau in Silesia. From LUNDBOHM'S determination of boulders from East Prussia it was however certain, that a boulder found at Königsberg was Påskallavik por-

phyry. There is no doubt about the correctness of the determination, but as the exact place of finding the boulder is not indicated, there might be a question of its having come there artificially. As it has however been shown by investigations in Russia (next section), that boulders from Dalarne and the Åland region have been distributed in a south-easterly direction over the Baltic, with north-easterly boundaries of distribution almost parallel to the line Påskallavik-Königsberg, it can no longer be considered as impossible that the boundary of the distribution of the Påskallavik porphyry really lies so far to the east and not in West Prussia—Silesia. Sufficiently characteristic indicator-boulders of gang-porphyry from the Småland region are however on the whole too rare to be suitable for the determination of the boundaries of distribution. Even in their main region of distribution they are relatively rare as boulders.

After my investigation in North-East Germany had been made it has been proved that basalt boulders from Scania have also been distributed as far to the east as to the region dealt with here, namely to Drossen and to Massin at Landsberg in Brandenburg, whilst their occurrence further to the east than at Eberswalde was not previously known.

Furthest extension of the North Baltic and Dala boulders to the east. — Observations from Russia.

When this investigation was begun, it was so to speak quite a neglected question, how far to the east and north-east the Swedish and Åland boulders had been carried into Russia by the Scandinavian inland ice. Only some few notices on the subject existed. Hj. Lundbohm in his treatise on »the earlier Baltic ice-stream in South Sweden« (1888) had indicated in a note (p. 174), that 2 boulders of »Rödöquartzporphyry« (red Baltic quartz porphyry), found in Livland (without any more exact indication of the place), were present in the collections of the Geological Survey of Sweden at Stockholm. The next indication was given by G. de Geer in »Skandinaviens geografiska utveckling« (p. 71), where he speaks about the great extent of gravel-hills at Ösel, »that it is the eastern boundary of the numberless Åland boulders, which are distributed all over the island as far as and to this plain but not further«. Lastly, J. J. Sederholm in v. Toll's treatise: »Geologische Forschungen in Gebeite der Kurländischen Aa (1898)« states regarding the boulders found by v. Toll, that the majority »bezieht sich

auf Gesteine, deren anstehendes Gebiet an den Küsten des Südlichen Theiles des Bottnischen Meerbusens zu suchen ist«. »Auffallend ist das Fehlen typischer Varietäten der Ålands-Rapakiwi-Gesteine, die ich aber aus der Umgegend Wilnas aufgelesen habe«.

After the investigation in the summer of 1901 to find out which crystalline indicator-boulders were present in the extreme north-eastern Germany, it was soon clear to me, that these indicator-boulders were very common there. They must also occur probably further to the east in Russia and it should be possible to determine the furthest boundary of their distribution there.

In an endeavour, with the above mentioned sparse indications as a basis, to settle the north-eastern and eastern boundary of distribution of the »Rödöquartzporphyry« (red Baltic quartz porphyry), the Åland Rapakivi kinds of stones, HEDSTRØM's Baltic quartz porphyry (brown Baltic quartz porphyry) and porphyries from Dalarne, it was necessary first of all to procure a preliminary general view of the distribution and then to settle more exactly the boundaries of the distribution. For the preliminary orientation the following places were chosen: Eydtkuhnen, Vilna (and Landvorovo), Minsk, Smolensk and Moscow, partly because these places are conveniently situated for the investigations, partly because they are relatively far from the centres of distribution.

To settle the boundaries of the distribution more exactly — as far as it was possible during the limited time — a region was chosen nearer to the centres of the distribution, namely, the Russian Baltic provinces and the adjacent countries, the distances and the means of communication not preventing the work so much here as farther towards the outer margin of the region of distribution.

Eydtkuhnen—Moscow.

Eydtkuhnen. The diluvial landscape around Eydtkuhnen is apparently a moraine level. The little boundary river Lepone which makes its way north of the town through a valley ca. 100 m. broad, has at some places, by hollowing out the valley, formed sections up to 8 m. in height and consisting of red-yellow, weathered moraine-clay with few stones and at some places showing signs of pressure. On such a slope $^1/_2$ km. N. of Eydtkuhnen, at a place where the water had washed some stones out of the naked ridge of clay, were found: red Baltic quartz porphyry, brown Baltic quartz porphyry, Åland granite, Rapakivi, Rapakivi-like quartz porphyries and Bredvad porphyry.

Vilna and Landvorovo. The moraine level extends almost uninterruptedly along the railway from Eydtkuhnen to the east to Kowno, where it is traversed by the deep river valley, the steep slopes of which show splendid sections of red-yellow moraine clay covering horizontal, stratified sand. From Kowno the plain extends further in the direction of Vilna. Whilst between Eydtkuhnen and Kowno it is apparently very poor in stones, the number of the boulders obviously increases on approaching Vilna. Near Landvorovo, the station where the railway lines Warsaw—Vilna and Königsberg (Eydtkuhnen) — Vilna meet, great heaps of boulders are found on the fields, and immediately near the railway station there are gravel layers containing abundance of boulders. In the summer of 1902 a long section ca. 10 m. in height was found here, the gravel in which was much rolled and contained a very considerable number of large boulders. Many boulders of red Baltic quartz porphyry were found among the latter and the Åland boulders were represented by: granite, Rapakivi-like granite, quartz porphyry and Rapakivi-like quartz porphyry, 1 boulder of brown Baltic quartz porphyry and 1 Bredvad porphyry.

At Vilna the river Vilejka, which flows through the town from the south to the north, has made some steep naked slopes in the high Krestovaja hill. The high sections consist mostly of extensive sand layers with interjacent layers of moraine-clay. These layers are all rather poor in stones; at the foot of the steep slopes a considerable number of stones, washed out of the Quaternary layers, was however found. The following boulders were found from Åland: granite, quartz porphyry, Rapakivi-like quartz porphyry and Haga-granite(?); from the bottom of the Baltic: red Baltic quartz porphyry and brown Baltic quartz porphyry; from Dalarne: Bredvad porphyry Grönklitt porphyrite (1 boulder), Hornstens porphyry (Rännås) (1 boulder). Besides these were found fragments of a quartz porphyry, which seemed to be nearly related to the quartz porphyries on the island of Hogland in the Finnish Gulf.

Minsk. The neighbourhood of Minsk is level and poor in boulders; in a small section 2 km. south of the town a fluvio-glacial sand-layer with a good many stones was seen, among which 12 fragments of red Baltic quartz porphyry, granite and Rapakivi-like granite(?) from Åland were found. Nearly west of the town some fragments of Åland granite and 1 red Baltic quartz porphyry were found in some small gravel-pits. In GREWINGK's collections of boulders in the geological collection of the Dorpat (Jurjeff) University I had later an opportunity to see a boulder of Bredvad porphyry found at Minsk.

Smolensk. The old part of this town, surrounded by its stately fortress wall, is situated on the southern slope down towards the river valley of the Dnieper, which traverses the town. North and south from Smolensk extends a flat undulating tableland of moraine-clay. This plain towards the Dnieper is deeply traversed by funnel-shaped ravines, in the sections of which moraine-clay is predominant. Gravel deposits are however also found north of the Dnieper at several places in the immediate neighbourhood of the town. Thus sections are found north of the railway station, but they are quite insignificant and their only material is earthy, sandy and with but few stones. Farther to the east there are on the other hand very large gravel-pits with sections, 10—15 m. in height, from which Smolensk town gets stones and gravel. The gravel-layers are covered by a material, which is stratified but nevertheless moraine-like and partly clayey, partly sandy. This uppermost cover is varyingly thick, weathered and of a reddish colour. The largest of the stones in the gravel-layers reach 1 cubic foot but much fine material is intermixed. The gravel is distinctly fluvio-glacial and the stones are well rounded. These are mostly from sedimentary kinds of rocks; at some places they are (as far as one could judge) 70—80 pCt. of the whole quantity. Crystalline boulders however also appear abundantly and there was here an excellent opportunity for making a collection. Besides some boulders, the origin of which was no doubt Finnish, 2 boulders of red Baltic quartz porphyry and 1 of brown Baltic quartz porphyry were found. There was on the other hand no certain boulders from Åland or from Dalarne. Boulders of quartz porphyry found in the gravel-layers probably came from Hogland.

Moscow. Nearly west of Moscow an extensive profile is found, where a considerable number of large and small stones, of which many originate from Finland, occur in a large gravel-pit. It was on the other hand impossible to find a single boulder, which could be considered as Swedish or North Baltic. The result of an excursion to the well-known locality of inter-glacial layers from freshwater, Troizkoie, and to another inter-glacial locality west of Moscow, was quite the same.[1]

The result of this reconnoitre, following a line from the west to the east from the Prussian boundary to Moscow, is that all the mentioned types of boulders in the region investigated can be found eastwards beyond Minsk. The North Baltic boulders occur at Smolensk, only however as single stones. At Moscow there are no signs of the

[1] At both places a small quantity of plant-containing interglacial material was collected, which on return home was given to Mag. N. Hartz for determination.

presence of boulders from the most northern parts of the Baltic, neither at places where investigations can be made now, nor in earlier collections.

Vesenberg—Wolmar.

In large parts of Estland the main directions of the ridges, the »drumlins« etc., is distinctly north—south to north-west—south-easterly. This is specially remarkable in the surroundings of Vesenberg and Taps (the Petersburg—Riga railway), where a considerable number of ridges — mostly from north to south — can be seen. Vesenberg ås also extends in the same direction from Vesenberg several kilometers southwards. It contains an extraordinarily large quantity of boulders of sedimentary kinds of stones, which is distinctly seen on the steep slopes of the numerous characteristic ravines in the ridge. Crystalline boulders are on the other hand relatively few in number and the indicator-boulders sought for do not seem to be present here.

The direction of the ice-stream in Estland appears very distinctly, besides at the åses, at several places in the drumlins formations on the landscape. The railway passes through such a landscape north of Dorpat (Jurjeff), the direction being almost north-west —south-easterly. The landscape consists of several parallel rows of hills, extended and often flat with interjacent valleys. According to the topographical maps (with scale 1 : 126000) a landscape of this character apparently extends between 10 km. and 32 km. north of Dorpat, its breadth being from south-west to north-east 12 km. The topographical maps show, that formations of the landscape of the same kind and with about the same direction are found at Weisenstein north of Wirz Järv and north of Wolmar. The direction of the hills in these drumlins landscapes, from north-north-west to south-south-east, gives a picture of the direction of movement of the melting ice-cover in these regions.

At Dorpat we have the most northerly traces of the boulders which had their origin from the region south of Åland, namely red Baltic quartz porphyry. In the immediate neighbourhood of the town the diluvial surface is moraine-clay and extends as a plain on both sides of the river Embach which flows through Dorpat from north-west to south-east. As is often the case, gravel deposits are found in the slopes along the river. The most considerable of such deposits are here in the immediate neighbourhood of Dorpat, namely, near the churchyard on the north-western outskirt of the town. There are several gravel-pits there with deep profiles in fluvio-glacial sand, containing irregular, considerable gravel-layers. Any special moraine-

cover on the fluvio-glacial layers was not visible. Sedimentary rocks from Estland and Livland chiefly occur in the gravel, but also many crystalline boulders. Among these it was however not possible to find Swedish or Åland indicator-boulders for certain nor other boulders originating from the North Baltic region; 2 small boulders of red Baltic quartz porphyry were on the other hand found a little to the south-west of the town in some gravel heaps, which were said to be used for improving the roads and originated from the gravel-pits mentioned.

A quantity of Finnish Rapakivi kinds of rocks occur as field-stones in the neighbourhood of Dorpat, e. g. near Wahi 3 km. north of the town. Boulders of a characteristic quartz porphyry, originating from the Island of Hogland in the Finnish Gulf, likewise occur. Whilst a very large number of the boulders in the gravel-layers at Dorpat are sedimentary rocks, the field-stones are solely crystalline kinds of stones.

Walk. The significance of the discovery of red Baltic quartz porphyry at Dorpat has been confirmed by similar discoveries at Walk, ca. 80 km. S. S. W. of Dorpat. The layers from the Glacial Period are here almost devoid of stones. North of the small river which flows through the town, the terrain is moraine-clay and — nearest to the river — blown sand. Profiles in small-grained gravel with few stones occur south of the river. 1 boulder of red Baltic quartz porphyry and 1 boulder of Åland granite were found in such a gravel-pit at Kalumelder mill 4 km. N. W. of Walk.

Wolmar. More numerous discoveries have been made in the surroundings of Wolmar. North of this town is a region the character of which with distinct directions is only seen on the general staff's map (1 : 126000) and recalls the drumlins. It is described by B. Doos[1] and its formation is quite analogous with the drumlins-landscape in Pommerania described by Keilhack. The directions of the drumlins-hills at Wolmar is mainly N. W.—S. E., thus indicating the direction of movement here of the last ice-cover. The whole region extends 28 km. in N. W—S. E. and 22 km. in N. E.—S. W. Several boulders of red Baltic quartz porphyry, 1 Åland granite and 1 Åland quartz porphyry were found, partly as field-stones and partly in gravel heaps along the road here.

In a gravel-pit 500 m. S. of Wolmar railway station a boulder of Rapakivi-like quartz porphyry from Åland was found; in Kaugershof gravel-pit 5 km. S. E. of Wolmar Åland granite and red Baltic quartz porphyry were found. Both these gravel-pits had only a small

[1] B. Doss: Ueber das Vorkommen von Drumlins in Livland. Zeitschr. d. Deutschen geol. Gesellschaft. 1896.

depth; the gravel appeared without moraine-cover. The first gravel-pit was rich in stones, Kaugershof gravel-pit small-grained and sandy especially in the upper layers. At both places the collecting of boulders was difficult, the pits being much filled with water.

In a gravel-pit at Wegin ca. 5 km. N. E. of Wolmar a high section occurs in the northern side of a small glen lateral to the large valley of the river. About 1 m. of moraine-clay almost without stones occurs uppermost; beneath it is sand containing gravel-layers with a considerable number of larger and smaller stones. The original layers were at the time of investigation almost quite covered by displaced and sloping masses of earth, but in the material dug out several fragments of red Baltic quartz porphyry, Åland granite and Åland quartz porphyry were found, besides 2 boulders of Bredvad porphyry from Dalarne in Sweden.

This discovery is of special interest when one remembers that the eastern boundary of the distribution of the Dala boulders in Sweden's Quaternary passes almost through Stockholm, and that these boulders are but seldom found in the most northern part of Gothland. The most eastern boundary of distribution of Bredvad porphyry seems almost certainly to be situated somewhat more easterly than that of the other Dala boulders. It is thus mentioned by Lundbohm, that boulders of Bredvad porphyry have been found even more to the east than Stockholm, though only sporadically. According to Hedström (1895) such boulders have also been found on Gotska Sandön. The line of connection between the outermost distribution of the boulders in Sweden and in Livland seems however to indicate, that there has been a part of the Glacial Period during which the direction of movement of the ice in these regions was inclined more to the east than was the case during the last movements forward of the ice.

The drumlins landscape mentioned indicates that the last direction of movement of the ice-cover at Wolmar was north-west—south-easterly. An ås at St. Matthia[1] west of Burtnecker See has a direction quite in agreement with this. The group of lakes at Lemsal[2] about 45 km. west of Wolmar seems to indicate a still more north-south direction of the ice's movement. The direction of movement of the last ice-cover in these Livland regions, as well as also in the more northern regions of Estland has thus apparently on the whole been N. N. W.—S. S. E.

[1] B. Doss: Über die Åses von St. Matthia in Livland (Korrespondenzblatt des Naturforsch. Verein zu Riga. 38 1895.)

[2] B. Doss: Zur Geologie der Yungfernhofschen Seen und ihrer Umgebung in Livland. Ibid.

In Central Sweden the direction of the åses indicates that the direction here during the melting was almost north—south to north-west—south-east. The last movement passed Gothland in this direction.

The Bredvad porphyries have thus evidently been carried to Livland by ice-streams which have deviated to the east. It is however not unlikely, that the boulders also in Sweden have been spread farther to the east than the present boundary of distribution shows. And it is not unlikely, that boulders, originally carried from Dalarne south-easterly towards and to the surroundings of the Åland islands, have been again taken up by an ice-stream from the Gulf of Bothnia and carried in a more southerly direction to be deposited in Livland together with Åland and other Bothnia-Baltic stones. The scarceness of the Dala boulders in Livland is explained in this way; they are thus here on a sort of secondary bed in relation to the Åland boulders.

The conditions of the diluvial surface in Estland and in the parts of Livland spoken of here indicate as mentioned that the movement of the ice during the melting of the last cover was from north-west to south-east. In the surroundings east of Riga the »Kangers« however indicate another west-easterly direction, and conditions showing the same are found already at Wolmar, namely, the river-terraces along the Livland Aa.

From Wolmar to Wegin we follow the old highroad towards Walk along the river Aa and for a long distance follow the boundary between the high land and a river terrace. The high land is a moraine level and in immediate connection with the flat undulating drumlins-landscape between the Aa and the Burtnecker lake. The terrace at some places has a breadth of several hundreds of meters and is quite a horizontal surface situated about 15 m. above the normal flood water-line. It is most developed over a distance between 1 km. and 3 km. north-east of Wolmar and immediately at the town merges imperceptibly into the higher situated landscape; 1—2 km. east of the town the river has cut a section into the terrace 5—600 m. in length, from which we can see how regular its construction is. A sand layer of 1 m. in thickness is uppermost, under this is a stratified layer, partly sandy clay of a blue-gray colour and 1 m. in thickness. The clay layer covers a sand layer of a thickness of several meters with homogeneous grains and quite horizontally stratified in the whole extent of the section. The absolute height of the terrace is 50—55 m. above the level of the sea (the General Staff's map in 1 : 420000 gives for Wolmar a height of 170 Eng. feet [= 51,8 m.]), and Wolmar railway station is situated at a height of 51 m., about the same as the terrace.

About 10 m. lower than this terrace lies another which is most distinct ca. 5 km. north-east of Wolmar. It also appears in the neighbourhood of Wolmar but is here much hidden by blown sand.

The origin of the terraces is however probably to be sought for in a once present ice margin towards the west, whereby a dam has been formed for a lake into which the sand and clay layers of the terraces have been deposited. The direction of several of the Livland rivers, among others also the Aa, is perhaps also partly due to an ice margin between the Aa and Riga Gulf. The further course of this ice margin to the south is seen from the conditions in the neighbourhood of Riga.

The neighbourhood of Riga.

The terrain surrounding Riga consists over a wide circuit of a flat plain on which rise several åses. Their direction is parallel to the near-lying rivers, and as these in the region of the Riga plain have the shape of a fan convering towards Riga, the directions of the ridges have a similar fan-like disposition, each ridge pointing towards Riga. Many of these åses are known from the literature and could from beforehand be expected as excellent localities for collecting boulders. The most easterly, the small Kanger, the great Kanger and Oger Kanger have been described by B. Doss.[1] Galgenberg, Rullekaln and Kruschkaln and some few others have been described by E. v. Toll.[2]

E. v. Toll through his investigations has collected a good many crystalline boulders. With regard to their nature and origin J. J. Sederholm has communicated to v. Toll[3] the following: »Die Mehrzahl der Blöcke bezieht sich auf Gesteine, deren anstehendes an den Küsten des südlichen Theiles des Bottnischen Meerbusens zu suchen ist, und das weist auf einen Geschiebetransport aus diesen Gegenden hin. Was den iotnischen Sandstein anlangt, so steht er nicht nur bei Björneborg an, sondern Geschiebe desselben finden sich an allen Ufern des Bottnischen Meerbusens; deshalb ist es nicht leicht den genauen Fundort der in Kurland gefundene Blöcke festzustellen. Dasselbe gilt

[1] B. Doss: Die geologische Natur der Kanger im Rigaschen Kreise unter Berücksichtigung ihrer weiteren Umgebung. Mit 7 Tafeln. Festschrift des Naturforscher Vereins zu Riga in Anlass seines 50 jährigen Bestehens. 1895. p. 161—260.

[2] Bulletin du Comité Géologique 1892 XI p. 182. — Bull. du Comité Géol. 1895 XV p. 153—155. — Bull. du Comité Géol. 1896 XVI p. 155—190. — Sitzungsberichte der Naturforscher-Gesellschaft bei der Universität Jurjeff. 12. 1898. p. 1—33. (Titel: Geologische Forschungen im Gebiete der Kurländischen Aa).

[3] Toll: Geologische Forschungen etc. l. c. p. 13.

vom Olivin-Diabas. Der ältere porphyrische Diabas dagegen stimmt vollkommen mit solchen überein, welche an den Grenzen der Ålands-Rapakiwi-Gesteine verbreitet sind. Auffallend ist das Fehlen typischer Varietäten der Ålands-Rapakiwi-Gesteine, die ich aber aus der Umgegend Wilnas aufgelesen habe. Das stimmt mit der Thatsache überein, dass nämlich auch in den Sammlungen des Kopenhagener Museums die Varietäten des Quartz Porphyrs vorherrschen, im Gegensatz zu ihrer heutigen Ausbreitung auf den Ålands-Inseln«.

»Unter den übrigen Gesteinen ist der Uralit-porphyrit besonders charakteristisch. Das Vorhandensein von Blöcken dieses Gesteins beweist für sich schon, dass die Gletscher zum Theil über das Finlandische Festland gegangen ist. In Anbetracht dessen, dass in Kurland Ålandsgesteine vorhanden sind, kann man erwarten, dass mit der Zeit auch Gesteine gefunden werden, welche zu den typischen Rapakiwi von Raumo und Nystadt gehören«.

At other places also, v. Toll mentions the discoveries he has made by his investigations, and B. Doss mentions several times in his treatise on the »Kangers« that »Gerölle finnlandischer Gesteine« are found here.

Galgenberg at Tukkum. The country westwards from Riga is quite low and flat until quite close to Tukkum. A stream flowing in the direction west-east runs south of the town, and to the north we find conical hills which seem generally to contain gravel and stones abundantly. Galgenberg lies 1 km. west of the town and its direction is north-south. Its southern end is a little north of the stream mentioned and a large section is found here, partly a transverse section, partly a longitudinal one with a height of about 25 m. The material is predominantly fine gravel with finer sand layers but also with numerous stones up to the size of a fist. Of stones numerous boulders of red Baltic quartz porphyry were found here, granite, quartz porphyry, Rapakivi-like quartz porphyry from Åland and a doubtful boulder of brown Baltic quartz porphyry.

North from this extends Galgenberg with a typical ås shape for many kilometers and with several sections. At a section north of the churchyard situated on the ås, north-west of Tukkum, where the material contained more stones and was on the whole of a coarser nature than that at the southern end of the ås, boulders were found of red Baltic quartz porphyry, Åland granite, Rapakivi-like quartz porphyry and one Bredvad porphyry. In the numerous gravel-pits north and north-east of Tukkum many boulders of red Baltic quartz porphyry were also found and Åland kinds of rocks, but on the other hand no brown Baltic quartz porphyries or porphyries from Dalarne.

Oger Kanger is a long row of hills extending along the Düna river 25—50 km. S. E. of Riga. The course of the single parts of the ås is very complicated and branching and they contain numerous large ravines. The extensive »Ballastgrube« 5 km. south-east of Oger was especially suitable for the investigation of the boulders. A section occurs here which however only uncovers essentially the uppermost of the gravel-layers of the hill, which are very stony, but beneath these layers sand layers are also seen with discordant parallel-structure. A large number of boulders of sedimentary origin especially were found. Among the crystalline boulders several were found of red Baltic quartz porphyry and Åland Rapakivi-like quartz porphyries. Dala porphyries or brown Baltic quartz porphyry were on the other hand not found.

Rullekaln is a flat region with åses which begins ca. 6 km. south of Mitau and continues to the south-south-west along the Schwed brook, its length being ca. 9 km. It is very regular in its course, and its breadth is very great in proportion to its height. At its northern end there is a very large section, 5—600 m. in length, showing excellently the stratified, coarse material contained by the ridge here, in which the sedimentary boulders are predominant. Among the crystalline boulders many were found of red Baltic quartz porphyry and the Åland kinds of stones: quartz porphyry, Rapakivi-like quartz porphyry, Rapakivi and granite. In addition to these 4 boulders of brown Baltic quartz porphyry and 1 boulder of Bredvad porphyry were found. E. v. Toll has given a description of the section in his »Geologische Forschungen«.

Kruschkaln is a row of hills 10 km. in length, 4 km. south of Behnen station on the railway line Mitau—Libau (ca. 45 km. S. W. of Mitau) and extends in continuation of the Sala brook in an east-west direction. It is on the whole rather broad and of a considerable height with but few irregularities in its course. North of Kaijen Krug, 4,5 km. S. S. W. of Behnen station, a section was found with rather fine grained gravel, in which I succeeded in finding the following indicator-boulders: red Baltic quartz porphyries in many specimens, Rapakivi-like granite, quartz porphyry, Rapakivi-like quartz porphyry from Åland and one boulder of brown Baltic quartz porphyry.

In a large gravel-pit at Kruschkaln Krug, 4,5 km. S. S. E. of Behnen station, numerous boulders of red Baltic quartz porphyry and of the Åland rocks were found; further, several boulders of brown Baltic quartz porphyry and 2 boulders of Bredvad porphyry and 2 of Grönklitt porphyrite from Dalarne.

The investigations on the crystalline boulders in the deposits of gravel in the neighbourhood of Riga thus show, that boulders of red

Baltic quartz porphyry and of Åland rocks are abundantly present here. Brown Baltic quartz porphyry appears in the deposits south and south-west of Riga, not commonly however, but have not been found in the »Kangers« east of Riga; the same is the case with Bredvad porphyry. The discovery of the Grönklitt porphyrites in Kruschkaln also shows however, that this place is inside the region of distribution of the Dala boulders, even if Bredvad porphyry is excepted, which may also be found in fixed rock farther to the north than in the Elfdal-region.

The surroundings of Reshitza.

In the neighbourhood of Kreutzburg north of Düna we find a country which extends several hundreds of square kilometers and is very distinctly orientated in the direction W. S. W.—E. S. E. It consists of long parallel ridges with intermediate valleys. The result of my observations, partly in the near neighbourhood of Kreutzburg partly along the railway eastwards from there, is that the ridges essentially consist of moraine-clay. This orientated row of hills may possibly be considered as drumlins-like formations deposited from the west during a period, when a glacier which has covered the Riga region extended thus far to the east.

Further to the east this regularly undulating terrain passes over into a quite smooth plain, consisting partly of sand, partly of moraine deposits and partly of peats. Along the railway line Kreutzburg—Reshitza this plain only ends 7 km. east of the station of Veliony or 17 km. west of Reshita. A landscape is found here, which is not exactly very hilly but it contains an unusually large number of boulders, partly of the size of a fist or a head, partly considerably larger. The contrast between the low-lying plain with so few stones and this landscape with such a number of boulders is very striking. It has an east—west extension of ca. 3 km., and is continued eastwards by an undulating hilly landscape without many stones; in such a landscape Reshitza is situated.

In some small gravel-pits 2 km. south of Reshitza 2 boulders of red Baltic quartz porphyry were found and one boulder of possibly Åland granite.

An excursion was made from Reshitza to this landscape, rich in boulders, which extends from the railway east of Veliony northwards past the church-town Dritzane and the manor-house Taunagi 20 km. N. W. of Reshitza. The road from here to Dritzane passes through an undulating landscape without many stones. In gravel-pits which were passed only a single Åland granite was found. At Dritzane

begins the terrain with plenty of stones. A terrain occurs here which can be characterized as a terminal moraine landscape extending south-south-west in the direction of Veliony and northwards and north-eastwards, perhaps past the church-town Rogowka situated 12 km. N. E. of Dritzane and 21 km. N. of Reshitza. The landscape is rather hilly, and the longitudinal extension of the hills surrounding Dritzane and Taunagi is apparently N.—S. Whilst this landscape, rich in boulders, borders to the east and south-east on a moraine landscape without many stones, to the north-west and west — towards Lubahn Lake, it is limited by a sand and peat plain of immense extension. Between Dritzane and the manor Taunagi 3 km. more to the north, red Baltic quartz porphyry was found among the field-stones and the following boulders from Åland: Rapakivi, granite, quartz porphyry and Rapakivi-like quartz porphyry.

The discoveries on the railway line 10 km. east of Veliony in the same moraine region were: 2 red Baltic quartz porphyries, 1 Åland quartz porphyry, 1 Rapakivi-like quartz porphyry, 2 Rapakivis from Åland and a doubtful Åland granite.

The glacier which — from the south and south-east — deposited this stretch of marginal moraine and carried down the Åland and the Baltic boulders here, has however farther to the south left a much more distinct track in the form of indicator-boulders.

An excursion was made from Reshitza to the town of Ostrof. The terrain from the railway station Iwanowka, 25 km. N. E. of Reshitza, where the hilly moraine landscape crosses the railway line, and farther north is very flat and with few boulders right to Ostrof. There are also but few stones near Ostrof. I did not succeed in finding Åland boulders here, but on the other hand several Finnish, among these also quartz porphyries from Hogland.

Svenziany—Glubokoi.

On going by the railway southwards from Reshitza past Dwinsk, a region mapped out by Miss A. Missuna is reached at Ignalino station ca. 60 km. south of Dwinsk. The region, 22 km. in length, from here to Svenziany station is characteristically sandy from the melting away of the ice-cover; the same is the case with the region eastwards from Svenziany station to Svenziany town situated 10 km. to the east. This sand also extends a little to the east of Svenziany town. The terrain here however soon changes its character. About 3 km. S. E. of the town there is a large quantity of stones of the size of a fist and others not so large lying loose on the surface. An unusually large number of boulders of red Baltic quartz porphyry occurs here,

and a great many Åland rocks. I took with me 23 boulders of red Baltic quartz porphyry and 12 boulders of granite, quartz porphyry and Rapakivi-like quartz porphyry from Åland. In addition 4 boulders of brown Baltic quartz porphyry and 4 boulders of Bredvad porphyry were found.

Farther to the east the number of the stones increases still more and the size of the stones becomes larger, but the terrain is still quite flat. At Jantschung 5 km. E. S. E. of Svenziany boulders of the size of a fist and up to a head appear abundantly. Westwards the terrain is as mentioned flat; eastwards there is a steep slope towards a peat-bed overgrown with trees, to the east of which is a more hilly moraine landscape. From Jantschung northwards to Bidawtschischki (or Widawtschischki) the terrain gradually alters to a region with many small hillocks, the ridges of which do not show any particular orientation. An unusually large number of stones large as the head appear on the surface, whilst on the other hand no very large boulders are found. Miss MISSUNA's designation »terminal moraine landscape« is here very fitting. It seems difficult to distinguish any single marginal moraine here, but the character of the whole landscape is undoubtedly terminal moraine-like. An enormous number of red Baltic quartz porphyry and of Åland boulders occur here. I took with me 11 red Baltic quartz porphyries, 13 boulders of Rapakivi, granite and quartz porphyry from Åland. Besides, I found 6 boulders of brown Baltic quartz porphyry and 1 Bredvad porphyry.

This abundant quantity of indicator-boulders from the Åland region showed that the latter might be found still considerably farther to the east. From Svenziany a railway runs 100 km. eastwards to Glubokoi. From Svenziany south-eastwards the railway first traverses the outwash-plain; in the neighbourhood of the first station Lyntupy, a landscape, enormously rich in boulders, is passed and at the station itself we go through the inner, north-easterly side of the terminal moraine. The railway from here and to the last station Bereswetsch (Glubokoi) crosses an extended, uniform moraine plain, to the south of which stretches the terminal moraine in a great curve, the most easterly part of which is reached near Glubokoje. About $4^1/_2$ km. from this little village a numerous quantity of stones, large as a fist and smaller, occur loose on the surface or gathered in small stone heaps. The indicator-boulders found were 27 red Baltic quartz porphyries, 19 boulders from Åland of all the known types of Rapakivi rocks, 8 boulders of brown Baltic quartz porphyry and 1 boulder of Bredvad porphyry. This number of stones was collected during 2—3 hours, and a specimen was taken of each of the boulders, the identity of which with known types could be settled with secur-

ity. According to Miss MISSUNA the terrain is here sand outside the moraine line. — Many large boulders however appear firmly fixed in the earth's surface, rather indicating that a moraine deposit is present here.

Silesia—Saxony—Hanover—Westphalia.

Our knowledge of the distribution of the Scandinavian boulders in the southernmost glaciated regions in Central Germany is if possible less than our knowledge concerning the Baltic region in the more restricted sense. We know that Baltic boulders — also the Gang-porphyry from Småland — have been met with as far to the east as in Silesia. But from countries still farther to the east we have on the whole only one observation, G. DE GEER having found quartz porphyry from Åland at Przemysl west of Lemberg.

The northern boulders have been investigated in Silesia by TH. LIEBISCH in 1874; unfortunately his work appeared too early to get the importance for Quaternary Geology, which it no doubt would have had if it had appeared several years later.

The only known indicator-boulders at that period were the Dala porphyries. LIEBISCH also mentions, that in the country between Polkwitz and Dalkau, he found Elfdal porphyry with fluid-like structure. From Rixdorf near Berlin he mentions discoveries of quite the same kind and from Lyck in East Prussia a similar boulder. With regard to Silesia LIEBISCH says in general that the Elfdal porphyries »in faust — bis kopfgrossen vereinzelten Stücken« are found in this country rather frequently in the northern diluvial deposits.

In addition to the boulders of Dala porphyry which are mentioned by LIEBISCH himself, it may be stated, that the boulder from Trebitsch near Glogau, which he has described in his paper on pag. 23, 4 and 2 b, is also Elfdal porphyry. As I have mentioned before, I have had the opportunity to see a fragment of this boulder in the collection at the Dorpat University. The boulders from several »Fundorten des Kreises Glogau, Polkwitz, Wilschau, Dalkau« belonging to the same group in LIEBISCH's treatise have probably also their origin from Dalarne; but this can only be settled by a new investigation.

Some others of the boulders investigated by LIEBISCH are Åland quartz porphyry, for instance a boulder (3 a pag. 18 in the treatise) from Gross Leipe, of which I have seen a fragment in the collection at Dorpat. Probably this is the same boulder which is mentioned by G. DE GEER in his treatise »Om den skandinaviske landisens andra utbredning« (pag. 31). G. DE GEER has here further mentioned dis-

coveries of Åland Rapakivi at Waldenburg and at Striegau in Silesia and of Åland quartz porphyry at Striegau and at Breslau.

Finally, I may again mention a discovery of Påskallavik porphyry at Suckau near Glogau which has been noted before. I had an opportunity to see a fragment of this boulder in Grewingk's collection at the Dorpat University. Probably it is a fragment of the same boulder, which G. DE GEER has seen in the museum of Breslau.

From the Kingdom of Saxony Scandinavian stones, the native home of which could be determined, have been known since 1872; in that year A. PENCK discussed the occurrence of basalt boulders from Scania at Leipzig.

Later, H. CREDNER (in 1879 and 1880) mentioned discoveries of Elfdal porphyry at Kleine Steinberg near the station Beucha on the Leipzig—Dresden railway, at Leipzig and at Taucha, further, discoveries at Leipzig of Rapakivi-like granite from Åland. In 1881 A. E. TÖRNEBOHM was able to determine the presence of Cancrinitsyenite from Dalarne at Leipzig.

In »Erläuterungen zur geologischen Specialkarte des Königreichs Sachsen« many discoveries of boulders from Åland and Dalarne are mentioned and further — on some few maps — also discoveries of basalt from Scania. Supposing that the determinations are correct, we see that boulders of rocks from Åland and Dalarne are distributed over the whole northern part of the Kingdom of Saxony, and to the east they are met with almost to the southern boundary of the extension of the land ice. The discoveries of the basalt boulders from Scania especially are interesting. The latter are found on several maps in the north-western part of Saxony both to the east and west of Leipzig.

During a visit (in 1904) to the Museum of the Saxony Geological Survey at Leipzig I had an opportunity to observe boulders of quartz porphyry and of Rapakivi-like quartz porphyry from Åland, Bredvad porphyry and other porphyries from Dalarne. Further, I noticed in the collection boulders which possibly originated from Ångermanland, 1 boulder of red Baltic quartz porphyry, boulders of Gang-porphyry from Småland (Påskallavik porphyry) and also boulders of basalt from Scania. In the explanation of the geological map Wurzen (No. 13) is mentioned a discovery of a rhomb-porphyry from the neighbourhood of the Christiania Fjord. This fragment is also contained in the collection, but is not a rhomb-porphyry. Possibly it is a boulder of Gang-granite porphyry from Småland (Påskallavik porphyry or some nearly related kind of stone).

In the environs of Halle, K. VON KRAATZ-KOSCHLAU has investigated the Scandinavian boulders and collected material especially in the gravel-pits at Goldberg a little to the north-east of Halle. Using

A. G. HÖGBOM's determinations as a basis he states in his treatise (1898) that Rapakivi granite and quartz porphyry from Åland are common, Bredvad porphyry and other porphyries from Dalarne: common, Helleflints from Småland: common, Påskallavik porphyry and Wirbo granite from Småland: not common, basalt from Scania: not common. As a result of his investigations VON KRAATZ-KOSCHLAU maintains that the majority of the crystalline boulders met with in the neighbourhood of Halle originate from Småland and Dalarne; from this he concludes, that the direction of movement of the land-ice, which has deposited the material of boulders, has been between N.—S. and N. N. E.—S. S. W.

During a visit to Halle in the summer of 1904 Prof. K. v. FRITSCH kindly obtained for me the opportunity to study the boulders which had been investigated by VON KRAATZ-KOSCHLAU and are now in the collection of Halle University. Here I saw, besides the boulders mentioned by v. K.-K., among others also a boulder of brown Baltic quartz porphyry, which had been found at Goldberg. On the same occasion I made an excursion with Dr. E. WÜST to the gravel-pits at Goldberg. Here I found the following boulders:

1 Red Baltic quartz porphyry,
1 Brown Baltic quartz porphyry,
2 Åland quartz porphyry,
5 Åland Rapakivi-like quartz porphyry,
4 Åland Rapakivi,
1 Åland granite,
4 other Baltic granites,
7 Bredvad porphyry,
1 Grön-klitt porphyrite,
1 Hornstone porphyry.

20 of these boulders were thus of Baltic origin whilst only 9 originated from Dalarne. I also saw Helleflints but no Påskallavik porphyry. We took away specimens of almost all the crystalline indicator-boulders we found, but the material was not so exceedingly large that we could expect to get from them a complete picture of the composition of the group of boulders. The collection however shows a decided majority of Baltic materials.

A collection in a gravel-pit 2 km. west of Schraplau (a railway station ca. 22 km. W. by S. of Halle), which I also had an opportunity to visit, gave a more distinct impression of the relative frequency of the Dala boulders in this part of the glaciated region. The boulders were here predominantly fragments of local rocks, among

which however a number of Scandinavian indicator-boulders were seen. A chalk cover on almost all the boulders made the search for indicator-boulders difficult. I found the following:

1 Red Baltic quartz porphyry,
2 Åland quartz porphyries,
2 Åland granites,
9 Bredvad porphyries.

The relatively large number of Bredvad porphyries from Dalarne is rather striking here. Their numerical preponderance to the Baltic boulders is however somewhat neutralized by the absence of other Dala porphyries than Bredvad porphyry.

The glacial striation in the surroundings of Halle and of Leipzig indicates a direction of movement from N. N. W. to S. S. E. The presence of the basalt boulders points somewhat in the same direction. The most easterly boundary of their distribution is near here; the main distribution is much farther to the north-west. The few boulders of basalt from Scania, found in Saxony, can therefore not be used as an expression of a normal or direct movement of the ice in north-south direction from Scania to Saxony. At any rate they can partly have been carried by a movement more N. W.—S. E. which, from the central region of distribution of the basalt, has distributed single boulders fan-shaped laterally. The fact, that boulders of South Swedish kinds of stones like the basalt here are to be found near the boundary of their most easterly distribution, shows that the Dala boulders in Saxony have not been carried directly from Dalarne over Scania to Saxony. A part of the material from Dalarne has probably gone over Denmark and has — together with the basalt boulders — been brought to Saxony by a north-north-west—south-south-easterly direction of the ice, as is indicated by the striæ.

A large part has however probably arrived together with the Baltic material from the N. N. E. or N. E. Considering especially the discoveries at Goldberg the Baltic material is present in no small quantity. This is seen both from the relatively large number of boulders and from the abundant presence of the different varieties of boulders. It is not single types which have been heaped up here but the whole family of boulders is represented. In this lies especially the predominance over the material from Dalarne. It is probable, that the Baltic glacier-stream, which carried down this material, has also brought the main number of the Dala boulders to this part of Saxony. Among material from the south-easternmost part of Sweden in this stream there are Helleflints and Påskallavik porphyries, but the main stream has been more Baltic than radial.

Extremely little information about the distribution of boulders in the region farther to the north-west in Germany is available. F. WAHNSCHAFFE in a paper from 1885 states discoveries of Åland boulders in the neighbourhood of Magdeburg and in the neighbourhood of Altenrode north of Harzen. The same investigator in 1882 mentions discoveries of Elfdal porphyry and »Finnlandrapakivi« at Velpke 30 km. N. E. of Brunswick; in the same treatise it is noted, that the boulders at the Drömling more to the north »vorzugsweise aus Nord- und Süd-Dalekarlien sowie aus Småland stammen«. It does not appear from the treatise how far this observation is based upon a real statistical examination, but this has probably not been the case. There is also good reason for doubting the correctness of placing Småland so much in the foreground as WAHNSCHAFFE has done in this connection. Småland can scarcely be considered to be the native place of an exceptionally large number of such crystalline boulders, for which the determination of the native place is possible with security. As will be seen from the following there may on the other hand be some probability that the statements with regard to Dalarne are correct.

As has been shown, boulders from Dalarne appear in the Quaternary surrounding Halle in no inconsiderable quantity. The relative number of the Dala boulders is however much more prominent in the countries between Brunswick and Hanover. In 1904 I had an opportunity to make investigations and a collection of crystalline boulders in two gravel-pits at the near-lying villages Horst and Wipshausen ca. 17 km. N. W. of Brunswick; the boulders were in fairly large number and of about a hen's egg in size. From the two localities I took with me specimens of all the observed indicator-boulders, which turned out to be the following:

	Horst	Wipshausen	
Red Baltic quartz porphyry	»	5	Baltic
Åland quartz porphyry	2	1	
Åland granite	2	1	
Åland Rapakivi	2	2	
Bredvad porphyry	23	34	Dalarne
Grönklitt porphyrite	10	4	
Red Särna porphyry	1	»	
Kåtilla	1	»	
Granite-like porphyry	1	»	
Rhomb-porphyry	»	1	Norwegian

With regard to these two localities it may be said with truth, that the material, the native place of which can be determined, »vorzugsweise aus Dalarne stammt«. According to the enumerations more

than $^3/_4$ths of the crystalline indicator-boulders have their origin from Dalarne, whilst less than $^1/_4$th is Baltic. The boulders of Bredvad porphyry are certainly also very predominant here compared with the other Dala boulders, but 5 boulder-types in all are however represented.

From the strong representation of Dala boulders at Horst and Wipshausen in proportion to Baltic boulders shown by these two discoveries, it is very clear, that Central Swedish material has been transported directly by the ice over Denmark to North-West Germany. The conditions here indicate in much higher degree than those round Halle, that the Dala boulders have been carried down by a movement of the ice which has passed the western part of Sweden and the eastern part of Denmark and then continued almost directly southwards, possibly in conflict with the Baltic ice and taking up Baltic material. At Halle and in Saxony such a movement of the ice was indicated both by the Dala boulders and by the basalt from Scania. Farther eastwards no material is yet available for judging as to the two directions of the movement of the ice: the radial and the Baltic and their relative strengths. If they have existed as separate glacier-streams in the region Saxony—Silesia, their tracks will doubtless also be found expressed in the relative number of the determinable boulders.

A boulder of rhomb-porphyry was found at Wipshausen; in the literature we have no earlier information regarding discoveries of rhomb-porphyry in this part of Germany. Its occurrence however cannot be considered as specially remarkable. Considering the large number of boulders of Dala porphyry at Horst and at Wipshausen and the occurrence of the basalt boulders in Saxony, it is not improbable that boulders of rhomb-porphyry may also be found east of Brunswick.

In Westphalia Wilhelm Meyer (1907) has made an investigation of indicator-boulders in the surroundings of Münster and Neuenkircken, namely, in the three marginal moraine regions: Salzbergen —Neuenkircken—Sendenhorst, Sprakel—Münster—Hiltrup—Albersloh —Sendenhorst and at Delbrück. At two places an enumeration was made with the following result:

	Münster	Neuenkirchen
Bottnische Gesteine	3	3
Bredvadporphyr (Dalarne)	3	2
Quartzporphyr (Rödö)	6	5
Granitporphyr (Åland)	8	4
Ostseequartzporphyr	8	6
Småland: Påskallavikporphyr	»	1
Småland: Lönnebergeodacit	»	1
Småland: Lenhofdaporphyr	1	»
Småland: Einsprenglingsarme Hälleflinte, wahrscheinlich von Småland	9	9
Unbestimmbar	5	4

According to W. Meyer Bothnian boulders — i. e. boulders from the Gulf of Bothnia on the Swedish coast except »Rödöquartzporphyr« — were present in »great number«. Many red Baltic quartz porphyries (Rödöquartzporphyr) were found. Åland boulders appeared abundantly and every variety occurred. Only three varieties of Dala boulders were present and these boulders were on the whole rare; Bredvad porphyry commonest, of Elfdal porphyry 3 examples (1 of which Blyberg porphyry). Many Småland boulders were found, but they were uncertain. Of basalt from Scania 2 boulders were found, and it is far from being so common as in Oldenburg. Only 1 example of Christiania boulders was found, namely, a Nordmarkite porphyry.

With regard to the determination of brown Baltic quartz porphyry (Ostseequartzporphyr), some remarks must be made. Meyer notes discoveries of three varieties of this porphyry, (1) »Rotbraune Gesteine« which, according to the description, must be considered as belonging to brown Baltic quartz porphyry; (2) boulders with »graubrauner Grundmasse und lichtgelbliche oder grünliche Feldspatindividuen, die sich dann schärfer abheben. — In keinem der graubraunen Stücke konnte ich z. B. Quartzkörner makroskopisch wahrnehmen«. Judging from the description this variety does not belong to brown Baltic quartz porphyry, but is possibly Grönklitt porphyrite from Dalarne. He continues as follows: »die hier gehörigen Gesteine sind den Sandgruben meist leicht und zu erkennen an der charakteristischen Verwitterungsfigur, welche die Feldspatkristalle auf violettgrauen Grunde zeigt«, which, like the absence of macroscopically distinct quartz, is characteristic of Grönklitt porphyrite in contrast to brown Baltic quartz porphyry. (3) »Schwarze Gesteine«, concerning which is said: »Die Quarze treten in grosser Zahl auf und erreichen nicht gerade selten eine Grösse von 1 cm.« This variety is on the whole different from the two first, in that »die Einsprenglinge erreichen erheblich grössere Dimensionen«. According to this characterization it is improbable, that this variety belongs to brown Baltic quartz porphyry. Its origin must for the present remain unsettled.

Meyer's statement that Bothnian boulders appear in great number is scarcely in accordance with what is otherwise the case in the south-western part of the Scandinavian region of glaciation.

It would be of great interest to have the conditions in the region mentioned more closely examined, just with regard to the relative number of the characteristic boulders from the different native places.

Oldenburg—Netherlands.

Extensive investigations on the occurrence of boulders have been made in Oldenburg by J. MARTIN. In his studies on the diluvial deposits, »Das Haupteis ein baltischer Strom«, he summarises his observations as follows, »dass unter den oldenburgischen Findlingen eine ganz hervorragende Stellung die Dalagesteine einnehmen. Eine kaum geringere Menge hat der südwestliche Theil des bottnischen Meerbusens geliefert . . . . . Recht zahlreich sind hier des ferneren Gesteine vertreten, als deren Heimath die östliche Hälfte des mittleren Schweden und das angrenzende Ostseegebiet erkannt wurde, und endlich haben wir ein überaus häufiges Vorkommen schonenscher Basalt in unseren Geschiebeablagerungen feststellen können«. In detail it may be mentioned that amongst 40 porphyries from Dalarne MARTIN found 11 Grönklitt porphyrite (Orsa porphyry), a single Klittberg porphyry but no cancrinitsyenite; various other varieties of porphyry from Dalarne also occurred. The majority of these however consisted of Bredvad porphyry.

The red Baltic quartz porphyry was almost as strongly represented. There were boulders of Påskallavik porphyry from Småland, as also probably many boulders of Helleflint. Of Scanian basalt J. MARTIN has been able to collect over 300 boulders within a relatively short time. Of rhomb-porphyry on the other hand he has only found in all 3 boulders in Oldenburg.

The glacier-stream, »das Haupteis«, which brought down these materials to Oldenburg, pursued the following course according to J. MARTIN'S views: »Von den Hochgebirgen Jemtlands, und Dalarnes ausgehend floss es in südostlicher Richtung nach dem Bottnischen Meerbusen und der Ostsee ab, folgte der Küste bis etwa zur Höhe der Nordspitze Ölands, wo es wahrscheinlich das Festland wiederum betrat, und ging alsdann allmählich aus der nordnordost — südsüdwestlichen in eine nordost — südwestliche Stromrichtung über, welche es von Schonen bis zum Oberrhein bewahrte«. I shall discuss this question more closely later.

In Holland investigations on the crystalline boulders have been made by v. CALKER, SCHROEDER v. D. KOLK, ERENS etc. J. MARTIN (1895) has in part gone through these investigations critically, in part given the results of his own investigations. The result of these studies is, that boulders from the Åland islands are present in rich quantities in the Dutch glacial deposits. Several discoveries of red Baltic quartz porphyry were also made. Brown Baltic quartz porphyry has also been found a few times according to the literature, as H. HEDSTRÖM showed in 1895. Småland boulders seem to occur

here very rarely; SCHROEDER V. D. KOLK (1895) mentions that he only knows of Påskallavik porphyry being found in Holland 3 times. With regard to Scanian basalt, V. CALKER (1898) has determined 8 boulders of that kind from Kloosterholt in Groningen; SCHROEDER V. D. KOLK only mentions a few discoveries of basalt in his papers. On the other hand, J. MARTIN considers that Scanian basalt occurs somewhat commonly in the Netherlands as well as in Oldenburg. Boulders of Rhine basalt likewise occur however in the southern parts of Holland, and the question whether Scanian basalt is present is therefore uncertain. Dala boulders occur not rarely in the Netherlands; the commonest is Bredvad porphyry; amongst other certain Dala boulders may be mentioned Grönklitt porphyrite. V. CALKER (1889) also mentions Cancrinitsyenite found at Groningen.

As mentioned, the literature notes a few discoveries of boulders of the brown Baltic quartz porphyry. These are in fact very common in certain parts of the land and even seem to constitute the great majority of the crystalline indicator-boulders. This is the case, for example, in the province Utrecht from which many crystalline indicator-boulders are to be found in the collections of Utrecht University — which through the kindness of Prof. A. WICHMANN I was permitted to examine in 1904. Amongst these numerous examples of the brown Baltic quartz porphyry were present; also, a few boulders of red Baltic quartz porphyry, a single boulder from Åland and likewise a single boulder of Småland Gang-porphyry. Of Dala boulders there were a Grönklitt porphyrite as also a few other varieties, but no boulders of Bredvad porphyry. Of rhomb-porphyry there was one single boulder.

I was able to confirm by an excursion to the railway station »Doldersche weg« between Utrecht and Amersfoort, that this preponderance in number of the brown Baltic quartz porphyry, which the geological collection of boulders from the province of Utrecht showed was also present in nature. In a sand-pit with a number of boulders, scattered over a fairly large area, I found:

9 specimens of brown Baltic quartz porphyry,
1 — - Åland quartz porphyry, and
2 — - Rapakivi-like quartz porphyry;
1 — - granite-like porphyry from Dalarne.

The majority of the other boulders found consisted of indeterminable granites and gneiss; there was also a strikingly large number of large boulders of red sandstone and sandstone dashed with red, so-called »Dala sandstone«, as also a few boulders of flint, diabase and diabase porphyry.

Though the number of indicator-boulders collected at Doldersche weg was small, they nevertheless strikingly confirm the fact, that boulders of the brown Baltic quartz porphyry are here predominant in comparison with the other crystalline indicator-boulders. It appears also from the University collections, which possess boulders from many parts of the province, that this condition is not restricted to the single locality which I had the opportunity of visiting, but is a general phenomenon over the whole province of Utrecht.

The determinable boulder material thus seems to have been chiefly brought down from the Baltic region as far south in Holland as the inland ice itself has reached. This appears both from the observations at Doldersche weg and from the geological collection in Utrecht. The same appears also from the literature. Baltic materials are nowhere rare in the Netherlands glaciated region wherever a number of boulders occur. It is also apparent from the investigations which have been made in Holland on the fossil-bearing boulders.

How large has been the material which in comparison with the Baltic material has been carried down to Holland from the central parts of Sweden (such as can be expressed by means of indicator-boulders from Dalarne) is a question which still remains unanswered; an investigation would be of great interest. From Norway, on the other hand, there is certainly but an inconsiderable quantity of materials in the Holland Quaternary layers. Rhomb-porphyry seems undoubtedly to belong amongst the rarest of the crystalline indicator-boulders in the Dutch deposits from the Glacial Period, just as in Oldenburg.

If we now pass from the parts in Holland which have been directly covered by the inland ice, to the land which lies south of the Rhine and has not been directly covered but where Scandinavian indicator-boulders are present in the river diluvium, we find that what has been said regarding the relative frequency of the indicator-boulders no longer holds good.

In the diluvial deposits of South Holland V. Becker and A. Erens have found several specimens of rhomb-porphyry, amongst other places at Oudenbosch (from which I have also seen a piece in Utrecht) and Delvaux has also found some at Oud Gastel. Further, J. Petersen from a discovery at Oudenbosch has been able to determine a Nordmarkite. The discovery of rhomb-porphyry in Belgium has been noted by V. Madsen in 1895.

Through the great kindness of Burgmaster A. Erens I was able in 1904 to see through his private collection of boulders at St. Gerlach near Valkenburg. The Scandinavian boulders in this consisted mainly of granites and gneiss, but it is impossible to determine the exact localities in narrowly restricted parts of Scandinavia from which

they have come. From Oudenbosch however there were both rhomb-porphyry as well as a few other boulders of undoubtedly Norwegian origin; further a possible(?) Dala porphyry. On the other hand, there was not a single crystalline indicator-boulder of Baltic origin.

There is thus, with regard to the boulders carried down, a striking contrast between the part of Holland which has been directly under the glaciation and the southern part which lay outside the boundary of the Scandinavian ice (Carte géol. internat.). In the former area the Baltic boulders are relatively frequent, whilst Norwegian boulders only occur quite sporadically; in the latter, the southern, boulders of Norwegian origin are found just as in the northern area — certainly but few, but apparently just as frequently as in the northern part of the country —; but, on the other hand, not a single crystalline indicator-boulder of certain Baltic origin has as yet been found in the diluvial deposits in Southern Holland.

J. MARTIN has endeavoured (in 1895) to weaken the importance of A. ERENS' investigations by a series of considerations, which however in spite of their elaborateness and the labour taken are unable to weaken the facts themselves. But whether these will stand direct and more exact investigation, the future must decide; provisionally we must be content to build upon the facts that are known. J. PETERSEN (1901) has also critically examined the boulder-studies from this part of Holland. He maintains as the result of J. MARTIN's considerations and his own criticism: »so kommt man zu dem Ergebniss, dass im südlichen Holland sicherlich norwegische Geschiebe vorkommen, dass aber für ein Vorherschen solcher von den schwedischen unter dem aus Skandinavien stammenden Material kein Beweis erbracht wurde«. To this it may be said in the first place, that it is naturally impossible to prove that Baltic boulders are lacking in Southern Holland, as the possibility that they may be found is not excluded. But whoever denies the evidence from their not having been found hitherto should naturally seek to obtain direct evidence or other corresponding evidence to support his criticism.

If PETERSEN here uses the term »schwedische« in the same signification as »Baltic«, I am unable to agree with his statements. Since, whilst Norwegian boulders are certainly present, no trace of Baltic materials has been detected. It seems fairly improbable that ERENS would quite overlook and omit the for the rest so distinctive Baltic boulders, if they had been present, considering how large the material was he had collected, not only of Scandinavian origin but also from the Rhine district and the Ardennes, and not only of characteristic but also of non-characteristic Scandinavian material. However striking the contrast between the boulders in

Northern and Southern Holland may be, we are obliged to build upon the available data until new facts have shown the error of the old.

We are with V. MADSEN (1895) obliged to conclude from the available data, that the Scandinavian materials found among the diluvial deposits of Southern Holland have been carried down by an ice-stream, which obtained its quantum of material from Western Scandinavia; also, that this transport had taken place before the land ice loaded with Baltic and Eastern Scandinavian materials had come down so far as to cover the Netherlands.

The solution of the conditions discussed must be left to future investigations. In this connection however, we may with reason refer to the evidence of the rich quantities of Dala boulders found between Brunswick and Hanover, as also further to the considerable number of Dala boulders which according to J. MARTIN are found in Oldenburg. If West Scandinavian glacier-streams could carry down Dala boulders so far to the south as to Hanover, they must also have been able on a line further west to bring down boulders from the Christiania district so far, that they could come into contact with the Rhine diluvial deposits and be included in these. An investigation of the transported boulders in the region between Hanover—Brunswick and Southern Holland would possibly contribute to throw light on these conditions, namely, the unequal distribution of boulders in the Netherlands south of the Rhine and north of the Rhine.

An investigation of the distribution of the boulders in the provinces Hanover and Westphalia and surrounding territories would on the whole undoubtedly be an interesting and profitable task from the standpoint of Quaternary geology. We are here so far from Scandinavia that all the indicator-boulders from there to an equal extent display the directions of the ice-flow; and according to the views at present obtaining we are also beyond the influence of the last final impulse of the Scandinavian inland ice. At the same time we are here at a boundary region, to all sides of which there are problems to be solved: to the east around Hanover the Dala boulders are comparatively richly represented; in the province of Utrecht and possibly other places of the Netherlands these occur but little. In the district round Hamburg the boulders of rhomb-porphyry are still fairly common; in Oldenburg and the districts to the south of this they seem to be very rare. In Oldenburg according to MARTIN boulders of Scanian basalt are amongst the commonest occurring of the crystalline indicator-boulders; in the districts south and south-east of this they are almost unknown; in the southern part of Holland their occurrence has scarcely been sufficiently investigated, as they are mixed here with boulders of basalt from the Siebengebirge.

East coast of England.

The first to mention the occurrence of Scandinavian indicator-boulders in England is most probably HELLAND (1879). Since that time a goodly number of boulders from the Christiania neighbourhood have gradually been found, namely, in the eastern part of Yorkshire along the whole stretch of coast; also in Lincolnshire and in Norfolk as far south as to Wymondham, south-west of Norwich. Of the post-silurian, eruptive rocks of the Christiania neighbourhood rhomb-porphyry is the most abundantly represented in the English Quaternary layers. In Yorkshire especially great efforts have been made within recent years to collect and preserve the Scandinavian indicator-boulders. In addition to rhomb-porphyry the following types of boulders from the same place of origin have been found, namely, augite-syenite (Laurvikite), foyaite, eleolite-syenite, as also a »syenitic dyke-rock«, which according to determination by Prof. W. C. BRÖGGER may have come from »Longen valley north of Christiania«.[1]

In addition to boulders of Norwegian origin discoveries of boulders of Swedish and Baltic rocks have also been noted from the English drift deposits. Thus, according to the determinations of HJ. SJÖGREN and H. BÄCKSTRÖM the following boulders of Swedish origin have amongst others been found on the beach from Cromer to Mundesley: »cancrinite-syenite of Särna, Dalarne; quartz-porphyry, Dalarne; sparagmite conglomerate, Scania«.[2] Yet V. MADSEN (1893) has first found a couple of rock types from Dalarne. All the places lie on the north coast of Norfolk. That such boulders should occur here is in itself quite probable, but it must be remarked regarding some of the discoveries hitherto noted, that the boulders are too little characterized to enable one to be certain as to the correctness of the determination of the place of origin, so long as the discoveries stand so isolated as is the case here. For example, to state quite generally the discovery of »quartz-porphyry« from Dalarne is not of very great importance. It would be reasonable to suppose that the boulder is a Bredvad porphyry, if it is from Dalarne; but in such a case the two authors mentioned would certainly have noted this. It is only when the boulders found are referred to more exactly defined types of rock, or their own petrographic and general character more definitely described, that we shall be able to attach any weight to the discoveries.

One of the two boulders found by MADSEN and determined as Dala porphyries by E. SVEDMARK has in general appearance some resemblance to Grönklitt porphyrite, but has not been examined

[1] Report Brit. Assoc. Adv. Sci. for 1903.
[2] Report Brit. Assoc. Adv. Sci. for 1904.

microscopically and does not seem to be typical for this kind of rock. The other is a dark, almost black quartz porphyry with quite small porphyric quartz crystals and dense ground-mass. To which of the Dala porphyry varieties it could possibly be compared, is unknown.

Whilst we do not know, whether the most widely distributed of the Dala boulders, namely Bredvad porphyry, has found its way to England, it is quite apparent that cantrinite-syenite (Fonolite) from Särna has been found amongst the boulders determined by SJÖGREN and BÄCKSTRÖM. This type of rock occurs in reality extremely seldom as boulder in the Quaternary layers outside Scandinavia. If therefore, the determination of this boulder is correct, it must be considered as granted that such indicator-boulders from Dalarne, which elsewhere belong to the most common types, must also be very common in the English Quaternary layers. Prof. N. V. USSING has however kindly informed me, that on a short visit to Cromer, which he made with Dr. J. J. SEDERHOLM and Dr. K. O. BJÖRLYKKE and when his attention was specially directed to Scandinavian indicator-boulders, he did not find any indicator-boulder of more easterly origin than from the Christiania neighbourhood amongst the stones on the beach. However the actual conditions may be, whether true Dala boulders are found on the east coast of England or not, it is safer to consider the question as unsettled, until typical specimens of the commonest indicator-boulders of Dalarne have been determined there.

With regard to the discovery of »sparagmite conglomerate from Scania«, it must be remarked as for the Fonolite, that if boulders of such a type occur in the English drift deposits which can with certainty be said to have come from Scania, then we may certainly expect to find in England boulders of Scanian basalt, which occur so frequently along the south-east side of the North Sea. Now, as a matter of fact, in the coastal regions of England where Scandinavian materials are present, a number of basalt boulders occur, the place of origin of which is not known from the British Isles, and it is therefore possible, that closer examination will show that they come from Scania. But for certain proof of this we must await future investigations.

In addition to boulders from Dalarne and from Scania, discoveries are also noted from Holderness of »post-archæan granite from Ångermanland or Åland«.[1] The first of these has been determined by H. MUNTHE. When Ångermanland is given as the possible place of origin for indicator-boulders, it must, according to what we know of

[1] Rep. Brit, Assoc. Adv. Sci. for 1897, 1898 and 1902.

the distribution of the Scandinavian boulders in the Quaternary deposits, be considered as very doubtful, whether the determination can be maintained. Characteristic types of rock from Ångermanland are on the whole extremely rare as boulders in the drift-deposits of the South-West Baltic, even where the Baltic character is otherwise strongly pronounced. On the other hand, the possibility must not be excluded altogether, that boulders may occur in England from Åland and the northern region of the Baltic. When we remember that such boulders are very common in Holland, the possibility mentioned does not seem so far-fetched. Yet the proof of their presence in England, just as for the Dala boulders and the Scanian basalt, must await future investigations. The discoveries mentioned are too vaguely characterized to be taken as proof.

Places investigated and indicator-boulders found.

	Norway		Dalarne			
	Rhomb-porphyry	Rhomb porphyry conglomerate	Bredvad porphyry	Heden porphyry, coarse	Heden porphyry, fine-grained	Brown porphyry
Central Sweden.						
Katrineholms ås	....	....	30+	5		....
Ås near Södertelge	....	....	11	2		....
Sealand (and Hven).						
As S. of Hornbæk	....	1	.....	....	....	....
Beach near Hornbæk	3	2	3	1		....
Ås near Havreholm	....	1	.....	....	....	....
Strødam, 2½ km. N. W. of Hillerød	3	2	1	1	....	....
Hven, strand-stones from moraine-clay	....	4	4	1	....	....
Freerslev Station S. W. of Hillerød	2	....	2	....	....	....
Strø Bjerge near Ølsted	2	2	11	1	1	1
Beach S. of Frederiksværk	5	1	12	....	3	1
Gravel-pit near Farum	....	1	17	1		1
Gravel-pit near Roskilde	5	6	20	1		....
Vangede near Gentofte	....	....	5	....	....	....
Gravel-pit near Vordingborg Station	....	....	5	....	....	....
Gravel-pit near Stenlille	....	1	25	1	....	1
Blæsinge Bakker N. of Slagelse	....	1	7	1	....	....
Kirkebjerg, 3 km. N. of Mørkøv Station	4	4	3	....	....	....
Lynghuse near Grevinge	....	....	1	....	....	....
Agnsøgaard near Svebølle Station	1	....	9	....	....	....
Langeland and Funen.						
Gravel-pit S. E. of Rudkjøbing	....	....	6	....	....	1
Fattigbakke S. E. of Rudkjøbing	....	....	10	....	....	....
Gravel-pits E. of Svendborg	3	3	18	1	....	....
Aktie gravel-pit E. of Svendborg	2	5	21	2	4	....
Gravel-pit near Høje Bøge	2	....	7	2	1	....
Gravel-pit near Kirkeby railway station	....	....	12	1	....	1
Vantinge ås	7	5	45	2	3	....
Højby ås	4	1	14	....	....	....
Grindløse ås	1	1	15	....	....	1

Dalarne									Sweden	Scania	Små-land	Åland					The Baltic	
Särna porphyry, brown-violet	Särna porphyry, red	Garberg porphyry	Kåtilla	Red, grained porphyry	Grönklitt porphyrite	Venjan porphyrite	Hornstone porphyry	Undetermined Dala porphyries	Kinnediabase	Basalt	Påskallavik porphyry	Rapakivi	Granite	Rapakivi-like granite	Quartz porphyry	Rapakivi-like quartz porphyry	Brown Baltic quartz porphyry	Red Baltic quartz porphyry
2	3	4	2	2	13	1	4	....	.....	.....	....	....	....	....	...	...	...	...
...	2	....	....	2	10	....	....	....	.....	.....	....	....	....	....	...	...	...	...
...	....	....	....	....	2	....	....	....	many	.....	....	....	....	....	...	...	...	...
...	1	....	2	....	1	....	....	1	.....	.....	1	1	....	...	2	...	5	1
...	....	....	....	....	....	....	....	....	.....	.....	....	....	....	....	...	...	...	...
...	....	....	....	....	1	....	....	....	.....	5	....	....	....	....	...	1	1	1
...	....	....	1	....	3	....	1	....	numerous	5 (+)	1	8	13	...	2	7	41	22
...	....	....	1	....	2	....	....	....	.....	2	....		4	...	1	1	5	1
...	....	....	3	1	2	....	....	1	.....	2	....	....	1	...	4	3	9	4
...	1	....	1	....	9	....	1	....	.....	3	4	....	21	...	11	11	49	4
...	1	....	....	2	6	2	2	....	.....	.....	....		6		2	7	3	1
...	1	1	2	2	7	....	....	....	.....	9	....		7		1	2	4	7
...	....	....	2	....	5	1	....	....	.....	2	1	....	....	...	2	...	19	11
...	1	....	....	....	4	....	....	....	.....	3	1		3		2	5	9	6
1	3	....	1	1	5	....	1	....	.....	1	4	1	....	...	3	1	15	1
...	....	....	....	....	3	....	....	....	.....	1	....	....	1	...	1	1	4	2
...	....	....	1	....	1	....	1	....	some	4	....	....	1	...	...	1	1	...
...	....	....	....	....	....	....	....	1	.....	1	....	....	....	....	...	1	...	...
...	....	1	....	....	1	....	....	3	.....	.....	1	....	1	...	1	4	8	1
...	....	1	....	1	3	....	....	....	.....	.....	3	....	1	...	...	1	6	...
...	1	....	1	....	1	1	....	1	.....	.....	4	....	7	...	2	...	13	...
1	2	1	....	2	2	....	....	2	.....	1	....	....	....	1	1	...	2	2
...	3	1	....	1	7	1	....	2	many	.....	....	....	8	...	2	1	1	3
...	1	....	2	1	2	....	2	....	.....	1	....	....	5	...	...	2	...	...
...	2	....	3	....	2	....	3	....	several	1	1	....	1	...	2	...	4	2
...	4	....	2	1	11	....	1	5	several	3	1	1	23		1	8	6	16
...	....	1	2	....	11	....	....	3	.....	5	1		12		2	3	7	5
...	1	1	2	....	4	1	1	3	.....	2	2		3		1	10	5	5

	Norway		Dalarne			
	Rhomb-porphyry	Rhomb porphyry conglomerate	Bredvad porphyry	Heden porphyry, coarse	Heden porphyry, fine-grained	Brown porphyry
Jutland, northern part.						
Flamsbakke, Aasted parish, W. of Frederikshavn	190		5	1	....	4
Skansebakke near Nørre Sundby	220		15	1	....	2
Svinkløv	47	13	14	....	....	1
Hanstholm	38	18	22	....	....	3
Bislev, 4 km. S. of Nibe	51	18	8	....	....	....
Ræbild, W. of Skjørping railway station	115	35	14	....	....	....
Gravel-pit near Langaa Station	101	13	11	....	....	....
Fieldstones between Møldrup and Hvam	ca. 100		10	....	....	....
Bovbjerg, Beach, 1. enumeration	345	65	18	1	....	....
Bovbjerg, Beach, 2. enumeration	....	....	21	....	....	1
Gravel-pit E. of Lomborg, S. of Lemvig	135	36	7	....	....	....
Jutland, eastern part.						
Gravel-pit N. W. of Rosmus Station	11	5	24	2	1	1
Gravel-pit S. of Løsning Station	2	....	21	....	....	1
W. Hornstrup, S. of Jelling	10	....	7	....	....	....
Nordbæk field, W. of Egtved	8	1	19	....	....	....
Gravel-pit near Bølling, S. E. of Egtved	22	2	55	....	....	....
Gravel-pits N. W. of Verst Kirke	9	....	24	....	2	....
Gravel-pit near Gamst poorhouse	2	....	9	....	....	....
Dollerup, S. W. of Lunderskov	27	5	60	....	3	....
Rolsmølle, N. E. of Lunderskov	8	....	17	....	....	1
Gravel-pit S. of Ødis-Bramdrup mill	12	1	21	....	....	1
Gravel-pits S. W. of Kolding	20	2	35	2	3	2
Field-stones near Bække	....	....	1	....	1	....
Harebjerg, S. of Brørup Station	3	....	22	....	1	....
Gravel-pit E. of Vittrup, Lindknud parish	5	....	5	....	....	....
Gravel-pit N. W. of Læborg	5	2	9	....	....	....
Sandsø, 2 km. N. E. of Vorbasse	7	1	36	1	2	....
Rostbanke between Hejnsvig and Vorbasse	2	....	1	1	....	1
Road-section N. W. of Hejnsvig	6	1	6	....	....	....
Gravel-layer over marl, Stilbjerg	5	2	4	....	....	....

Dalarne									Sweden	Scania	Små-land	Åland					The Baltic	
Särna porphyry, brown-violet	Särna porphyry, red	Garberg porphyry	Kåtilla	Red, grained porphyry	Grönklitt porphyrite	Venjan porphyrite	Hornstone porphyry	Undetermined Dala porphyries	Kinnediabase	Basalt	Påskallavik porphyry	Rapakivi	Granite	Rapakivi-like granite	Quartz porphyry	Rapakivi-like quartz porphyry	Brown Baltic quartz porphyry	Red Baltic quartz porphyry
1	3	....	1	....	1	1	....	....	.....	.....	....	1	....	..	2	6	..	1
....	2	....	1	1	8	2	....	....	.....	.....	....	1	....	..	2	3	..	..
....	....	....	1	....	....	2	1	....	.....	.....	....	....	....	..	..	1	..	3
....	1	....	1	....	....	....	1	....	.....	.....	....	....	....	..	1	1	1	..
....	1	....	....	....	1	....	1	....	.....	.....	....	....	1	..	2	..	2	4
....	2	1	....	....	3	....	....	....	.....	.....	1	....	....	..	3	3	1	4
....	....	....	....	....	3	2	....	....	16	1	....	4			2	6	2	1
....	1	....	....	....	2	....	....	....	.....	.....	....	2			2	1	..	..
....	2	....	....	1	2	2	....	....	a few	.....	....	....	....	..	1	2	..	1
....	2	1	1	1	4	3	1	3	.....	3	1	....	4	..	1	5	..	3
1	....	....	....	1	4	....	....	....	a few	.....	....	....	....	..	..	1	1	..
....	1	....	....	1	8	1	....	3	12	.....	....	24			2	8	7	19
....	3	....	1	....	4	2	....	....	1	4	6	9			6	3	15	2
....	....	....	....	....	2	....	....	....	.....	1	....	....	5	2	4	1	2	5
....	1	....	1	1	1	....	....	....	2	11	....	4	5	2	..	4	6	3
1	3	2	....	....	9	....	3	....	.....	.....	....	....	12	..	4	2	16	6
1	5	....	1	....	7	....	....	....	a few	3	1	1	7	4	5	3	11	6
....	....	....	....	....	4	....	....	....	.....	.....	....	....	2	..	1	..	2	1
....	5	....	3	....	8	....	1	....	a few	.....	1	1	14	..	3	4	11	7
....	1	....	....	....	4	1	....	....	some	.....	....	....	3	..	..	5	5	1
....	3	....	2	....	8	....	1	4	a few	.....	....	5			2	1	8	5
1	2	....	1	1	10	3	2	4	.....	4	2	17			2	8	5	9
1	1	....	....	....	....	....	....	....	.....	40	3	....	....	..	1	2	1	..
....	1	....	1	....	4	....	....	....	some	.....	....	....	1	1	1	1	..	3
....	1	....	....	....	1	1	....	....	.....	.....	....	....	....	1	1	1	2	1
....	....	....	....	....	3	....	....	....	.....	3	....	....	1	..	..	3	..	..
....	1	....	4	....	6	....	....	....	.....	4	1	2	4	3	3	2	39	1
....	....	....	....	....	....	....	....	1	.....	1	....	1	1	..	..	..	..	..
....	....	....	....	....	1	1	....	....	.....	.....	1	....	1	2	1	..	2	..
....	1	....	....	....	....	....	....	1	.....	.....	....	....	....	..	..	..	1	2

	Norway		Dalarne			
	Rhomb-porphyry	Rhomb porphyry conglomerate	Bredvad porphyry	Heden porphyry, coarse	Heden porphyry, fine-grained	Brown porphyry
Field-stones S. W. of Uhe	....	....	2	....	....	....
Toppelunds hill, 1 km. N. E. of Lindballe	30	3	22	....	....	....
Krogvad bridge, 1600 m. S. S. E. of Farre Station	7	....	10	....	....	....
Klavrbjerg between Ringive and Give	11	....	11	....	....	1
Gadebanke S. W. of Give	8	....	.....	....	....	....
Gravel-pit, 1400 m. S. E. of Thyregod	12	....	7	....	....	....
Jutland, western part.						
Gravel-pits S. E. of Raasted Church	126	4	10	1	3	....
Gravel-pit near the road, Aulum	169	6	7	....	....	....
Gravels between Holstebro and Aulum	218	15	4	1	....	....
Gravel-pits W. of Herning	482	36	5	....	....	....
Frifeld, 13 km. W. of Herning	39	....	.....	....	....	....
Gravel-pit near Ølstrup, 12 km. E. of Ringkjøbing	61		.....	....	....	....
Gravel-pit near Vennergaarde, S. E. of Ringkjøbing	42	9	11	....	....	1
Gravel-pit near Dalager, Borris	18	2	4	....	....	....
Field-stones between Dalager and Fasterkjær	....	....	10	1	....	....
Gravel-pit in Svollibjerg, S. Omme	49		3	1	....	1
Gravel-pits E. of Korskro	38	4	4	....	....	1
Gravel-pits N. of Tjæreborg Station	137	19	21	1	3	1
Sleswig.						
Gravel-pits near Rødekro	7	5	56	1	1	....
Gravel-pit E. of Flensborg	2	....	10	....	....	1
Gravel-pit S. of Flensborg	2	....	7	1	....	....
Beach near Emmerlev cliff	6	2	23	3	2	1
Lüneburg.						
Vastorf, E. of Lüneburg	1	....	23	1	....	....
Pomerania.						
Trampke, N. E. of Stargard	....	....	1	....	....	....
Neighbourhood of Nörenberg	....	....	.....	....	....	....
Steinberg, S. of Nörenberg	....	....	1	....	....	....
Gravel-pit S. of Schlawe	....	....	5	....	....	....

Dalarne									Sweden	Scania	Små-land	Åland					The Baltic	
Särna porphyry, brown-violet	Särna porphyry, red	Garberg porphyry	Kåtilla	Red, grained porphyry	Grönklitt porphyrite	Venjan porphyrite	Hornstone porphyry	Undetermined Dala porphyries	Kinnediabase	Basalt	Påskallavik porphyry	Rapakivi	Granite	Ravakivi-like granite	Quartz porphyry	Rapakivi-like quartz porphyry	Brown Baltic quartz porphyry	Red Baltic quartz porphyry
....	....	....	....	....	....	....	....	....	.....	1	....	....	1	2	3	4	..	..
....	2	....	....	....	3	....	....	....	.....	.....	....	....	....	..	1	..	..	3
....	....	....	....	....	1	....	....	....	.....	.....	....	....	3	..	2	3	5	3
....	....	....	....	....	....	....	....	....	.....	.....	....	....	....	1	..	..	1	4
....	....	....	....	....	....	....	....	....	.....	1	....	....	....	..	1	..	..	..
....	....	....	....	....	....	....	....	....	.....	.....	....	....	1	..	..	..	2	..
....	2	....	....	....	....	2	....	2		1	....	1	....	1	..	..	1	..
....	....	....	1	....	3	....	....	....		.....	....	....	....	..	..	..	1	..
....	....	....	....	....	1	....	1	....		.....	....	....	....	..	..	..	..	1
....	....	....	....	....	....	1	....	....		.....	....	....	....	..	..	..	..	..
....	....	....	....	....	....	....	....	....		1	....	....	....	..	..	..	..	..
....	....	....	....	....	1	....	....	....		.....	....	....	....	..	..	..	..	..
....	2	....	1	....	3	....	1	1	.....	.....	....	....	4	1	1	1	1	2
....	....	....	1	....	1	....	....	....	.....	.....	....	....	....	..	1	..	..	..
....	....	....	....	1	1	....	....	....	.....	.....	6	4	....	..	1	3	4	..
....	....	....	....	....	1	....	....	....	.....	.....	....	....	....	..	..	..	..	..
....	1	....	1	....	....	1	....	....	.....	.....	....	....	....	..	1	..	..	..
3	2	....	....	....	4	....	....	2	.....	4	1	....	....	..	..	..	..	..
....	3	....	....	2	10	....	....	....	.....	.....	1	19			3	9	18	14
....	....	....	....	....	2	1	1	....	.....	3	....	....	5	..	..	3	7	1
....	....	....	....	....	5	1	3	....	just a few	.....	....	....	3	..	..	2	5	2
2	5	....	....	....	20	3	1	2	22	6	2	2	6	..	6	9	9	3
....	1	....	....	....	14	....	2	....	.....	1	1	14			26		23	38
....	....	1	....	....	....	....	....	....	.....	.....	....	....	1	1	1	..	2	..
....	....	....	....	....	....	....	....	....	.....	.....	....	3	1	..	..	..	5	1
....	....	....	....	1	1	....	....	....	1	.....	....	....	1	..	1	2	1	2
....	....	1	....	....	1	....	2	....	.....	.....	1	....	2	..	1	2	1	1

	Norway		Dalarne			
	Rhomb-porphyry	Rhomb porphyry conglomerate	Bredvad porphyry	Heden porphyry, coarse	Heden porphyry, fine-grained	Brown porphyry
Posen.						
Schilling, 1,5 km. N. of Posen	....	....	2	....	....	....
Johannisthal, 1 km. E. by S. of Posen	....	....	.....	....	....	....
West Prussia.						
Bank of Weichsel River at Thorn	....	....	1	....	....	....
Warlubien	....	....	.....	....	....	....
Schwarzwasser W. of Laskowitz	....	....	1	....	....	....
Buschkauer Forst, 20 km. S.W. of Dantzig	....	....	.....	....	....	....
Terrace at Kahlbude, 20 km. S.W. of Dantzig	....	....	.....	....	....	....
Nenkau Brickworks, 5 km. W. of Dantzig	....	....	.....	....	....	....
Dantzig	....	....	2	....	....	....
Hoch Redlau, N. of Dantzig	....	....	2	....	1	....
Beach near Adlershorst, N. of Dantzig	....	....	1	....	....	....
East Prussia.						
Soldau	....	....	.....	....	....	....
Neidenburg	....	....	2	....	....	....
Neighbourhood of Allenstein	....	....	2	....	....	....
Neighbourhood of Passenheim	....	....	2	1	....	....
Bärwalde, W. of Königsberg	....	....	1	....	....	....
Beach near Warnicken-Rauschen	....	....	3	....	....	....
Beach near Cranz	....	....	.....	....	....	....
Russian Poland.						
Neighbourhood of Warsaw	....	....	4	....	....	....
Russia.						
Eydtkuhnen-Wirballen	....	....	1	....	....	....
Landvorovo, W. of Vilna	....	....	1	....	....	....
Vilejka River, Vilna	....	....	1	....	....	1
Minsk, Gravel-layer, 2 km. S. of the town	....	....	.....	....	....	....
Gravel-pits N. of Smolensk	....	....	.....	....	....	....
Galgenberg near Tukkum, northern pit	....	....	1	....	....	....
Galgenberg near Tukkum, southern pit	....	....	.....	....	....	....

Dalarne									Sweden	Scania	Småland	Åland					The Baltic	
Särna porphyry, brown-violet	Särna porphyry, red	Garberg porphyry	Kåtilla	Red, grained porphyry	Grönklitt porphyrite	Venjan porphyrite	Hornstone porphyry	Undetermined Dala porphyries	Kinnediabase	Basalt	Påskallavik porphyry	Rapakivi	Granite	Rapakivi-like granite	Quartz porphyry	Rapakivi-like quartz porphyry	Brown Baltic quartz porphyry	Red Baltic quartz porphyry
1	....	....	1	....	....	....	....	....	.....	.....	1	....	4	..	1	1	..	..
....	....	....	....	....	....	....	....	....	.....	.....	....	....	1	..	1	3	..	..
....	....	....	....	....	....	....	1	....	.....	.....	....	....	1	..	3	2	3	..
....	....	....	....	....	....	....	....	....	.....	.....	....	....	....	..	..	..	2	1
....	....	....	1	....	2	....	....	....	.....	.....	....	2	....	..	2	1	..	..
....	....	....	....	....	....	....	....	....	.....	.....	....	....	1	..	1	..	1	1
....	....	....	....	....	....	....	....	....	.....	.....	....	....	2	..	..	..	..	..
....	....	....	....	....	....	....	....	....	.....	.....	....	....	....	..	..	..	..	1
....	1	....	....	....	....	....	....	....	.....	.....	....	....	4	..	1	3	1	..
....	....	....	....	....	....	....	....	....	.....	.....	....	....	....	..	..	..	1	1
....	....	....	....	....	....	....	....	....	.....	.....	....	....	....	..	1	1	..	..
....	1	....	....	....	....	....	....	....	.....	.....	....	....	2	..	..	1	2	1
....	....	....	....	....	....	....	....	....	.....	.....	....	....	1	..	1	1	..	3
....	....	....	....	....	....	....	....	....	.....	.....	....	1	4	..	..	2	5	3
....	....	....	....	1	1	....	1	....	.....	.....	....		2		3	4	3	4
....	....	....	1	....	3	....	....	....	.....	.....	....	....	3	..	..	2	2	3
....	....	....	3	....	2	....	1	....	.....	.....	....	....	3	..	3	2	2	1
....	....	....	....	....	2	....	....	....	.....	.....	....	....	....	..	..	..	..	..
....	....	....	1	....	1	1	....	....	.....	.....	....	....	5	..	3	5	2	3
....	....	....	....	....	....	....	....	....	.....	.....	....	....	4	..	..	1	3	3
....	....	....	....	....	....	....	....	....	.....	.....	....	....	3	..	1	1	1	3
....	....	....	....	....	1	....	1	....	.....	.....	....		4		5	1	1	2
....	....	....	....	....	....	....	....	....	.....	.....	....	....	4	1	..	..	..	12
....	....	....	....	....	....	....	....	....	.....	.....	....	....	....	..	..	..	1	2
....	....	....	....	....	....	....	....	....	.....	.....	....	....	4	..	..	4	..	3
....	....	....	....	....	....	....	....	....	.....	.....	....	....	4	..	1	7	..	17

	Norway		Dalarne			
	Rhomb-porphyry	Rhomb porphyry conglomerate	Bredvad porphyry	Heden porphyry, coarse	Heden porphyry, fine-grained	Brown porphyry
Kruschkaln, S. of Behnen Station (western)	....	....	.....	....	....	....
Kruschkaln, S. of Gut Kruschkaln (eastern)	....	....	2	....	....	....
Rullekaln, 6 km. S. of Mitau	....	....	.....	....	....	....
Oger Kanger, S. E. of Oger	....	....	.....	....	....	....
Gravel-pit, 500 m. S. of Wolmar	....	....	.....	....	....	....
Kaugershofs gravel-pit, S. E. of Wolmar	....	....	.....	....	....	....
Wegin gravel-pit, 5 km. N. E. of Wolmar	....	....	1	....	....	....
Fields N. of Wolmar	....	....	.....	....	....	....
Gravel-pits W. of Walk	....	....	.....	....	....	....
Gravel-pit near Dorpat Churchgard	....	....	.....	....	....	....
Gravel-pit S. of Reshitza	....	....	.....	....	....	....
Fields N. W. of Reshitza	....	....	.....	....	....	....
Marginal moraine landscape near Taunagi, N. W. of Reshitza	....	....	.....	....	....	....
Railway near Pedeli, W. of Reshitza	....	....	.....	....	....	....
Fields 3 km. E. of Svenziany	....	....	4	....	....	....
Fields 5 km. E. of Svenziany	....	....	1	....	....	....
Fields 4 km. E. of Glubokoi	....	....	1	....	....	....
Saxony.						
Goldberg near Halle	....	....	7	....	....	....
Gravel-pit near Schraplau, W. by S. of Halle	....	....	9	....	....	....
Hanover.						
Horst	....	....	23	....	....	....
Wipshausen	1	....	34	....	....	....
Holland.						
Doldersche weg N. of Utrecht	....	....	.....	....	....	....

Dalarne									Sweden	Scania	Små-land	Åland					The Baltic	
Särna porphyry, brown-violet	Särna porphyry, red	Garberg porphyry	Kåtilla	Red, grained porphyry	Grönklitt porphyrite	Venjan porphyrite	Hornstone porphyry	Undetermined Dala porphyries	Kinnediabase	Basalt	Påskallavik porphyry	Rapakivi	Granite	Rapakivi-like granite	Quartz porphyry	Rapakivi-like quartz porphyry	Brown Baltic quartz porphyry	Red Baltic quartz porphyry
....	....	....	....	....	....	....	....	....	.....	.....	....	....	....	3	3	7	1	18
....	....	....	....	....	2	....	....	....	.....	.....	....	5	5	1	5	7	6	14
....	....	....	....	....	....	....	....	....	.....	.....	....	1	....	1	3	4	4	17
....	....	....	....	....	....	....	....	....	.....	.....	....	....	2	1	..	2	..	4
....	....	....	....	....	....	....	....	....	.....	.....	....	....	....	..	..	2	..	..
....	....	....	....	....	....	....	....	1	.....	.....	....	....	2	..	..	..	..	1
....	....	....	....	....	....	....	....	....	.....	.....	....	....	4	..	1	..	..	4
....	....	....	....	....	....	....	....	....	.....	.....	....	....	2	..	1	..	..	5
....	....	....	....	....	....	....	....	....	.....	.....	....	....	2	..	..	..	..	1
....	....	....	....	....	....	....	....	....	.....	.....	....	....	....	..	..	..	..	1
....	....	....	....	....	....	....	....	....	.....	.....	....	....	1	..	..	..	..	2
....	....	....	....	....	....	....	....	....	.....	.....	....	....	1	..	..	..	..	..
....	....	....	....	....	....	....	....	....	.....	.....	....	1	3	..	2	1	..	2
....	....	....	....	....	....	....	....	....	.....	.....	....	1	2	..	1	1	..	2
....	....	....	....	....	....	....	....	....	.....	.....	....	....	2	..	5	6	1	23
....	....	....	....	....	....	....	....	....	.....	.....	....	2	3	..	3	4	6	11
....	....	....	....	....	....	....	....	....	.....	.....	....	3	3	4	5	4	8	27
....	....	....	....	....	1	....	1	....	.....	.....	....	4	1	..	2	5	3	1
....	....	....	....	....	....	....	....	....	.....	.....	....	....	2	..	2	..	..	1
....	1	....	1	1	10	....	....	....	.....	.....	....	2	2	..	2	..	..	..
....	....	....	....	....	4	....	....	....	.....	.....	....	2	1	..	1	..	..	5
....	....	....	....	1	....	....	....	....	.....	.....	....	....	....	..	1	2	9	..

Lines of distribution and chronological order.

The lines along which the North Baltic boulders became distributed were determined in the main by the Baltic basin which formed a main channel or course for the ice-masses. From this basin the ice spread out over the Baltic lands of Russia and Germany. The extension furthest to the east has been conditioned by the degree to which the ice-masses from Finland spread down over the Gulf of Finland and the Russian Baltic provinces. At the time when the Åland boulders were being carried down in extremely great quantities into the region round Swenziany and Glubokoi, the ice-masses of Finland were greatly hemmed in and their advance retarded. Further to the north on the other hand, in Estland, the ice-masses from the Baltic basin have only advanced to a smaller extent. Here it has in much greater degree been ice from the north and north north-west which has brought down the boulder material and shaped the land.

In the southern Baltic region we find on the land the marks of oscillations in the ice-margin conforming to the line of the Baltic coast. This is most distinct nearest to the Baltic and we see here how the Baltic basin has been the line from which the ice-lobes have extended up over the adjoining valleys.

From the western part of the Baltic the ice-masses have spread out in quite a fan-shaped manner. A Baltic glacier has simultaneously covered the Danish Islands, the East Jutland coastal region, Sleswig, Holstein and extended still further to the south and south-east. It is only here, namely in Scania, that we find any trace of the ice-masses from the Baltic basin having forced their way in over the Swedish mainland to any essential extent. At almost all other places, from the Åland region to Bornholm, the Baltic ice-stream has been prevented from spreading over the present Swedish coasts by the ice-masses which extended down over South Sweden towards the Baltic basin.

Whilst the North Baltic boulders show the distribution the ice-masses with main direction down through the Baltic basin had, the boulders from the Swedish mainland, Dalarne, Småland and Scania show the influence on the Baltic ice-stream the ice exerted which came from the region of South and Middle Sweden. The pressure of the ice from this side caused the Baltic ice-stream to spread out over the eastern and southern margins of the Baltic down over the West Russian and North German lowlands. The Swedish boulders from the region between Dalarne and Scania, which were thus at various parts along the Swedish coast-line carried side ways into the Baltic stream, accompanied the latter towards the south-east, south, south-west and west over the lands beyond the Baltic. In this manner porphyries from Dalarne were carried to the east as far as the Russian Baltic provinces (and Polish Livland) and in large numbers also to the north-eastern German provinces. Boulders of Småland Gang-porphyry (Påskallavik porphyry) were likewise spread over north-eastern Germany and in Silesia, boulders of basalt from Scania as far east as the neighbourhood of Landsberg in Pomerania and to the kingdom of Saxony.

These lines of distribution are sometimes cited as evidence that a »radial« movement of the ice has taken place,[1] which would seemingly imply a transverse glacial movement across the southern part of the Baltic, a »meridian stream« as HOLMSTRÖM[2] has called it. It should be remembered, however, that these outermost boundaries are far from indicating a normal direction of movement; on the contrary, they only show the extreme deviations from the normal direction. Excluding the region from Denmark southwards, to which there has been a direct movement of the ice from western Sweden, we have scarcely full proof that Scandinavian boulders have been carried to any part of the region once covered by ice, without the ice-stream along the Baltic basin having some influence on the direction of transference. It must also be added, however, that the investigations which alone can settle this question are quite lacking. Investigations, specially directed to determining the relative quantities of the North Baltic and Swedish indicator-boulders in the East German and West Russian glaciated region, both beyond and behind the boundary of the last glacial extension, might possibly throw light on the influence the Baltic basin has exercised at the different periods. According to what the present investigation has shown, the boulders from Dalarne

[1] See for example V. MADSEN: Om inddelingen af de danske kvartærdannelser. (Medd. fra Dansk geol. Foren. 5. 1889, p. 17).

[2] Öfversigt af den glaciala afslipningen i Sydskandinavien. Geol. Fören. Förh. Stockh. 26. 1904, p. 416.

are fairly common in the north-eastern parts of Germany, but nevertheless scarcer than the boulders from the Åland region. On the other hand, boulders from Kalmar län are only met with quite sporadically. Investigations in Silesia and southern Poland will possibly give somewhat different results in this regard and we should thus obtain a means of judging the conditions of distribution quite wanting at present. Here as indeed in the whole of the North German lowlands there is a wide field for investigations of the same kind as the present.

That ice which has passed the island Hogland in the Gulf of Finland has moved in a south-westerly direction, is shown by discoveries of Hogland quartz porphyry, for example, at Dantzig and Thorn. We have also various statements from earlier times that Finnish Rapakivi boulders have been found in the West Baltic region. If these came from the western Finnish Rapakivi region, their line of distribution would thus not be essentially different from that which the boulders of red Baltic quartz porphyry and the Åland boulders followed. In this connection may be mentioned the observations near the Småland coast, which HOLMSTRÖM (l. c. p. 397) has called attention to and which seem to show that glacial movements have occurred in the region north of Öland from the Baltic basin up towards the Småland highlands.

With regard to the conditions in Vorpomerania and at Rügen COHEN and DEECKE have come to the result, »dass das Eis, welches unsere vorpommersche Küste erreichte, von den Ålandsinseln an im Ostseebecken gegen Süd-südwest vorgerückt ist und über Kalmarsund, die Småländische Küste und Bornholm unsere Gegend erreichte«. They likewise state, »dass zwingende Gründe für die Voraussetzung einer zweiten anderen Flussrichtung vollständig fehlen«. With regard to the occurrence of Dala porphyries COHEN and DEECKE say: »Schon die geringe Zahl der identificirten Stücke bei uns zeigt, dass es sich wahrscheinlich um Fremdlinge handelt, die nur unter besonderen Umständen, also am Anfang und Ende der Hauptvereisung durch seitliche Zufuhr in den baltischen Eisstrom geriethen«.

That these conclusions are not correct appears from the quite common occurrence of the Dala boulders further to the east than Pomerania. It would be quite misleading if we called these »Fremdlinge« in the Quaternary deposits of East Prussia. Further, we can see in what manner the North Baltic boulders have been distributed over the eastern part of the Baltic, namely fan-shaped out from the Åland region. The indicator-boulders from all other localities are distributed in the same manner. There is nowhere any question of the transport having taken place solely along a single line of move-

ment. It will similarly be quite wrong, with regard to the places of discovery, to consider that the boulders have been brought down along a single line. Every single place where indicator-boulders of different origin have been found is indeed a focus of converging directions by which the boulders have come; similarly also in Neu-Vorpomerania and Rügen. If the main mass of the indicator-boulders here come partly from the Åland region, partly from eastern Småland — as COHEN and DEECKE state is the case — this is by no means the same as saying, that the direction by which the Åland boulders have come down must have been by way of Kalmarsund. It only shows in fact that the ice-stream which carried down the Åland boulders to North Germany by way of the Baltic basin received additions from the side from the southern Swedish highlands, and that these additions at a later period, when the boulders were deposited in the district round Rügen, constituted an essential portion of the Småland indicator-boulders contained by the ice-stream. All the discoveries of boulders throughout the whole of East Germany and West Russia bear witness to this lateral addition of Swedish materials to the Baltic stream.

Coming now to the more western parts of the glaciated region, West Germany, Holland and Denmark, we find distinct traces of an ice movement which has been in part independent of the Baltic basin, but has likewise been partly in contact with the Baltic outflow. As far as we can follow the glacial formations towards the west in this region, traces are still to be found of the extension of the Baltic ice. Even furthest south in the Netherlands we find that the only ice-stream which reached so far brought down chiefly Baltic materials. In Oldenburg, where as in the Netherlands we only find traces of one ice covering, J. MARTIN also believes that »das Haupteis« was »ein baltischer Strom«. He imagines its course from Scandinavia to Oldenburg to have been as follows: »Von den Hochgebirgen Jemtlands und Dalarnes ausgehend, floss es in südöstlicher Richtung nach dem Bottnichen Meerbusen und der Ostsee ab, folgte der Küste bis etwa zur Höhe der Nordspitze Ölands, wo es wahrscheinlich das Festland wiederum betrat, und ging alsdann allmählich aus der nord-nordost-südsüdwestlichen in eine nordost-südwestliche Stromrichtung über, welche es von Schonen bis zum Unterrhein bewahrte«.

The same objections made above against COHEN and DEECKE'S views regarding the line of transport of the boulders to the neighbourhood round Rügen also apply here. The spiral line of direction constructed by J. MARTIN cannot have been followed by one single ice-stream, as should have been the case according to his view. The transport of the different kinds of material to this part of Germany

must have taken place by different routes. The North Baltic boulders, as already mentioned, have been carried along the direction of the true Baltic stream, and likewise boulders from south-eastern Sweden. It was quite natural for the ice-stream, which could follow the Baltic basin without pressure from the Swedish highlands, to keep to this south of Sweden right to its westernmost limit. We have the clearest possible remains of this »Baltic ice-stream« in its truest sense in south-eastern Denmark and along the western margin of the Baltic. The indicator-boulders which chiefly show the directions by which the ice has reached the region Oldenburg-Hanover, also indicate however that there has been another line of movement different from that which has followed the whole length of the Baltic. As J. MARTIN (1898) has shown, the large quantities of basalt boulders in Oldenburg indicate that transport has taken place in a fairly direct line from Scania to north-west Germany. The relatively large numbers of the Dala boulders which, in comparison with the North Baltic boulders, occur to the east of Hanover, indicate further that an ice-movement has taken place even more directly north to south. This is also strengthened by the discoveries of the large quantities of boulders from Dalarne and from the neighbourhood of Christiania which have been made in the Quaternary deposits of Denmark. All these discoveries indicate that there must have been at some time a very extensive ice-movement over south-west Sweden and Denmark and further in a south-southwesterly direction. That such an extensive transport of boulders must have occurred has already been pointed out, especially by JOHANNES PETERSEN, whose supposition has now been confirmed.

This movement has sometimes gone in a direction right across that of the Baltic stream; for example, numerous boulders have been carried from the neighbourhood of Christiania to the Danish Islands; considerable quantities of the Dala boulders have been transported to Sealand and South Funen and even further to the south to the regions between Halle and Oldenburg; finally, basalt from Scania has been carried in large quantities to a few places in New Brandenburg. At other times the ice-movement over south-west Sweden and the Kattegat has been to a great extent diverted by the Baltic stream. This is shown by the occurrence of enormous quantities of basalt in the extreme south of Jutland, as also by the celebrated occurrence of boulders from the Christiania neighbourhood and possibly also from Sweden on the east coast of England.

If we should now endeavour to draw conclusions from the available data with regard to the chronological order in which the boulders have been distributed from the various places of origin to

the different places of dicovery, we must essentially consider the western and south-western parts of the glaciated region. The boulders in the more eastern regions have as yet been far too imperfectly investigated to form the basis of any conclusions. Even in the western regions the investigations distinctly show that they are not sufficient to permit the conclusions to be considered as more than probabilities.

In the part of Holland which lies south of the actual region once covered by the ice, in the diluvial land of rivers, we find boulders of rhomb-porphyry and other Norwegian stones but no trace of Baltic kinds. Compared with the conditions in Northern Holland, where quite a few Norwegian boulders have also been found in the glacial deposits, these discoveries show that the extension of the ice to these regions has begun with ice-masses containing Norwegian materials, which have come down from the north probably over Denmark. This stream however has not reached so far to the south as Holland, probably because it was subjected to lateral pressure by the ice-masses which streamed down from the eastern side of Scandinavia and from the Baltic region and thus was diverted towards the west over towards the English coast. The Norwegian ice-stream has nevertheless succeeded in reaching so far down that its boulders could be carried further to the south partly by means of the rivers, partly by and included in the moraine materials in the following Baltic glacier. The mode of occurrence of the Norwegian boulders in Holland, both to the south and to the north of the extreme limit of the ice-cover, is thus evidence of the passage at an early period of a Norwegian ice-stream down over Denmark before any Baltic ice had reached so far.

The only ice-sheet which reached down over Holland contained mostly Baltic materials and was essentially Baltic ice. In addition to the inconsiderable quantity of Norwegian kinds of boulders which this ice took up and carried further, there were also boulders from Southern Sweden, e. g. many basalt boulders from Scania. In Holland this ice-sheet extended to the neighbourhood of Utrecht. It cannot be determined with certainty how far this Baltic ice reached to the west and north-west of Sleswig and Denmark, but in each of these countries there is no necessary reason for refusing to believe, that it was Baltic ice which at one and the same time distributed boulders from the Åland region, from the Kalmarsund district and from Scania over the westernmost parts of Sleswig and Denmark, where they are now found in the oldest known Quaternary deposits.

Further, there is every reason to suppose, that it was this Baltic ice which caused the ice-stream from Southern Norway to bend to-

wards the west along the Norwegian Channel, by which means boulders from the Christiania district as also boulders of chalk and flint (from the Skagerak) and possibly likewise of Swedish materials (e. g. porphyries from Dalarne) were transported to Lister and Jæderen at the south-west point of Norway. This outflow of Baltic ice over North-West Germany, Holland and Denmark is thus very probably also closely connected with the extension of the Scandinavian ice-cover over the North Sea to the English east coast and the neighbourhood of the Shetland Isles.

Whilst the boulders found in Holland, e. g. in the province of Utrecht, indicate that the ice there has been preeminently Baltic, the conditions in Oldenburg and Hanover seem to indicate that the Baltic ice-masses were later replaced by others which had a more western origin. This seems to be indicated by the considerable quantity of basalt boulders to be found in the northernmost part of Holland and in Oldenburg. Further evidence in the same direction is furnished by the distribution of the Dala boulders, which according to MARTIN are far more common in Oldenburg than in the south in Holland and which are much more numerous between Hanover and Brunswick than the North Baltic boulders. In Oldenburg and the southern part of Hanover we only know deposits from one ice-sheet, just as in Holland. If the conclusion is correct, that the Baltic ice here has been replaced by ice-masses of more western origin, this must have occurred without any essential break in glaciation, that is, by means of a continuous and gradual transition from a more east—west to a more north—south direction of movement resulting in a change in the nature of the moraine materials. This altered nature is shown in the increased number of Dala boulders in Hanover; it appears in a similar manner in the neighbourhood of Halle and possibly also the occurrence of Scanian basalt in Saxony may have some connection with it. Detailed investigation of the relative quantities of the boulders here would be of great importance, as many discoveries would without doubt thus be made which could throw light on the manner in which this hypothetical change in the direction of the stream from Scandinavia has expressed itself in the peripheral regions of the glaciated territory.

The conditions as we know them in Holland and in the regions to the east of Holland as far as to Hanover seem thus to indicate, that the glacial inflow during the portion of the Glacial Period considered here has proceeded varyingly from the more western and from the more eastern parts of Scandinavia. The chronological order has then been: (1) northern ice, (2) Baltic ice and (3) northern ice.

If we turn now to Sleswig and Jutland, where deposits are found from different portions of the Glacial Period and separated by interglacial deposits, we meet with the question, which of these glacial deposits agrees in age with the one just dealt with. Of the interglacial freshwater deposits those from the two following regions are of special interest: the sand-covered peat layer in the Brørup neighbourhood and the »Tuul« on Sylt. The peat bogs at Brørup are younger than the main mass in the western hilly regions of West Jutland, and in the Rødeklev the »Tuul« distinguishes the old sand diluvial deposits from the over-lying head moraine. The peat layers, which at both places contain pines as also Brasenia and Dulichium,[1] are considered by USSING[2] as belonging to a single period of formation, »a pleistocene forest period, older than the period for the formation of the great outwash-plains«.

Of the marine, interglacial deposits the Eem deposits in Holland, which according to V. NORDMANN'S[3] new investigations belong to the same order as the Cyprina clay on the Danish Islands and the deposits on the South Jutland and Sleswig coasts, show that the drift deposits in Holland are older than the period represented by the formation of the Eem zones. The glacial deposits in Holland, Oldenburg, Westphalia and Western Hanover can thus in the first place not be referred to the deposits of the last ice-sheet, as O. TIETZE[4] and F. SCHUCHT[5] have supposed.

The question arises in the second place, which of the glacial horizons in the Rødeklev on Sylt is to be considered the equivalent of the moraines in Holland and Oldenburg — the old sand diluvial deposits under the »Tuul« or the main moraine above the »Tuul«. When the interglacial peats at Brørup and the »Tuul« on Sylt can be regarded as of one and the same period and if the head moraine in the Rødeklev corresponds to the glacial drift of Holland and thus also to the moraines on the east coast of England which contain Scandinavian materials, namely the »Basement Clay« of Yorkshire and the »Cromer Till« of Norfolk, this would mean that the inter-

[1] The last two were found for the first time in the »Tuul« on the Danish Geological Association's excursion to Sleswig in the summer of 1907. Medd. fra Dansk geol. Foren. 13. 1907. p. 121.

[2] Om Floddale og Randmoræner i Jylland. Overs. kgl. dansk Vid. Selsk. Forh. 1907.

[3] Molluskfaunaen i Cyprinaleret og Mellem-Europas andre Eem-Aflejringer. Kbhvn. 1908.

[4] Beiträge zur Geologie des mittleren Emsgebietes. Jahrb. Preuss. geol. Landesanstalt f. 1906.

[5] Geologische Beobachtungen in Hümmling. Jahrb. Preuss. geol. Landesanstalt f. 1906.

glacial peat layer at Brørup must have been passed over by the ice-sheet, which had the wide distribution described. This is however a possibility which may be excluded without further discussion; these peat layers with their slight depth under the surface of the ground have been too little disturbed to give it countenance. If the interglacial peat layers in the two regions are of the same period, then the moraines in Holland and Oldenburg must be considered as equivalent to the old sand-diluvium under the »Tuul«.

The necessary condition for the head moraine on Sylt to have been deposited during the same period of glaciation as the moraine layers in Holland is, that the interglacial layers on Sylt and at Brørup must have originated each at its own interglacial period and that the times of their formation must have been distinctly separated by the portion of the Glacial Period at which the great glaciation of Europe took place. If this can be considered as improbable, then we come as above named to the conclusion, that it is the sand diluvium under the »Tuul« and the glacial deposits analogous to this in the south-western part of Jutland which are comparable in age with the moraine layers of Holland and Oldenburg.

The old sand diluvium in the Rødeklev and the gravel layers in the hilly regions of south-west Jutland resemble one another in that the majority of the indicator-boulders are Norwegian or West Swedish; only a very small part is of Baltic origin. In this small quantity of Baltic indicator-boulders we have then in all probability the equivalent of the Baltic moraine in Holland and in the southern part of Holstein. It is not to be expected that the conditions on the west coasts of Sleswig and Jutland would give us information regarding the oldest Norwegian ice-stream, if a change in the direction of movement followed after the Baltic invasion, by which a preponderating quantity of Norwegian materials was deposited.

Thus, as mentioned earlier, it cannot be stated with certainty how far to the west and north-west in or beyond Denmark this Baltic ice reached. For the ice-cover in question L. HOLMSTRÖM[1] has used the term »the old Baltic ice-stream«. With J. PETERSEN[2] he considers the possibility not excluded that the glacier-stream has carried the North Baltic boulders right across Sweden to Denmark. If it were a possible explanation that the North Baltic boulders had been carried by an east to west ice-stream in over the South Sweden highlands, there would however be no reason to believe with regard to their distribution in Denmark, that this ice had reached further

[1] L. HOLMSTRÖM: Öfversigt af den glaciala afslipningen i Sydskandinavien. Geol. Fören. Forh. Stockh. 26. 1904.

[2] J. PETERSEN: Geschiebestudien II. Geogr. Gesellsch. Hamburg. 16. 1900.

than to the region round Vestergötland, as the boulders could have been carried further from there by the north-east to south-west, West Swedish ice-streams, evidence of which is found in the presence of Kinnediabase in Vendsyssel. The distribution of the North Baltic boulders to the extreme north-western parts of Denmark might thus be explained by such an ice-stream, without its being necessary to assume that this had of itself ever reached the localities where the boulders now occur. But on the one hand, all evidence is lacking to show that boulders from the Åland region have been carried to any appreciable extent in on to the now Swedish mainland north of Scania; and further, it is not only the North Baltic boulders but also boulders of the Scanian basalt which by their occurrence in the deposits of North-West Jutland show, that a transport of Baltic materials has taken place round the south of Sweden and thence in a north-westerly direction over Denmark.

With regard to North-West Germany, it has been supposed that this Baltic ice by gradual and continuous transition in direction from east—west to northeast—southwest has changed its character, by which means a relatively greater quantity of West Swedish materials has gradually been brought down than was possible for a true Baltic ice-stream. Such a change in the direction of movement of the ice has made itself apparent however in Denmark to a much higher degree; the preponderance of northern materials here shows that the main inflow previous to the interglacial period has been chiefly from Southern Norway and the neighbouring parts of Sweden. The same appears from the investigation of the indicator-boulders in the old sand diluvium in the Rødeklev. It is possible that the rich quantities of boulders from Norway and from Dalarne, which occur in the gravel layers on South Funen and in patches on Sealand as also the rhomb-porphyry boulders found in relatively large quantities in the one moraine sheet at Ristinge Klint on Langeland and on the coasts of Fehmarn, have been carried down at the same epoch of glaciation, but there is also the possibility that this transport has only taken place much later. This is indicated, for example, by the situation of the moraine level mentioned in Ristinge Klint in comparison with the Cyprina clay.

In describing the discoveries of indicator-boulders in the localities east of Ringkjøbing Fjord it has been mentioned, that a strikingly large number of Baltic boulders occur there at places as loose stones on the surface of the ground. In their Baltic nature they stand in sharp contrast to the character of the indicator-boulders in adjacent gravel deposits, where the rhomb-porphyry is numerously represented whilst the Baltic boulders are almost quite wanting. Such a contrast

between the contents of the surface moraines and the underlying gravel deposits has also been remarked upon at several other places. The conditions to the east of Ringkjøbing Fjord show possibly that the Norwegian ice-stream, which brought down the majority of the indicator-boulders of the western hilly regions, was again replaced by Baltic ice towards the end of the glaciation epoch. If we might suppose that this glacial extension, which succeeded to the ice-free epoch represented by the »Tuul« on Sylt and the interglacial peat beds at Brørup, had also covered the land at Ringkjøbing Fjord with ice, we might possibly consider this Baltic surface moraine as having come from this later glaciation epoch, but as no evidence for this supposition has been forthcoming hitherto, we must provisionally conclude from its presence that Baltic ice-masses were once again carried down to the westernmost parts of Denmark before the end of the previous glaciation. Observations are necessary however over a much larger area before we can form even an approximate idea of how this question has to be solved.

We might also set up the possibility, that the Baltic surface-moraine in the district east of Ringkjøbing Fjord has even been formed from the melting of the same (oldest) Baltic ice-stream, which forced the Norwegian ice towards the west into the North Sea and which became the main ice-sheet in Holland and neighbouring parts of Germany. Thus, the conditions in the district round Ringkjøbing Fjord have presumably been that the ice-movement has only altered once, with the first inflow from the north, but the direction of inflow has gradually changed and the northern ice replaced by Baltic ice-masses. There can in any case scarcely be any talk of an inflow of ice from the north to these districts after the Baltic surface-moraine had been deposited here. What the conditions in this regard are towards the south and north, has not been closely investigated. It is only known, that the districts further to the north-east (in the direction of Holstebro) and to the east (in the direction of Herning) bear unmistakable signs of having been last covered by ice of northern origin.

Some remarks may still be added regarding the conditions at Sylt. If the view of the age of the »Tuul« maintained by Stolley is correct, the head moraine in the Rødeklev (as it is earlier than the »Tuul«) must be considered as belonging to the same age as the sand layers which cover the interglacial peat beds at Brørup. If, however, we cannot as Stolley does consider the »Tuul« as lying between »the old sand diluvium« and the head moraine, but must regard it as earlier than the head moraine, then the conditions are different. As already mentioned earlier, this head moraine must be regarded as

relatively a Baltic moraine according to the result which STOLLEY's and J. PETERSEN's investigations of the boulders have given. The Baltic character appears distinctly in contrast to the nature of the underlying »old sand diluvium« chiefly because the materials are of northern origin. If the head moraine has this age, older than the Brørup peat beds, it is not unreasonable to connect its Baltic character with the occurrence of the Baltic surface moraine east of Ringkjøbing Fjord and with the lower moraine at Wedel (Ütersen-Schulau).

How far towards the west the ice-sheet which followed after the »interglacial« time has carried the ice-masses in Jutland and in Sleswig is still unknown, nor can it be considered as certain, at what epoch all the »interglacial« deposits in the Quaternary layers were laid down, whether they belong to the same or to different epochs of formation. From the position at which the investigation of the indicator-boulders stands at present, possible differences in age may be practically ignored, as in only few of the interglacial localities have the contents of the glacial layers in indicator-boulders been at all made the object of study. In West Germany we may conclude from the German investigations, that the boundary for the glaciation mentioned extended in a north-westerly direction from the neighbourhood of Magdeburg over the northern part of Hanover to somewhere between Hamburg and Oldenburg and further north. GAGEL[1] considers the boundary to have gone between Emmerlev cliff and Sylt. In Jutland USSING[2] seems to consider that it reached in over the West Jutland hilly regions.

To judge from the discoveries of the indicator-boulders, this extension of the ice has begun so far as Denmark is concerned by the advance of ice-masses from the north and north-east before the Baltic ice-masses reached so far. It has already been mentioned as probable, that such an advance of the ice from the north after the interglacial epoch has been the cause of the occurrence of the rich quantities of northern materials in South Funen and in the centre of Sealand as also at many places in the East Jutland gravel layers. The presence of the extensive moraine bank in Ristinge Klint, which contains various Norwegian boulders and which according to V. MADSEN's investigations[3] lies above the interglacial deposits, may also be noted as pointing in this direction; similarly also the large quantity

[1] Ueber einen Grenzpunkt der letzten Vereisung (des Oberen Geschiebemergels) in Schleswig-Holstein. Jahrb. der Kgl. Pr. Geol. Landesanstalt f. 1907 (cfr. the present work p. 74).

[2] Om Floddale og Randmoræner i Jylland. Oversigt over det Kgl. D. Vid. Selsk. Forh. 1907. Nr. 4.

[3] V. NORDMANN: Molluskfaunaen i Cyprinaleret etc. 1908. p. 8—9.

of basalt boulders which are found at New Brandenburg. In Jutland we have apparently the extreme boundary for the extension of this ice in the region between Holstebro and Ringkjøbing. Ussing[1] considers several of the sand ridges there to represent marginal moraines formed by the inland ice which followed after the interglacial period. That we find the extreme boundary in this region for the north-south extension of the ice-stream appears moreover from the presence of the Baltic surface moraine east of Ringkjøbing Fjord. The region where this Baltic surface moraine is present cannot have been covered by a later ice-stream from the north and we have here therefore an extreme boundary even for the extension of the ice, though under the supposition that the Baltic surface moraine mentioned has been laid down previous to the interglacial epoch.

The Baltic ice-stream which followed after the ice-stream from the north and in part replaced this has apparently reached as far as the mid-Jutland ridge of hills. There has probably been a continuous transition from the one direction of movement to the other. The basaltic surface moraine in the localities east of Brørup may perhaps be considered as one of the formations from this transitional stage, compared with the surface layer so poor in indicator-boulders in the hilly mid-Jutland localities somewhat further north. But the investigations here have as yet been over too restricted areas to be able to form a sufficient basis for conclusions.

The Baltic ice-stream has gradually advanced so far, that the materials transported may be considered as having been essentially Baltic at the time when the glacial margin extended westwards over the East Jutland fjords and reached the Kattegat coast at Grenaa, as Poul Harder[2] has shown. The large quantity of northern materials comes from the earlier ice-stream descending from the north.

Later, when the ice-cover on melting had withdrawn to the hilly localities at Odsherred in Sealand, a considerable change in direction of the transport of materials must have taken place. The material from the Baltic is here reduced to an obvious extent, and the same is also the case with the northern materials. The transport must rather be considered as having taken place from the localities along the South Swedish Kattegat coast, as indicator-boulders from the regions lying further away are almost entirely lacking in the gravel layers which were laid down along the borders of the ice.

Whether, in contrast to this, the transport to the more southern parts of Sealand and the southern Baltic regions has always been

[1] l. c. p. 197 and 209.

[2] En østjydsk Israndslinie og dens Indflydelse paa Vandløbene. Danmarks geol. Undersøgelse, II R. Nr. 19.

from the Baltic, the investigations are too incomplete to determine. The remains distinctly of northern materials, known from mid-Sealand, may however be referred to the above-mentioned north-south ice-streams.

In the north-east of Sealand, on the other hand, we find certain signs that there has also at a later period been a glacier movement from the north-east and north alternating with the Baltic ice. With regard to the indicator-boulders, this is shown in the great differences between the contents of boulders in near-lying localities. This appears also both from the geological surface conditions and on the whole from the boulder contents of the moraines. What HOLMSTRÖM calls the »retreating ice-streams« have at a very late period sent out from south-west Sweden offshoots into the Kattegat and over north-east Sealand, alternating with Baltic ice-streams, until finally the inland ice melted away both towards the north-east and south-east and quite left the Danish lands.

Resumé.

Skandinaviske Ledeblokke i Kvartærlagene.

Naar nærværende Afhandling er bleven trykt paa et fremmed Sprog, skyldes dette, at Ämnet dels for en væsentlig Del er hentet fra Lande uden for Danmark og dels er af en saa speciel Beskaffenhed, at Redegørelsen for de undersøgte Forhold væsentligst, og særlig hvad Enkelthederne angaar, maatte anses at have Interesse for Kvartærgeologer, for hvem en Fremstilling paa dansk vilde være utilgængelig. Der skal imidlertid her gives en kort Redegørelse for Hovedresultaterne af de foretagne Undersøgelser. Hvad Enkelthederne angaar, henvises derimod til den engelske Tekst.

Studiet af Ledeblokkene har hidindtil i Hovedsagen drejet sig om Blokkenes Udbredelse i horizontal Retning. For en Del Steders Vedkommende er der hertil føjet Undersøgelser af deres Optræden i vertikal Retning, men disse Undersøgelser har endnu ikke faaet stor Betydning. Der er saaledes for Danmarks Vedkommende ikke paavist noget Lag af Moræne eller Gruslag fra Istiden, hvor der ikke kan paatræffes Blokke af nordlig og Blokke af baltisk Oprindelse Side om Side. En kvalitativ Adskillelse af Lagene ved Hjælp af Ledeblokkene har ikke med Held kunnet gennemføres. Derimod er det velkendt, at der i ulige Dele af Danmark er stor Forskel paa Hyppigheden af Blokkene fra de forskellige Hjemsteder. Medens Blokke fra Kristianiaegnen er meget hyppige i de nordlige og vestlige Dele af den jydske Halvø, er der visse Dele af Fyn og store Dele af Sjæland, hvor de er yderst sjældne. Omvendt med Blokke af baltisk Oprindelse. Men nogen nøje Bestemmelse af Mængdeforholdet mellem de to Slags Blokke har ikke været foretaget. Med Hensyn til de Blokke, som hidrører fra Dalarne, har man vel skælnet mellem en Del forskellige Typer, men noget egentligt Karaktermærke med Hensyn til deres Tilførselsmaade eller Kendskab til deres Hyppighed har man ikke haft.

De Blokke, som i Afhandlingen er gjorte til Genstand for Undersøgelse — nemlig Blokke fra Kristianiaegnen, Dalarne, Skåne, det østlige Småland, Ålandsøerne og Østersøens Bund Syd derfor — kan alle findes i Danmark og kan anses for at være spredte over alle Dele af Danmark. Ligesaa kan de alle findes i Holland og den nordvestlige Del af Tyskland. Vender man sig derimod til det nordøstlige Tyskland og Rusland, naar man, efterhaanden som man gaar mod Øst, Østgrænserne for de forskellige Blokkes Udbredelse. Hvor disse yderste Spredningsgrænser omtrent gaar, ses paa Tavlerne 1 og 2. Tavle 1 viser Nordøstgrænserne for de Blokke, der stammer fra Åland og den nordlige Del af Østersøen (den røde og den brune Østersøkvartsporfyr) og for Blokke fra Dalarne. Tavle 2 viser Østgrænserne for Basalt fra Skåne og for Rhombeporfyr fra Kristianiaegnen.

Den foreliggende Undersøgelse har for de østlige Omraader, Rusland og Nordøsttyskland, nærmest haft til Opgave at undersøge Blokkenes Udbredelse i horizontal Retning. Hertil er samtidig knyttet Iagttagelser over Blokkenes Mængdeforhold. I det vestlige Omraade og da navnlig i Danmark er Undersøgelsen gaaet ud paa ved systematisk Indsamling og Optælling af Ledeblokkene, hvor saadanne var til Stede i nogenlunde rigeligt Antal, at tilvejebringe en Oversigt over den relative Hyppighed af Blokke fra de forskellige Hjemsteder. Uden kvantitative Bestemmelser er Studiet af Ledeblokkene i det vestlige Glacialomraade uden nogen væsentlig Betydning.

Ved at betragte de forskellige Kort, som er gengivne i Tavle 1—4, vil man kunne finde de væsentligste af de Resultater, Afhandlingen bringer, og som dels er nye, dels Stadfæstelse af ældre Formodninger.

Hvad selve Udbredelsen af Blokkene angaar, ser man af Tavle 1, at de, der er kaldt nordbaltiske Blokke, og som hidrører fra Åland og den nordlige Del af Østersøen, er spredte i sydøstlig Retning ind i Rusland; de yderste Grænser, hvortil de er trufne, er Dorpat og Smolensk. Fra Przemysl og Vest paa er de trufne helt til Ydergrænsen for det største Isdækkes Udbredelse mod Syd. Mod Vest er de førte ud over Holland, de frisiske Øer og hele Danmark. Af det svenske Fastland er det derimod væsentlig kun i Skåne, at der er fundet nordbaltiske Blokke i de glaciale Lag.

Det paafaldende ved det Omraade, hvortil disse Blokke er hidførte, er i særlig Grad den buede Spredningsgrænse Syd om Sverige, som Kortet viser. Medens Blokkene forekommer i talrig Mængde paa Gotland og Øland, paa Hven og i de sydlige Dele af Danmark samt saa nordlig som i Vendsyssel, er der intet Spor af disse Blokke fundet i de mellemliggende, nordligere Dele af Sverige. Den Isbevægelse — den baltiske —, hvorved de er førte ud imod Omraadets

Vestgrænse, maa da tænkes at være foregaaet efter en Linie, langs Østersødalens dybeste Del i en stor Bue uden om Sverige. At de ikke er bleven førte ind over det svenske Fastland, maa skyldes et Modtryk, som kun fremtrængende Ismasser fra selve dette Fastland ud imod den baltiske Dal kan have været i Stand til at yde. Den Form, som den baltiske Isstrøm har haft, saaledes som den er bestemt ved Ledeblokkenes Udbredelse, kræver altsaa, at Sydsverige samtidig har været isdækket.

Disse samme, svenske Ismasser, hvis Udbredelse ud over Sydsveriges Kystegne har hindret den baltiske Is i at naa ind paa Fastlandet, har ført rige Mængder af karakteristiske Porfyrer med fra Dalarne. De af disse Porfyrblokke, som er førte ned til den svenske Østersøkyst og ud i den baltiske Dal, er derfra spredte videre sammen med de nordbaltiske Blokke mod Sydøst, Syd og Sydvest. Men foruden de Blokke, som fra Dalarne er førte i Retning af Østersøen, er en anden Del af Blokkene ført i sydvestlig Retning fra Dalarne, nemlig over Sydvestsverige, Kattegat og videre mod Sydvest. Dette giver sig tydelig til Kende paa Kortet Tavle 1, der viser Dalablokkenes stærke Tiltagen i Nordvestdanmark i Sammenligning med de nordbaltiske Blokke. Hvis Dalablokkene i Hovedsagen var førte til Danmark med baltisk Is, var en saadan Overvægt i Vestdanmark i Forhold til de baltiske Blokke udelukket.

Tavle 2 viser Udbredelsen og den relative Hyppighed for Basaltblokkenes og Rhombeporfyrernes (samt de deraf opstaaede Konglomeraters) Vedkommende. Basalternes Hovedudbredelse falder mod Vest og Sydvest fra Skåne, men de findes ogsaa spredte baade lige i Syd (endda lidt østlig) og mod Nordvest fra Findestederne for faststaaende Basalt. De norske Ledeblokke findes i rigest Antal i det nordvestlige Danmark, men en stor Del er ført i stik sydlig Retning. Forekomsterne paa Lister og Jæderen samt paa Englands Østkyst i Forbindelse med Isskuringens Retninger paa Shetlandsøerne viser imidlertid, at de Ismasser, som har ført Kristianiaegnens Blokke, har maattet lide en Afvigelse mod Vest. Sandsynligvis har denne Afvigelse fundet Sted som Følge af tilstrømmende Ismasser fra den baltiske Dal, just en saadan mægtig Tilstrømning, som Formen af de baltiske Blokkes Spredningsomraade og deres rige Antal i Nederlandene er et Udtryk for.

Foruden selve Udbredelsen viser Kortene ogsaa vedkommende Blokkes relative Hyppighed saaledes, at

Tavle 1 viser nordbaltiske Blokkes og Dalablokkes Udbredelse og Mængdeforhold,

Tavle 2 viser Basalternes og Rhombeporfyrernes (samt Konglomeraternes) Udbredelse og Mængdeforhold.

Tavle 3 viser Mængdeforholdet mellem nordbaltiske og norske Blokke i Danmark,

Tavle 4 viser Mængdeforholdet mellem Dalablokke og norske Blokke i Danmark.

De Blokarter, der udtrykker de mest ulige Isbevægelsesretninger — fra Nord og fra Sydøst — hvorved der er ført Blokke til Danmark og tilstødende Omraader, er de norske og de nordbaltiske. Kortet Tavle 3 viser disses relative Fordeling i Danmark. De nordbaltiskes største Hyppighed falder i det sydøstlige Danmark, de norske Blokkes mod Nordvest. En noget buet Linie fra Grenaa til Ribe angiver omtrent det Bælte, hvor de undersøgte Ledeblokke af de nævnte Slags er lige hyppig til Stede. Endvidere vil man af Kortet se, hvorledes de to Elementer i dette Blokselskab — det baltiske og det nordlige — er ulige stærkt repræsenteret selv indenfor mindre Omraader som f. Eks. de danske Øer. Det baltiske Element træder særlig stærkt i Forgrunden i Egnene ved Øresund og Storebælt, hvorimod det nordlige Element gør sig stærkt gældende i visse Dele af det nordlige og nordvestlige Sjæland samt i Sydfyn.

Ved at betragte Kortet Tavle 1 ser man, at Dalablokkenes Fordeling i Forhold til de baltiske falder efter de samme Hovedlinier, som her er omtalt for de norske Blokkes Vedkommende. Der findes et ganske tilsvarende Kurveforløb over de danske Øer som paa Kortet Tavle 3. Dalablokkene viser sig herved — ligesom ved den tiltagende relative Hyppighed mod Vest — at forholde sig paa lignende Maade over for de baltiske som Kristianiaegnens Blokke. At en stor Del af Dalablokkene ligesom Blokkene fra Kristianiaegnen er kommen til Danmark fra Nord (og Nordøst) giver sig for Øernes Vedkommende tydelig til Kende i disse Blokkes rigelige Mængde i det nordlige Sjæland og det sydlige Fyn, de samme Omraader, hvor ogsaa norske Blokke er forholdsvis rigelig til Stede.

Disse Kort viser saaledes, hvilke Omraader i Danmark der fortrinsvis er prægede af det baltiske Element (Egnene ved Øresund, Storebælt og omkring Smaalandshavet samt visse sydøstjydske Partier), og hvilke der i Modsætning hertil er mere prægede af det nordlige Element (nemlig — foruden hele det nordvestlige Danmark — især det nordlige Sjæland og det sydlige Fyn). Og ganske svarende hertil er det Billede, som Tavle 2 viser af, hvilke Egne der er særlig paavirkede af den baltiske Isbevægelse, og hvilke der er særlig paavirkede af Nordfra kommende Is.

Naar maa nu ud fra denne Afgørelse af, hvorledes det baltiske og det nordlige Element i Blokselskabet giver sig Udslag, foretager en lignende Undersøgelse af Forholdet mellem de norske Blokkes og Dalablokkenes Hyppighed, viser det sig, saaledes som man ser af

Tavle 4, at Kurverne ogsaa her har et Forløb, der i Hovedtrækkene svarer til det, der er vist paa de andre Kort. De Omraader, hvor der findes mange baltiske Blokke i Forhold til nordlige, viser sig ogsaa at have en relativ stor Mængde Dalablokke i Sammenligning med norske. De af nordlig Is prægede Strøg indeholder derimod en forholdsvis ringere Mængde Dalablokke. Disse viser sig da herved i Forhold til de norske selv at indeholde et baltisk Element. Dette stemmer med, hvad man kan udlede af Kortet over Dalablokkenes Udbredelse (Tavle 1). Det Materiale fra Dalarne, som af sydøstsvenske Ismasser førtes ned i den baltiske Dal, maatte, som nævnt, herfra følge den samme Vej som den baltiske Is. Hvor meget dette udgjorde, kan man maaske bedst faa Underretning om ved lignende Undersøgelser i østlige Dele af Nordtyskland som dem, her er foretagne for Danmarks Vedkommende. Med Hensyn til Dalablokkenes Tilførselsveje til Danmark viser Undersøgelserne saaledes, at der dels har fundet en direkte Transport Sted og dels en Transport fra Dalarne mod Sydøst ud i den baltiske Dal og derefter videre med baltisk Is ad dennes forskellige Veje.

Af Kortet Tavle 2 ser man, at der paa Jæderen og Lister Nordvest for Norges Sydspids findes Blokke fra Kristianiaegnen. Den Afvigelse i Gletscherbevægelsens Retning, hvorved disse Blokke er førte ad deres ejendommelige Bane, skyldes maaske den norske Rende. I saa Fald maatte Afvigelsen dog rimeligvis nærmest være af lokal Natur, hvad den imidlertid ikke synes at være. Isskuringen paa Shetlandsøerne og Ørkneyøerne samt Kristianiaegnens Blokke paa Englands Østkyst viser, at en tilsvarende Afvigelse mod Vest, som Rhombeporfyrerne paa Jæderen er Udtryk for, ogsaa har afsat Spor andetsteds. Det ligger derfor ikke fjærnt at sætte den i Forbindelse med den mægtige Fremvælden af baltisk Is, saaledes som den navnlig har sat sig Spor i de talrige, baltiske Blokke i Holland. Man ledes derved til at antage, at disse paafaldende Afvigelser i vestlig Retning alle er Udslag af en og den samme mægtige Kraftytring: den baltiske Isbevægelse. Det bliver derved tillige sandsynligt, at man foruden Kristianiaegnens Blokke ogsaa paa Jæderen og Lister vil kunne finde svenske Blokke, saaledes f. Eks. Porfyrer fra Dalarne. Det fortjener i denne Sammenhæng at fremhæves, at medens der ved Hanstholm toges 56 Blokke af Rhombeporfyr og deraf opstaaede Konglomerater, blev der sammen med disse fundet ikke mindre end 28 Blokke med Hjemsted i Dalarne. Hvis altsaa nogle af de Rhombeporfyrblokke, der findes paa Jæderen, er naaet dertil ad en buet Vej, hvis sydlige Del nærmede sig Vendsyssel og Thy, er der Mulighed for, at man ogsaa i det sydvestlige Norge kan finde Dalablokke. En Paavisning

heraf eller Sandsynliggørelsen af det modsatte vilde da være af betydelig Interesse.

En anden Opgave for Studiet af Blokkenes Udbredelse i horizontal Retning angaar Forholdene ved Englands Østkyst. Herfra kendes med fuld Sikkerhed kun norske Blokke. Muligheden af, at Dalablokke og baltiske Blokke kan være førte saa langt mod Vest, er dog ingenlunde fjærn, især naar man ser hen til de rigelige Mængder af Dalablokke i Vestdanmark og Nordtyskland og af baltiske Blokke i Holland. En sikker Bestemmelse af disse Blokkes Tilstedeværelse i England vilde være af stor Betydning for Kendskabet til Styrken af den baltiske Is, dengang den trængte længst frem mod Vest.

Endnu et Punkt af særlig Interesse er Fundene af norske Blokke i det sydligste Holland, uden for den Grænse, hvortil det egentlige Isdække antages at have naaet. Der findes her norske Blokke; derimod er der ingensinde fundet Spor af baltiske Blokke, medens disse dog i Egnene lidt længere mod Nord, f. Eks. i Provinsen Utrecht, er særdeles hyppige, og medens norske Blokke her ligesom i det hele i Holland kun er meget faatallig til Stede.

Medens Studiet af Ledeblokkene kan give betydningsfulde Oplysninger med Hensyn til de Veje, ad hvilke Isen har gaaet, er det endnu kun sparsomme Oplysninger det giver om de forskellige Isstrømmes Plads i Rækkefølgen. De Omraader, hvorfra man kan hente Oplysninger i saa Henseende, er endnu væsentlig kun Holland, Nordvesttyskland og Danmark.

Til de ældste Spor af den skandinaviske Indlandsis synes de norske Ledeblokke at høre, der er paaviste i det nederlandske Floddiluvium, Syd for selve Landisens yderste Udbredelsesgrænse. Deres Tilstedeværelse tyder paa, at Ismasser fra Nord har trængt saa langt mod Syd, at Floder har kunnet føre Blokke derfra videre ud til Omraader, som hverken Isen selv eller det efterfølgende baltiske Isdække naaede. Den Nordfra kommende Is blev rimeligvis tvunget til at bøje af i vestlig Retning som Følge af baltiske Ismassers Fremtrængen. Vi kan derved sætte de enkeltvis forekommende norske Blokke i det sydligste Holland i Forbindelse med Forekomsten af de norske Blokke paa Englands Østkyst. Den baltiske Isstrøm, som fortrængte Isen fra Nord, naaede i Holland Landisens yderste Udbredelsesgrænse. Ledeblokkene er her af overvejende baltisk Karakter, og af norske Blokke er der kun fundet yderst faa.

Østpaa fra Holland aftager imidlertid Mængden af baltiske Blokke i Forhold til Ledeblokke af nordlig Oprindelse. Disse stammer rigtignok ikke fra Norge, men fra Dalarne (se Tavle 1). En saadan Ændring i Ledeblokkenes Mængdeforhold maa efter al Sandsynlighed

skyldes, at nordlig Is atter har trængt sig frem, medens Tilstrømningen af baltisk Is er aftagen. Da der fra de paagældende Omraader — Holland, Oldenburg og Hannover — kun kendes Moræneaflejringer fra en enkelt af Istidens Afdelinger, maa man gaa ud fra, at den anførte Skiften mellem nordlig Is, baltisk Is og atter nordlig Is er foregaaet kontinuerlig, uden Afbrydelse af nogen isfri Mellemtid.

En lignende Skiften af Isbevægelsesretningerne finder man Spor af i det vestlige Danmark. Hvor langt man end her kommer mod Vest og Nordvest, finder man saavel Blokke, der er tilførte fra Sydøst, som Blokke, der er tilførte fra Nord og Nordøst. Men Mængdeforholdet imellem de forskellige Arter af Blokke er forskellig selv for de ulige Dele af Landets vestlige Egne.

De ældste kendte Aflejringer, saaledes som de kommer for Dagen i de nederste kvartære Lag paa Sylt, indeholder fortrinsvis Blokke af nordlig Oprindelse, men dog ogsaa enkelte af baltisk Herkomst. Det samme er Tilfældet med de Grusaflejringer i de sydvestjydske Bakkeøer, som kan regnes blandt de ældste af Danmarks kvartære Dannelser. Disse Gruslag og de nævnte Lag paa Sylt kan dog næppe anses for at være ældre end Hollands glaciale Aflejringer. Det stærkt nordlige Præg, som Blokindholdet viser, tyder da i Retning af Samtidighed med den Fremtrængen af Is fra Nord, der antages at være fulgt efter den baltiske Isdækning af Holland og de nordlige Ismassers Afvigelse mod Vest. Sporene af den tidligste Isinvasion fra Nord er derimod ikke med Sikkerhed paavist i Danmark.

Efter denne anden Invasion af Is fra Nord maa man imidlertid antage, at Isen paany er trængt frem fra det baltiske Omraade. Dette fremgaar af Forholdene omkring Ringkjøbing Fjord, hvor der — som næsten alle Kortene viser — er et Parti med et stærkere baltisk Præg end Egnene længere mod Øst. Dette giver sig til Kende i de fluvioglaciale Gruslag, men dog især i Karakteren af Markstenene, d. v. s. Blokkene fra den øverste Moræneaflejring paa Stedet. Den yngste Moræne her bærer pletvis Præget af at være fuldstændig baltisk.

Der er næppe Grund til at antage andet, end at denne anden baltiske Fremtrængen af Isen ligger forud for det interglaciale Stadium, der bl. a. kendes fra de sanddækkede Moser ved Brørup. I Egnene mellem Holstebro og Herning er de Aflejringer, man træffer i Overfladen, imidlertid af udpræget nordlig Karakter, saaledes som ogsaa Kortene Tavle 3 og 4 viser. Ismasserne, hvorfra de øvre Lag i Bakkedragene mellem Holstebro og Herning stammer, har ikke været trængt saa vidt frem mod Sydvest som til Egnene Øst for Ringkjøbing Fjord. N. V. Ussing har antydet den Mulighed, at nogle af disse Bakkedrag er Randmoræner fra det samme Isdække, foran hvilket de midtjydske Hedesletter afsattes paa et senere Stadium. Hertil kan altsaa yder-

ligere føjes, at der mellem Dannelsen af disse Bakkedrag, hvis Blokke hovedsagelig stammer Nordfra, og Omraadet omkring Ringkjøbing Fjord, med baltiske Blokke, ligger en udpræget Skiften fra en Isbevægelsesretning til en anden. Det er sandsynligt, at vi herved har den yderste Grænse betegnet, hvortil Isdækket i dette Afsnit af Istiden naaede.

Formodningen om, at Isen i dette Afsnit af Istiden strakte sig ud over en Del af de jydske Hedesletters Omraade, finder ogsaa Støtte i visse Forhold længere mod Syd. Af Tavle 2 fremgaar det, at der i et Omraade, der strækker sig i Nordøst-sydvestlig Retning over Brørup og Vejen, findes en særlig rigelig Mængde Blokke af Basalt. Dette Omraade, hvis største Del ligger Vest for Hedesletternes Østrand, strækker sig længst mod Nord ind i Egne betydelig Øst for Hedesletterne og antyder derved, at disse ulige Egne, trods deres forskellige Beliggenhed i Forhold til Hedesletternes Østgrænse, er nær sammenhørige med Hensyn til Dannelsestid. Omraadet med den rige Mængde Basaltblokke kan antages at strække sig videre mod Sydvest i Retning af Sylt, hvor der ogsaa findes Lag, som udmærker sig ved sin Rigdom paa Basaltblokke, og som derved peger hen paa Samtidighed med de basaltrige Morænelag og Gruslag i de nævnte sydjydske Egne.

En saadan Modsætning mellem Egne med særlig nordligt Præg og Egne med særlig baltisk Præg, som her er omtalt for det vestlige Glacialomraades Vedkommende, er hidtil ikke paavist i Omraaderne længere mod Øst. Der er utvivlsomt ikke en saadan udpræget Modsætning til Stede mellem radialt tilført Materiale og transversalt (baltisk) Materiale, som man finder f. Eks. i Danmark. Thi i det østlige Nordtyskland har Tilførslen rimeligvis til enhver Tid været paavirket af Ismasser, der havde en Tendens til at følge den baltiske Dals Længderetning. Nogen egentlig radial Bevægelse gaaende fra Sverige tværs over Østersøens Dal, synes Blokkenes Spredning ikke at tyde paa. De sydsvenske Ledeblokkes Hovedudbredelse ligger mod Sydvest og Vest, og de østre Grænser for deres Udbredelse synes at gaa efter Linier tværs over den baltiske Dal. Imidlertid kan den radierende Isbevægelse fra det svenske Fastland ned imod den baltiske Dal selvfølgelig til forskellige Tider have været ulige stærk i Forhold til den baltiske (transversale) Isbevægelse, og Blokselskabets Sammensætning i det nordlige Tysklands forskellige Egne kan have bevaret Sporene deraf. Kvantitative Undersøgelser af Ledeblokkene vil da netop under disse Forhold være af Betydning.

Den Betydning, saadanne Undersøgelser kan have, forøges yderligere af et andet Forhold. Det har nemlig vist sig, at Ledeblokke fra hinanden nærliggende Hjemsteder kan optræde paa en ejendommelig, uregelmæssig Maade. Dette fremgaar paa flere Steder af Listen

over Blokkene og af Teksten. Det er allerede omtalt, at skånsk Basalt optræder overordentlig hyppig paa en Strækning fra Vejle Aa Dal Nord for Egtved, over Brørup og Vejen og rimeligvis videre i sydsydvestlig Retning. Lignende paafaldende Mængder af lokalt hobede Basaltblokke har J. MARTIN omtalt. Påskallavikporfyr, der i det store og hele er sjælden som løs Blok, kan pletvis optræde meget hyppig; saaledes kan f. Eks. nævnes Forekomsten mellem Dalager og Fasterkjær Øst for Ringkjøbing Fjord. Ligeledes kan visse sydjydske Egne rimeligvis her komme i Betragtning. De to Østersøkvartsporfyrers Forhold til hinanden er ogsaa betegnende i saa Henseende. Den brune Porfyr er mange Steder absolut dominerende i Forhold til den røde. Nævnes kan saaledes den største Del af Sjæland, Langeland og en stor Del sydøstjydske Forekomster. Ved Stranden Syd for Aarhus er Forholdet imidlertid ganske omvendt. Der findes her rød Østersøkvartsporfyr i overvældende Mængde, mens den brune er ret sjælden. Hermed stemmer Fundet ved Rosmus Station. Paafaldende er ogsaa Fundene i Provinsen Utrecht i Holland, hvor den brune Østersøkvartsporfyr er overordentlig almindelig fremfor de øvrige nordbaltiske Blokke.

Hvad der er Aarsag til disse Forskelligheder i Blokkenes Optræden, kan ikke endnu siges. For at faa Svar derpaa kræves sammenlignende, kvantitative Undersøgelser over store Omraader. Saadanne Undersøgelser vilde der være særlig Anledning til at foretage i Tyskland, hvor nordbaltiske Blokke i det hele forekommer i rigelig Mængde. Der kunde herved fremskaffes Materiale til Bedømmelse af, om der her kan paavises flere ulige Isbevægelsesretninger, selv om Modsætningsforholdene i Blokkenes Fordeling ikke er saa iøjnefaldende som i Danmark og det nordvestlige Tyskland.

Appendix: Bibliography.

Abbreviations:

S. G. U. Sveriges geologiska undersökning.
G. F. F. Geologiska Föreningens i Stockholm Förhandlingar.
D. G. U. Danmarks geologiske Undersøgelse.
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Explanation to the plates.

Pl. 1. Map showing the distribution and relative abundance of the North Baltic and Dala indicator-boulders.
Pl. 2. Map showing the distribution and relative abundance of the Christiania boulders (rhomb-porphyry and conglomerates) and the basalt boulders of Scania.
Pl. 3. Map showing the relative abundance of North Baltic boulders and rhomb-porphyry (and conglomerate) in Denmark.
Pl. 4. Map showing the relative abundance of Dala boulders and rhomb-porphyry (and conglomerate) in Denmark.

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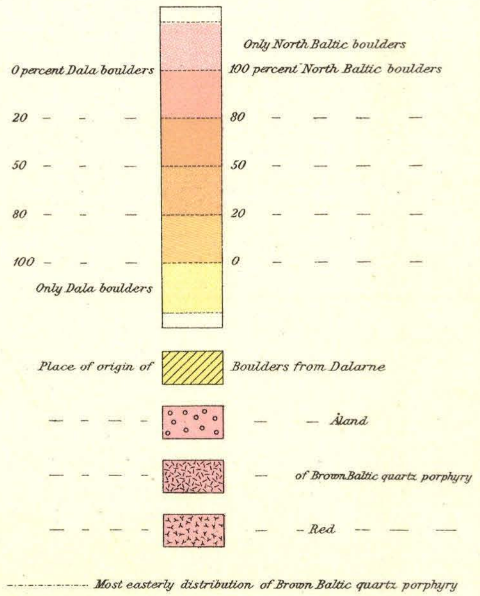

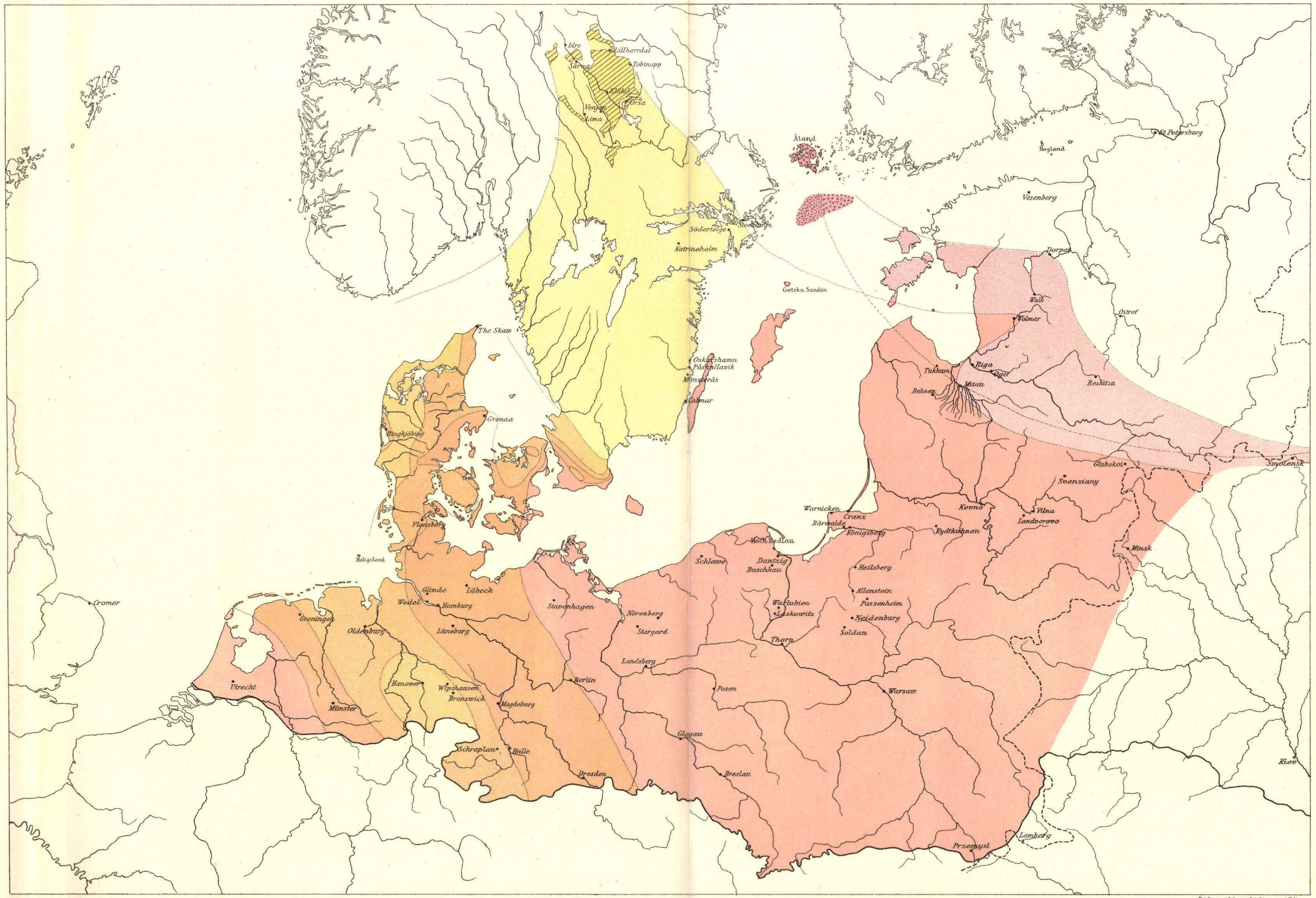

Fototrygr. ved Generalstabens top. Afdeling

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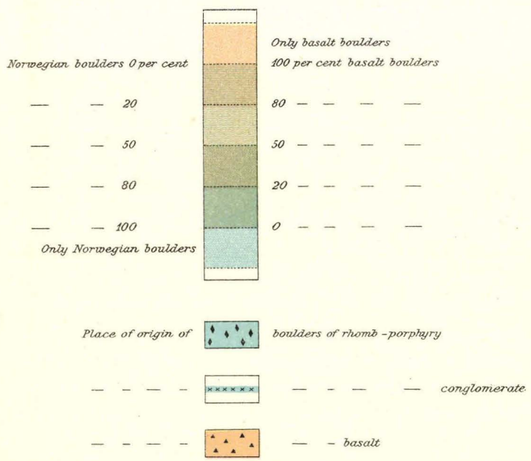
Only basalt boulders
100 per cent basalt boulders
Norwegian boulders 0 per cent
80
20
50
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80
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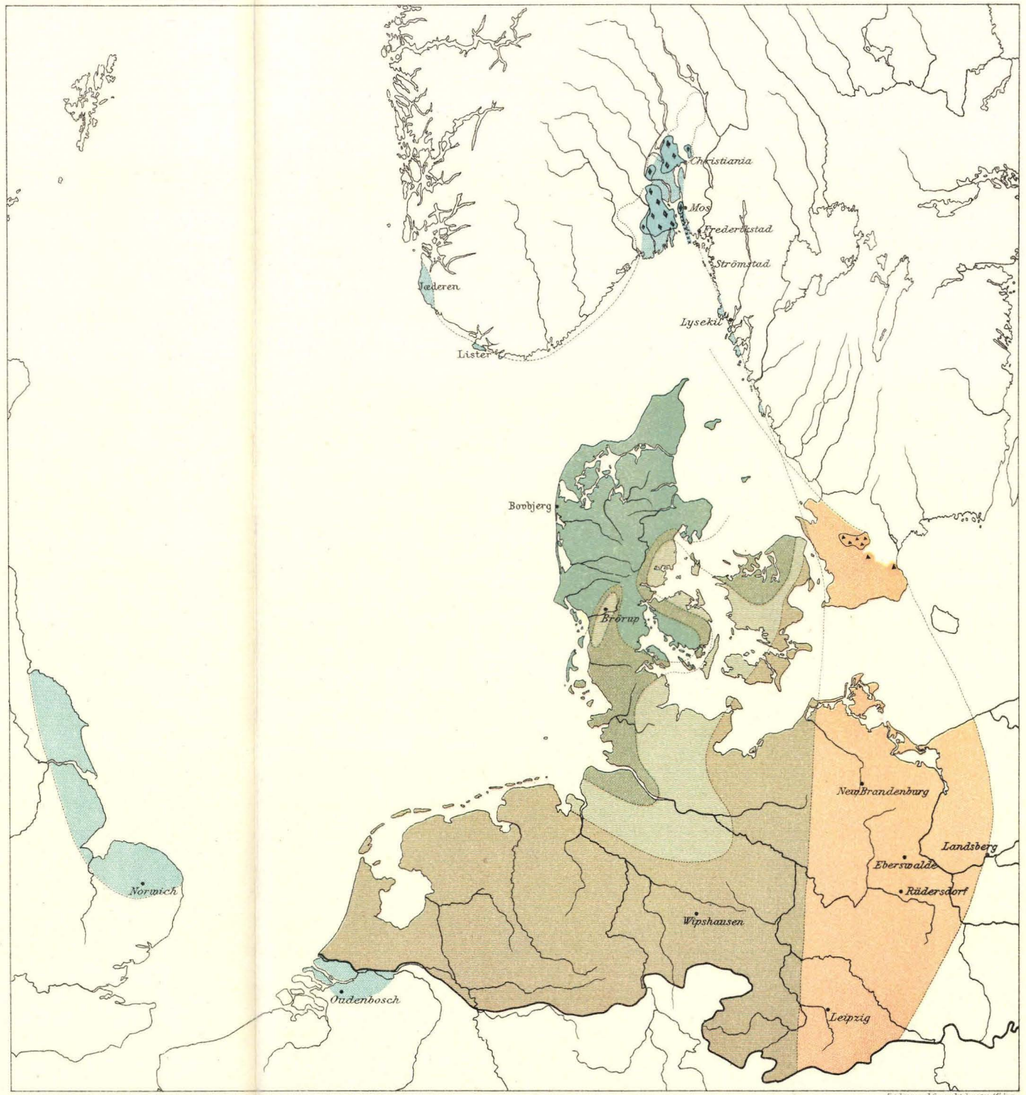
Only Norwegian boulders
Place of origin of
boulders of rhomb-porphyry
conglomerate
basalt


Christiania
Mos
Fredrikstad
Strömstad
Væderen
Lysekil
Lister
Bovbjerg
Brörup
Neubrandenburg
Landsberg
Eberswalde
Rüdersdorf
Wipshausen
Norwich
Osdenbosch
Leipzig

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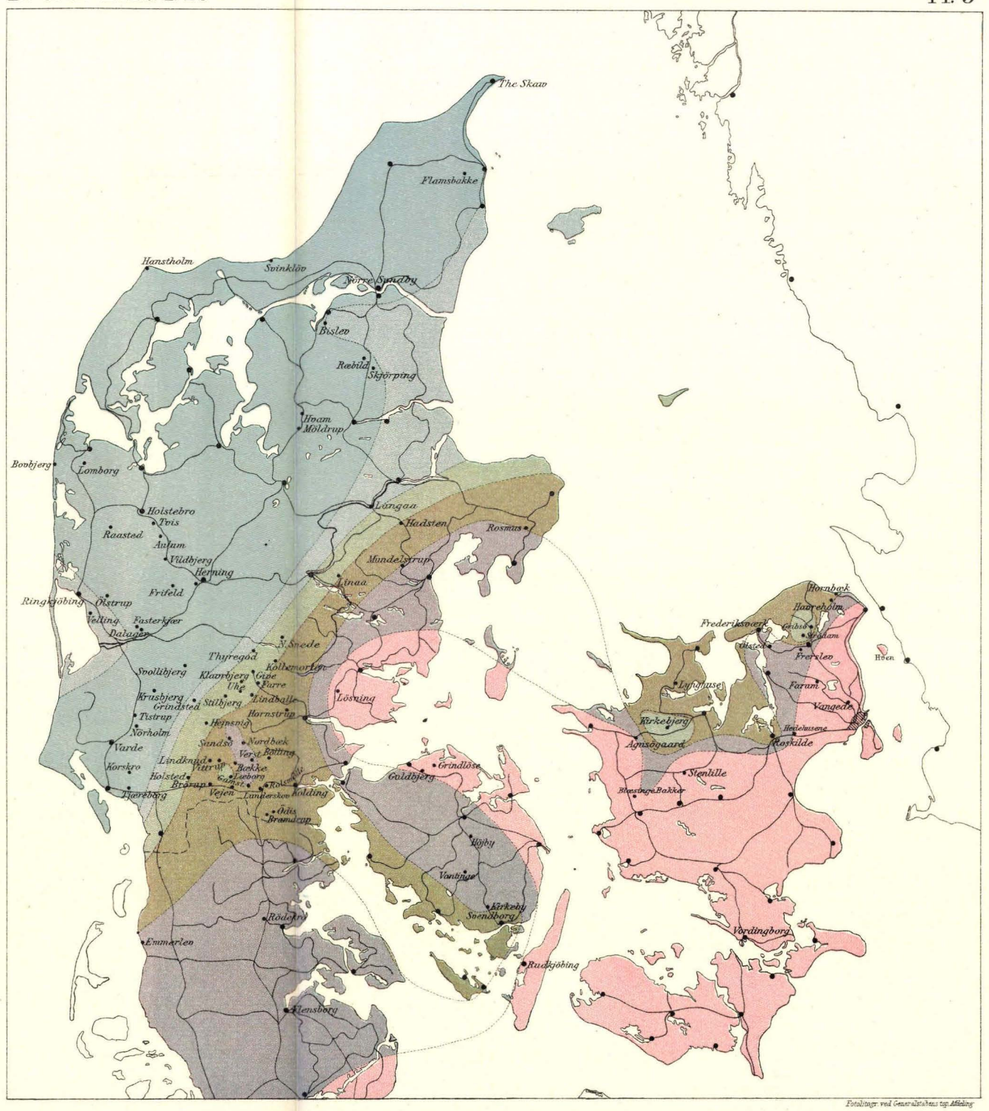
North Baltic boulders 90 per cent. 10 per cent. Norwegian boulders

80 20

50 50

20 80

10 90



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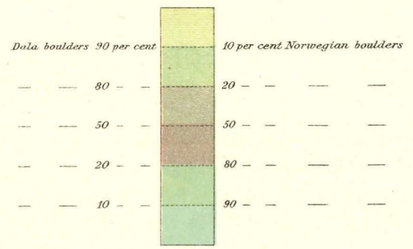

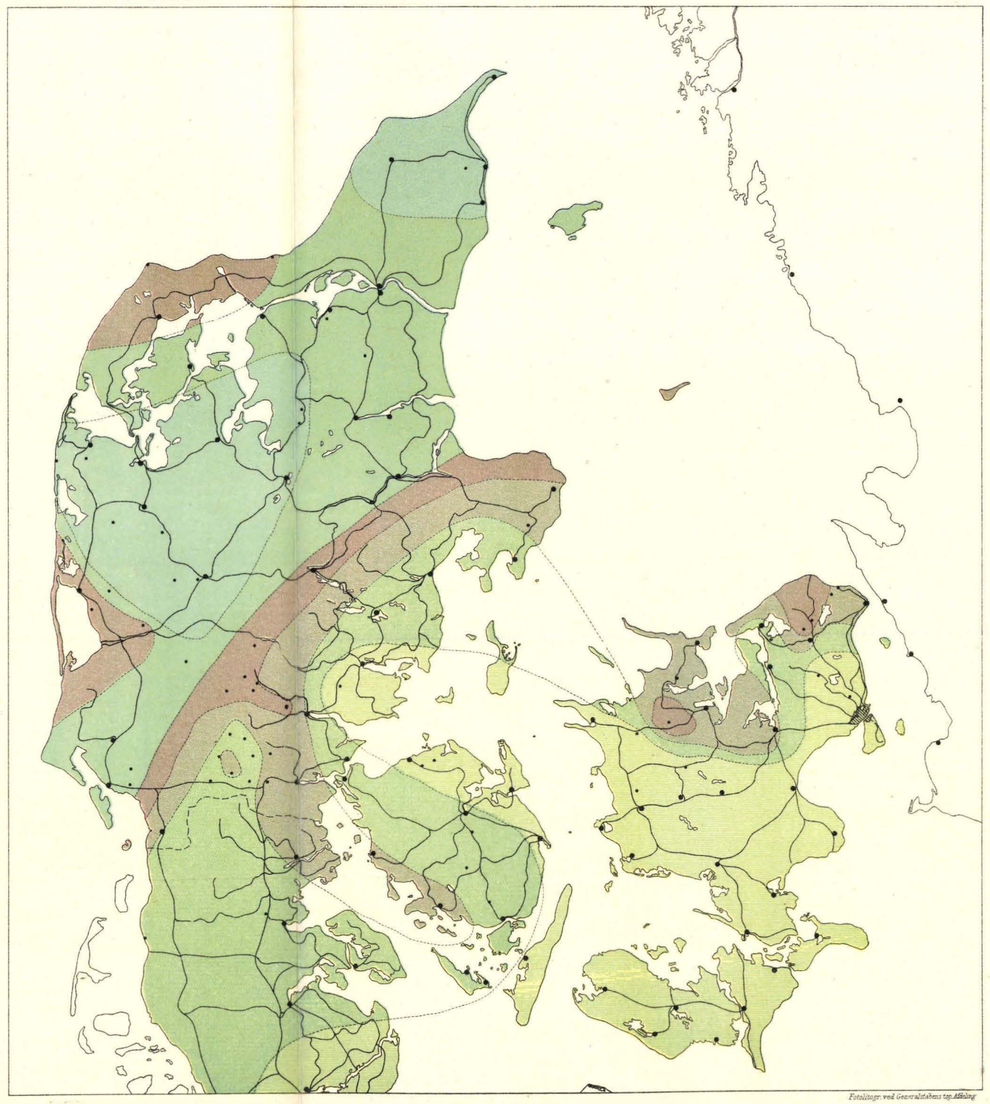

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