

SVERIGES GEOLOGISKA UNDERSÖKNING

SER. C.

Afhandlingar och uppsatser.

N:o 218.

ÅRSBOK 3 (1909): N:o 1.

THE CLIMATE OF SWEDEN IN THE
LATE-QUATERNARY PERIOD

FACTS AND THEORIES

BY

GUNNAR ANDERSSON

WITH 11 FIGURES AND 2 PLATES.

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STOCKHOLM

KUNGL. BOKTRYCKERIET. P. A. NORSTEDT & SÖNER
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Introduction.

It is of extreme importance for the understanding of the natural phenomena of past times to possess a sure knowledge of the climatic conditions that prevailed during them. In this, as in so many other geological questions, it is easiest to make a start and obtain the safest methodical results if we begin with present times and study the conditions nearest to hand, i. e., those of the Quaternary period. During the last few decades much work has been undertaken by Scandinavian investigators in researches of such a kind as lead to conclusions, more or less certain, about the climate of the late-quaternary period¹. Of these conclusions there are some upon whose established correctness all are agreed, while others are founded upon observations about whose interpretation there is still disagreement. The Scandinavian investigators can say, however, without vaunting, that they have done more than those of most other countries for the knowledge of the climatology of the Quaternary period in their own territory, both with regard to irrefutably established facts and to fecund hypotheses. The meeting of the world's geologists at Stockholm in 1910 has induced the Swedish geologists to think that it would be desirable if, in the interval, those interested in these

¹ By »late-quaternary» I mean both »post-glacial» and »late-glacial» times in conformity with the usual terminology, i. e. the whole period from the beginning of the latest ice-melting in Northern Europe to the present time.

questions would test the results obtained in the N.W. continent of Europe within their own territories. Then only shall we know whether the phenomena observed deal with climatic changes that embrace vast districts or merely local ones, perhaps in connection with changes that have taken place in the distribution of land and water. For this reason I have, as a matter of principle, refrained from dealing with phenomena observed outside Denmark, Scandinavia and Finland.

What we may claim of a definitive presentation of the geological climates, is that it is in absolute accordance with the results of climatology, animal and plant biology, geography and geology. The weakness in many climatic hypotheses is, in my opinion, that they only partly satisfy this claim. Just as nowadays we cannot admit land-connections over wide oceans, due to the difficulty of otherwise explaining, let us say, the spread of some species of animal; as unready should we admit the assumption of changes in climate which conflict with established climato-physical laws, because perhaps for the moment we cannot otherwise find any quite satisfactory explanation for some interesting facts that we have observed. It must also be borne in mind that in cases like these, where every method at our disposal is invested with serious uncertainty and conditionality, it is of the utmost importance that a number of methods should be tested. Only when, within the bounds of probable errors, these yield the same results, have we reached a certainty which we are justified in regarding as resting on a scientific basis.

The Swedish investigators, in their study of the »fossil climates», have struck out into two main paths. On the one hand, the present writer and many others have aimed in the first place at collecting facts touching the changes the temperature has undergone. R. SERNANDER and his pupils at the University of Uppsala have, on the other hand, followed the Norwegian AXEL BLYTT, and have laid chief stress on the attempt to elucidate eventual alternations between »wet and dry periods».

The following account deals first with the purely methodic questions, then with established or presumptive results. Its shortcomings may be excused partly because there was not sufficient time for all the preparatory investigations desired by the author, partly because of the enormous scope these questions have in the various sciences. The causes of the climatic changes that we have had occasion to admit have only been touched on in passing, owing to considerations of space.

A. Methods for ascertaining the climatic development in the late-quaternal period.

1. Geological and stratigraphical reasons.

The method for determining the number of years that the ice took to melt, as G. DE GEER has pointed out in a recent article (1908)¹, also implies a means of determining the relative changes in climate during the period of melting, which according to him lasted some 5,000 years. In the first instance it is probably changes in the supply of warmth that reveal themselves in the form of unequal rapidities of ice-recession in the separate periods, but it must not be overlooked that changes in atmospheric precipitation can also have been the reason. The change that the geographical outlines of Scandinavia underwent, partly through its distribution into land and sea, partly through the disappearance of the ice itself, must be held to have influenced the atmospheric precipitation in no insignificant measure. But no systematic examination on this point has as yet been undertaken.

Noteworthy from the methodic point of view is the rapid melting of the ice in central and northern Sweden, as proved by DE GEER, pointing to a rapid rise in temperature. I had

¹ The date within parenthesis refers to the paper written by the author mentioned and quoted in the bibliography under the year stated.

already come to the same conclusions in 1903 by paleontologic proofs. As these evidences had been obtained in different ways, quite independent of one another, it seems to me that we have got as near to certainty as empiric methods allow, no other evidence pointing in a contrary direction.

Stratigraphy of peat- and forest-beds. In a very large number of Scandinavian peat-bogs quantities of tree remains, roots, stems and stools occur. The latter show that the trees lived on the peat-mosses at some time of their development. The stools, in my opinion, are most often irregularly distributed in the peat, but in not a few cases collected at certain levels, so-called »forest-beds». But in examining small sections it is very hard to decide which the case is. BLYTT (1876 and 1893) and after him SERNANDER (practically all works quoted) and the Uppsala school now assume that the stools and stool-layers that are met with in the peat-mosses are a proof that the surface of the mosses was dry during the origin of the stools. As the stools are common in the peat they believe furthermore that a great number of peat-mosses were dry during one or more periods, and that this dryness had its cause in a dry climate, deficient in precipitation. As indisputably in certain peat-mosses and particularly in certain sections some strata are lacking in or are deficient in tree remains, these are looked upon as having been formed during periods in which the peat-mosses were so damp that trees could not live on them. Inasmuch as these strata interstratify stubbed ones, they are held to represent not only damper periods for the peat-mosses itself, but for all Scandinavia. This has given rise to the assumption of alternating »wet and dry periods». Now, if it is a fact that the stool-layers are dependent on general climatic periods, it is evident that the upper stool layers in the swamps should, as a rule, be of about the same age, which is also the opinion of the BLYTT-SERNANDER school. If there are two stool-layers, the lower is of the same age as the others similarly situated in the peat-mosses of the other parts of Scandinavia, and so on. It is indisputable that if this theory is correct a particularly easy

and convenient specification of time has been brought within our reach.

Despite this, a large number of the most experienced Scandinavian investigators of peat-bogs, such as STEENSTRUP and HARTZ in Denmark, HOLMBOE and STANGELAND in Norway, TOLF, HAGLUND, KURCK and the present writer in Sweden, have not found it possible to subscribe to this view; it follows that there must be certain gaps in the argument, and these, in my opinion, have not been sufficiently taken into consideration by SERNANDER and his followers. A short summary of the objections that have been raised may be given here in as far as they lie in the domain of stratigraphical geology; the remaining objections will be considered later.

BLYTT (1893, p. 45) says: »Although we are consequently living in one of the theoretically 'dry periods', it is far from the fact that all peat-mosses are wooded. And therefore, in my opinion, this has also been the case in preceding dry periods. Thus the theory demands that peat-mosses with stool-layers shall occur mingled with peat-mosses without any.» This brings to light a circumstance which considerably diminishes the value of stool layers as time indicators. Even SERNANDER (1902, p. 433) points out, quite theoretically, that for instance in mountains under »Sphagnum layers there occur remains of old woods, which need by no means be sub-boreal» (i. e. belong to the most recent dry period) »but fairly recent», and he quotes a number of examples where he »cannot yet decide whether they are sub-boreal or more recent». Other supporters of BLYTT's opinions, too, frequently complain about the difficulty of deciding with certainty whether both sticks, stems and wood as well as more isolated stools really represent a dry period or only chance local conditions. (Cf. also HAGLUND 1908, p. 296.) Similar uncertainty with regard to decision meets the naturalist in a number of cases in nature, of course, but it has always seemed to me as if with the BLYTT theory we are uncommonly often brought into a state of doubt. The objective reason is lacking, and the personal equation,

when one is influenced by one's theoretical views, comes into play. This explains how conscientious investigators can come to such different results in examining the same peat-moss (HAGLUND 1907, SERNANDER 1908). The objection would to some extent be removed if the theoretical reason were carefully tested by close and well planned examinations of a great number of the peat-mosses within some one or several well chosen districts. This has not been the case in Sweden, but one has been content with finding and describing a number of cases which seem to accord with the theory; it is particularly the most recent peat-mosses that have been examined. In Norway, on the other hand, BLYTT (1882), with certainly an unsatisfactory method, but still with the conscious intention of collecting a large material for evidence, has examined a good number of peat-mosses. He considers the result decisive in favour of the theory. I have closely criticised this view myself (1892). BLYTT (1893) protested against my collocation of his results. This was answered by his countryman HOLMBOE (1903, p. 40), at present the leading expert in Norwegian peat-mosses, who says: »In the main his (ANDERSSON's) grouping may be held to be justified.» I have here included all the corrections claimed by BLYTT (1893, p. 37), so that the results are as favourable as possible to him. From the accompanying table may be seen how many peat-mosses of those examined by BLYTT in SE. Norway, at the utmost correspond with the demands the theory makes on stool-layers.

	Agree with the theory.		Disagree with theory.	
	Number.	%.	Number.	%.
15—45 m. above the sea; should have 1 stool-layer .	8	61	5	39
45—105 m. » » » » » 2 stool-layers .	10	45	12	55
105—180 m. » » » { » » 2 » » } and 3 peat-layers with- out tree-remains . . . }	8	35	15	65
over 180 m. » » » should have 3 stool-layers	16	27	44	73

It is striking that the peat-mosses which demand least of

the theory, i. e. only one forest bed, give the best results. This, in my opinion, is due to the fact that here in many cases we have peat-mosses that are so dry that only the stools of the first forest vegetation have been retained, the others have wasted away, just as on firm ground, and leave a much decomposed peat-layer above the stools. In a very great number of other cases, as has been shown by HAGLUND (1908), the woods have been on fire, and this has most usually resulted in sphagna finding a favourable habitat and quickly causing a very un-nutritious peat, in which the forest trees could only live with the greatest difficulty.

As a matter of fact the above figures are too favourable to BLYTT'S theory, since in various cases horizons, in which the existence of stool-layers is very questionable, have been included as proofs of a dry period. Both from personal observations and from the literature on the subject I have the firm conviction that more than *one* clearly and distinctly developed stool-layer is extremely rare in Scandinavia. In the district of Ilmola in Finland, where I have seen sections with two exceedingly distinct stool-layers, only one is demanded by the theory. For me this is a proof that it is difficult to find a sure interpretation, the existence of forest-beds, their number, position in the peat, etc. often being due to local and chance conditions, now very difficult to unravel. This is not the place to discuss the manner in which stool-layers have originated; even if they are not perfectly cleared up, one has no right for that reason to conclude that they are due to climatic changes.

We will now leave the peat-mosses in which one or more pronounced forest-beds undoubtedly occur, and pass on to the incomparably larger number in which tree remains occur irregularly distributed through the whole mass of the peat. This is very often seen to be the case, but only in two Scandinavian peat-moss sections (HOLMBOË 1900) has a careful survey been undertaken with measurement of the position of the stools (Pl. 2 *a* and *b*); *all the rest are skeleton drawings, in which ocular measurement and a personal view have prevailed* (Pl.

2 c and Fig. 5). There is no doubt that many stool occurrences that are looked upon as pronounced, would reveal themselves as less clear if surveyed in detail than has been assumed from an ocular examination of what are often very small sections. It must however be pointed out that an accurate measurement of this kind is a very tedious, laborious and often costly work. Those who have already been convinced of the correctness of the BLYTT theory, are sure to consider such work superfluous, its opponents hold that the proof devolves on the proposer of the hypothesis and that there are so many other more attractive works of a positive nature.

BLYTT took as his ground that 3 stool-layers should exist in all peat-mosses situated over the highest marine limit; SERNANDER expresses himself with great cautiousness concerning the oldest one and considers that climatic conditions at the time when it was formed are very little known; v. POST (1906, p. 302) who has recently been studying the peat-mosses of Norrland from BLYTT's point of view, speaks as follows: »Of BLYTT's periods only the 3 last-named» (corresponding to a stool-layer with overlying and underlying peat) »have left traces behind in the peat-mosses of Norrland, while in the most northerly districts of Norrland not even these have been distinguished.» He considers the cause to be that the land has been covered by ice for such a long time. As will be seen from the latter part of this account, such an assumption is scarcely justified.

What has been quoted shows that the stratigraphy of the stool-layers is by no means so simple, regular and uniform as BLYTT imagined and some still think. If to this we add that in innumerable peat-mosses in shallow basins and, to judge a priori, with every presumption for the existence of stool-layers, there are none to be found, one should, I think, look about for other explanations. We shall assuredly not get full information upon the subject before we have considerably enlarged our knowledge of the oecology of the *hygrophyte* plant-communities. When we consider the great variation that in our

own time, which is held to be dry, prevails within quite a small area, it seems scarcely probable that the majority of swamps should have been so homogeneous in older times that the same stratigraphy should have appeared in them. In consistency with a contrary view SERNANDER (1905, p. 81) has also at times emphasised as a proof and above all as a way of parallelising the stratigraphy of different peat-mosses, that »at about the same depth in bogs and peat-mosses he came across old forest beds». I think that HOLMBOE (1903, p. 3) is perfectly right in saying: »The measurer of time which in the popular opinion appears as the easiest, namely the thickness of the covering peat-layer, has proved to be absolutely unserviceable and has long ago been abandoned by all who occupy themselves with investigations of his nature». For the rest, I find it difficult to understand why the amount of precipitation should be able to determine whether a peat-moss is dry or wet. What decides the dampness is the *drainage system*. Even in such dry climates as that of the steppes of Baraba large peat-bogs without trees are numerous. It seems more likely that an abundant precipitation would more easily cut away the outflow and thus bring down the water-level and make the swamp dry, than the reverse. It is the great capacity of most species of peat for *retaining* water that conditions the specific qualities and wetness of these areas, not particularly the quantity of the precipitation.

It has been emphasised that the peat that underlies the stool-layers in their upper parts, should show evident traces of decay, proving that the peat-mosses have long been dry. I do not find that any conclusive proofs of this have been adduced, and as far as my experience of fieldwork goes, everything goes to prove that the woods of the forest-beds in the peat-mosses have grown upon tolerably sour soil, as is the case on the majority of the wooded fens of Northern Sweden. An additional proof of this is, that the stools, as far as my experience goes, unless they are examined at the collar, where of course the annual rings are always very large by reason of

their wryness, generally show themselves to be particularly slow grown. Their great hardness and resinousness point in the same direction. HEMBERG (1904) has illustrative diagrams given here, Fig. 1.



Fig. 1. Parts of pine-trunksections.
 a. Fossil pinewood of normal type from S. Skåne. b. Normal section from recent, planted pine-forest, Skåne. After Hemberg (1904).

The result of my studies is that stool-occurrences in the peat-mosses of Scandinavia represent all the phases of the Post-glacial Period, and that even if they are localized in one peat-moss to a certain horizon of the peat, one has no right, at least on the strength of investigations undertaken hitherto, to parallelise them with another as to time.

Stratigraphy of the Calcareous Tufas. It has been known for a long time that in the larger calcareous tufas, hard and soft layers alternate in the sections, showing, consequently, that the conditions under which they were formed were dissimilar. In certain places these changes have gone so far that the tufa formation from time to time has ceased and been supplanted by a soil formation pointing to very dry conditions, which have usually left traces behind them of thin seams of humus holding calcareous silt, usually containing land molluscs. The best known habitat for a series of this nature is Skultorp in Västergötland (Fig. 2), where 3 of these humus-seams occur, though two of them are only divided by a thinnish and not very typically developed tufa stratum (Fig. 3).

SERNANDER and his followers (HULTH 1899) assume that the humus-layers date from periods which were so dry that



Fig. 2. The calcareous tufa at Skultorp in Västergötland. After Hulth (1899).

the springs ceased to flow and that it was not until a subsequent wet period that the tufa deposition, along with the resumption of the subsoil water, began again. It may of course be possible that this interpretation is correct, but various circumstances seem to me to controvert it. In the first place the stratigraphy just described is by no means the rule in Scandinavian calcareous tufas. In Benestad, the largest and most carefully studied of the occurrences of tufas in this country, a humus-ledge, according to KURCK (1901), is lacking in every section except one, a fact that points to great local variations in the deposition of the tufas, due perhaps to the water taking another course when the tufa-layers had reached a certain thickness, only to return again when the new tufa-layers had grown in thickness. On the whole we may call to mind that the detailed

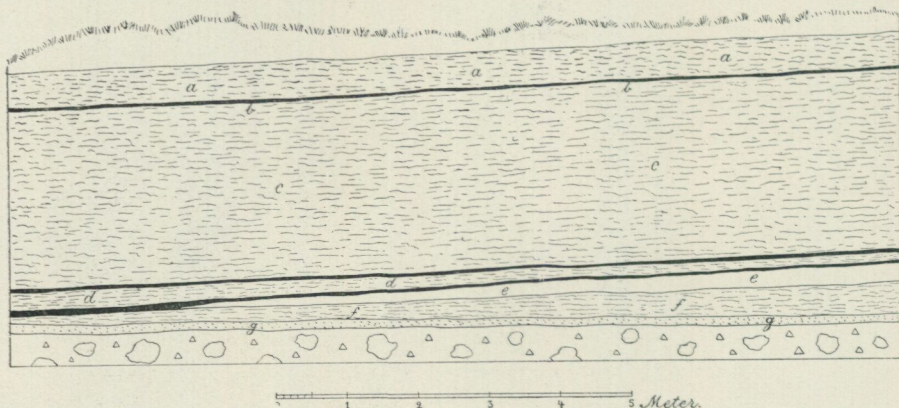


Fig. 3. Section through the calcareous tufa at Skultorp. *a, c* and *f* tufa-layers. *b* and *d* dark humus-seams; *d* is divided in two parts by a thin tufa-bed. After Hulth (1899).

conditions for the formation of the various kinds of tufa are practically unknown, furthermore that especially in limestone rock the subsoil water takes a very varying course during different geological phases, owing chiefly to the great dissolving power of the water on this kind of rock.

But, as Hesselman and others have recently pointed out, even in other, far more resistant material (our moraines consist mainly of primary rocks) intermittent capriciousness in

the course of the subsoil water is noticed; this, it is true, cannot yet be fully explained, but it urges us to be very careful in our conclusions. The assumption of so dry a climate that the springs in our calcareous regions should have dried up, leads to the hypothesis of practically a desert climate, for, by way of example, in the arid Karst districts of to-day there are many springs, and, especially during the more rainy period of the year, tufa-deposits take place here, as I have made sure from visits to habitats in Dalmatia and elsewhere. TANFILJEFF with reference to the Baraba steppes already mentioned, points out several times that huge fountains occur.

The question of the accordance or dissimilarity of the stratigraphy of the calcareous tufas in different countries is of such a kind that it can be cleared up quite exhaustively at the Geological Congress in 1910 if scientists who are interested in the subject will undertake investigations in the meantime, especially in calcareous countries. Should the accordance prove to be great in a large number of habitats, we must naturally hit upon a common cause of a general nature, and then possibly SERNANDER'S cherished theory, that this is of a climatic nature, will be backed up in a way that is at present lacking.

Stool-layers at the bottom of lakes. As far back as 1890 an attempt was made by SERNANDER, in a little essay describing a stool-layer, which stretched down under the surface of the lake Axsjön in Närke (Fig. 4 and 5), to establish by evidence that stool-occurrences were due to there having been a dry period, during which »the level of the water in Axsjön, which, like forest-lakes in general, is very susceptible to even a short period of rain or dryness, had sunk very considerably and had clothed this area with possibly several generations of lofty pines, one after the other». The proof is as follows: »No other explanation of the occurrence of this stool-layer in the peat can readily be imagined than the one that follows BLYTT'S theory. The insignificant outflows which the extensive Fågla-mossen possesses, even if they were considerably cleared out or extended by, for instance, some violent spring flood, would

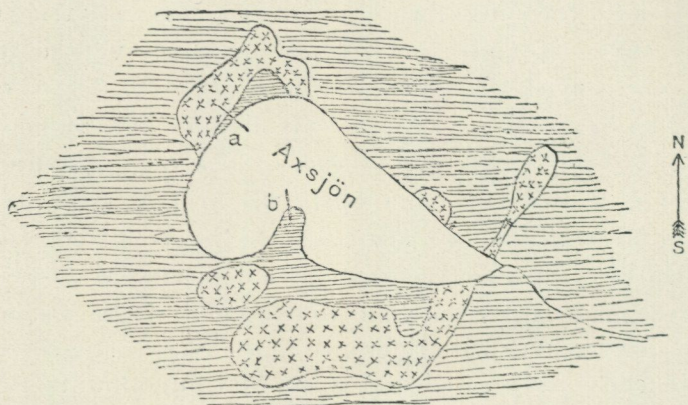


Fig. 4. Sketch of the lake Axsjön and the surrounding peat-moss Fågelmossen in Närke. After Sernander 1890.

||||| Peat-moss.
 XXXX Morainic area with Pine-woods.

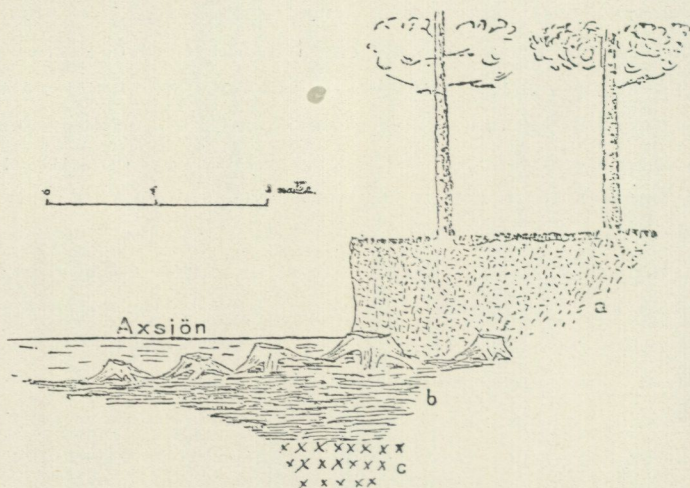


Fig. 5. Section at *b* in fig. 4. *a* Sphagnum peat. *b* Mud. Over *b* the Stool F. *c* Moraine. After Sernander 1890.

be unable to any appreciable extent to drain the peat-mosses, which retain moisture like a sponge. A long period with dry, continental climate should, however, have gradually more or less dried up the swamp, however wet it may have been, and consequently promoted the development of more and more xerophilous formations, until the whole peat-moss would

be covered with dwarfed wood or wellgrown pine wood.» An argument based upon »no other explanation can readily be imagined» seems to me unsatisfactory when such important inferences are at stake. I think we might just as readily imagine that here there was a little basin, in which the mud indicated in the section was deposited, filling the basin so that the woods continued across its surface. As the *Sphagnum-peat* began to form on the surrounding peat land, over which the basin was drained, the latter was dammed more and more, and an open sheet of water arose afresh. A detailed examination may perhaps give an entirely different interpretation, but what is evident is that a greater and more convincing precision is wanted before we can consider these stool-layers as conclusive proof of dry climatic periods. The same holds good of some other of the stools at the bottom of lakes as described by SERNANDER. Besides, there are, it appears, only two lake-occurrences which the Uppsala school now credit with conclusive proof in this respect, viz Hornborgasjön in Västergötland, dealt with by SERNANDER (1908), and the lakes of the highlands of N. Småland, described by GAVELIN (1907).

On the calcareous plain of Västergötland, below the Silurian mountain called Billingen, there lies a good-sized lake, the Hornborga lake, about 11 km. in length and up to 4 km. in breadth, with a surface of about 3,000 hectares, and a watershed including about 60,000 hectares, i. e. consequently about 20 times greater than the lake. The lake itself is a shallow basin with a present depth of from 1.5 to 2 meters, and is surrounded by large peat-mosses. The stratification is, in the main, ooze deposited in the lake, reed and sedge peat-layers, a forest-bed of pine and above these *Sphagnum-peat*, formed of species that will endure dryness. The stool-layer continues out along the bottom of the lake and stools are met with up to at least 1 metre below the present surface.

The three investigators, MUNTHE, HAGLUND, and SERNANDER, who have had an opportunity of examining the deposit more closely, have all three arrived at absolutely dissimilar

results, which proves that some caution is required when climatological conclusions are drawn from these investigations. SERNANDER (1908) makes the whole succession of strata out to be very recent (*Litorina* period), but considers that this naturally proves BLYTT'S opinion about climatic alternations. MUNTHE considers the lower portions date from a much older period and is in doubt as to its showing climate changes, HAGLUND considers it does not prove any thing at all in that respect.

We cannot here enter into details. For me it is conclusive that the old shore-line, 1.5 above the present surface of the lake, at which, according to SERNANDER (1908, pp. 79 and 82) »the subatlantic lake's boundary line may conveniently be placed», from what HAGLUND (1908, p. 311) seems to have shown, formed the boundary of the lake in our own time up to its sinking in 1874. On the whole SERNANDER'S exposition does not pay sufficient regard to the possible influence that man has exercised over the level of the water in this shallow lake, which was comparatively easy to dam. For many centuries there have been people dwelling here, who, according to the various demands of material culture, now for fishery, mill building and so on, have had occasion to raise the level of the water, or for other ends to lower it. (As can be proved, this happened at the beginning of the 19th century, in 1874, and now.) No sure foundation for presumptive climatic changes can be gained from such material.

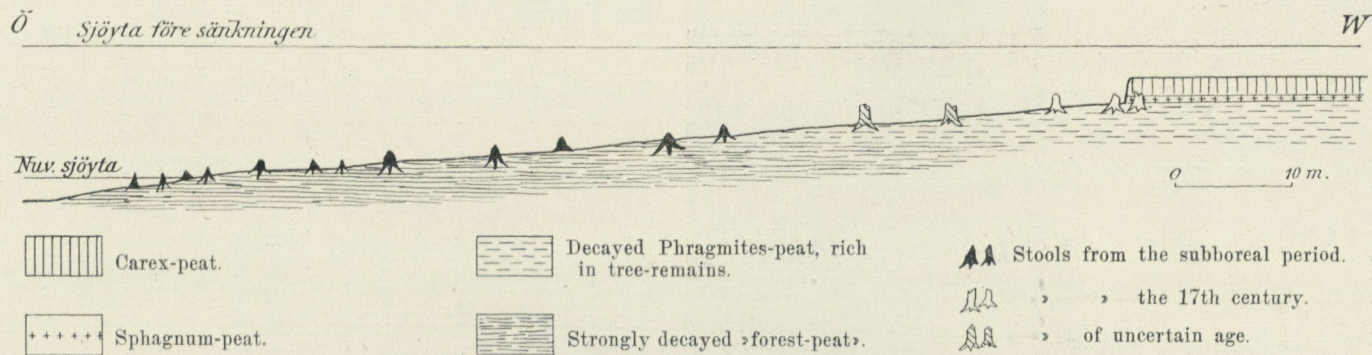
The most valuable, scientifically, of the Swedish investigations, hitherto undertaken, into the lakes possessing forest-beds, are those carried out by GAVELIN (1907), dealing with Vänstern and Frucken in N. Småland, situated a little to the E. of Vättern. Here stools have been found to a depth of 2.5 m. below the high-water line that marked the highest level of Vänstern before the sinking of 1903, and 0.25 m. below the present low-water mark. It has been proved from historical documents that the lake was dammed up between 1681 and 1744 from 0.5 to 0.7 m., but the rock-sill itself, over which the outflow now passes and which was blasted through in 1903,



Fig. 6. Part of the shore of lake Vänstern after the sinking. Numerous stools visible.
After GAVELIN.

lies, according to GAVELIN, at least 1.8 m. higher than the lowest stools in Vänstern. From this he draws the conclusion that »the surfaces of the water (in Vänstern and Frucken) have sunk so much during this period that the lakes have become *without outlets*». As oak and other southern growths have been found in beds under the stools, this period must be assigned to a proportionally late one in post-glacial times.

It is a question of exact investigation, the investigator's task being concerned with centimetres. Without having seen the place it is not possible to express a definite opinion about it. Likewise, it seems hard, judging from this map, to affirm with certainty that no lower passage in the vicinity of the present one can be found for the outflow of the Vänstern. In any case, it is a very remarkable anomaly that for a long period the Vänstern should have been



›Sjöyta före sänkningen› = sea-level before the sinking. ›Nuv. sjöyta› = present sea-level.
Vertical scale about 5 times larger than the horizontal.

Fig. 7. Section through peat-bog forming the shore of lake Vänstern. After Gavelin.

without an outlet, while (according to GAVELIN'S statement) the Noen, only a few km. distant, was not. Both are big lakes with *about the same extent of water area* in proportion to their surface. GAVELIN'S section also arouses the reader's astonishment. In a perfectly even gentle slope there stand *in a row* a number of stools, of which the lower ones are explained as being from the sub-boreal period, a few close by them as being of uncertain age, and the uppermost as being from the 17th century (fig. 6 and 7). Between the stools from the sub-boreal period and the 17th century, surely peat without stools should have been formed. In any case, in the upper higher parts of the section stools from the sub-boreal period must occur, for the climate can hardly have been so dry that woodland did not exist at a distance of some twenty metres from the shore of the lake without an outlet. As now, according to the united opinion of the supporters of BLYTT'S theory, we are living in at any rate a fairly dry period, it is a contradiction to assume that the level of the water before the sinking, irrespective of damming, stood so high that it practically corresponded with a wet period. I will also ask if it is quite impossible that the stools can have sunk out in the deeper water?

With all due regard to the fine investigation, it seems to me, when it is a question of fundamentals of such far-reaching conclusions as are given below, that a yet more exact examination should be undertaken even by investigators who are not inclined a priori to interpret the stratigraphical condition as proofs of climatic alternations.¹

In order to establish whether in some place or other there are districts of the kind assumed by GAVELIN, where, of lakes that are quite adjacent and with about the same water-area, the one is without an outlet, the other with, I applied to the well-known authority on lakes, Professor W. HALBFASS, and this was his reply to my question:

¹ GAVELIN'S views have gained in probability by HINTZE'S recently published interpretations, which are cited below (p. 67) and which indicate a very dry climate during the *Ancylus* age, but this time was in a much older period than G. has assumed. (Note added while this paper was in press.)

»Lakes of the kind you mean occur on a small scale on the plateau of the Baltic lakes in NE. Germany, e. g. in Further Pomerania in the district of Bublitz and Neusletten. These lakes are always to be looked for in the neighbourhood of watersheds. Their origin often results from accidental circumstances, human activity, etc. I can really not attach much importance to the idea of outlet and absence of outlet; a lake is not rarely without an outlet now, that had one not long ago, and may have one again soon. Frequently a difference of 30 % in the atmospheric precipitation of successive years will cause the change. The lakes mentioned are but small, scarcely 1 km. in size, rarely larger. Any *secular* cause whatever I consider quite out of the question. In Further Pomerania there are woods in the neighbourhood of these lakes without outlets, but only of moderate extent.»

Evidently the phenomenon described by Prof. HALBFASS is of quite a different kind from that which GAVELIN thought he had succeeded in discovering. The climate his theory demands is of a more extreme nature, of which more further on (p. 41).

Flowing soil in mountain regions. In connection with the Swedish polar voyages attention has been drawn in both the North and South polar regions to the very extensive sliding of surface stratum, which results in the ground being characteristically terraced. In the mountainous districts of S. Sweden SERNANDER (1905) has proved that to quite a large extent there exists »fossil flowing soil», i. e. similar terraces entirely overgrown with vegetation. He considers, with good reasons, that this points to a rainy period in the mountains. The difficulty, however, is to determine with certainty the epoch during which this occurred, a point also emphasised by SERNANDER himself; still, he finds it most plausible to identify it with the last of the wet periods of BLYTT's. It might with about equally good reason be assigned to another period of the Quaternary time. A careful examination of this phenomenon within a number of mountainous territories would be

of great interest for our knowledge of the climate in past times. However, as there are no post-glacial traces to be found in Sweden of an extensive advance of glaciers (cf. p. 76), such a wet period in the mountains must naturally coincide with a warmer period than the present; otherwise the glaciers would have advanced. According to other evidence, a period like this occurred about the time of the maximum extent of the *Litorina* sea.

The relation between the glaciers and the shore-lines. This point will be with below (p. 76).

Changes of levels. The investigations of the last few decades, especially those of DE GEER (1896), have made clear the main features in the very important geographical changes that have taken place in Scandinavia since the Glacial period, chiefly owing to the risings and sinkings that have succeeded each other. Climatologically viewed, they have, of course, operated in two directions, partly by changing the altitude of the land above sea level, partly through the different distribution of land and water that they have entailed. However, the former have not very much to do with the conclusions it is possible for us to draw about the climate of past times, since the districts from which the evidence is drawn did not in post-glacial time oscillate more than up to 50—100 m. over the sea level, wherefore the result is only affected in fractional parts of degrees. In most cases correction can be applied for this.

Greater is the influence exercised by the changes in the distribution of land and water. It is evident that a correct appreciation of their significance for the climate is absolutely necessary if the results are to be correct. But this involves great difficulties, and a further development of our opinions in this respect, supported by meteorological and geological experience, is badly wanted.¹ In the following chapter the pre-

¹ Compare p. 67 concerning the influence upon the climate caused by the large upheaval of the present seabottom, which has been indicated by HINTZE's interpretations. (Note added while printing off.)

sent state of our knowledge on this point will be more closely touched upon.

Orographic forms. In the following (p. 40) I have attempted to deal with the consequences, from a meteorological point of view, of BLYTT and his followers' presumed dry and wet periods. These are such that it seems to me highly probable that the purely orographical forms of the surface of the land should have left traces of the same behind them, had these periods really occurred.

Loess-formations, even if only to a small extent, should have arisen during the dry periods, just as other phenomena in connection with a dry climate, not only the hitherto very slightly studied moulded soil, which one has credited oneself with finding in certain peat-bogs. During the wet periods, on the other hand, we might expect the development of characteristic erosion phenomena in both loose layers of earth and in solid rock; such do not seem to occur. That the forms of this kind in Sweden, which are in connection with a large supply of water, date from late-glacial times and the melting of the ice, we may reasonably be of one mind about (DE GEER 1896).

2. Paleontological evidences.

It is, we suppose, generally known that the circumstance which first gave rise to the theory that climatic alternations took place during the late-quadernary period, was the observation that certain species of plants and animals are found fossilized in peat-bogs, clays, layers of sand, calcareous tufas, etc. within territories where they do not live now. These finds are chiefly twofold:

a) northern species are found to the *south* of their present southerly limit,

b) species more dependent on heat are found to the *north* of their present northerly limit.

Both cases could be exemplified to-day in many examples,

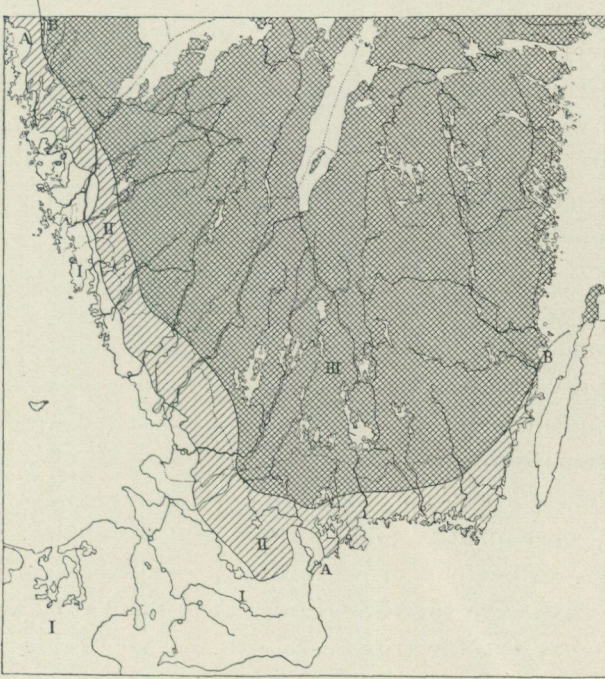


Fig. 8. Map showing the present southern limit of the pine (*Pinus silvestris*) in southern Scandinavia (A-A.) Within the whole area south of this limit (I) there are found remains of it in large quantities in the peat-bogs, but no wild living trees. In the lined area (II) the pine-forests are degenerated and sickly, but to the north of it (III) the development of the pine is normal and good. After HEMBERG.

of which, however, only a few are described in detail, while the majority represent scattered observations. Nevertheless, a number of these throw light upon the question, in that they show that the several species were more generally diffused through the frontier districts of the area of distribution, where now they are rare and confined to places with exceptional, ecological conditions; the northerly ones to cold habitats (fens) and to the cold depth in lakes and in the ocean, the southerly to warm (mountain bases, southerly slopes, shallow warm bays). By this means we can verify that this is not a question of species in the act of spreading, but of true relics.

The best investigated of the former conditions of distribution — as far as they concern us here — may be said to be the

following. The former distribution of an *arctic flora*, rich in species, over southern Sweden, Germany, Great Britain, Denmark, the Baltic Provinces, and the peripheral parts of Fennoscandia (NATHORST 1870 and 1891, ANDERSSON 1906). Stratigraphically this flora always belongs to the basal parts of the late-quaternary sedimentary strata.

The general distribution of the pine (*Pinus silvestris*) over large parts of W. Europe and S. Scandinavia, where it is now quite lacking in a wild state (Fig. 7) points to a climatic improvement, but to what extent it involves the proof of change in the supply of warmth or in the precipitation, cannot at the present moment be decided with any certainty, seeing that new investigations into the pine races show that there is a number of fully developed oecological types of this tree in N. Europe, and that, consequently, one has no right, from the result of cultivations hitherto carried out, to draw conclusions about the cause that have forced the pine, in competition with other species, to retreat towards the north. When, some day, the experimental cultivations now being carried out with different pine races in W. Europe, have been completed, and close comparisons have been made between these and fossil remains, a path will have been cleared for sure and resultful climatological conclusions.

Molluscs now living in the northern seas (*Yoldia arctica*, *Saxicava arctica*, *Tellina torelli*, and others, which occur as fossils in South Scandinavian strata, just as fishes, the Polar cod, *Gadus saida*, in the clay at Lomma near Malmö) show exactly the same as the plants, viz that species less dependent on warmth had a considerably greater distribution than now. Through the hydrographic investigations of recent years, by Scandinavians and Russians, we have obtained a much more extensive and a deeper knowledge of the requisite conditions of life of the sea-molluscs from which exceedingly reliable conclusions should gradually be reached, in one direction touching the salinity of the sea, in another the relative warmth during various phases of the formation of these strata.

What is wanting, it seems to me, in order to complete the investigations already undertaken, and most carefully carried out lately in Norway by BRÖGGER (1900 and 1905), is specific monographic works in addition to the present local monographic ones, by means of which a full survey of the former distribution of certain proof-bearing species would be obtained. Hereby a close comparison and verification between the evidential climatological material gathered from marine animals and land plants might be secured. Unfortunately such works, up to the present, only exist for a few species (JENSEN 1905).

The former distribution of land animals also affords isolated proofs of a greater distribution of northern forms in southerly districts of today. So the *polar bear* on Kullaberg in Scania, (HOLST 1902) probably the lemming, *Myodes*, (HARTZ 1903) and with certainty the small freshwater crustacean *Apus glacialis* (NATHORST) in Scania and Denmark, but above all the reindeer (*Rangifer tarandus*) within the whole South-Baltic territory. A quantitative valuation of the amount of the climatic change, for reasons we have not space to enter into here, can scarcely be obtained from these finds. The Ethnological Society of Lund has of recent years systematically carried out investigations of the strata in which reindeer-remains are found, which have shown that in Scania they are to be met with exclusively in the basal (late-glacial) parts of the strata. The same has been found to be the case in Denmark.

It should be remarked that the negative conclusions that are sometimes drawn from the absence of mammal remains, prove nothing when we are dealing with districts poor in lime, for there the bones are dissolved by humus acids.

From a climatological point of view of importance, though hitherto only casually observed and studied, are the abundant fossil remains of fishes. NORDQVIST (1903) has drawn attention to the close connection between the distribution and the spawning-seasons of fishes. This suggestion could be made use of for important conclusions, especially with reference to

spring and autumn temperature at the time of the deposition of the layers in which certain fishes are found.

Quite as numerous as the traces of northern species in southern districts are the fossils which show a greater distribution towards the north than now on the part of southern species. The stratigraphic distribution, however, shows everywhere that the latter phenomenon (with possibly one exception, p. 32) is considerably more recent than the former.

Best known among the plants in this respect is the hazel (*Corylus avellana*; ANDERSSON 1902), and the former extension of the limit of trees (REKSTAD 1903, etc.). In the following we shall deal with this and a number of other plant-species. In general, it is the state of the temperature and the length of the summer which can be fairly correctly established with the help of these species.

Fresh and salt water molluses, too, show several examples of great moment (*Tapes*, etc.) that point to greater extension towards the north. It seems to me as if the very intimate knowledge we now possess of the biology of many of them has scarcely been put to the fullest use in a climatological respect. This is especially true of winter temperature.

Among the mammals there are several whose spread towards the north undoubtedly stands in connection with warmer climate and a more abundant vegetation (*the tortoise, wild boar, deer, and possibly roedeer*). It is also to be remembered that in SW. Norway are found as fossils *Mustelius putorius* and *Podiceps nigricollis* (?) which have to-day their northern limit in Denmark (A.W. Brögger 1908). However, so many different circumstances are bound up with the occurrence of all these animals, that as yet it only gives a general support for the assumption of more favourable climate, and in matters of detail scarcely adds to our knowledge of the subject.

A more detailed study of the fossil insect fauna, of which certain species (*Platydema violacea* in Finland; ANDERSSON 1898) are found to the north, and many to the south of their

present ground, might possibly yield more climatologically than has been the case hitherto.

3. Biogeographical evidences.

Long ago the animal and plant geographers tried to explain a number of animal and plant occurrences that are distant from their proper sphere of distribution, by assuming that they were connected with other early climatic conditions than the present. This relic theory has been developed in Sweden especially by F. W. C. ARESCHOUG (1867), who showed that in southern Scandinavia there are relics of both arctic origin, pointing to a cold climate, as well as of more southerly origin, which through their isolated occurrence pointed to a warmer climate than the present. He himself says: »Many of the plants that immigrated during that time (i. e. the time for species with a SE. distribution in Scandinavia) now occur in Europe in such scattered spots, that one might almost be tempted to assume that they disappeared for the most part owing to a return of a colder climate or as the results of other natural conditions that are unknown to us.»

The study of these relics, during the forty odd years that have elapsed since ARESCHOUG wrote, has been carried on very strenuously. Especially SERNANDER (1894), NATHORST (1896), and the present writer (1896) have, by pointing out so-called pseudo-relics or species, which in certain cases probably spread to their present habitats in a much later time than if they were true relics, made an important contribution to the critical estimation of the demonstrative value of the state of the distribution nowadays with regard to the climate of past times.

Although, consequently, extensive preparatory work has been carried out in Scandinavia for making use of the distribution of the flora of to-day for climatological conclusions, there is unfortunately as yet no modern comprehensive rearrangement of the material. Still it affords valuable evidence along 5 different lines:

- a) A number of scattered relic localities of a plurality of

species in southern and central Sweden go to prove that a much colder climate existed during which these species had a more connected area of distribution. This latter assumption is supported in several cases by fossil finds.

b) A number of occurrences (chiefly in peat-bogs) in districts which during the last few thousand years have risen above the level of the sea, go to prove that northerly species during the space of time indicated have spread to the south, whence possibly the climate has become more favourable to them, i. e. colder.

c) In a large number of spots, in particular the more mountainous parts of N. Sweden, one has come across a rich and very homogenous collection of species which otherwise only occur normally in districts situated considerably further south. As the spots indicated are southerly rock-bases or other sunny, warm places, shallow warm bays, etc., weighty reasons point to the species in question having formerly, when the climate was warmer, had a wider distribution in those parts where they now occur as relics. This assumption is supported, in some cases, by fossil finds.

d) In the calcareous tracts of S. Sweden there occur, more or less isolated, a number of species with their chief centres in the steppe and upper karstenite regions of SE. Europe. This supports the assumption of a former dry climate in such tracts where the species named are now to be met with only on very dry and warm habitats.

e) Along the maritime district of W. Scandinavia, abundantly in Norway, though for the most part very rarely in Sweden, there occur several species which have their true area of distribution in Great Britain, the Atlantic coast of France and to the south of that. These have been regarded as relics of a former distribution, going back to a time when the climate was warmer and, especially in SW. Sweden, damper than now.

A very weak point in climatological demonstration on the strength of such relic areas of species and groups of species,

is that in the case of hardly a single one of them have exact investigations been carried out concerning the true area of the climatic distribution of the species, by reason of which well founded comparisons between the climatic conditions of the present and the past can only be undertaken in a very narrow field. In the future, however, important results may be obtained by this method, especially as it both amplifies, and is itself often amplified by the fossil finds.

As far back as 1861 SVEN LOVÉN wrote a treatise on some of the crustacea (*Idothea entomon*, *Mysis relicta*, *Pontoporeia affinis*, *Gammaricanthus loricus*) in the big lakes of central Sweden, Vänern and Vättern, which had been found in the deepest parts of these lakes, but the proper habitat of which is the Arctic ocean off the Siberian coast. LOVÉN regarded these occurrences as relics and proofs of a glacial climate at the time when these creatures first migrated to the Vänern and Vättern. Numerous finds of not only crustacea, but also fishes, seals, etc. have supported this assumption and consequently point to a colder climate in the past. Similarly the distribution of certain fishes in relic-like occurrences north of their proper area of distribution has been interpreted, undoubtedly with good reason, as proofs of a warmer period (LUNDBERG 1899, ANDERSSON 1900, NORDQVIST 1903). The last-named has, moreover, as has already been mentioned, connected the question of distribution with the temperature of the lakes at spawning-time, in a way that opens up possibilities of very important conclusions with respect to the climate of former days, if the suggestion is worked out in detail.

Lastly, we may briefly refer to a suggestion of TANFILJEFF touching »the polar limit of the oak in Russia» (Die Polar-grenze der Eiche in Russland¹). In opposition to GRIESEBACH, KÖPPEN and others, who connect the northern limit of this tree with different isotherms, while THESLEFF and MAYR held that a low winter temperature (— 30° C.) determined its

¹ A Russian treatise with a short resumé in German. The reprint does not state place of publication.

northerly limit, TANFILJEFF attempts to show that it is the ground temperature in May, and partly also in June that determines the limits of the tree. In places where, at leafing time, the soil has remained practically at the freezing-point, the roots of the oak cannot take up enough moisture for growth and transpiration, which are so strong at that time. If this is true of the oak, it must certainly also be true of a number of other deciduous trees that accompany the oak in the woods of N. Europe. As, however, the temperature of the soil in May stands in close connection with the winter temperature and the depth of the frost in the ground, a method could be established in this way of obtaining a surer knowledge of the winter temperature.

As to the contribution to our knowledge on this point to be obtained from *Taxus* and *Hedera*, see p. 65.

AXEL BLYTT (1876) attached great value to the distribution of a number of rare species in the Norwegian flora in regard to the climate of past times. Inside the fjords, on the warm, dry southern slopes, he discovered colonies of trees, woodland plants and perennials which he considered could not possibly have come to their present habitats except during a dry (boreal) period, in which even along the Atlantic coast, along which he assumed that they spread, a dry, continental climate held sway. This was the basis of his much talked of climatic theory. Here, as in his treatment of all such questions, BLYTT has been too strictly schematic. The majority of the species in point are to-day by no means so rare, even out in the west Norwegian coast districts, as BLYTT represented. ANDR. M. HANSEN (1904) has shown that the species in dispute need not by any means have reached the interior of the fjords in that way, but that this happened, in all probability, to a great extent over the present mountain-passes with fertile soil, formed from soft slates, during the warm period (p. 65), when the limit of trees lay some hundred metres higher than now (cf. plate in ANDERSSON 1906, p. 81).

Constancy of biological characters. In the course of the discussion between Scandinavian investigators about the climate of former times, a vital question has now and again been debated, viz to what extent we may with any certainty assume that, during the thousands and tens of thousands of years we have to deal with, the necessary amount of warmth, precipitation, etc. required by the various species has not altered. On this rests ultimately the value of all the paleontological and biogeographical evidences for accepting climatic changes, i. e. the most important we possess. WARMING (1904) says on this point: »Provided no morphological changes can be proved, we may, I think, assert that the biological qualities cannot have changed either. Otherwise all our conclusions about climatic conditions in past times would have no real foundation.» I cannot agree with this opinion. If there is reason to assume a change in the ecological demands of the species which we use in evidence, let us rather abandon all imaginary knowledge about the climate of past times. A close and critical treatment of these questions has been furnished by WESENBERG-LUND (1906). Especially one circumstance of great weight has been pointed out in that work. In paleontological investigations one often makes the morphological extent of the variation of the species excessively large and at the same time one marks out narrow and sharp limits for the biological. As an example he takes the case of *Anodonta* spoken of below (p. 56). Furthermore, he opposes the dogma, »biological variation always involves morphological variation». From a purely theoretical point of view these objections are undoubtedly justified, and if we only had one or a few species to base our opinion on, the conclusions would not be worth much. As is here shown, however, there are whole troops of species, living under the most varied ecological conditions, plants as well as animals, alive in the air and in the water. If they give the same result, then we have reached an empirical certainty of probabilities that all of them cannot have changed their biological demands in the same direction, which seems to me about as

safe as the certainty in the scientific proof of probabilities, taking it all round.

This, however, by no means excludes the necessity of paying the very greatest attention, critically, to the actual fossils. I am quite convinced that certain species have changed their demands. Thus, it is quite certain that the pine (*Pinus silvestris*) of the Pine age in S. Scandinavia had quite different demands from the pines that now live there, for the reason that the pine, from an œcological point of view, is not one species, but several species. Whether all these existed at the beginning of the post-glacial period, is another question. *Cladium mariscus*, which certainly immigrated with the birch, is not content in our time with the amount of heat which suffices for the latter and the accompanying flora, and which was then probably offered it. For the pine I think that morphological dissimilarities could certainly be proved (anatomy of the needle and of the wood); of the morphology of *Cladium* during that earliest time we shall certainly never obtain exact knowledge. We must be content, with the help of the fruit-stones, to establish its existence; these were absolutely like the present ones.

4. Astronomical evidences.

Quite independent of all the above-named reasons the astronomers, supported by purely mechanical calculations, have foretold continual changes in the temperature on certain parts of the earth, with periods thousands of years in length. These have their cause in the long-periodical changes in the inclination of the earth's axis to the ecliptic (fig. 9) and in the variations of the excentricity of the earth's orbit. However, we shall only touch here upon such consequences thereof as may be placed together with the other experiences of the post-glacial climate.

As far as Scandinavia is concerned, this problem has been worked up by N. EKHOLM (1899, II). According to his version there are two maxima and one minimum of tem-

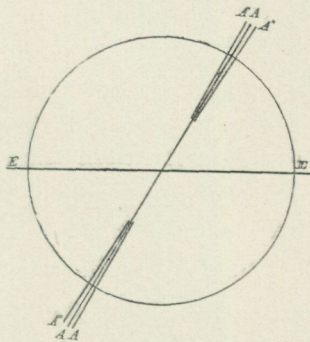


Fig. 9. Schematic figure showing the greatest and the least as well as the average inclination of the earth's axis to the ecliptic. E. E is the line of intersection with cut through the earth's axis; A. A the average position of the earth's axis, A.' A' and A." A" its farthest positions. (After N. EKHOLOM.)

perature, which have occurred so late in the quaternary period that we ought to examine whether they could be compared with other experiences concerning the climatic changes in late-quaternary times (Fig. 10). The periods just referred to occurred the following number of years ago (reckoning from 1900):

Maxima of Temp.	Minimum of Temp.
9,126 (Julian) years ago.	28,346 (Julian) years ago.
48,072	» »

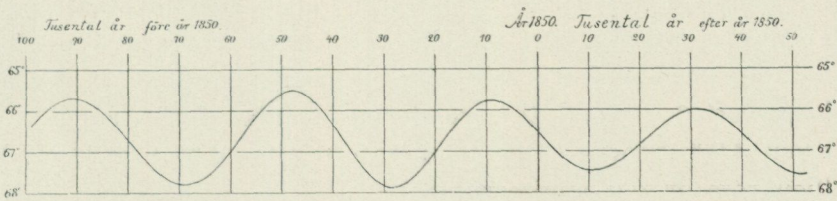


Fig. 10. Curve showing the variations in the inclination of the earth's axis to the plane of the earth's orbit. 0 = anno 1850.

Each perpendicular line on the left signifies 10,000 years before 1850, each line on the right after that year. (After N. EKHOLOM.)

The values expressed in years are not, of course, reliable down to the decades; however, in order to obtain a point of appui for the probable error, I have addressed myself to

Professor CHARLIER, who considers the error of no consequence for the geological time here in question, viz thirty to forty thousand years.

According to EKHOLM, the climatological results are briefly these: The time during which the sun uninterruptedly remains above the horizon at the most northerly meteorological station in Sweden (Karesuando $68^{\circ} 26' N.$, $22^{\circ} 30' E.$ Greenwich) is now 54 days, but during the most favourable period, 9,100 years ago, it was 62 days, and during the least favourable, 28,300 years ago, 38 days. The difference has thus been not less than 24 days. It is obvious that this exercised a very considerable influence upon vegetation. EKHOLM has also undertaken calculations of the difference in the force of the sun's rays (cf. op. cit. p. 383), and has found that for the 6 months in the summer (April—Sept.) the temperature 28,300 years ago was, simply taking into account the warmth brought from the sun, $3.5^{\circ} C.$ lower in the extreme N. of Sweden and $2^{\circ} C.$ lower in the extreme S. The 6 winter months, on the other hand, received so much more warmth than now as to correspond to $1-2^{\circ} C.$ However, it must be strongly emphasized that these values may have been more or less affected by the meteorological conditions (winds, etc.).

Of great importance from the point of view of plant geography is, at any rate, that these cold and warm periods do not represent a short succession of years, but that during a long period, around the wandering points of the curve — about 4,000 years — the temperature altered but little, and then rose or fell uninterruptedly.

To what extent these astronomical results accord with the remaining observations will be dealt with in what follows.

Here we may simply point out that in the investigations just referred to we have a support for estimating the length of the late-quaternal period. Without in any way wishing to represent my opinion as being reliable, I will mention that all the investigations hitherto carried out in Scandinavia seem

to agree with the calculations EKHOLM has arrived at. We assume that the last ice age coincided with (was not exclusively caused by!) the cold period with a minimum 28,300 years ago, and that the rising temperature began about 26,000 years ago. We know that the melting of the ice and with that the oldest immigration of arctic and forest vegetation took, roughly speaking, 5,000 years (DE GEER). On the other hand, man's period as a tiller of the ground began after the spontaneous development of vegetation was practically completed. The former period can, with tolerable certainty, be estimated at 6,000 years, but man has lived here a far longer time as a hunter and a fisherman. The two periods here named therefore embrace 11,000 years. The remaining 15,000 years seem to me to correspond fairly well with the changes that we know to have taken place between the two periods named: certain shiftings of land and sea with deposition of clay, layers of sand, etc., the chief formations of peat-bogs, immigration of animals and plants and the arrangement of their societies, etc.

The special value of the astronomical method is that it gives us information about summer and winter climate separately.

As we know, BLYTT, when he worked out his theory towards an attempt at a comprehensive geological chronology, based it upon CROLL's theory of the change in the excentricity of the earth's orbit. CHARLIER (1901) and BALL agree with the opinion of CROLL, that the only agent that alters the climate conditions of the seasons is the difference between the length of the summer- and the winter-halfyear, which depends upon the exentricity. CHARLIER has calculated the difference in the length of the seasons resulting therefrom for different epochs. From his table it appears that it may have exercised an important influence on the climate of the period which we are now dealing with. He considers the variations in the heat resulting from the obliquity of the ecliptic as insignificant, when compared with the effect caused by the variation in the length of the seasons.

5. Importance of meteorology and climatology in the interpretation of the evidences obtained from other sources.

It goes without saying that the climatological conclusions we draw from the distribution of organisms and other phenomena of various kinds are based entirely upon the experience of the relations in which they stand in our time to the now prevailing climatic conditions. Therefore, in my opinion, it is incumbent on the scientists who occupy themselves with »geological climates» to attempt, as far as possible, to gain a clear idea of all the climatological consequences that follow from hypotheses based on the observations of certain facts. In the uncertainty that still exists in the relation between climate and oecology, and between climate and physico-chemical phenomena, we must, in order to get a final picture of any certainty, be especially careful in this particular. In two directions, however, this has been neglected, as I think, at least in Scandinavia. Very few of the many who have ventured to draw conclusions about the climate of past ages, have tried to acquire a more than superficial knowledge of meteorology and climatology. The result has been, as a rule, that writers have expressed themselves in general terms about »climate», instead of trying to thrash out the influence of the separate climatic elements on the several phenomena. I should be the last to deny that great difficulties would be encountered, but no sure results will be gained by simply passing them over.

In conformity with this one should try to analyse to what extent a certain fact can be considered to depend on change of temperature, or precipitation, or other climatological factors, or combination of two or more such factors. It is of special importance to study closely what are tolerably »pure»

phenomena, i. e. such as stand, more than is usually the case, in connection with only one climatological phenomenon. Examples of such phenomena will be given in the following paragraphs.

Another means which must be made more frequent use of than has been the case hitherto, is to attempt to *determine quantitatively the amount of the changes*. The consequences of the hypotheses set up are understood much more easily and criticised more clearly and strictly if they are expressed in degrees and millimetres than if they are simply called »colder» or »warmer», »dry» or »damp», and so on. The attempt should therefore be made, in my opinion, within as narrow limits as possible and with the clear consciousness of possible faults, to determine the extent of the changes that have been reflected in the way we have expressed them in the foregoing. Then alone it will be possible to enter into a close and comparative study of the climate of our time as compared with the assumptive climate of the past. When we know the geographical conditions (distribution of land and water) of the late-quaternary age, and their influence on climate, we have obtained the necessary control which can determine whether assumptions founded on other bases are possible or not. Such must not, for instance, lead to climatological combinations that do not exist now, since it is very improbable, at least for the short period we are here dealing with, that any chief climatic type should have entirely disappeared.

In these respects there remains a considerable amount of work which must be done here before we can be said to have attained a really scientific certainty as to the climate of olden times.

The most difficult problem to solve is undoubtedly changes in atmospheric precipitation, and it is here that opinions are most sharply divided. It also seems to me as if the BLYTT-SERNANDER school, in their assumptions about alternating wet and dry periods, had come to hypotheses that do not tally with our climatological experiences. As we have hitherto scarcely

discussed these questions, a few points of view may be introduced at this juncture.

The proofs of alternating wet and dry periods must be held to chiefly consist, for those who maintain this theory, in the above-named forest-beds in the peat-mosses, in stool-layers in the present-day lakes, and in a number of present-day relic occurrences. As, consequently, woods occurred even during the dry periods whose climatology can first be taken into consideration here, we must take as parallels present-day districts where woods occur, at least in some places, but where again lakes without outlets are found. To find indications of where such districts may be looked for, I have conferred with the eminent specialist in this branch, Professor WOEIKOFF of St. Petersburg. After I had communicated to him the postulates for the assumption of the dry periods, he declared that of the temperate districts known to him and climatologically somewhat closely studied, the steppe of Baraba in W. Siberia should correspond most closely to the climate demanded by the BLYTT theory for its dry periods. After looking closer into the natural conditions of that district, I fully subscribe to that opinion. No Archæan rock-district with the same topography as ours seems to possess such a climate in the present time.

The steppe of Baraba (or Barabinska) is situated to the south of the Siberian Railway, which passes its northern corner, between the rivers Irtysh and Ob. In the chief town, Kainsk (110 m. above the sea-level), meteorological observations have been carried on for a long time, as also in Omsk (80 m.) in the west, and Tomsk (70 m.), in the east of the area in question. On those observations are mainly based the meteorological data given below, which are taken from the great meteorological survey, »Atlas climatologique de l'empire de Russie 1844—1899 (St.-Pétersbourg, 1900), published by the Observatoire physique centrale Nicolas. As basis for the following short notes on nature and vegetation lie partly MIDDENDORF'S »Die Baraba» (Mém. de l'acad. impér. des sciences

de St.-Pétersbourg, Vol. 14, 1890), partly TANFILJEFF, »Die Baraba und die Kulundinsche Steppe» (St. Petersburg 1902, with a German resumé and a map).

The Baraba area is an old tertiary sea-bottom now from 100 to 230 m. above sea-level. Numerous large and small shallow basins occur, filled with a very large number of lakes and fen pools of varying sizes, almost exclusively without outlets. A large number of them are salt lakes, but the salinity does not seem to depend on a concentration of thousands of years, but on salt leaking out from underlying tertiary clay. In the cases where the affluents go through sand and loess the lakes are fresh. »Close beside salt lakes there often exist fresh-water lakes, which, however, are not fed by subsoil water, but by rain and snow-water and never reach the salty clay» (TANFILJEFF). The N. and N.E. part is a »Birch steppe» with fertile black earth, characterized by »extremely frequent occurrence of little birch-groves, which occupy flat plate-shaped depressions in the surface of the ground». These birch-groves form sparse forests and among the species common in Sweden, which TANFILJEFF enumerates, may be mentioned: *Thalictrum simplex*, *Cirsium heterophyllum*, *Tanacetum vulgare*, *Tragopogon pratense*, *Solidago virgaurea*, *Spiræa ulmaria* and *fili-pendula*, *Lysimachia vulgaris*, *Ranunculus polyanthemus*, *Viola canina*, *Hypericum perforatum*, *Lathyrus pratensis* (and *tuberosus*), *Trifolium pratense*, *Vicia sepium* and *cracca*, *Rosa cinnamomea*, *Potentilla argentea*, *Rubus saxatilis*, *Epilobium angustifolium*, *Galium verum* and *boreale*, *Hieracium umbellatum*, *Linaria vulgaris*, *Rumex acetosa*, *Orchis maculata*, *Avena pubescens*, *Dactylis glomerata*, *Festuca rubra*, *Poa pratensis* and *nemoralis*, etc. It follows from this list that a comparison with S. Scandinavia is fully justified. In the wood-islands, but still more on the steppe between them, are found a number of the species which we in Scandinavia hold to be south-eastern, and of which group mention is made in p. 68. I will mention: *Libanotis montana* (abundant and characteristic), *Sanguisorba officinalis*, *Polygala comosa*, *Silene nutans*,

Vicia pisiformis, *Onobrychis sativa*, *Dracocephalum ruyschianum*, *Asparagus officinalis*, *Phleum boehmeri*, *Lavatera thuringiaca*, *Stipa pennata*, *Pulsatilla patens*, *Adonis vernalis*, *Astragalus hypoglottis*, *Fragaria collina*. On sandy soil, especially in river valleys, there are pine-forests (of *Pinus silvestris*) apparently of a stunted, sparse type, with a flora very like that of our dry woods. Of mosses *Dicranum undulatum* and *Hypnum schreberi* are common, while large reindeer-moss (*Cladonia rangiferina*) heaths with *Vaccinium vitis idæa* occur; moreover we may mention *Geranium silvaticum*, *Potentilla tormentilla*, *Fragaria vesca*, *Antennaria dioica*, *Melica nutans*, *Majanthemum bifolium*, *Lycopodium clavatum*, *Pteris aquilina*. Also fenlands occur very extensively and here and there *Sphagnum*-mosses, among which we note our wellknown Northern species *Eriophorum vaginatum*, *Vaccinium uliginosum* and *oxycoccus*, *Rubus chamaemorus*, *Ledum palustre*, *Drosera rotundifolia*. Perhaps it should be pointed out, that beside those named not a few species are met with that are foreign to the flora of Scandinavia.

The following table will give an idea of the climate in which this plant world lives and in which exist the many lakes without outlets, of which the largest are of a considerable size (Kulindinskoje 36 versts in length and 24 in breadth, and about 4 m. deep), but of a shallow depth (up to 6—8 m.). I have preferred to give the extreme figures rather than averages. The comparative figures from Sweden are after H. E. HAMBURG (in NYSTRÖM, Sveriges geografi), and refer to the various readings from a large number of stations in S. and Middle Sweden, and a few in Norrland. The figures are mostly given in round numbers:

Temperature and humidity.

Time	Mean temperature of the warmest and coldest stations		Mean humidity of the air in % at the rainiest and the driest stations			
	Baraba	Göta- and Svealand.	Baraba	Göta- and Svealand	Norrland	
Yearly . . .	± 0— + 2	+ 4 — + 7	75	79—80	79—82	
Spring	March . .	—10— —12	— 4 — + 0.7	75—82	80—82	78—85
	April . .	± 0— + 2	+ 2 — + 5	67—72	71—75	73—78
	May . . .	+ 9— +12	+ 1.5— +10	58—63	65—69	67—73
Summer	June . .	+16— +18	+14 — +15.6	60—65	64—69	64—68
	July . .	+19— +22	+15.5— +17.6	60—70	69—72	68—73
	August .	+16— +18	+14 — +16	65—75	75—76	75—77
Autumn	Sept. . .	+10— +12	+10 — +12.5	70—75	79—81	81—82
	Oct. . . .	+ 1— + 3	+ 4 — + 7.8	75—80	82—86	83—87
	Nov. . .	— 8— —11	± 0 — — 3.5	80—85	85—89	87—92
Winter	Dec. . . .	—16— —18	± 0 — — 6	80—85	87—91	89—92
	Jan. . . .	—18— —20	— 0.5— — 6	80—85	86—90	88—92
	Feb. . . .	—16— —18	— 0.5— — 6	80—82	86—89	85—91

Precipitation in mm.

Precipitation in mm. at the rainiest and the driest stations		
Time	Baraba	Göta- and Svealand
Yearly	300—400	360—740
Spring	50— 75	65—150
Summer	150—200	135—245
Autumn	50—100	115—240
Winter	25— 50	60—180

It should be noted that since the figures for precipitation, for instance, represent the extremes for a large number of stations, the annual totals need by no means correspond to the sums of minima or maxima for the various periods of the year.

The above figures show that the summer temperature in

the steppe of Baraba corresponds to that of S. Sweden during the optimum of climate (p. 65), though probably somewhat higher, and considerably higher than now. The winter temperature is considerably lower than in Sweden. Also the precipitation is, on an average, much lower, though there are a number of E. Swedish stations where the difference in the annual precipitation is little or none. It depends upon the division into seasons. Spring and especially summer may be fairly well compared, but it is the precipitation in autumn and winter that is so considerably less than with us. It is also the lack of a soil saturated with water during these seasons, that constitutes the qualification for a steppe and for lakes without outlets. When the warm season comes, with relatively little humidity in the air, but a great want of transpiration for the plants and strong evaporation from the surface of the lakes, there is not sufficient water in the ground for the transpiration of the trees or for the springs to be able to feed the lakes. But, on the other hand, this type of climate is required if the stool-layers, calcareous tuffs and lakes are to be interpreted as BLYTT and his adherents want. The comparison with the steppe of Baraba may therefore be considered an especially good one.

HAGLUND (1908) seems to have come to a similar result; he says: »According to SERNANDER the dry period was characterized by the climate being so dry that the springs dried up. Under such circumstances — the climate must have been a 'steppe'-climate — there was certainly no forest-vegetation on the firm ground, since experience has taught us that our rainiest summers are most favourable to forest-plants, and the same result has been arrived at by HESSELMAN in his studies of the growth of the pine during various years.»

The question then arises: is it possible that we have had these extreme climatic conditions during the late-quaternary period again and again (at least twice)? This will be dealt with below (pp. 69 and 78). For my part, I scarcely think it possible. During a period when the Baltic was isolated from the Ocean,

it may possibly be conceivable, but scarcely during two or three repeated periods. During the last (the one chiefly investigated in Sweden) of the »dry» periods that BLYTT's theory demands, and which SERNANDER (1908) places in the Bronze age, i. e. 2,400 to 4,000 years ago (BRÖGGER 1905), the distribution of land and water was, in the main, like the present, if possible somewhat more favourable to a more abundant supply of salt and warm water to the coasts of Sweden. From a meteorological point of view there is no probability, under these circumstances, of the dry climate of the steppe of Baraba having prevailed in Scandinavia; for, probably, nowhere on the earth are the conditions mentioned found within a level sea-girt country so close to a large sea traversed by a *warm* sea-current. The physical laws for the evaporation of water and the movements of the air, etc., must be considered as the foundations of the climate, especially when we are dealing with what, geologically considered, are such recent times as those in question, and the geological and biogeographical climate-hypotheses must not stand in obvious conflict with them. If they do, then we must suspect some fault in the latter.

But the theory of alternating dry and damp periods also demands that, when such rainy periods occurred, practically all swampy grounds stood sour for so long in the year that wood cannot have grown anywhere on the swamps. If such was not the case, it is naturally practically impossible to be able with certainty to read off from the stratigraphy of the swamps the alternating periods. In the W. of Sweden, with a precipitation of c. 600—700 mm., we have yet in many places a growth of timber on unditched peat-mosses. Therefore, during the damp periods the amount of precipitation must have been considerably greater. About 1,200—1,500 mm. is the least amount we can assume, let us say, and this amount must have fallen over the E. of the Sweden of to-day as well.

From a meteorological point of view there is a very important fact to be considered with regard to the theory of alternating wet and dry periods. The investigators who have

thought to prove them with the help of the evidence of the swamps, seem only exceptionally (L. v. Post 1906) to have found any striking differences in the occurrence and clarity of the proof in the various parts of the vast Scandinavian territory. It is indisputable that pine-stools and interstratified layers poor in trees occur in the further islands of northern and western Norway, in N. and S. Sweden, on the islands of the Baltic, and in Denmark. Even if for the more northerly districts we might assume for the dry periods a lower temperature than for the steppe of Baraba, we must also necessarily assume a very much lower precipitation than for these, and that right away to the Atlantic border. For southern Scandinavia, however, the consequence is an extremely low precipitation, a »continental climate», right out to the Atlantic border (this was also BLYTT's conception, 1878) with a July temperature of about 18° C. Consequently under extremely similar geographical circumstances to those that now prevail, the precipitation, if the theory is correct, on the W. coast of Norway, where forest-beds occur abundantly in the peat-mosses, should during the Bronze age have been $\frac{1}{5}$ to $\frac{1}{8}$ or less of the present precipitation. Climatologically considered, this is highly improbable, as is the assumption that a very great difference should not, as now, have prevailed in the different parts of the country; the difference in Sweden is now (according to the average of 30 years) very considerable: in Borås, W. coast, 891 mm. (35 inches), Kalmar, E. coast, 371 (15 inches) and Karesuando, extreme N., 313 mm. (12 inches). In Norway we find an absolute maximum of 3,200 mm. (126 inches) in the Hovlandsdalen in Söndfjord (after AXEL STEEN), 1,300 mm. (51 inches) at Buge north of the Trondhjem Fjord, 1,200 mm. (47 inches) within Rödö; otherwise the rainfall diminishes eastwards inland towards the Swedish frontier, at several places, to as little as 500—400 (20—16 inches). The lowest precipitation, 250 mm. (10 inches), in Norway is on Dovrefjäll.

Remarkable also is the great irregularity at adjoining

places; thus 600 mm. (24 inches) at Kristiania, whereas in Nordmarken, a woody district some tens of kilometers from it, there is a precipitation of 1,100 mm. (43 inches), according to a communication from A. W. BRÖGGER. Under such circumstances it is scarcely probable that the regularity, as BLYTT's theory will have it, could have existed in old times.

From what has been stated above, we may assert with good justice that the theories set up about precipitation and evaporation in late-quaternary times, are not meteorologically so worked out as they should have been.

They are also far from being so with regard to the physiological qualifications for the climatological conclusions, for from that point of view it is utterly heterogenous conditions that may determine the distribution of the species, and with that our conclusions about »wet» and »dry». For transpiration is connected partly with the supply of water in the ground, partly with the relative humidity of the atmosphere. But the precipitation on which the former depends, and the relative humidity of the atmosphere do not, as is well known, depend directly on one another. Thus the islands in the outer fringe of the Stockholm skerries have a flora that points to a much greater precipitation than falls there; the great humidity of the air lowers the transpiration and thereby makes the existence of this flora possible.

From the presence in the peat-mosses of pine (it is chiefly this tree that has formed the stool-layers), conclusions have been drawn about their dryness, but what renders their existence on the fens difficult, is less the abundant supply of water than the *nature* of the water. For it is saturated with humic acids, which makes it very difficult to take up (SCHIMPER); it is, according to the still unpublished analysis of HESSELMAN and my own, almost devoid of oxygen, which hinders the respiration of the roots, etc. In the present state of our physiological science we can therefore argue with some justice as follows: the more copious the precipitation, the greater and quicker the running off, and more active the subsoil water,

the less the humic acids in it, and the greater the possibility for trees to do well on boggy ground. Experience has also taught us, that if we wish to have wood on fens, we must not ditch them and make them too dry. It is by no means my intention to represent the above argument as the last word on the subject, scientifically, but I do wish to point out to those unversed in biology upon what an uncertain groundwork one has been pleased to set up the climate of thousands of years.

B. Climatological Results.

The results that have been gained by methods indicated above, are naturally of very unequal value. Some are incontestible and recognised by practically all scientists; others are working hypotheses, for which certain reasons can be advanced, but against which others speak. I will try, as objectively as possible, to state then for reconsideration, first mentioning what may be considered sure, then the contested questions. I shall omit, however, what are purely and evidently fanciful speculations.

1. Late-Glacial period.

The melting of the ice during the last Ice age began under quite arctic conditions, but the supply of warmth increased rapidly, and during its melting away from Scandinavia proper an exceptionally high temperature, broadly speaking, prevailed, if we compare it with what has been assumed of the preceding age. Several minor periods of lower temperature undoubtedly seem to have occurred during this period.

The proof of a high-arctic temperature in Scandinavia during late glacial times is to be derived from the fauna in the so-called *Yoldia Clay*, in which has been found in Jutland, in Halland (Varberg), in Bohuslän, at Moss and in a number of other localities around the Kristianiafjord in Norway (communicated in a letter from W. C. BRÖGGER), one

or both of two *Tellina* species (*T. torelli* and *T. lovéni*), which according to JENSEN (1905 I. and II.) throw a great deal of light on the supply of warmth. »At the depth at which *T. torelli* lives at Spitzbergen and in the Kara Sea (about 20—30 fms.) the sea-water hardly ever has a warmth of more than $+ 2.5^{\circ}$ C. and in many places is down below zero, even during the warmest months of the year.»

According to BRÖGGER (1900), the mollusc fauna in the oldest late-glacial strata in S. Norway argue in favour of a yearly temperature of at least -8° to -9° C., such as now prevails in Danish N. Greenland, the most northerly part of Spitzbergen and the S.W. of Novaia Zemlia. At the end of the period the marine molluscs point to a yearly temperature of $+ 2^{\circ}$ C., i. e. that at present prevalent in the extreme S. of Greenland, certain parts of Iceland, central Norrland, and the N. part of central Finland. Consequently, climates of essentially divergent types. A closer conception of this, for at least a part of the period of the marine deposits, is given by the investigations into the nature of the land vegetation.

NATHORST'S (1870 and 1891) and other scientists' (ANDERSSON 1906) discoveries of numerous remains of arctic plants, insects, etc. in clays under peat-beds and in marine clays have shown conclusively, as far as the land is concerned, that a low temperature prevailed in the south of Sweden during the time of the rapid melting of the ice.

Supported by the numerous remains of hydrophytes, which are always met with together with the flora of arctic growths, which occur in the clay of fresh water directly upon moraines and other strata from the Ice age, I assumed (1903) that the supply of warmth during the summer corresponded, in the S. Baltic area, already in the period immediately after the melting of the ice, to that of the S. Greenland of to-day and that of the lower mountainous tracts of Scandinavia, i. e. a vegetation period of four months, and a July temperature of about $+ 6^{\circ}$ C. This increased, during the period of the tundras, to a season of five months' vegetation and a July temperature of $+ 9^{\circ}$ C.

A number of scientists, such as SERNANDER and others, ally themselves with this interpretation.

A. C. JOHANSEN (1904 and 1906), however, from his studies in the fossil fresh-water mollusc fauna in the same plant-bearing late-glacial strata, felt justified in drawing the conclusion that the July temperatures I had assumed were too low, and, by reason of the occurrence, especially of *Anodonta cygnea* in certain strata containing arctic plant-remains, considered that these could not have been deposited in a climate with a lower July temperature than 13—14° C., a temperature which undoubtedly, if we observe the most northerly species of the flora (*Salix polaris*), is not in harmony with the conditions under which they now live. He considers the July temperature during the late-glacial period to have varied between 8 and 14° C.

This view has been criticised by a number of Danish scientists, especially WESENBERG-LUND (1906), who considers on the one hand that our knowledge of the northern limit of the *Anodontas* is most incomplete, and also that, for biological reasons into which we cannot enter here, we have no right, from the northern limit of the fresh-water molluscs, to draw any sure conclusions touching the July temperature of the air from that. It is certain that JOHANSEN has not satisfactorily solved the difficulty, so that it may still be considered under discussion.

On the strength of investigations at Toppeladugård in Scania, where abundant pollen of *pine* was found in a small mud layer interstratified in clay with arctic plants, N. O. HOLST (1906) has concluded that the temperature of the air during the whole late-glacial period was high (14° C. July). There are, however, some very weak spots in the arguments, for: 1) the pine pollen does not seem to have been found in the clay, even in the thick layer that contains glacial plants, 2) HOLST should, of course, show that a number of previously known glacial fresh-water clays are also pine-bearing, 3) it must be remembered that no other parts of the pine save the pollen, which as can be proved, may be transported in great quanti-

ties for long distances by storms, were found.¹ Of the lower part of the layers in question we shall speak later on.

The precipitation during the late-glacial period is more difficult to judge of; the climatological points of appui that are forthcoming are almost entirely of a general nature. Not rarely do we see the assumption that the climate was

¹ In Öja mosse near Ystad LAGERHEIM in 1908 found pollen in the glacial clay »at least 1 m. under the peat» (HOLST 1908). The fragment of a little pine-twig found in the glacial clay at Toppeladugård (HOLST 1908) is for him a good argument that the pine lived there, but I myself have often found that small fragments of recent plants appeared in the samples although I have taken them very carefully. I cannot understand why the pine, when it lived in the environs, should be so rare that the extensive investigations carried out by Dr HOLST, have failed to find other traces of it, while it is so abundant in the peat. In every case it is of great importance to make detailed examination of the question.

Because of the great importance, attributed of late, especially by HOLST, to the finds of pollen by LAGERHEIM in samples taken by HOLST in the basal beds of the peat-bogs of Skåne and containing, for the rest, only an arctic flora, I will here cite a statement I made already in 1895 (Geol. Fören. Förh. Vol. 17, pag. 44) arising out of a discussion with SERNANDER, who had found pine pollen in the lowest layers at Fröjel, Gotland which, according to his own examinations and mine, contained of macroscopic vegetable remains only such as speak for a birch region. This proof to the contrary has *not* been cited by HOLST.

»That such light things as pine pollen have, in considerable quantities, been carried northward from the pine forests, evidently not many degrees of latitude distant, need not surprise us, as WILLE's find (Kungl. Svenska Vet. Akad. Förhandl. Öfvers. 1879, Nr. 5, pag. 15) of *Pinus* pollen in collections of algæ from Gåskap and Matotschkin in Novaia Zemlia gives a direct proof that the wind has carried them much farther (about 700—800 km.) than has probably been necessary in this case. That the pollen is thus carried in large quantities far beyond the region of pine forests is also clearly shown in KERNER's statement (Pflanzenleben I, pag. 36. Leipzig 1888) that in *every examined sample* of 'red snow' from the glaciers of the Alps he has found pollen of different sorts of coniferæ».

I will here only point out that the forests which have furnished the pollen found by LAGERHEIM in the clay of Southern Skåne, *can* have grown in the valley of the Rhine, or the plains of Bohemia or at the foot of the Carpathians, without having therefore been carried further than that found in the little lakes (ponds) in Gåsland and at Matotschkin Shar. In any case it is no safe support for climatological speculations à la HOLST.

HOLMBOE (1903, p. 140) also says: »In conformity with the pine's abundant development of pollen, this is found almost invariably in all strata, which are deposited after the immigration of the pine.»

(Added while printing off.)

»cold and damp». This may be connected with the very prevalent idea that the climate of a glacial period must be so. This is not altogether correct. The greater part of the ice-covered northern polar tracts have an annual precipitation of between 250 and 125 mm., i. e. much less than that of Europe to-day. When we also consider that the late-glacial period was the time of the rapid melting of the ice, there is no physical reason against assuming *that the climate was what is usually designated dry*. The species of land flora we know in a fossil state, are practically all species adapted to drought (xerophilous). This is also BLYTT's opinion, formulated by L. v. POST (1906) thus: »The arctic period with continental, arctic climate.»

In connection with the »continental» character of this period one has tried to place (WARMING 1904) a very remarkable find made by JAP. STEENSTRUP in the cliff of Lönstrup in N. Jutland of the pronounced steppe animal *Spermophilus rufescens* (JESSEN 1899, NORDMANN 1905). The succession of strata is quite clear, the bone found (a lower jaw) must have entered the layer where it was found at the end of the time of the arctic flora; the appearance of the jaw showing it not to be of secondary occurrence. As this is the only find of fossil steppe animals in the Dano-Scandinavian area, no decisive conclusions should be drawn from it (cf. the note p. 67).

VAHL (1902) in his exposition of the influence the inland ice, as such, must have exercised on the climate comes to the conclusion that, for meteorological reasons, a barometric maximum must be held to have lain over the inland ice; at the same time the large masses of cold water along the western Atlantic brought about a displacement to the S. of the barometric minimum, which now usually lies in the N. Atlantic, and with that also an abatement of the W. and S.W., and an increase of the S.E. and E., i. e. the dry winds. The descriptive account he gives essentially holds good of the late-glacial melting period, when the inland ice-remains still were of considerable extent at the time of the formation of the layers referred to above. It amounts to this: on general meteorological reasons the spring

must have been most rainy, since the barometric minima must have been formed as soon as the snow-melting had taken place in the spring. During the height of summer the rising difference of temperature between the inland ice-remains and the tracts free from ice brought with it an increase in the force of the wind, and with the rising temperature diminished the humidity of the air and the precipitation, consequently a dry and stormy summer. Nothing in the character of the fossil flora is at variance with this. The winter must have had prevailing S.E. winds and rather slight precipitation, consequently a type favourable to the rapid melting which we know from DE GEER'S investigations.

I have now given some account of what we know about the general climatic conditions during the late-glacial epoch, and the opinions that are divergent concerning them. A few words may be added about the smaller oscillations that have been traced with more or less certainty.

a) In the late-glacial clays on the Danish islands (Fyen, Seeland, Bornholm) and in Scania (the Snårestad fen. and especially the above-mentioned Toppeladugård) have been observed of recent years (chiefly by HARTZ 1903; cf. also MADSEN 1902, and HOLST 1905) mud (gyttja) and peat layers with an over-layer, and in several cases also an under-layer, of clay. The flora and to some extent also the fauna in these beds (5—60 cm. thick) decidedly points to a higher temperature at the time of their formation than at that of the over- or under-layers: the former contain birch (*Betula odorata*, *B. nana* × *odorata*, *Arctostaphylos uva ursi*) and, at Toppeladugård, pine pollen, together with a number of hydrophytes and insects, fishes, pike (*Esox lucius*) and perch (*Perca fluviatilis*); the whole collection of species points to a climate corresponding to that of the most northerly wooded regions or a mean temperature for July of about 12° C. The underlying clay (at Stensstrup) bears a flora of the most northerly type we know from the late-glacial fresh-water strata (July temp. circa 6° C.) with *Dryas* and *Salix polaris* (though the diagrams show *S. her-*

bacca!) as characteristic plants, while *S. reticulata* and a few bog plants point to a little higher summer temperature for the clay strata lying above the mud.

As to the value of the proof afforded by the fresh-water molluscs, what was said above touching JOHANSEN'S and HOLST'S investigations holds good. As *Anodonta*, which seems to be the mollusc requiring most heat and in its distribution is one of the best known of all the molluscs, and upon which therefore the whole burden of proof rests, occurs in all three layers, a temperature, according to its evidence, of at least 14° C. for July prevailed during the whole of the late-glacial period, a conclusion also drawn by HOLST (1906), but to which JOHANSEN (1906) will not subscribe. HOLST altogether overlooks the fact that at Toppeladugård an important part of the late-glacial series seems to be missing, viz the lower clay with arctic plants that was found at Alleröd (Seeland) and Stenstrup (Fyen). Does this possibly depend on the ice, at the time of the deposition of the lower clay strata at the places named, not having disappeared from Scania? The situation of the ice-border at the time of the formation of the fossiliferous late-glacial strata is unfortunately little known; it now seems as if the assumption that Alleröd was an ice-bound lake, has been abandoned, while no unanimity has been come to, from a geological point of view, as to whether the fresh water at Stenstrup was ice-bound (discuss. in Dansk Geol. För. 1906). From a botanico-climatological point of view there is the difficulty of imagining an active inland-ice embanking the lake here in the plains at the time of the existence of the birch.

It results from a summing up of the above that further detailed investigations, preferably in fresh localities, are wanted, but that we may take it for proved that *during the earlier part of the late-glacial time there was a period to be reckoned in centuries at least, when the temperature rose rapidly, only to fall again, though scarcely so much as before the rise.*

b) It has been pointed out long ago, especially by DE GEER (1890), how the huge terminal moraines in S. Nor-

way and the Swedish provinces of Västergötland and Östergötland point to a lengthy standstill in the melting of the ice. He has succeeded in fixing the length of time, roughly, that the melting ceased, at »100—200 years». »The cause of this break in the great retreat of the ice must evidently have been a somewhat colder climate» (DE GEER 1908). To couple this period with the later one referred to under 'a) is plainly impossible, for not only is the time very short, but also, under the existing temperature conditions, we should be tolerably justified in assuming that pine and birch wood survived at a distance of 300—400 km. from the ice-border. No discoveries of another kind, supporting this evidently well marked oscillation, are known to us. The oldest plant-bearing strata in central Sweden are, however, very little known. Nor does BRÖGGER seem to have been able, in studying the sea-molluscs in the clay strata around Kristiania, to notice any influence of such a period of altered conditions upon the constitution of the faunas.

c) In central Scandinavia, 30—40 km. W. of the ice-shed HÖGBOM discovered, beneath a moraine of up to 7 m. in thickness, stratified sand and clay layers of considerable thickness, containing traces of gnat larvae and scanty fragments of some widely spread mosses. It will probably be agreed unanimously that my proposed interpretation of these strata, as deriving from a local advance of the ice at a time when the still remaining inland ice was not considerable, represents the one that best satisfies the conditions as far as they are now known. Further investigations are wanted in Norrland and the Kola Peninsula, in order to clear up whether the scattered observations made there and pointing to both a lengthy pause in the melting of the ice, as well as to small advances, indicate simultaneousness with the moraine-covered ice-lake sediments at Storsjön.¹

¹ To the E. of the ice-shed, about 150 km. from it, on Härnön near the town of Härnösand, H. MUNTHE (1904) found a sandy mudlayer covered by moraine. He considers it to be, in a strict sense, interglacial, i. e. a proof that during an older phase of the glacial period a melting away

For a calculation of the amount of the change in temperature indicated by the strata just named, we have not yet got sufficient data.

As mentioned above, EKHOLM has shown that about 28,300 years ago a period of low summer temperature must have occurred owing to the change in the position of the earth's axis to the ecliptic (p. 37). There is, of course, the possibility of one of the above-named periods having coincided with this astronomical period. However, it seems very improbable, for as far as we can grasp the circumstances, not one of the three temperature minima named was of the length and extent of this astronomical period, which may rather be coupled with some older period during the glacial period itself. But we cannot speak with any degree of certainty on this point.

2. Postglacial period.

At the end of the late-glacial period, the warmth increased for a long stretch, so that the temperature of Scandinavia became not only as favourable as now, but even considerably warmer; following on that maximum, the temperature sank again.

With the exception of A. G. HÖGBOM (1907), who considers that the facts at hand show that the summers were colder and longer, the winters milder, all scientists who have looked into this question are practically unanimous with reference to the above assertion. But this is about the end of the unanimity as to the post-glacial climate. It results, then, that our investigations are still partially incomplete and inexact, and that they can be interpreted in different ways.

Let us therefore consider the more important problems, of the inland ice took place, completely or practically so. In that case, it does not belong to our present interpretation. In other quarters, however, the interglacial character of the stratification has been emphatically denied (HOLST and others 1906). It might possibly belong to the period now in question (ANDERSSON 1906); but most probably it is of præglacial age, a large block in the moraine.

in as few words as possible, that are being weighed in the balance. And it will be convenient, in the first place, to glance at the older phase of the post-glacial period, or what we may call the *Ancylus* age, though an exact demarcation is difficult for many reasons; then we shall pass over to the later phase, or the *Litorina* age.

Ancylus age. The first question that we encounter, is then: what was the character of the temperature curve? The last phase of the late-glacial period was, as shown above, possibly not characterized by the rapid rise in temperature that asserted itself during the melting of the ice in Svealand and southern Norrland. In its place there possibly entered (to judge from the intramorraine strata of Jämtland) in connection with the advance of the ice, a shorter phase with lower temperature. The older phase of the *Ancylus* age is in every respect the least unravelled of the late-quaternal age. What we know with certainty is only that everywhere where the older *Ancylus* strata are more closely studied, they are characterized by a monotonous, pine wood flora, pointing to a dry climate, not especially warm (circa 12° C. July). But this possibly holds good of only the Baltic territory. On the whole, the synchronising of this period occasions unusual difficulties, for neither the development of the vegetation, nor any shore-line, nor any other known means makes any such possible as yet for the whole of the Scandinavian territory.

SERNANDER and the Uppsala school considers that the stools and tree remains sometimes found in the basal parts of our peat-mosses are a horizon which renders possible such a synchronising. All my twenty years' experience of peat-bog investigations decidedly points to the contrary, and I am supported by HOLMBOE and the Danish scientists; the regularity in the stratification is too imperfect. To this must be added the remaining arguments (pp. 8—14) against it.

In the peat-bogs of S. Scandinavia are found huge strata containing remains of pine, but not of the next recent in order of the wood-forming trees, the oak. This pine zone, as HOLST'S

and my own investigations (HOLST 1899) have conclusively proved, is contemporary in S. Sweden with the oldest and middle Ancyclus period. *At the end of the latter we may, I think, confidently assume that the temperature rose considerably, probably in a short time, for then appear, according to the finds, in many places in a fairly collected troop, a number of foliferous trees and shrubs of a southern type (cf. also HOLMBOE 1903). A few of the most important may be mentioned: black alder (*Alnus glutinosa*), curled birch (*Betula verrucosa*), linden (*Tilia europæa*), hazel (*Corylus avellana*), *Rhamnus frangula*, *Cornus sanguinea*, *Solanum dulcamara*. These several species seem to me very decidedly to favour the belief that the summer temperature rose a few degrees to a July temperature of about 15—16° C. The period of vegetation in S. Sweden, therefore, at the beginning of the latter part of the Ancyclus period corresponded to that of the northern Mälarpvinces of to-day.*

The improvement in temperature did not, however, stop there. The oak (*Quercus pedunculata*) was soon added, and at about the same time the Norway-maple (*Acer platanoides*) and ash (*Fraxinus excelsior*), and still later the common maple (*Acer campestre*) in the southernmost part of Scandinavia, to name only a few characteristic plants.

In S. Sweden it is especially one hydrophyte, *Najas marina*, of which at present such abundant finds are being made that quantitative results as to the temperature might be drawn from its present and former distribution as a *fresh water plant*; in brackish water it lives under other œcologic and competitive conditions (ANDERSSON 1891). As it keeps always to about the same depth of water and ground, we shall scarcely be wrong in comparing its distribution with the July isotherms. It would then appear that its former distribution in S. Norway, N. Småland and other places, compared with the limits of a somewhat more general present occurrence in the fresh water of Germany, points to a displacement of the July isotherm of somewhat over 2° C. to the South.

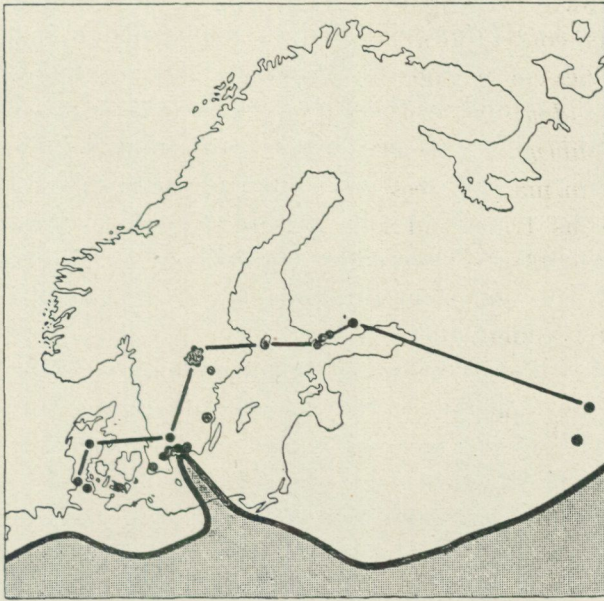


Fig. 11. Map showing the earlier distribution of *Trapa natans* (its former Northern limit indicated by the broken line). The points indicate fossil occurrences; within the lined area the plant is still living in very scattered localities.

In addition to *Najas*, a number of other S. Scandinavian species have also moved southward since that time. The finds as yet are too few, and the study of them not sufficiently worked out, for them to be used for anything like a sure interpretation of the amount of fall in the temperature. Of importance is the caltrop (*Trapa natans*), fossilized at 18 spots in W. Prussia, at 6 in Denmark, at at least 15 in Sweden up to the valley of the Mälars, at 4 in Finland, living in a Scanian locality, but somewhat more prevalent at first in central and southern Europe. Probably *Cladium mariscus*, now common on the island of Gothland and in certain parts of Öland, also belongs to this group. Its great age (p. 36) in our flora makes it necessary, however, for us to be somewhat careful in drawing conclusions from its distribution at present and in the past.

Directly or indirectly, the former extensive spread of certain vertebrates certainly stands in connection with the more

favourable climate. Most demonstrative seems to be the land tortoise (*Emys lutaria*), found in many places in Denmark, Scania, and up to central Öland and Östergötland. Now it lives in middle and southern Europe, and does not seem to be found living in historical times in Scandinavia. The remains of wild boar (*Sus scrofa*) are found up to Gothland, Bohuslän and S.W. Norway (Jæderen); of stag (*Cervus elaphus*) to Gothland, Bohuslän, S. Dalecarlia (Säter) and W. Norway to 66° n. lat.; still living in many places up to the Trondhjem Fjord (Otterön; GRIEG 1909).

The fossil mollusc fauna in S. Sweden also offers us landmarks, showing that certain southern species (*Acne polita* and many others) formerly had a far wider distribution (KURCK 1904, HÄGG 1908).

The present S. Scandinavian flora reveals not a few species that are now only met with as relics in isolated, favourable spots, but have their more connected area of distribution considerably further S., on the continent of Europe. However, the facts are not yet worked out in detail, except for a few species. As examples may be mentioned the giant horsetail (*Equisetum maximum*) found in a few localities in Denmark, one on the island of Hven in Öresund, one in Kurland (KUPFFER 1902), and the common maple (*Acer campestre*), living here and there in S. Denmark, rare in the N., and in a single locality in Scania (fossil in another: Ystad).

If we turn from S. to N. Scandinavia, we also find illustrative proof of a once more northerly distribution of a number of species, which can hardly be interpreted otherwise than as a proof of a higher temperature during the period of vegetation.

The example worked out most completely is probably the hazel (*Corylus avellana*), which I have dealt with (1902; cf. also 1906) in a detailed monographic account. In it were described 209 localities for fossil hazels outside the carefully determined actual N. boundary of to-day. In the time that has elapsed since then, another 60 localities have been added, so that there are now about 270 such localities known to me within

a territory of over 84,000 sq. km., from which the species has been pressed back since its widest distribution. The same is the case in Norway (HOLMBOE 1903). See Pl. 1, where the limits formerly and now in Sweden and South Western Norway are drawn and the find-places, indicated as far as the scale allows it, are marked.

A detailed discussion of its occurrence, compared with the present climate, led to the conclusion that *the period of vegetation at the time of the widest distribution of the hazel was 2,4° C. warmer than now*. Of the general reliability of this conclusion we can be quite assured. I have also shown »that the N. boundary of the hazel in Sweden is determined by its ecological demand for a comparatively long period of vegetation with temperatures for August and September rising to an average of 12° C.», or, in other words, we used to have *a longer and warmer autumn* in the centre of Norrland than is the case now.

Within the same districts as where the hazel once had a wide distribution, have also been found, though more sporadically, not a few other species, which are now forced back to the S. of the northern boundary they once reached. Such are, of the trees, the oak (*Quercus pedunculata*), the linden (*Tilia europæa*), the elm (*Ulmus montana*), the beam-tree (*Sorbus scandica*), and of fen and water plants *Carex pseudocyperus*, *Sparanium ramosum*, *Lycopus europæus*, *Iris pseudacorus*, *Ceratophyllum demersum*, and *Najas marina* as a brackish water plant. Moreover, a number of species, such as especially the common alder (*Alnus glutinosa*) and the curled birch (*Betula verrucosa*) have had a much more general distribution than now. A very large number of species, trees and shrubs as well as herbs, which have their present northern boundary in Norrland, only occur on specially warm and favourable spots, such as the foot of mountains and southerly slopes, from which there is good reason, phyto-geographically, to regard them as relics of a bygone, warmer age.

Also the fossil mollusc fauna points in the same direction,

although the data as yet are only scattered and incomplete. Most remarkable seems to be KJELLMARK'S (1904, cf. also HÄGG 1908) find of *Patula rotundata* in calcareous mud at Rösta, somewhat N. of Östersund. The most northerly places it is known to live in are Stockholm and S. Norway. Also the previously mentioned discovery of the beetle *Platydemia violacea* together with *Trapa* in S. Finland is of a considerable value as proof, since it is a pronounced southern species, which, just as *Trapa*, is now lacking in the land.

Still further north and higher above the sea, traces are seen of a formerly warmer climate. Everywhere in Scandinavia, both within the more southerly mountainous districts as well as among the most northerly tundras, traces are found of a once wider distribution of both birch and pine (*Betula odorata*, *Pinus silvestris*), but not of spruce (*Picea excelsa*). In other words, the tree-limit lay considerably higher than now. For S. Norway REKSTAD (1903) undertook a comprehensive exposition of the most important finds known, and came to the result that it lay 350—400 m. higher than now. After deducting the influence exercised by the lower level of the country (30—50 m.) at the time of the highest wood limit, the lowering of the pine limit should indicate that the mean temperature was 1,9—2,2° C. higher. These figures correspond roughly to the actual facts, we may take it, but the whole question of the quantitative valuation of the amount of the climatic change indicated by the lowering of the pine and birch limits, is far from unravelled, both as to the ecological moments and the purely geological. So we have in Sweden only scattered observations (KELLGREN 1893, ANDERSSON 1903, SERNANDER 1902 and 1905, GAVELIN 1908) pointing to a lowering of at least 150—200 m. After all we can only say with certainty that in the mountainous districts the pine and birch forest were spread over considerable parts of Scandinavia now situated above the wood-limit, and that the distribution of the pine in particular demanded a very considerably greater warmth than now prevails up there.

The same conclusions are indicated by various circumstances in the present distribution of the mountain flora, islands of birch wood, often of considerable extent, being met with in warmer exposures considerably above the present distribution, as well as islands of pine wood in birch regions; mountain plants, which have their proper abode in the sub-alpine tracts, are met with in »colonies» higher up. However, these circumstances are not yet satisfactorily cleared up.

Skirting the whole of the W. of Scandinavia, in numerous places from Denmark to far up along the Norwegian coast, a fossil marine fauna has been found in the marine strata, which by the presence of southerly warm-loving species, shows that the sea was warmer than now. Especially the species of the genus *Tapes* are of value here as proof. BRÖGGER (1906) considers that this warm fauna in the district of Christiania points to an August temperature of about $2\frac{1}{2}^{\circ}$ C. higher than now, i. e. a result that almost coincides with those drawn from *Najas*, the hazel and the wood-limit. These investigations will be mentioned again later.

If we sum up the above, it appears that *in the whole of Scandinavia, from the most southerly to the most northerly parts, there are found, on land and in the sea, traces of a warmer period in post-glacial time during which the time of vegetation was considerably longer than now, and with about $2,5^{\circ}$ C. mean temperature higher, while the winters were presumably about the same as now or inconsiderably warmer.*

To support this last assertion, two reasons may be adduced.

Among the plants that have a relic-like distribution in Central Sweden, are the yew (*Taxus baccata*) and the ivy (*Hedera helix*). For neither of these have any fossil occurrences been discovered north of the present relic area, but a number of now extinct occurrences within the same area can be noted. However, the disappearance of the yew is due, at least in part, to extirpation at the hands of man. KÖPPEN

and KUPFFER (1904, p. 77), who have closely studied the distribution of these species in Russia, are of one mind that their northern limit, at least within the Baltic area, is conditioned by *the winter temperature*. »It is the January isotherm of -4° C., or perhaps still better the isochime (for Dec., Jan., Feb.) of $-3\frac{1}{2}^{\circ}$ C., which coincides almost perfectly with that boundary-line. Moreover, it has been observed for a long time that it is just the severe winters which imperil the ivy in our country.» This last statement also holds good for Sweden. If we compare the careful chart of January isotherms, which EKHOLOM (Ymer 1899, pl. 7) has drawn up, with the distribution of the yew and the ivy, we shall find that the majority of localities are within the isotherm for -3° C. Only a few yew localities in Värmland and Närke, and one ivy locality in Södermanland seem to lie between that and the one for -4° . Not a single relic locality lies outside the latter. This, in my opinion, indicates that *the winter temperature during the warmest period was about the same as now*, for otherwise relic localities should have been met with further north, as is the case with the oak and many other species. Here again, it is desirable that a further, detailed examination of the question be taken in hand.

The above result is probable also from an astronomical point of view, for the displacement of the earth's axis towards the ecliptic (p. 38) does not entail any change worth considering in the winter climate that could surpass the influence of the Gulf-stream, though it is otherwise with the summer climate.

As to the atmospheric precipitation during the Ancyclus age, we have still but very few points of appui. Through the definitive melting of the inland-ice the meteorological conditions were manifestly altered (cf. p. 54) with respect to winds and the like. The geographical conditions, too, underwent an abundant change during the earlier Ancyclus age, as already during the late-glacial period a considerable rising of the land commenced, which caused a very large part of the present

shallow southern Baltic basin and of the Skagerrack and North Sea to become land and the Baltic an inland sea.¹ It is not yet possible to draw up any certain map of the appearance of the land, and consequently still less possible to attempt to solve in detail the influence of these geographical changes on the precipitation and winds in Scandinavia, which were immediately influenced by them. However, it would seem as if the difference between a moister W. coast climate and a drier E. coast climate, which is even now becoming clearly marked, had been still greater then than now. The monotonous pine-wood flora, containing a few xerophils, within the well studied strata of the older, colder Ancyclus age along the coast of E. Sweden, points in the same direction. But the material is not sufficiently abundant to admit of a sure conclusion. For W. Sweden there are only very incomplete investigations; the same is true as far as Norway is concerned.²

¹ There are peat-mosses at from 15—20 m. below the surface of the Baltic and also at a great depth in the North Sea.

² Since this was written and just as the treatise was to be printed, I received a new investigation from the Danish geologist V. HINTZE (Den Nordeuropæiske Fastlandstid. — Dansk geol. Foren. Meddel. Bd 3, 1909) which, as far as I understand, contains a possibility for a new suggestion for determining the climatic circumstances of the period in question. By using a special method and the enormous number of deep-soundings which, nowadays, exist for the northern shallow seas, he has succeeded in constructing curves with a fathom's equidistance for the Baltic south of Åland, the Danish seas and the North Sea (German Ocean), etc. The close lying curves reveal at the bottom of the sea, grand systems of valleys corresponding to large rivers with all their tributaries. HINTZE's investigations make it, however, as far as I can understand, probable that the rising of the land, after the melting of the ice (therefore during the late glacial period and the older part of the Ancyclus period), as he himself lays stress on, has changed the sea to land as far as the regions west of the British Islands i. e. to the limit of deep sea. Farthest off in the west the crust of the earth was more than 300 m. higher than now. (Compare HINTZE's plate 7.)

The course of the river valleys within the Baltic region tends, however, to show that the Baltic basin, during the greater part of this period, has not had any outflow through Öresund and the Belts, *but has formed a region without an outflow*, divided into a number of smaller basins.

It requires, of course, rather much time to study and criticise a suggestion of such great and extensive importance, but I can not agree with

During the latter part of the Ancyclus age, when the temperature rose to about its maximum, which is shown among other things by the presence of the common maple (*Acer campestre*) in peat *beneath* the present level of the sea in the harbour of Ystad, and by *Trapa natans* in fresh water mud *beneath* marine deposits from the Litorina age only 2—3 m. above the sea at Ronneby, the assumptions for a dry E. Swedish climate still continued. Although no conclusive discoveries are as yet forthcoming, I have, for reasons indicated, for many years represented the opinion that a number of species found in E. Sweden, especially in its dry calcareous area, which have a very variable desire for warmth, but a pronounced eastern distribution, immigrated into Sweden during the more continental Ancyclus age. As to SERNANDER's somewhat divergent opinion of recent years (1908), see below. If this can be conclusively proved on other grounds, we have in the occurrence of these plants a good proof that there was a drier period in *E. Scandinavia* during the Ancyclus age. No corresponding indications for W. Scandinavia are known to me.

An estimation of the precipitation on the basis now given cannot be undertaken before the oecology of the steppe species in question has been more closely studied. SERNANDER (1908) has recently furnished a valuable exposition of their occurrence.

According to the BLYTT-SERNANDER school, the Ancyclus

HINTZE in the opinion that the Baltic must have been a salt lake. For the formation of the small Baltic basins without an outflow, such as HINTZE's map shows, it should, however, not require a drier climate than that of the Baraba steppe (p. 42). Nor does it change anything in the above criticism of BLYTT'S-SERNANDER'S views, for the latter, in particular, in his latest writings, assigns the principal dry period (the »sub-boreal») to a considerably later time than the mainland period, to the knowledge of which HINTZE has contributed.

It is remarkable that stool-layers in peat-mosses are so rare just from this period (the boreal and sub-arctic) when, taking everything into consideration, we had a dry period. On the other hand it is very probable that the continental region with a dry climate, for which I have stated the reasons in this paper, extended considerably further westward than I had thought before. Time, however, does not allow of a closer investigation.

age had two dry periods and one intervening wet period. BLYTT (1893) considers this to be certain by reason of the find in Norwegian peat-mosses of 3 forest-beds and 4 peat-layers, of which the two oldest stool-layers belong to the *Ancylus* age. In Sweden, however, no clear localities with this succession of strata have been hit upon, and SERNANDER often expresses himself evasively about the oldest »dry» period during the *Ancylus* age. (Cf. also v. Post 1906, p. 296.) The more often, on the other hand, is stress laid by him and the Uppsala school on the »boreal» period, proved according to that conception by humus-ledges in calcareous tufas and stools in the lower parts of the peat-mosses. These stool-layers are, however, very seldom well developed, and the complaint is frequently made in the detailed descriptions that it was difficult to identify the boreal stool-layer with certainty (GAVELIN 1907, SERNANDER 1908).

For reasons already mentioned, I have come to the conclusion that the stool-occurrences cannot be used as climatic indicators, and though in the parts of S. Sweden where the necessary qualifications should occur I have had the opportunity of examining a large number of bogs, there is *not a single locality, known to me, with three distinct forest-beds separated by peat-layers pointing to moister conditions*. I have not even seen peat-beds with two stool-layers of oak. The oak stools in the deeper parts of the peat-mosses are found only near the border of the moss, and have never, like the birch and the pine, lived on the fen itself.

We have already spoken (p. 34) about BLYTT's conclusions drawn from the present distribution in W. Norway of the higher plants, of a dry continental climate there.

The Litorina age. The last part of the post-glacial period is the one in which the Baltic basin was again connected with the Ocean. During the maximum of the land-sinking that occasioned this, Öresund and the Belts, as well as the sills at Åland and in the Gulf of Bothnia lay much deeper than now, for which reason a much more extensive and rapid circulation

of the water took place there than in our time; a result of great climatological importance. An exact fixing of the date of the passing of the Ancylus Lake into the Litorina Sea is extremely difficult and is scarcely accomplished, but the proofs already offered may be held to be conclusive in showing that *the temperature, already at the beginning of the Litorina age was higher than now in Scandinavia, and probably touched about its late-quadernary maximum.* On this point opinion is practically unanimous. To determine exactly the time when the actual maximum of temperature set in, is not easy, for it was perhaps reached slowly, and possibly too the temperature slowly sank again. If we consider that the displacement in the position of the earth's axis to the ecliptic (p. 37) was the very probable cause of the maximum of temperature, this should according to EKHOLOM (1899) constitute a biological optimum for the majority of southerly species of about 4,000 years. Nothing seems to argue against such having been the case, and *hence the warmest period lasted from the latter part of the Ancylus age into the Litorina age.* How long into the latter it lasted, however, is a matter of much dispute. In insisting one-sidedly, as I think, in regarding the very common upper forest-bed near the surface of the peat-beds as practically a sure time-indicator, SERNANDER and the Uppsala school have been forced, when such beds were met with at a particularly low level, to extend the climatic optimum very far forward in time. This is absolutely consistent, but seems to me to be a reason against their interpretation of the stools, resulting in a large number of phenomena which most naturally spread themselves over a considerable part of the late-quadernary period, being crowded together into the last thousands of years. According to SERNANDER's opinion, the climate became worse with great rapidity at the end of the Bronze age. As this age is only some 2,400 years behind us, it is to be expected that such a considerable deterioration in the temperature, if it extended beyond Scandinavia, should easily be provable by foreign scientists, partly in a purely historical way.

If, however, the stool-layers are held to be, as I hold them to be, of very varied age, we must try to find other means of ascertaining when the maximum of temperature was markedly followed by less warmth. Such a one, though not exact, is the study of the extent to which the southern species succeeded in spreading over the »Litorina areal», i. e. that part of Sweden which was once the bed of the Litorina Sea. I have made such investigations (1902) as far as the hazel in Norrland is concerned, and the result I came to is that the occurrences grow fewer and fewer as the height above the sea decreases; they are almost lacking at below 50 m. From this I draw the conclusions: that »already when the Litorina land-rising began, a change began to set in in the favourable external factors that once made possible the extensive spread of the hazel in Norrland». This unexpected result led to a surmise that »the Litorina uplift proceeded much more quickly at the beginning than towards the end». This surmise has found a good support in BRÖGGER's investigations in the neighbourhood of Christiania; he has succeeded there in showing that a reduced intensity in rising (circa 1,2 m. per century) was followed by an increased one (circa 2,2—2,1 m. per century) which afterwards diminished to 1,8 and 1 m. The rising ceases at the beginning of the Iron age (2,400 years ago). Under such circumstances, and since especially MUNTZ's investigations have made it probable that the risings proceeded very irregularly in different parts of Fenno-Scandia, the method mentioned above yields no safe conclusions as to the *point of time* when a considerable deterioration in the climate took place.

It should however be noted that it need not occur at the same time all over Scandinavia, for the undoubted influence exercised in S. Scandinavia and especially the coast-land, by the abundant quantities of salter and warmer water which poured into the Litorina Sea, may very well for a long stretch of time have fully outweighed the increase of warmth derived from other sources. How dependent the climate of the S. Baltic area is in our days upon the supply of water from the

Ocean, appears from the figures published by O. PETERS-SON:

At Karlskrona

14. 11. 1902	temp. of sea-surface	7,6° C.,	warmth in the sea ¹	375,250 cal.,	Nov. temp.	+ 3,1
5. 11. 1903	>	>	9,1	>	>	+ 4,0
6. 11. 1906	>	>	10,1	>	>	+ 7,3

If we draw conclusions from the distribution of animal or plant life at the period named above, we must also pay great attention to what part of the period of vegetation exercises the greatest influence on their development.

What has been said also applies to the proofs that L. v. POST in particular (1906, p. 274) has adduced for SERNANDER'S view about the occurrence of southerly species in Närke (*Trapa*), the Christiania district (*Tapes*), etc., down to a low level. Even SERNANDER'S supposition (1908) that the more general cultivation of millet (6 finds), which SARAUF fixed under the Bronze age for S. Scandinavia, should have stood in connection with a warmer climate during it, is by no means convincing. In extensive tracts where the millet flourished, it is no longer cultivated, because more easily cultivated and productive plants have become known. This was presumably the case also in our own country.

Further investigations may possibly prove that the warm period really lasted longer than would be presumed if we judged from the spread of the hazel, and that the spread of the hazel was actually prevented by other causes. The question is still open.

Whether or no this post-glacial fall of temperature reached any considerable extent 2,400 years ago, or, as I should at present consider more probable, 6 to 7 thousand years ago, all Scandinavian scientists are of one opinion as to its having taken place. We know little about the appearance of the temperature curve, unless we are willing to accept that given by EK-HOLM (1899, p. 381) fig. 10, based on astronomical reasons. This appears to me to be plausible also from a phyto-geographical

¹ He refers to the warmth contained in the uppermost 50 m. of the Baltic.

point of view, for an equable fall, taking place gradually, best suits the large number of relic spots we have throughout Scandinavia. If the plant communities had been subjected to a proportionally very rapid change of temperature, it would seem as if the peculiar relic communities we possess would have had more difficulty in coming into existence than if they had had a longer time for their formation. This, however, is merely a supposition.

But the view now presented does not agree with that indicated by the investigations of marine strata in the Christiania Fjord, so carefully examined in this respect. Summed up in a few words the results are as follows (BRÖGGER 1906, pp. 124—128):

a) During the *Older Tapes period*, when the land at Christiania was raised from 70 to 48—45 m. above the sea, a mild climate prevailed »with a circa $2\frac{1}{4}^{\circ}$ C. higher August temperature than now». BRÖGGER considers that it is »less certain» whether BLYTT's conclusion of the Atlantic period »can be supposed to have coincided approximately with the conclusion of the older Tapes period».

b) *The middle Tapes period* corresponds to the time of the land rising at Christiania from about 45 m. to 21—19 m. above the sea. »The climate during this period was somewhat colder than during the older Tapes period, and perhaps also somewhat colder than during the succeeding more recent Tapes period». BRÖGGER infers this from *Tapes decussatus*, *Pholas candida* and other southern forms having now disappeared. As to the parallelising of time with BLYTT's periods we read, »it is uncertain whether the limits of the sub-boreal period upwards and downwards coincide approximately with the limits for what is indicated above as the middle Tapes period».

c) *The Younger Tapes period* coincides with the time when the land rose from about 19 m. to 8—10 m. above the sea. This is »characterized by a mild climate, somewhat milder than the present and perhaps somewhat warmer than during

the middle Tapes period». The shell banks from that time contain a large number of southern species which migrated in at about that time and have now disappeared or are very rare. About this we are told, »that the sub-Atlantic period may have about coincided in time with what is designated above as the more recent Tapes period, seems to be beyond doubt».

d) *The Recent period* is »the space of time which has elapsed since the shore line at Christiania lay about 8 m. higher than now. In the course of this period the climate has assumed its present character».

Here, consequently, may be dimly observed another oscillation in temperature, less important than the great one we already know, it is true, but situated in an age which is recent, even from an archæological point of view; making use of BRÖGGER's own arguments and figures we find that the younger Tapes period must have been about 3,300—4,700 years ago.

Here we are in the presence of observations which are quite at variance with the results of BLYTT, SERNANDER, etc., since, according to SERNANDER, the sub-Atlantic period was cold and damp, while, according to BRÖGGER, it was warmer than the sub-boreal, about which SERNANDER and the Uppsala school unanimously consider not only that it was characterized by »great dryness», but also that it was »considerably warmer than the present» (SERNANDER 1908).

There is, however, one scientist, CLEVE (in HOLST 1899, p. 60), who feels justified, on the strength of a diatomacean flora, in drawing conclusions similar to BRÖGGER's. We may here quote his opinion.

Among the fresh-water deposits the »semen beds» are very characteristic and are marked off by an association of species which is often come across not only in Sweden but also in N. America, where these formations, at least in part, are considered to be interglacial. Characteristic for the »semen beds» are: *Navicula semen*, *N. amphibola*, *Pinnularia streptoraphe*, and in a less degree *Pinnularia cardinalis*, *P. streptoraphe* var. *minor* and *P. styliformis*, *P. lata*, *Navicula hebes* and *Melosira*

distans. *Stauroneis javanica*, common in N. American »semen strata«, occurs extremely rarely in Swedish strata. The association of species indicates a boreal, if not an arctic climate. The only locality in Sweden where living *Navicula semen* is known is the mountain Gellivare Dundret. As to the age of these deposits, CLEVE expresses himself as uncertain. According to HOLST's sections in Småland, they could belong to the middle Ancylus age, but according to sections taken by MUNTHE and BLOMBERG in Östergötland and Gästrikland they are held to be »more recent than the Litorina age«. »If it should prove to be true«, says CLEVE, »that 'semen strata' generally follow upon Litorina beds, we can conclude that a climatic change for the worse occurred.« He also suggests the possibility that they can be found at two levels in the post-glacial deposits.

I certainly think that we must accept climatic deductions based on Diatomaceæ with great caution, but we must certainly include these observations in a presentment of the opinions that are based on facts.

There is still one matter under dispute touching the temperature of these last few thousand years. Does the temperature continue to fall, or has a halt, possibly an improvement already begun? The supporters of the alternating climatic periods consider that the latter is the case, or at least the opinion has been asserted by SERNANDER; L. v. POST (1906, p. 298), however, scarcely seems to be of the same opinion.

The reason for this assumption does not appear to me to be quite clear. Essentially it comes to this, that SERNANDER, for phyto-physiognomic reasons, considers that the northern pseudo-relics which are found on the fens of the area once covered by the Litorina sea no longer tend to spread. I do not think this is at all satisfactorily made out.

The question whether the temperature rises or falls secularly is excessively difficult to answer, inasmuch as historical experience is obscured by a periodicity of short duration. EKHOLM (1899) considers that no sure conclusion as to the

climatic changes in W. and N.W. Europe during the last few thousand years can be drawn, »yet it seems as if a still continuing secular or vastly extended change from a more continental to a more maritime climate were by no means improbable«. Yet it seems to me that we have a very good proof of the non-existence of such a colder period than the present. It was HAMBERG (1901) who pointed out that in the mountains of Sarek (N. Lapland) there are shore-lines just in front of the terminations of the present glaciers. These lines, which were formed in ice-dammed lakes in connection with the melting of the ice, not only indicate that the climate where they were developed was not considerably worse than the present, but also that it has not been considerably worse than now in the meantime. Otherwise the glaciers would have advanced over the lines. (Another result has been arrived at, however, by ØYEN in Jotunheimen.) The astronomical reasons adduced above (p. 36) accord with this. At present, as far as I can see, no unassailable biological reasons for or against can be produced. The final outcome is, then, that *at the present moment a slow secular deterioration in temperature is probably taking place.*

It finally remains for us to touch upon the atmospheric precipitation of the Litorina age. It is evident that an increased humidity, if such can be proved, during the warmer period detailed above, must be intimately connected with an increased precipitation, since the evaporation increased with the increase of warmth. But this brings us to some of the hardest and hitherto least unravelled of climatological questions. Recent investigations have been thoroughly reforming the old-established conceptions about evaporation, circulation of underground water, etc. The exactitude of a number of the old methods for the experimental determination has had serious doubts thrown upon it, but we cannot deal with those problems here.

Nor are there any safe landmarks for estimating the precipitation during the period we are dealing with. There are

really two indisputable and uncontested facts which must positively be taken into consideration in agreeing upon the theory about the precipitation of this period. The former is the geographical change the division into land and water was subjected to, and which entailed quite different hydrographical conditions together with a considerable change in the extent of the surface of evaporation; the latter is the indisputable relics of plants suited to a maritime climate, which are or were met with, though rarely, living more or less far in the S. Baltic area. The more important of these are *Ilex aquifolium*, *Scolopendrium officinale*, *Digitalis purpurea*, *Hypericum pulchrum*, *Aspidium aculeatum* and its sub-species *braunii*. The same feature is shown by the discovery of the West-Indian papilionaceous *Entada scandens* or *gigalobium*, found under peat-beds in Bohuslän at the west coast of Sweden (ANDERSSON 1896). These great seeds are still transported by the Gulf-stream to Norway and Spitzbergen. The presence of this plant proves that warmer sea currents formerly washed the coasts of W. Sweden during the Litorina age.

In connection with what has been said before about the temperature, it should be clear that the latter part of the warmer post-glacial period coincided with this freer connection between the Ocean and the Baltic basin. Under such circumstances we are really justified meteorologically in saying that *in the Baltic basin, after a period that was warmer and drier than the present, during the latter part of the Ancylus age, there followed gradually, under the Litorina age, an equally warm but much wetter period.* From close studies of especially the requirements of *Ilex* and *Scolopendrium* in those parts of Europe where they have their proper area of distribution, I think we shall be able to get good points of appui for determining the amount of the precipitation during the wettest period. Circumstances have not made it possible for me to undertake such an investigation as yet, but preliminary calculations make me inclined to place the precipitation in S. Scandinavia at about 1,000 mm. In connection with the gra-

dually altered geographical conditions, the precipitation gradually decreased down to our own time.

In opposition to this view, which as far as I can see permits of an explanation of facts now known to us, stands that of BLYTT and SERNANDER, who consider the Litorina age to comprise *a)* a warm and »damp, Atlantic» period, *b)* a supervening »sub-boreal», warm and »dry» one, *c)* a third »sub-Atlantic», chilly and »damp», and *d)* a present drier one.

I have already, both in discussing the general reasons for conclusions about the »fossil climates», and also the temperature of the period we are dealing with, gone into the reasons advanced by the originators, as well as into those reasons that appear, to me and others, to be strongly opposed to them. In this place I will only call attention, once more, to the excessive difficulty, from a meteorological point of view, of imagining a Scandinavia surrounded on all sides by warm sea-currents, as in the Litorina age, possessing for a period a climate as dry as that of west central Asia to-day, of imagining it with the springs dry, the valley bottoms dry, and the lakes to a large extent without outlets. I wonder if such a climate would not have left behind it quite other and much more potent traces than those which in reality are found, in the vegetable and animal kingdom, in the soil and in the sculpture of the land!

C. Works referred to.

As the above exposition is intended to offer scientists who are not acquainted with the opinions concerning the late-quaternary climate in Scandinavia a perspicuous account of it, in order that they may be able themselves to test the results, it is thought advisable to furnish a simplified access to the sources by means of a list of works of reference. These are scattered about and sometimes hard to get at, but as many scientists abroad are well enough acquainted with Swedish to be able to read it, I have thought that even such works as are written in

that language and lack a resumé in some other language, might be of interest.

It has not been the author's intention to include all the works dealing with climatological questions, but of the older works only such as are corner-stones or contain a good bibliography. The more important publications of recent years dealing with the subject have been included, while what is omitted can easily be found from quotations in the works specified. The list embraces only Scandinavian publications.

1861. *Lovén, Sven*, Om några i Venern och Vettern funna krustaceer. (Some crustacea found in the lakes Venern and Vettern.) — K. Svenska Vet. Akad. Förh. Ofversikt, Vol. 18.

1867. *Areschoug, F. W. C.*, Bidrag till den skandinaviska vegetationens historia. (Contributions to the history of Scandinavian vegetation.) — Lunds universitets årsskrift, Vol. 5.

[In its day an excellent work, but little known abroad.]

1870. *Nathorst, A. G.*, Om några arktiska växtlämningar i en sötvattenslera vid Alnarp i Skåne. (On some arctic plant remains in a clay at Alnarp in Skåne.) — Lunds universitets årsskr., Vol. 7.

[The first work in which the find of fossil arctic plants in southern regions was announced.]

1876. *Blytt, Axel*, Forsög til en Theori om Invandringen av Norges Flora under vexlende regnfulde og tørre Tider. — *Nyt Mag. f. Naturv.*, Vol. 21.

[English translation bears the title: Essay on the immigration of the Norwegian flora during alternating rainy and dry periods. Kristiania 1876. The groundwork for BLYTT'S theories.]

1882. *Blytt, Axel*, Iakttagelser over det sydöstlige Norges Torvmyre. (Notes on the peat-mosses of S.E. Norway.) — *Christiania Vidensk. Selsk. Forh.* 1882, N:o 6.

1890. *Sernander, Rutger*, Om förekomsten af subfossila stubbar på Svenska insjöars botten. (Occurrence of subfossil stools at the bottom of Swedish lakes.) — Bot. Not. 1890.
1891. *Andersson, Gunnar*, Om *Najas marinas* tidigare utbredning under kvartärtiden. (Former distribution of *Najas marina* during the quaternary age.) — Bot. Not. 1891.
1891. *Nathorst, A. G.*, Ueber den gegenwärtigen Standpunkt unserer Kenntniss von dem Vorkommen fossiler Glacialpflanzen. — K. Sv. Vet. Akad. Handl. Bih., Vol. 17. N:o III.
[An admirably comprehensive work, with bibliography to 1891.]
1892. *Andersson, Gunnar*, Om de växtgeografiska och växtpaleontologiska stöden för antagandet af klimatväxlingar under kvartärtiden. (Phyto-geographical and phyto-paleontological proofs for assuming climatic changes in quaternary times.) — Geol. Fören. i Stockholm Förh., Vol. 14.
1893. *Blytt, Axel*, Om de fyto geografiska og fytopalæontologiske grunde forat antage klimatvexlinger under kvartærtiden. (Phyto-geographical and phyto-paleontological reasons for assuming climatic changes during the quaternary age.) — Christiania Vid. Selsk. Forh. for 1893, N:o 5.
1893. *Högbom, A. G.*, Om interglaciala aflagringar i Jämtland. (On interglacial strata in Jämtland.) — Geol. Fören. i Stockholm Förh., Vol. 15.
1893. *Kjellgren, A. G.*, Några observationer öfver trädgränserna i våra sydliga fjälltrakter. (Some notes on the tree-limits in our southern mountain districts.) — K. Sv. Vet. Akad. Förh. Öfversikt 1893, no. 4.
1893. *Sernander, Rutger*, Litorinatidens klimat och vegetation. (Climate and vegetation during the Litorina age.) — Geol. Fören. i Stockholm Förh., Vol. 15.

1894. *Nathorst, A. G.*, Sveriges geologi. (The Geology of Sweden.) Stockholm 1904.

[Comprehensive bibliography, numerous diagrams, a clear survey of the strata of the quaternary age.]

1894. *Sernander, Rutger*, Om s. k. glaciala relikter. (On so-called glacial relics.) — Bot. Not. 1894.

1895. *Nathorst, A. G.*, Ett par glaciala pseudorelikter. (Some glacial pseudo-relics.) — Bot. Not. 1895.

1896. *Andersson, Gunnar*, Svenska växtvärldens historia. (The history of the Swedish plant-world.) 2nd ed. Stockholm.

[The chapter on »the climate of the quaternary age» is now in some respects antiquated; the work contains a practically complete bibliography up to 1896. A German edition in Engler's Botan. Jahrb., Vol. 22, pp. 433—550.]

1896. *De Geer, Gerard*, Om Skandinaviens geografiska utveckling efter istiden. (The geographical development of Scandinavia after the Ice age.) Stockholm.

[Of special importance are the maps, showing the distribution of land and water at different phases of the late-quaternary age.]

1897. *Andersson, Gunnar*, Centraljämtska Issjön. (The ice-lake of central Jämtland.) — Ymer 1897.

1897. *Högbom, A. G.*, Några anmärkningar om de isdämda sjöarna i Jämtland. (Some notes on the ice-dammed lakes of Jämtland.) — Geol. Fören. i Stockholm Förh., Vol. 19.

1898. *Andersson, Gunnar*, Studier öfver Finlands torfmossar och fossila kvartärflora. (Studies in the Finnish peat-mosses and fossil quaternary flora.) — Bull. de la Commiss. géolog. de Finlande, No. 8.

[Contains a detailed resumé in German, and the most complete pictorial material, so far, of the fossil quaternary flora.]

1899. *Ekholm, Nils*, Sveriges temperaturförhållanden jämförda med det öfriga Europas. (The temperature of Sweden compared with that of the rest of Europe.) — Ymer 1899.

1899. *Ekholm, N.*, Om klimatets ändringar i geologisk och historisk tid samt deras orsaker. — Ymer 1899.
 [Translatad in the Quarterly Journal of R. Meteor. Soc. London, Vol. 27: »On the variations of the climate of the geological and historical past and their causes.»]
1899. *Holst, N. O.*, Bidrag till kännedom om Ostersjöns och Bottniska vikens postglaciala geologi. (Contributions to the post-glacial geology of the Baltic Sea and the Gulf of Bothnia.) — Sveriges geol. Undersökn., Ser. C, N:o 180.
 [A very comprehensive collection of fresh observations.]
1899. *Hulth, J. M.*, Ueber einige Kalktuffe aus Westergötland. — Diss. Uppsala.
1899. *Jessen, A.*, Kortbladene Skagen, Hirsholm etc. — Danmarks geol. Undersög., I Række, No. 3.
 [Pp. 236—242 contain the original description of the strata where *Spermophilus* was found.]
1899. *Lundberg, Rudolf*, Om Svenska insjöfiskarnas utbredning. (The distribution of Swedish fresh-water fishes.) — Medd. från K. Landbruksstyrelsen, N:o 10 för år 1899 (N:o 58).
1900. *Andersson, Gunnar*, RUDOLF LUNDBERG: Om Svenska insjöfiskarnes utbredning. — Ymer 1900.
 [Review of last-mentioned work and some climatological deductions from it.]
- 1900 & 1901. *Brögger, W. C.*, Om de sen-glaciale og post-glaciale nivåförändringar i Kristianiafeltet. (On late- and post-glacial changes of level in and around Christiania.) — Norges geol. Unders., N:o 31.
 [Contains a detailed resumé in English.]
1900. *Holmboe, Jens*, To torvmyrprofiler fra Kristiania omegn. (Two peat-bog sections from the environs of Christiania.) — Geol. Fören. i Stockholm Förh., Vol. 22.
1901. *Hamberg, Axel*, Sarjekfjällen. (The Sarek Mountains.) — Ymer 1901.
 [Pp. 186—191 contain a description of »post-glacial climatic conditions», of special interest because they are based on observations taken in a northern mountainous district.]

1901. *Kurck, C.*, Om kalktuffen vid Benestad. (On the calcareous tufa at Benestad.) — K. Sv. Vet. Akad. Handl. Bih., Vol. 26, Afd. II, N:o 1.
1901. *Charlier, C. V. L.*, Contributions to the astronomical theory of an Ice age. — Lunds universitets årsskrift, Vol. 37.
1902. *Andersson, Gunnar*, Zur Planzengeographie der Arktis. — Geogr. Zeitschrift. VIII.
1902. *Andersson, Gunnar*, Hasseln i Sverige fordom och nu. (The hazel in Sweden as it was and is.) — Sveriges geol. Unders., Ser. Ca, N:o 3.
 [The resumé in German is reprinted in Engl. Bot. Jahrb. 33 (1904), pp. 493 seq.]
1902. *Holst, N. O.*, Några subfossila björnfynd. (Some finds of sub-fossil bears.) — Sveriges geol. Undersökning, Ser. C, N:o 189.
1902. *Kupffer, K. R.*, Verbreitung des Riesen-Schachtelhalmes in der alten Welt. — Acta Hort. Botanici Univers. Imper. Jurjevensis, Vol. III.
1902. *Madsen, Victor*, Om den glaciale, isdämmede Sö ved Stenstrup. (On the glacial, ice-dammed lake at Stenstrup.) — Danmarks geol. Unders., Ser. II, N:o 14.
1902. *Sernander, Rutger*, Bidrag till den västskandinaviska vegetationens historia i relation till nivåförändringarne. (Contributions to the history of W. Scandinavian vegetation in relation to the changes of level.) — Geol. För. i Stockholm Förh., Vol. 24.
1902. *Vahl, M.*, De kvartäre Stepper i Mellemeuropa. (The quaternary steppes in Central Europe.) — Geografisk tidskrift, H. V—VII.
1903. *Andersson Gunnar*, Klimatet i Sverige efter istiden. (The climate of Sweden after the Ice age.) — Nordisk tidskr., H. 1.
1903. *Hartz, N.*, Bidrag till Danmarks senglaciale Flora og Fauna. (Contributions to the late-glacial flora and

- fauna of Denmark.) — Danmarks geol. Unders., Ser. II, N:o 11.
1903. *Holmboe, Jens*, Planterester i Norske torvmyrer. (Plant remains in Norwegian peat-bogs.) — Norske Videnskabs-Selsk. skrifter, I. Math.-naturv. Klasse, 1903, N:o 2.
- [The foundation stone for the knowledge of the history of the Norwegian plant life; full bibliography. There is a resumé in German in Englers Jahrb. Bd. 34 (1904), H. 2 and in French in Herb. Boissier, Vol. 1 (1908).]
1903. *Nordqvist, Oscar*, Some biological reasons for the present distribution of fresh-water fish in Finland. — Fennia, Vol. 20, N:o 8.
1903. *Rekstad, J.*, Skoggrænsens og sneliniens større höide tidligere i det sydlige Norge. (The former greater height of the forest-line and snow-line in S. Norway.) — Norges geol. Undersög. Aarbo 1903, N:o 5.
1904. *Hansen, Andr. M.*, Hvorledes har Norge faat sit plantedække? (How did Norway get her plant covering?) — Naturen, Vol. 28.
1904. *Hemberg, Eug.*, Tallens degenerationszoner i södra och västra Sverige. (The degeneration zones of the pine in S. and W. Sweden.) — Skogsvårdsfören. tidskr. 1904.
1904. *Kupffer, K. R.*, Bemerkenswerte Vegetationsgrenzen im Ost-Balticum. — Verhandl. d. Botan. Vereins d. Prov. Brandenburg, Vol. XLVI, Abh. I.
1904. *Kurck, C.*, Studier öfver några skånska kalktuffer. (Studies in some Scanian calcareous tufas.) — Arkiv för kemi, mineral. och geol., Vol. 1.
- [In this treatise there is a comprehensive exposition of the proof value of mollusc finds with regard to climatic changes.]
1904. *Kjellmark, Knut*, Om några jämtländska kalktuffer och blekeförekomster. (On the occurrence of some calcareous tufas and calcareous mud in Jämtland.) — Geol. Fören. i Stockholm Förh., Vol. 26.
1904. *Johansen, A. C.*, Om den fossile kvartäre molluskfauna i Danmark og dens relationer til forandringer i klimaet.

- (On the fossil quaternary mollusc fauna in Denmark and its relations to climatic changes.) — Köbenhavn. Diss.
[Contains a very comprehensive bibliography.]
1904. *Munthe, H.*, Om den submoräna Hernögyttjan och dess ålder. (On the sub-morainic Hernö mud and its age.) — Geol. Fören. i Stockholm Förh., Vol. 26.
1904. *Warming, Eug.*, Den danske Planteverdens historie efter Istiden (History of Danish plant life after the Ice age). Universitetsprogram, Köbenhavn 1904.
[Contains an extensive bibliography.]
1905. *Brögger, W. C.*, Strandliniens beliggenhed under stenalderen i det sydøstlige Norge. (The shore line in S. E. Norway during the Stone age.) — Norges geol. Unders., N:o 41.
[Valuable work for the determination of time for the Litorina age. Full resumé in German.]
1905. *Jensen, Adolf Severin*, Studier over nordiske Mollusker, III, and Tillæg til Studier over nordiske Mollusker, III. (Studies in Norwegian molluscs, III, and Addenda to studies in Norwegian molluscs, III.) — Vidensk. Medd. fra den naturh. Foren. i Köbenhavn 1905.
1905. *Nordmann, V.*, Danmarks Pattedyr i Fortiden. (The mammals of Denmark in former times.) — Danmarks geol. Undersög., III. Række, N:o 5.
[An excellent piece of work, with comprehensive bibliography, and a discussion of climatic conditions.]
1905. *Sernander, Rutger*, Flytjord i svenska fjälltrakter. (Solifluction in Swedish mountainous districts.) — Geol. För. i Stockholm Förh., Vol. 27.
1906. *Andersson, Gunnar*, Die Entwicklungsgeschichte der skandinavischen Flora. — Résultats scientifiques du Congrès international de Botanique. Wien 1905.
[Numerous maps and illustrations, etc.]
1906. *Andersson, Gunnar*, Nordligaste kända lokalen för fossil hassel i Sverige. (The northernmost habitat known for fossil hazel in Sweden.) — Ymer 1906.

1906. Diskussion om den senglaciale Temperaturoscillation ved mødet den 15 nov. 1906 i Dansk geol. Forening. (Discussion on the late-glacial oscillation in temperature at the meeting of Nov. 15, 1906 of the Danish Geol. Society). — Medd. fra Dansk geol. Foren., N:o 12.
 [Contains the opinions of a number of Danish geologists and biologists about the differences of opinion as to the temperature of the late-glacial age spoken about on page 52.]
1906. *Holst, N. O.*, De senglaciala lagren vid Toppeladugård. (The late-glacial strata at Toppeladugård.) — Geol. För. i Stockholm Förh., Vol. 28.
1906. *Holst, N. O.*, Om Dr. MUNTHE'S interglaciala Hernögyttja. (On Dr. MUNTHE'S interglacial Hernö ooze). — Geol. Fören. i Stockholm Förh., Vol. 28.
 [Dr. HOLST'S (in 1909 published) lecture was followed by a discussion, which is here reported, in which H. MUNTHE, G. ANDERSSON, E. MJÖBERG, R. SERNANDER, G. DE GEER and HOLST himself took part.]
1906. *Högbom, A. G.*, Norrland, naturbeskrifning. (The nature of Norrland.) — Norrländskt handbibliotek, I. Uppsala 1906.
1906. *Johansen, A. C.*, Temperaturen i Danmark og det sydlige Sverige i den senglaciale tid. (The temperature of Denmark and S. Sweden in late-glacial times.) — Medd. fra Dansk geol. Foren., No. 12.
1906. *v. Post, Lennart*, Norrländska torfmosstudier, I. (Studies in the peat-bogs of Norrland, I.) — Geol. Fören. i Stockholm Förh., Vol. 28.
1906. *Vahl, M.*, Bemærkninger angaaende lufttemperaturens anvendlighed i plantegeografiske og zoogeografiske undersøgelser. (Notes on the value of the temperature of the air in phyto-geographical and zoo-geographical investigations.) — Medd. fra Dansk geol. For., No. 12.
1906. *Wesenberg-Lund, C.*, Om kvartärgeologernes stilling til begrebet biologisk variation. (The position of the quaternary geologists towards the conception of biological variation.) — Medd. fra Dansk geol. Foren., N:o 12.

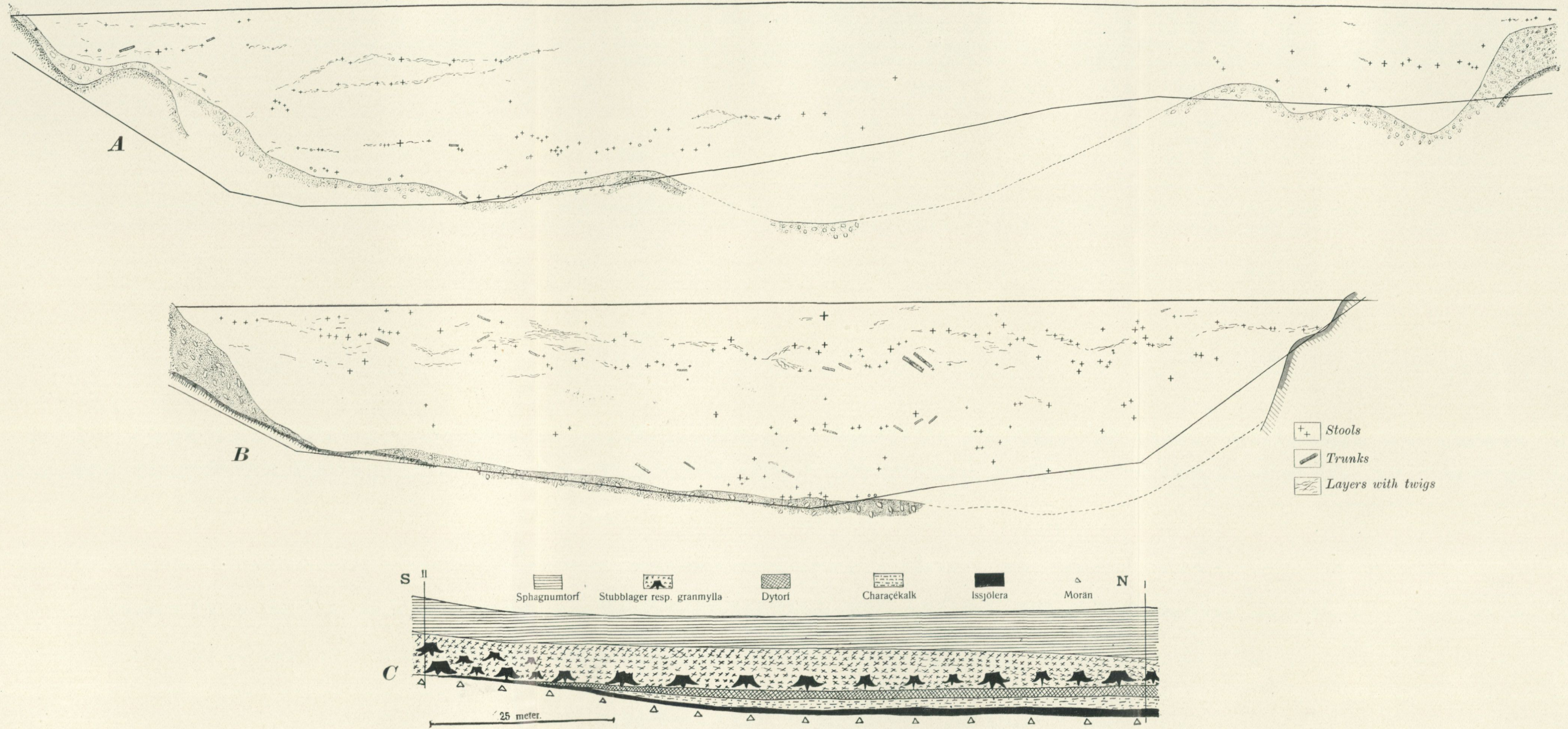
1907. *Gavelin, Axel*, Studier öfver de postglaciala nivå- och klimatförändringarna på norra delen af det Småländska höglandet. (Studies in the changes in level and climate in the N. part of the Highlands of Småland.) — Sveriges geol. Unders., Ser. C, N:o 204.
1907. *Haglund, Emil*, Om Hornborgasjön och omgifvande torfmarker. (The Hornborga-lake and surrounding peat-fields.) — Sv. Mosskulturforen. tidskrift 1907, H. 1.
1907. *Högbom, A. G.*, Om den postglaciala tidens klimatoptimum. (On the climatic optimum of the post-glacial age.) — Geol. För. i Stockholm Förh., Vol. 29.
 [This short report of a lecture is followed by the report of a discussion dealing with a question of principle, in which J. G. ANDERSSON, H. MUNTHE, R. SERNANDER and G. ANDERSSON took part.]
1908. *Haglund, E.*, Om våra högmossars bildningssätt. (How our sphagnum-swamps were formed.) — Geol. För. i Stockholm Förh., Vol. 30.
1908. *Sernander, Rutger*, Hornborgasjöns nivåförändringar (Changes in level of the Hornborga-lake). — Geol. För. i Stockholm Förh., Vol. 30.
1908. *Sernander, Rutger*, *Stipa pennata* i Västergötland, en studie öfver den subboreala periodens inflytande på den nordiska vegetationens utvecklingshistoria. (*Stipa pennata* in Westergötland, a study on the influence of the sub-boreal period upon the history of the development of northern vegetation). — Svensk botan. tidskr., Vol. 2.
1908. *Hägg, Richard*, Ueber relikte und fossile Binnen-Mollusken in Schweden als Beweise für wärmeres Klima während der Quartärzeit. — Bull. of the Geol. Instit. of Upsala., Vol. 8.
1908. *Holst, Nils Olof*, Efterskörd från de sen-glaciala lagren vid Toppeladugård. (Some new observations in the late-glacial strata of Toppeladugård.) — Sveriges geol. Unders., Ser. C, N:r 210.
1908. *Brögger, A. W.*, En Kjökkenmödding fra ældre Sten-

- alder i Norge. (A kitchen-midden from the older stone-age in Norway.) — *Ymer* 1908.
1908. *De Geer, G.*, On late-quadernary time and climate. — *Geol. För. i Stockholm Förh.*, Vol. 30.
1908. *Sernander, R.*, On the evidences of postglacial changes of climate furnished by the peat-mosses of Northern Europe. — *Geol. För. i Stockholm Förh.*, Vol. 30.
1908. *Gavelin, A.*, Trädgränsernas nedgång i de lappländska fjälltrakterna. (On the decline of the forest-limits in the Alps of Lappland). — *Geol. För. i Stockholm Förh.*, Vol. 30.
1909. *Hintze, V.*, Den nordeuropeiske Fastlandstid. (The continental period of N. Europe.) — *Medd. fra Dansk Geol. For.*, Vol. 3, p. 169.
- [I could use this paper only for a note p. 67.]
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This Paper was written in July 1908, but did not go to press before March 1909.



Earlier and present distribution
 of the
HAZEL (CORYLUS AVELLANA) in S. E. Scandinavia



Three Sections from Scandinavian peat-bogs.

A and B with stools, trunks and twig-layers placed in the section after careful measurements. After J. HOLMBOE 1900. — A. Sandumrose in Maridalen, Norway. The length of the section 242 m., the greatest thickness 3.6 m. — B. Tuemyr in Nitedalen, Norway. Length 159 m., greatest thickness 3.6 m.

C. A section in schematic drawing of the common type of the BLYTT-SERNANDER school. Kingstamyren in Nässkott, Jämtland, Sweden. — »Sphagnumtorf» is Sphagnum-peat, »Stubblager resp. granmylla» is stools and mud of *Picea excelsa*, »Dytorf» is mud, »Characékalk» is calcareous mud of Characean algae, »Issjölera» is glacial-clay, »morän» is boulder-clay. After L. V. POST 1906. Cf. p. 11.

