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GEOCHRONOLOGIA SUECICA
PRINCIPLES

BY

GERARD DE GEER

T E X T
WITH PLATES 1—53 AND 65 TEXT-FIGURES

A T L A S
WITH PLATES 54—90

STOCKHOLM
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To my wife, Ebba Hult De Geer
since more than thirty years my indefatigable scientific partner during all expeditions, every kind of field-work and redaction unto the last proof-leaf.

Stockholm 2. 6. 1940

GERARD DE GEER

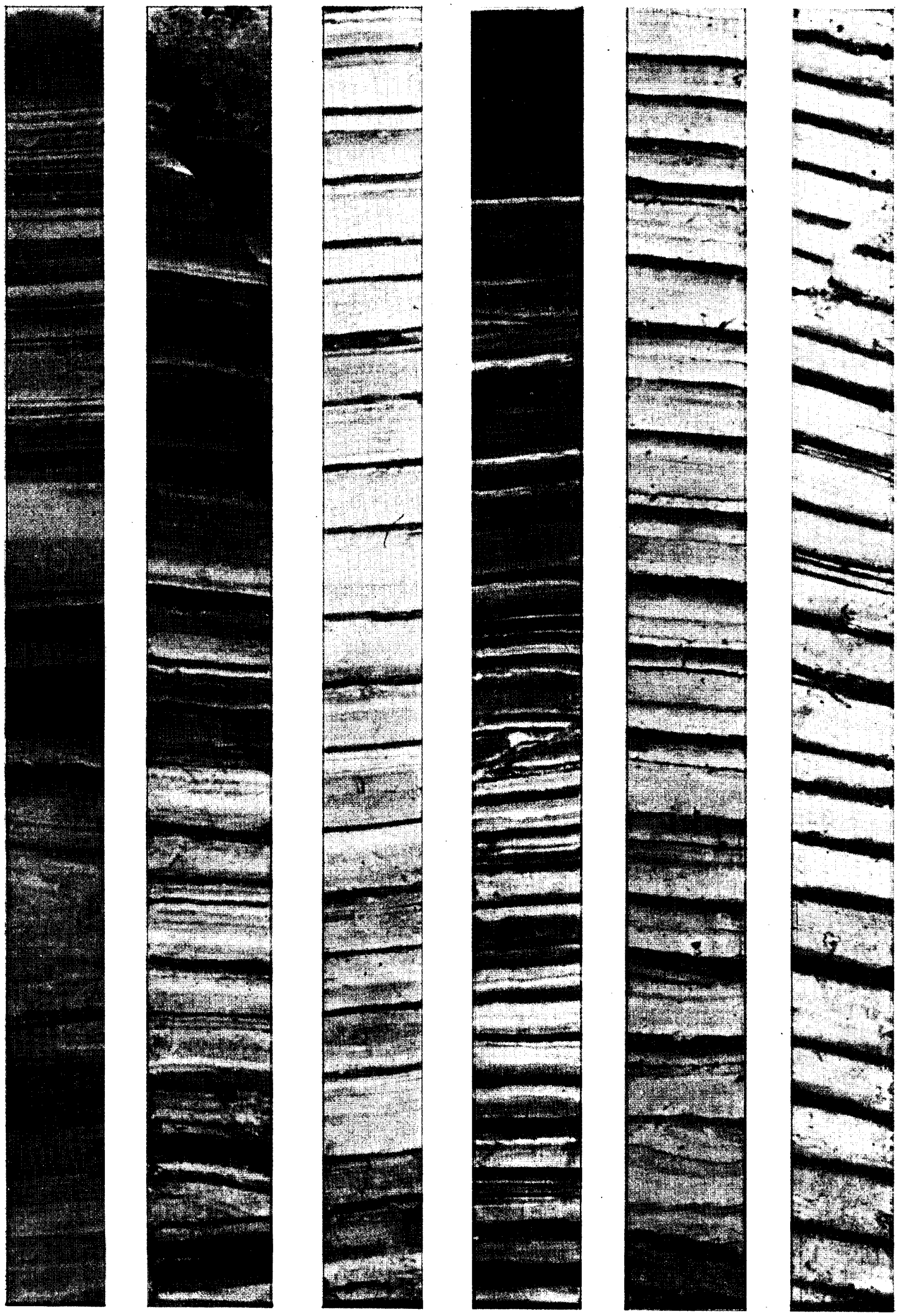
Frontispiece.

Varves from Scandinavia, I.

1. Ragunda lake varves, c. + 690— + 655, from Döviken, Lokedan. C. Caldenius, 1911.
2. Stockholm, Skarpneck. Lower half: soft-water lake-varves, deposited in the Baltic ice-lake. Upper half: after drainage of the ice-lake, varves darkbrown and thicker, deposited in brackish water. G. De Geer, 1936. Confer Figs 26, 27, and Pl. 72, F.
3. Uppsala, S:t Erik. Varves –751— –771. G. De Geer, 1917.
4. » » » –650 — –710. » » » 1917. Uppermost part, micro-varves.
5. Duved, Jl., W of the ice-shed. Ice-lake varves –715— –735. G. De Geer, 1917.
6. Randsfjord, Norge. Varves c. –55 — –82. O. Holtedahl, 1919.

Size 2:5.

1 2 3 4 5 6



Preface.

The purpose of this publication is to show how geochronology originated and how it was gradually built out in order to become a science of exact time determinations, embracing all parts of our planet.

Evolution of any kind requires a certain and often considerable amount of time and can not be really understood in lack of time determinations. As to exact scientific experiments, different kinds of refined chronological instruments are at hand, but generally this concerns only short actual changes. Thus for the illumination of different historical events as a rule we hitherto have been exclusively referred to written datings. Yet, with respect to earlier epochs such datings are rather scarce, often unreliable, or altogether missing. This being the case with many important items already during great parts of the so-called historical period, it means as to really prehistoric archaeology a total and very serious deficiency concerning those long series of slow evolution, during which mankind gradually acquired its dominating position.

The same total lack of real time determinations is true with respect to the corresponding evolution of the whole of the organic world and of its extended and complicated migrations, which have resulted in that marvellous adjustment to the environs, so conspicuous in our actual biogeography.

No less serious is the lack of time determinations concerning all the physical changes on our planet.

Thus the prehistoric evolution of man and the whole of his environments or, with other words, of geophysics, has afforded a rather incomplete history, being totally devoid of years or of any other reliable and exact time determinations at all.

A great number of attempts, often very elaborate, have been made in order to attain such determinations. But, as a rule they must be considered as doubtful or quite erroneous and, even if they had been acceptable, they were too isolated and too indistinct to allow of any special dating of definite events or conditions.

Still, the great principles closely attached to the names of LYELL and DARWIN have given rise to modern natural science concerning innumerable, most important questions. For the solution of these we have generally been restricted, concerning evolution, to such conclusions as may be drawn from the very short modern, really systematic experience of man.

With respect to the inorganic evolution of the actual nature and its changes, the goal must be to convert certain parts of geology into geophysics, to fix the rate of migrations and of different kinds of adaptations for an epoch sufficiently long thereby to get a more reliable start for conclusions as to earlier, less accessible stages of evolution.

It is fortunate also that nature itself has left us as a very remarkable prototype, an exact registration concerning precisely the most important epoch, immediately preceding our own, and allowing us to extend a scientific study of evolution all through those millennia during which man and his environment slowly developed unto its actual stage.

All since geological investigation was introduced in Sweden and the principal nature of Ice Age deposits has been recognised, one of these latter, the characteristic varved clay, also was observed and mentioned.

It is not more than about a century since a systematic geology on the whole can be said to have commenced, and this occurred when it was understood that the laws of actual evolution had ruled even during antecedent epochs. Still hereby an essential difficulty has met up by the fact that our knowledge concerning the actual evolution hitherto has been limited to a lapse of time so short, that it is utterly insufficient for comparisons with the immense ages which the earth has passed through. It is indeed like a mere point in comparison with a long line.

It is easily understood how desirable it were, being able to change this point unto something like a real starting-line, better illuminating the nature and rate of the long, antecedent evolution, far beyond every human tradition.

This is the main goal of geochronology.

At its present stage it embraces only a modest part of the last geological period, though this is exactly the important period of man's evolution. And furthermore geochronology makes it possible to exchange many mere assumptions into geophysical knowledge.

This is the case with the physics of the ice and the conditions determining its synchronous but very different extension within different countries and at different latitudes. That is true with respect as well to the great features of ice extension as to the detailed knowledge of many conditions, determining the recession of the land-ice and its bearing upon the effects on the remarkable, intense deluge of meltwater-masses, once interpreted as the great deluge of the Orient.

The chronological coordination of, for an example, gigantic drainings of ice-dammed lakes as well as the dating of the late Quaternary, very considerable changes of level will furnish a hitherto unknown amount of exact knowledge concerning the real effectiveness of many among those geophysic factors which, during eons begone, have controlled the evolution of the earth.

At the opening of the international geological congress in Stockholm in 1910 I had the opportunity of delivering a short report concerning what I called a geochronology, worked out during the foregoing three decades, affording an absolute, late Quaternary time scale, highly needed as a complement to the ordinary, only relative geologic time indicators.

On this occasion a quotation from TH. C. CHAMBERLIN and R. D. SALISBURY was still in its place: »The desire to measure the great events of geological history in terms of years increases as events approach our own period and more intimately affect human affairs. The difficulties attending such attempts are, however, formidable, and the results have an uncertain value. At least they do little more than indicate the order of magnitude of the period involved. Geological processes are very complex, and each of the cooperating factors is subject to variations, and such a combination of uncertain variables introduces a wide range of uncertainty into the results» (p. 413).

In 1914, after having acknowledged the new possibilities of geochronology, W. B. WRIGHT concludes his well-known text-book on The Quaternary Ice Age with the following words: »'When', says GILBERT, in the introduction to his monograph on Lake Bonneville, 'the work of the geologist is finished and his final comprehensive report written, the longest and most important chapter will be upon the latest and shortest of the geologic periods.' This daily becomes more obvious, as the record is slowly deciphered and new vistas of knowledge are opened up to our eyes. We have in the history of the Quaternary period a region of research, full of hope and of the most romantic interest, promising not only to reveal the events which accompany and influence the evolution of man, but to afford an outpost from which we can look back into the ages which preceded his advent upon the earth.»

A historic summary denoting how, from the first idea, I succeeded gradually to work out a *Geochronologia*, will be given below, where also are to be mentioned all my assiduous, mostly Swedish collaborators. To them I owe a large debt of gratitude for their enthusiastic cooperation in the field work, some of them during a life-long time.

Yet a continuation of this chronology still farther backwards in time is going on. Completions are very desirable, and such are already planned concerning the last as well as earlier stages, not represented within Scandinavia. Thus the middle parts of the time scale at present are most fully worked out and will be specially represented here, as being the most typical and best adapted for a description of the principles of the phenomenon, also affording a sufficient number and variety of details for the understanding and working out of coming extensions of the geochronology, which of course is unlimited as time itself.

Introduction.

Geochronologia Suecica is an exact, natural chronology, based upon direct measurement and controlled connection of individual, annual layers or VARVES, without any subjective assumptions, all through of Swedish origin, and only in Sweden possible to connect with historic time, hence the name.

Aims of geochronology.

For a closer study concerning natural evolution of any kind a reliable knowledge of the corresponding time factor is indispensable. Yet, with few and isolated exceptions, accurate time determinations of any kind have not been possible to perform until during the very last historic centuries. Even datings of that kind have been rather insufficiently utilised. This is true concerning physical and chemical as well as biologic evolution.

Now it is one of the principal aims of geochronology to bring about an exact Time Scale for historic as well as prehistoric time, making it possible reliably to date different stages of natural evolution, to begin with during the Quaternary period, or exactly that stage when man commenced to be worthy of that name.

At present the time scale reaches backwards into a part of the earlier or Palaeolithic Stone Age, but there is good hope of reaching farther back into its more remote stages, though these are not attainable within the political limits of Scandinavia.

Rational geophysics of land-ice and earth crust.

There is a rather unlimited field of natural evolution, where exact determination of the time factor will be rather helpful, especially so with respect to geophysics. While the recession of the land-ice affords the best accessible self-registration of the time scale, it offers, at the same time, a very valuable and manysided means of studying in detail the geophysics of the land-ice, as for an example, its simultaneous behaviour within regions of different topography, such as high mountains and extended continental lowlands, and at different latitudes as well as within different climates.

But, especially when the ice-border is receding in deep water, it is necessary to take into account the lifting power of this medium and the resulting, extra ice-recession by fracturing of ice-bergs. It is an important aim of the datings to determine the amount of this fracturing in different regions, the more so, as it has shown, sometimes, to have been remarkably great and rapid.

This well certified fact seems to have escaped some authors. Thus from the assumption of a regular and uniform ice-recession, its course, really fixed by mapping but seemingly rather varying, has been expressly doubted.

Being often a difficult task to make out, how much of the locally very different ice-recession may be due to the climatic factor and how this latter must have been rather varying in different parts of the formerly glaciated areas and, further on, how little these relations as a rule have been studied, it seems rather astonishing that from one quarter a totally illusoric parallel ice-recession has been postulated and proposed as a means of correlation between different glaciations.

To determine the complicated relation between climatic and fractural ice-recession is an interesting geophysical aim for geochronology, but it is in itself utterly unsuited for telecorrelation between often very different glaciations.

A most important aim for geochronology is to make a rational use of the amount of ice-melting as registering the climatic evolution. Hereby it is easily understood that the amount of melt-sediment at one single point is often very far from directly affording a reliable registering of the climatic variations. In the neighbourhood of the ice-border and the mouth of a melt-river, especially in shallow water, there are many sources of error which must be taken into account and be duly eliminated. This is discussed in detail in an enumeration of sources of errors, page 29. Practically all of these errors no doubt can be avoided by careful measurements of so-called microdistal varves, deposited at a great distance from the shore and the ice-border with their deflecting influence on the normal melt-sedimentation.

The possibility of in that way getting a normal, self-registered curve of those climatic factors which determine the ice-melting is an important aim of geochronology.

Modern geology, without years, is generally considered to have arisen about a century ago, when CHARLES LYELL in his *Principles of Geology* emphasised that natural evolution in times begone has worked at the same rate as nowadays. This implied to draw considerably upon the time factor, and that was also done. But there were no means to determine this factor. Historic registration was rather restricted and a reliable connection with natural evolution still more defective.

It is true that by the interesting estimates concerning the desintegration of radium minerals from different earlier geological periods a valuable general confirmation has been obtained concerning the considerable length of the telluric evolution postulated by LYELL. But the time estimates obtained by the method named are, evidently, utterly approximate; the estimated unit being one million of years, this unit ought therefore to be designated: *milli*, with omitting of the word: year, as here being utterly irrelevant.

It goes without saying that such approximate estimates are neither exact, nor at all applicable to certain stages of the natural evolution. The milli estimates of radium are too rough, and the historic time stages of man too short to admit a rational study of the forces which have determined the physical as well as the biologic evolution of the earth.

An important aim of geochronology being implied in the possibility now to fix for a not inconsiderable time the rate of different kinds of processes in the geophysical evolution of the earth, the geophysics of the land-ice, upon which the time scale is founded, has already been mentioned. Geochronology however also will be of significance for the geophysics of the earth crust.

Earthquakes. By exact datings it has lately been possible to determine the rate and nature of the great continental upheavals, the existence of which was denied altogether by such a master as EDUARD SUESS not very long ago. Recently such datings seem to have made it possible also to point out and fix certain earthquakes, most probably caused exactly by such movements in the earth crust.

Weathering. Further on, the datings now have made it possible in several cases also have allowed to determine the rate of weathering and eluvial processes after due elimination of stages during which the localities were covered by land-ice and water. In that way, by carefully choosing the localities, it will be possible to compare regions where the soil has been exposed to eluvial influence. For different lengths of time, up to more than 15 000 years, a very complete series, elucidating the different stages of soil evolution and their adaptability for crops and forests.

Erosion. As to more purely physical phenomena, the rate of erosion will now be accessible for rational studies with respect to the rate of erosion concerning as well running water as shore action by the waves, thus, for an example, as will be mentioned later, the maximal late Quaternary time, during which the actual Niagara Canyon has been accessible for excavation. This canyon, the best estimate of which until lately was considered of special value, now has been directly dated by varve measurement and found to be about four times too long, and furthermore, based upon quite wrong assumptions.

Especially within earlier glaciations the rate of physical erosion and accumulation will afford good examples for comparison with analogous phenomena during earlier periods.

Biotics. Important aims for the science of exact datings no doubt are to be expected within different branches of biologic evolution, the successive stages of especially the greater deglaciations afford rather unique possibilities for detailed studies concerning the gradual immigration of plants as well as animals and of man into a quite new-opened land. Hereby the exact datings are obtained directly from organic remnants within annual varves in postglacial sediments in Norrland and in Russia, or also indirectly by connection with different stages of land-upheaval, by which the important discoveries by means of pollen and diatoms can be brought into more or less direct connection with the time scale.

The same is the case with late Quaternary datable mollusca from different, formerly glaciated regions, affording points of support for faunal migrations in other regions. The same is true of certain postglacial annual migrations of fishes, birds and mammals.

Among the most important aims of exact datings is that implied in the much needed possibility of a more reliable knowledge concerning the real chronology of human evolution during its earlier Palaeolithic stages. It goes without saying how important it would be to get at least a few real datings of those olden remnants, hitherto so vaguely connected as well with each other as with our historic chronology.

Soil formation. The study concerning the formation and evolution of soil has got quite new possibilities by the introduction of geochronological determinations. Earlier there was no possibility at all reliably to determine the rate by which these processes were and even are going on, and accordingly to make suitable arrangements for times to come.

Such investigations, for an example, can be carried out with respect to normal till-deposits which all since their formation have been exposed to the air, in southernmost Sweden during a lapse of time about 15 000 years longer than in certain parts of north Sweden, according to the Swedish time scale and the gradual ice-recession. In the same way it is often possible to determine the lapse of time during which the late glacial sediments have been exposed to soil formation, and to some extent this is also feasible with respect to the length of time during which the soils within the lower parts of the land have been exposed above the postglacial water-covering.

Of course it will be necessary in every special case to take account not only of the time but also of local conditions, as well petrographical as hydrographical, the important rôle played by the earth-worms, by vegetation, by exposition to the sun, and so on, in order to eliminate all influences which are not in the same way due to the time factor.

Since the importance of this latter factor first had been indicated, some investigations in this direction already have been commenced by O. TAMM, concerning the forest soils.

Exactly with respect to the special kind of forest-mould the geochronological datings may be of interest. By the remarkable investigations of Professor VICTOR GOLDSCHMIDT it has been shown that the forest-mould mainly derived from mouldered leaves contains a most astonishing, multifarious assembly of different substances, of which several are generally considered as rather uncommon and scarcely of any known use for the plants. It seems most like a collection of curiosities.

Still it might be worth while to compare recent forest mould from lately upheaved land-regions to that from forest regions several thousand years old.

Dating of glacial striæ. During the early days of Quaternary geology glacier striæ played an important rôle in the intense discussion concerning floods, drift, and glaciers. The radial distribution of striæ, when measured and mapped, was one of the strongest arguments for the glacier theory. Yet, while affording a very valuable general support for that theory, the striæ have been somewhat misused in as much as striæ from very different stages of the Ice Age often have been in a rather misleading way put together, as indicated by more rational endeavourings to disentangle chronologically the very complex succession of different ice-movements during different stages of the glaciations.

Already the rather fan-like distribution of with certainty determinable leading boulders ought to have shown how inadequate was the information given by such schematical compilation-maps of heterogenous striæ.

Generally speaking, in every region the best preserved and dominating striæ are the youngest and may be considered as in the main synchronous with corresponding striæ at both sides. But, when the ice receded, very often the condition determining the general flow of the ice were somewhat changed, whereby the mere direction of more proximal striæ is no proof of synchronism.

Yet it was not until geochronology made it possible really to fix the whole succession of retiring ice-borders, that a means was acquired for dating the striæ pertaining to the last ice-recession. Especially in regions where this ice-recession could be fixed in detail also by means of annual moraines it has been possible to certify that the striæ are not always running at right angle towards the ice-border. This has been observed where the receding ice-borders were subaquatic, which indicates that in such places the trend of the receding ice-border sometimes was much influenced by fracture and not only by ice-melting.

The general direction of glacial striæ being as a rule also the last one is indicated on the map-sheets of the Geological Survey, but an ultimate discussion of their more definite relative age in reality requires more detailed, local informations concerning the topographic form and other investigations. Without such a sifting concerning the whole mass of observed striæ they will easily be misleading and their discussion may better be postponed.

Yet a few remarks may still be allowed.

A great number of measurements in the Stockholm region has shown that here the general and by far dominant direction of the striæ is about from N 5° W. In Sweden the direction of striæ showing from where the ice is coming is designated like the direction of the winds, the origin being the main thing, while it may be uncertain if the ice went any farther.

This direction no doubt was the last normal one as registrated in free situations. However on steep, deviating slopes more or less local striæ never ought to be reported on small-scale maps, where the cause of the deviation is not indicated. The neglect of this rule not seldom has given a totally undue weight to such purely local striæ.

On the contrary there occurs in the Stockholm region not seldom more or less preserved local striæ upon remnants of earlier ice-worn facets on the lee-sides of the last and dominant push- or shield-surfaces a system of somewhat older striæ, coming from about N 30° W and evidently formed when the ice-border was situated somewhat further towards the south, where the general ice-direction was rather corresponding and where the northeastern limit of the characteristic erratics from the province of Dalarna was cut across.

Noteworthy is that in the Bromma region, NW of Stockholm, where the receding ice-border is exceedingly well registered by a set of frontal moraines running about NW—SE and caused by a relatively local ice-fracture, there is still no group of strictly recessional striæ, readjusted towards the new ice-front, while the dominating N—S direction occurs everywhere.

At first in the northern parts of the morainic stroke or *Mora* an adjustment of the striæ seems to occur. This may indicate that striæ here scarcely were formed out to the very border of the land-ice, though being somewhat unexpected with respect to the considerable ploughing action exhibited at the formation of the frontal moraines.

Dating of Pre-Quaternary periods.

Geochronology has originated from Quaternary and especially glacigene deposits as being the most accessible and best preserved, especially so within the domain of Sweden. But the science of Time is not restricted to that short period, though it naturally affords a most valuable starting-line.

During a great number of pre-Quaternary geological periods, more or less extended glaciations have occurred and under the assumption that the ice-recessions, as shown for the Quaternary ones by the new datings, every special glaciation has been synchronous all over the earth, also in the same way they may afford analogous possibilities for geochronological teleconnections. In this way it will also be possible to compare affiliated, exactly synchronized fossil floras and faunas and to make out how far their composition is determined by real synchronism or, eventually, only by analogous migration stages.

No doubt it should be worth while for historic geology to get a number of such accidental tests concerning the real value of fossils as time indicators.

Teleconnection.

The principal aim of geochronology, however, was to bring about a universal time scale, affording reliable starting points for exact correlations of synchronous stages of evolution, geophysical as well as biologic, on different parts of the earth.

Such datings of synchronous events at great distances have been called *teleconnections*. They have already been performed and certified from a great number of distant localities in all the five parts of the earth, whereby all normal and undisturbed varve series, often of a considerable length, at some places up to a thousand varves, have been shown to be strikingly similar with several long and continuous series of characteristic and marked constellations at the most distant localities, following upon each other in the same order and at the same reciproque intervals.

Everyone who has really studied this very striking conformity must concede that it could not be possible without an identic impulse.

Certainly it has been suggested that the similarity could be explainable by an iterated rhythm and thereby not necessarily be taken as a proof of synchronism.

Already often very characteristic and detailed similar variations of the varve thickness made such a suggestion utterly improbable. But by a carefully performed and in detail published graph of seven thousand annual varves, it has been directly certified that no such hypothetical iterations at all have occurred.

Another, not less arbitrary objection against teleconnection is caused by a rather explicable reluctance against really identic variations at considerable distances.

But the very detailed similarity in fact is there, quite as striking between most widely separated as between neighbouring localities and definitely certifying that it must depend of a universal cause. Hereby it has not been possible to propose any other such cause than the radiation from the sun or, rather, that part of this radiation which reaches the earth and can affect the variation of ice-melting and varve thickness. Under such conditions it is necessary to remember that the distance from the sun to the earth is about 150 millions of kilometers and that the radiation from the sun passes this distance in a few minutes, whereas all distances on our little planet are totally irrelevant. Thus without any undue consideration to these latter distances it must be allowed that the varve registration of the solar radiation *a priori* must be expected to be congruent all over the earth, when not obscured by local deviations.

Origin of geochronology.

Historic sketch of early glacial geology.

In Iceland, where the inhabitants live surrounded by glaciers, they had of old observed and noted the movement of the land-ice and several features of its nature. Their denomination *skridjökull* means a moving land-ice, but the Icelandic authors were rather insular in those days, and, as well known, it was not until in Switzerland some scientific pioneers took up a closer study of the glaciers that a real glaciology was born and attracted a general interest.

The traces of glacial action soon were followed from the Alps out into their vicinity, and glacial markings, earlier misinterpreted as formed by great floods, were now believed to have originated from immense general ice-caps, once radiating from the poles.

The interest in glaciology was carried over to North America essentially by the known Swiss naturalist LOUIS AGASSIZ, when he emigrated to that part of the earth. But first he met with such an intense opposition as is often bestowed on new explanations.

In Great Britain glaciology was introduced principally by one of the founders of systematic geology, JAMES HUTTON, and his eminent successor, JAMES PLAYFAIR, followed by JAMES GEIKIE, ARCHIBALD GEIKIE, and many others.

In Scandinavia the pioneer work was principally done by HAMPUS VON POST by his masterly and original descriptions of the Swedish Quaternary layers, and OTTO TORELL, by his polar expeditions and his genial application of the observations of VON POST, of the Dane A. RINK concerning the existing great land-ice of Greenland as well as the subfossil Quaternary fauna discovered by SVEN LOVÉN.

TORELL laid stress upon the fact that the different glaciations were of local origin and not of a common polar one, and that it was land-ice and not polar drift that spead out the Scandinavian erratics over to North Germany. This corrected explanation at first met with the same kind of rather acid opposition as the pioneer work of AGASSIZ in North America. The known Swedish zoologist and archaeologist SVEN NILSSON, however, already in 1847 had suggested the idea of a general glaciation of Scandinavia, but scarcely on other than zoogeographical foundations.

As to Russia, the same explanation had been given by A. KRAPOTKIN, starting from his own studies in Finland.

Thus it was more and more generally understood, as stated by CHARLES DARWIN, that the glacial markings were quite as good witnesses of what had passed as the black ruins of a burnt house.

This was a great step forward in Quaternary geology, but only the very first one. The principle was admitted, but its part in the whole evolution of the Quaternary period remained to be worked out. This period being relatively short and its deposits in different regions seemingly rather irregular, they were difficult to subdivide systematically. This however was especially desirable, because it was the Quaternary evolution that formed the key to the understanding of the present nature.

Furthermore it was of essential importance for a really actualistic geology to get an objective knowledge concerning the rate of evolution with respect to different changes in the existing nature.

It was a very important principle that the earlier evolution had been essentially like the existing one, but the direct knowledge of this latter was so short that it was very insufficient for extrapolation out over earlier, utterly long geological stages.

Yet intense investigations were taken up in several regions by an ever increasing number of scientists. Here it is not possible to enumerate even the foremost ones of all those who have contributed to the enormous mass of valuable knowledge which is now at hand.

As some well-known examples I may only recall the ingenious contributions of T. F. JAMIESON in Scotland, the early mapping and faunistical work of F. W. HARMER, the probably first Quaternary land-survey of Sweden under A. ERDMANN as mainly based on Hampus von Post, the analogous detailed mapping of North Germany under G. BERENDT, based on L. MEYN and ultimately on the original sediment description of the known Danish scientist GEORG FORCHHAMMER. Among earlier Quaternary geologists from Germany here may be mentioned the diligent and scrupulous F. WAHNSCHAFFE and K. KEILHACK with his pioneer mapping of important ice-borders. Also everyone knows how Quaternary geology is indebted to ALBRECHT PENCK for his life's work, especially concentrated on the northeastern part of the Alps, where he had an excellent cooperator in his friend EDOUARD BRÜCKNER.

Further on in America we meet the acute Quaternary thinker and the excellent Quaternary pathfinders and cartographers T. CH. CHAMBERLIN and R. D. SALISBURY, not to speak of all their prominent followers.

Yet it seems necessary now to proceed from mainly qualitative statements over to closer quantitative determinations. As a rule several earlier assumptions must be considered rather subjective or even positively erroneous and, if they are in the main acceptable, they were too indistinct to allow any reliable dating of definite events or conditions.

Still, the great principles closely attached to the names of LYELL and DARWIN have given rise to modern natural science and the raising of innumerable important questions. For the solution of these we have generally been restricted to such conclusions concerning evolution as may be drawn from the very short systematic experience of man. Thus it is easily understood that it would be worth while, if this important starting point could be extended to a starting line reaching widely beyond every human tradition.

With respect to the physical evolution of the actual nature and its changes, the ultimate goal must be, as far as possible, to change certain parts of geology into geophysics and, with respect to the evolution of organisms, to fix the rate of migrations and different kinds of adaptation for an epoch sufficiently long to get a more reliable start for conclusions as to earlier, less accessible stages of evolution.

It is therefore very fortunate that nature itself has provided us with a very remarkable, exact registration, concerning exactly the most important epoch immediately preceding our own, and allowing us to extend a scientific study of evolution all through those millennia, during which man and his environments slowly developed unto its actual stage.

All since geological investigation commenced in Sweden and the principal nature of Ice Age deposits was recognised, one of these latter, the characteristic varved clay, was also mentioned.

First varve measurings.

To tell the aphoristic truth, I had the good luck of commencing my geological studies in 1878, when at the Uppsala University there was almost no information in Quaternary geology, may-be partly because at that time this branch of the science was still very little developed. This made it necessary, when out in the field, to use one's own eyes and to try to put together the facts observed.

Thus, during my very first geological field-work in the Stockholm region, I was struck by the marked cyclical banding of the varved clay or so-called *hvarfvig lera* (old spelling), so denominated from its alternating, tiny layers of fine sand and clay.

From the obvious similarity with the regular, annual rings of the trees I got at once the impression that both ought to be annual deposits.

Many years afterwards I found that some other naturalists had got the same impression. But a mere impression is no proof, and the next summer I commenced to investigate varved clay in Bleking, south Sweden, at Ronneby, in order by careful varve measurements to get a solution of the problem in question.

The following years I brought about some other measurements in southern and middle Sweden, but they could not be combined with each other, as having no common, connecting varves.

Finally, in 1884, close by Stockholm, at the deepening of the canal at Djurgårdsbrunn, I measured three varve sections at short intervals (A—C). From their corresponding variations of the varve thicknesses they could easily be connected with each other. Their bottom varve registered the very year, when the ice-border receded from the place, being immediately followed by the glacial sea and its clay deposition.

Now, at two following sessions of the Geological Society of Stockholm, I put forth a plan of bringing about a glacial time scale (*»en kronologi för istiden»*).

Still I believed that the necessary, long series of combined varve sections should require the work of generations. Thus I hesitated to start such a big enterprise, and for a long time performed only occasional varve investigations.

Finally, in the autumn of 1904, I measured a new varve section (P) about one kilometer east of those three above named from 1884 and found a striking similarity, forcibly suggesting the connection of identic years (Fig. 23, p. 97). Thus I determined now to make an earnest attempt in realising my original plan. It was exactly 20 years since it had been expressly put forth in print. During all this time nobody had taken it up, and it had not even been mentioned. Evidently it had been left aside as a pure phantasy.

First determination of raised shore lines.

Before entering upon the presentation of the measured annual varves of the geochronologic time scale, it may be in its place to give a review of the medium in which they were deposited and where they are accessible to further investigations.

As the varved structure of sediment is caused by marked, seasonal, climatic variations, the best developed varves were deposited in connection with the marked melting season of every year during the recession of the last glaciation, which latter as a rule, as far as it reached, had destroyed eventual varves from earlier ice oscillations.

During this epoch, especially within its central parts, the land was considerably depressed, whereby its lower regions were submerged below sea-level. At the same rate as the big ice-sheet receded from its peripheral regions towards its central parts, the sediment carried by the meltwater-streams was deposited in the bordering waters and thus principally within the extended, submerged lowlands, but also within ice-lakes occasionally dammed up by the receding ice-border. Even within ordinary land-lakes varves were deposited and often have become accessible at their proximal ends by unequal land-upheaval.

Now, at the beginning of the eighteen-eighties, the amount of land-depression in question was rather unknown. From a couple of isolated localities it seems as if the real limit of the submergence in question had been observed, but, as varved clay was known from several places also at much higher levels, even these latter occurrences were believed to be marine, and the real amount of submergence remained unknown.

In 1882, during my first visit to Spitsbergen, I made acquaintance with its exceedingly well preserved, late Quaternary shore-lines. The following summer, during geological mapping-work in northeastern Scania, I tried and succeeded to find out and determine the very highest shore-lines, marked out by the wave-action of the late Quaternary submergence. Thereby I found that this so-called Marine Limit had a definite gradual slope towards the south. This being at the southernmost end of the very Scandinavian archean region, consequently it led my thoughts over to the right opposite, northernmost end of the natural region named, where the prominent French physicist, AUGUSTE BRAVAIS, in 1835 made the remarkable discovery of unequally upheaved shore-lines with a marked dip northwards. Certainly his report had been doubted by EDUARD SUESS and others, but it was founded upon careful measurements, and that was not the case with the doubts.

The facts stated by Bravais together with those observed in Scania and at scattered occurrences of probably marine deposits in an open situation at higher levels within more central parts of Fennoscandia gave me the idea that this region had been uplifted as a whole. That was soon verified as well by a closer study of scattered data in the literature as by direct levellings of the marine limit at a number of places, especially in southern and middle Sweden. They all confirmed that there has been a local, but rather extended and considerable upheaval of the very earth crust, according to what later on Professor W. Ramsay called the law of Bravais-De Geer. It may have been the first undeniable proof of a vertical, continental upheaval of land, exactly at that time strongly doubted by the master geologist, Eduard Suess, himself, in his Antlitz der Erde.

At the same time it became evident that the emergence of Scandinavia just as little could be due, as supposed by some other prominent geologists, to a local attraction of the sea-surface by a now disappeared, heavy land-ice, as I could emphasise, how it was evident that the most upheaved marine deposits certainly occurred almost where the ice earlier had obtained its greatest height, but from where it had totally disappeared, when the marine deposits reached their maximum of fully 280 m, thus having nothing to do with ice-attraction.

Method of geochronology.

Introduction.

»Concerning the geochronological method it is true that everybody should learn to creep before walking and learn to walk before beginning to fly. The present scientific study thus hitherto has passed four stages of evolution.

»The first, or that of childhood, lasted from 1878 unto 1905 and was characterised by a gradual awakening to a conscious life with tentative attempts of creeping, or walking by small steps. In the years 1905—1915 the method passes its scholar stage with intense labour and considerable progress, but still without knowing all its possibilities. The years 1915—1920 are a period of youth, when the real possibilities of life begin to loom with perspectives of a fascinating future and accidental attempts to fly.

»But it was not until 1921 that this study reached its full age. After its first transmarine expedition or Atlantic flight it then proved capable of mastering its principal task, which all since essentially has aimed at an always more multifarious application of teleconnections, as the far distant connections are called by an international term.

»It may be, that single doubters until lately have tried to retain the method on its stage of childhood, but this does not succeed any more than when formerly people refused to believe in anything seemingly as problematic as the statement that the earth should be formed like a ball, floating in the empty space, with the rather ridiculous consequence that our antipodes should walk feet upwards and head downwards in relation to us on our side of the globe.»

This short and vivid uttrance is translated from a paper in Swedish by EBBA HULT DE GEER, as emphasising the gradual evolution of the method here to be described.

(Naturens egna krönikor i trä och lera. *Nature's own chronicles in wood and clay.* Jorden Runt, Stockholm, 1932, p. 281.)

Varves.

Character and terminology.

In eastern Sweden a great part of the cultivated soil is founded upon a clay which, when untouched of weathering and cultivation, shows a very marked lamination with a cyclic iteration of more or less fine-sandy silt and very fat clay in regularly alternating, tiny layers or varves, by earlier geologists called hvarf (old spelling). Concerning this it was also mentioned how the present author on his first geologic field work in 1878, when for the first time observing a natural section of varved clay, got a lively impression of their cyclic nature, whereby the conclusion that such a marked and regular natural cycle can be due to nothing else than the climatic cycle of the year was near at hand.

Like the rings of the trees representing the annual cycle, the varves are formed with automatical accuracy in regions with an accentuated seasonal melting of glacier-ice and therefore, during the retreat of the last glaciation, were getting a widespread distribution in the surrounding seas and lakes in Northern Europe. Through the land-emergence they are now accessible in the lowlands and coast-regions of the Baltic as well as also at higher altitudes of Scandinavia in certain former ice-lakes of the mountain regions.

As to the composition of the varves the most essential is the regular variation between darker and lighter layers, both of which in Sweden earlier were called varves in the sense of sublayers, until later, at the Geological Congress in Stockholm 1910, I proposed as an international term to call the whole of such a cyclic variation a varve with slight accomodations of the spelling for different languages: Swedish *varv*, German *Warw*, English *varve*, French *varve*, and so on, so as to secure most similar pronunciation.

The appearance of the varves as to colour, thickness, coarseness and schistosity is very different at different places and also in different parts of one and the same country.

It depends of the bed-rocks and morainic matter out of which the clay is derived as also of the distance from the mouth of the melt-river.

Thus there are varve-clays which are dark grey in different shades, while others are rather light, sometimes yellowish or even reddish. In western Himalaya the varves are rather white.

In brackish water the varves get a different character, brownish or even reddish. In real salt water varves are not developed, because the coarser material is deposited quite near the ice-border, while the fine clay is carried farther out. Only at stationary ice-borders discernible varves can be formed in salt water basins.

Grain. Generally the varves are very fine-grained, especially as to the autumn or winter layers which as a rule upwards have a sharp limit towards the lighter and somewhat coarser spring layers of the next, superjacent varve, while there are gradual transitions between the different parts of one and the same varve. As generally the autumn beds are the darkest, their marked upper limit often clearly indicates, even in a small specimen, the difference between up and down.

Fractions of the year. The generally dark or even black winter layers form a sharp contrast towards the superjacent basis of the next varve. In order to mark that such winter layers were well developed I used in the beginning to mark their special thickness with a bracket, but soon I found that their development very often was quite local and merely depending on the local occurrence of easily fine-ground, dark shales or other rocks which at other localities could be totally missing.

Thus it turned out that the thickness of the dark winter layers which sometimes could be of use for the comparison of neighbouring localities however were totally without value for connections at greater distances, wherefore they can be omitted.

At first I tried to mark out also other details, such as small, sandy layers in the varves, and so on. But these were found to be still more local and thus pertaining only to very special investigations of a restricted region.

For the ordinary varve measurements with the scope of comparison and identification of varves at somewhat greater distances it was sufficient to measure the whole thickness of the varve, while further details were of no use and only rather encumbrant.

But also the total thickness could have local deviations, thus in the neighbourhood of the outlet of the sediment-carrying melt-river at the ice-border.

After some years' recession of the ice-border this local influence on the varve thickness is diminished.

The thickness of the bottom varves may by comparisons simply be left out or else be correctly reduced by standardisation to a more normal, mean thickness. The same is true as to an extra varve thickness caused by oscillations of an ice-border, so as to make the curve more easily comparable although it is necessary to note and study the significance of such an extra varve-thickness.

Of course it is of value, when possible, to measure extra long varve series for control.

Different kinds of *observanda* are mentioned under the head: sources of error, which, once observed, generally are not difficult to avoid.

Macro- and micro-varves. Proximal, distal and microdistal varves.

Sometimes I have been asked: how thick are the annual varves? According to the truth I must answer: between one or two meters unto zero. The thickness is a function of several different factors. The greatest thickness occurs in the neighbourhood of the former ice-border, just at the mouth of a subglacial melt-river, but here the thickness is rather irregular as determined by rapid changes in the direction of the current. As to the most proximal varves, — thickness counted by decimeters — deposited near the ice-border, the normal thickness for a certain year may thus be difficult to determine, while farther out, in the somewhat more distal varves, — thickness counted by centimeters — those local deviations become less marked and less apt to conceal the variations of a general nature, characterising the amount of varve deposition from year to year. Therefore and on account of their smaller thickness the distal varves, as available in greater numbers, thus often form the main part of the varves to be utilised for the building of a chronology by their relatively long series of regular annual variations, well recognisable from one locality to another one.

The above mentioned proximal and moderately distal facies as a rule are varves fitted for measuring in the field, but still farther out from the ice-border the more and more distal and thinner varves finally pass over into a series of microdistal varves, thickness counted in a few millimeters or fractions of mm only, which must be measured on laboratory specimens by a glass or on photos magnifying at least by five, ten, or even twenty, to get the annual variations truly registered. These varves being rather seldom accessible, they will be mentioned later on in various connections.

Except this general succession from macro- to micro-varves, typical for most parts of the land, however in certain parts of the country, as e. g. the southern Norrland coast-region, the melt-deposition was reduced to micro-varves all through, so that the bottom- and proximal varves have a thickness to be counted by centimeters only, and the more distal series very soon are passing over into mere millimeter varves. Such micro-varves, even close to the ice-river outlet, prevail in the south Norrland coast region (Hälsingtuna to Gnarp and Njurunda) and are typically small in the region past Bollnäs and Arbrå of the time scale, as well as in the many localities measured by J. Öster (Fig. 39).

The number of varves, even the most proximal down to their very substratum, always, if possible, ought to be measured or at least carefully counted, as indicating the year when the land-ice retreated and the varve deposition commenced at the locality in question. This should also be indicated on the graphs, while the thicknesses of the lowest varves can be indicated by figures.

Generally accessible sections expose only a moderate number of varves, because the more distal ones as a rule have been eroded away or made indistinct by weathering. Thus generally in the Stockholm region, scarcely more than half a hundred could be measured at one and the same locality. But seldom, and only in places specially protected against erosion and weathering, the number of ordinary, distal varves accessible for measurement can be greater in middle Sweden, while in the deep Norrland river valleys the varves are preserved in hundreds or even thousands in one and the same place.

In some regions, as at Uppsala, where the varve sediment was abundant and the clay-particles very calcareous, the upper ones protecting the subjacent varves against weathering, even more distal varves can be accurately measured than as a rule in e. g. the Stockholm region, already because the Uppsala ose river was greater than that of Stockholm. But this is utterly seldom the case with the most distal or so-called microdistal varves, representing the very finest clay sediment which, with a varve thickness of one to less than half a mm., was deposited when the ice-border already had retired far to the north.

The method of measuring varves.

For measuring the thickness of the clay varves is required a vertical section, which is to be continued down to the subbasement, if a local statement of the very ice-edge is wanted.

The section through the clay varves is best smoothed by means of a flat, square spade, whereupon the varve limits are cut clean with a clay-trowel (Fig. 1). This is an ordinary mason's trowel of which the edge is cut off right across, so as to become a small spade-like instrument, of which the edge is to be sharpened

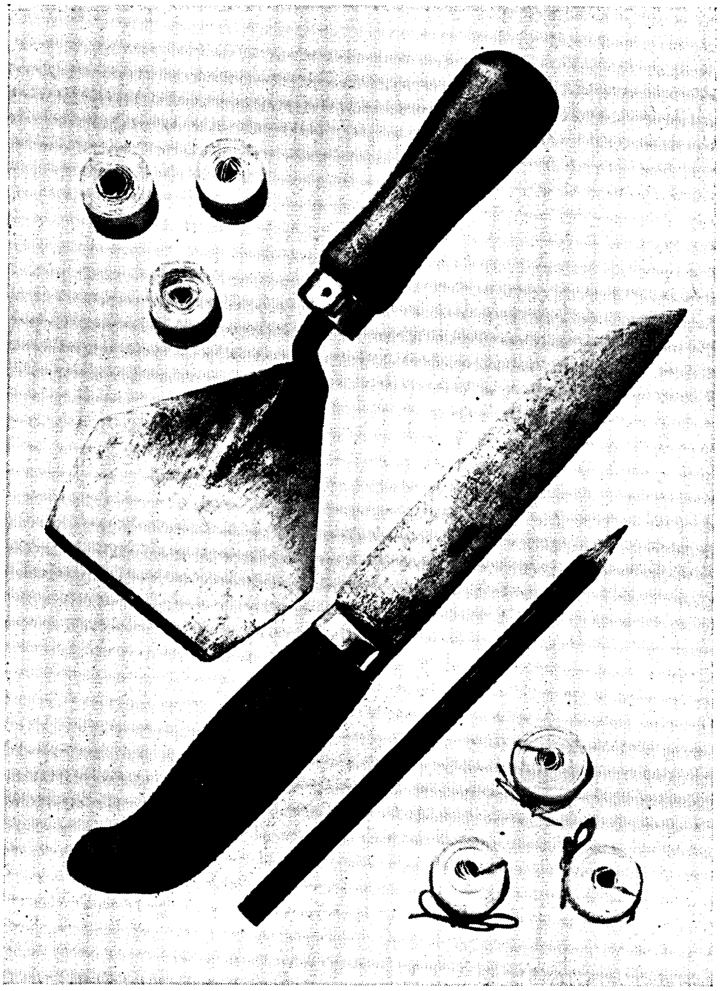
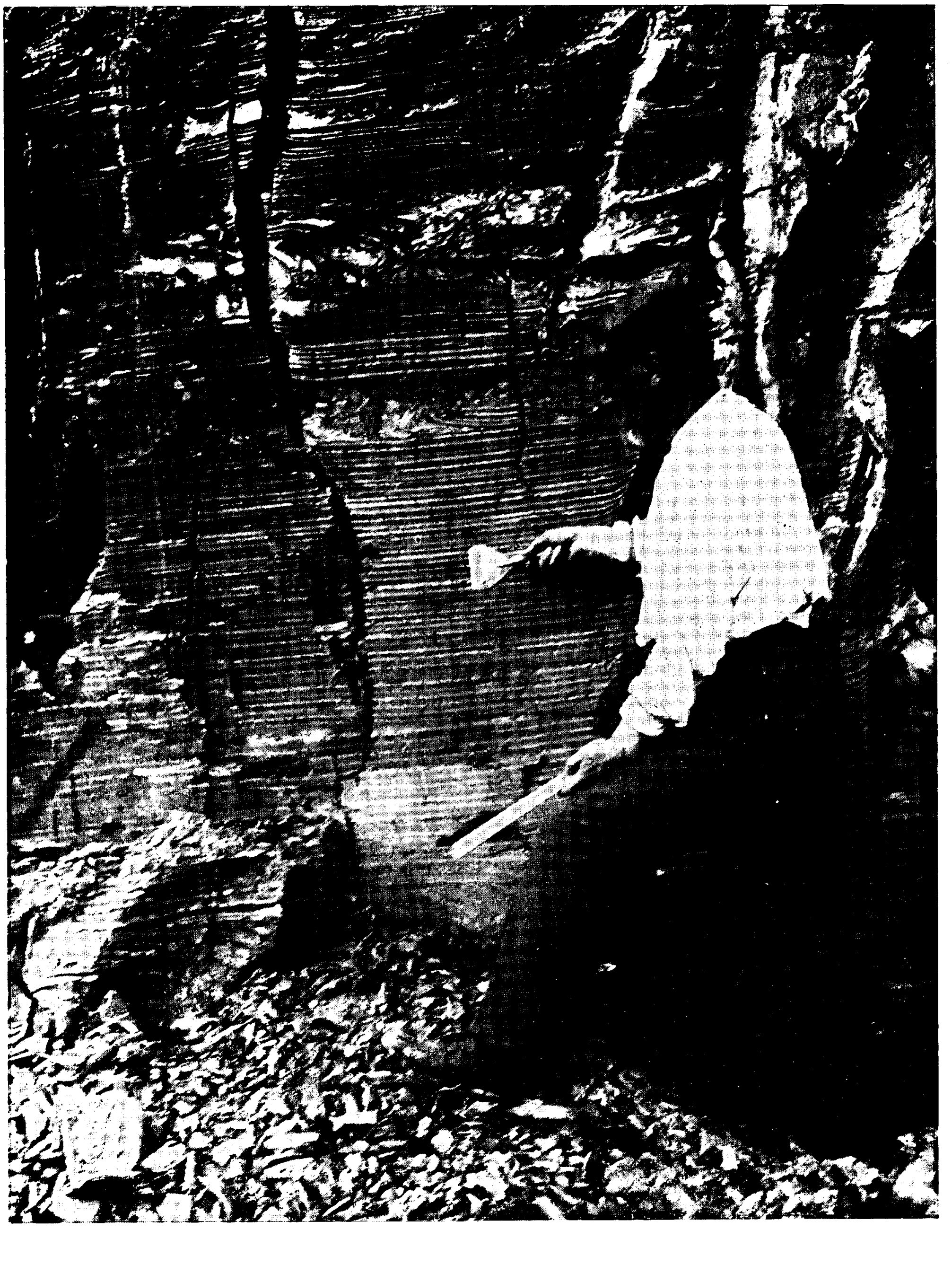


Fig. 1. Utensils for varve measuring, easily portable. For cutting the clay: a strong hunting-knife; and a clay-trowel or a mason's trowel cut straight across. For measuring the varves: rolls of thick paper tape, easily straightened by the thumb when opened; and a usual lead-pencil.

from the upper side, while the lower side is to be as even as possible, so as to avoid scratches in the clay wall when cutting along the direction of the varves. If the clay is too wet to allow cutting, the varve limits often however can be cleaned by rubbing the edge lengthwise along the varves so as not to conceal the limits.

The clay wall is to be cut clean and smoothed unto a breadth of a half or rather a whole meter so as clearly to show that the varves are parallell with their original relative thickness preserved, and not distorted by glidings: folded, thinned or thickened by rolling or through faulting along fissure-lines. In case of such dislocations the original thickness is made out by measuring undisturbed portions in different parts of the sections, whereby it is to be properly ascertained that no varves be left out, but that it be carefully indicated how they shall be joined to-



Normal clay varves in regular deposition. Local ice-drift disturbances not affecting superposing and underlying varves. Essex Junction, U. S. A. The first varve locality measured in N. America, viz. by G. De Geer in 1891, remeasured in 1920.
Photo Ebba Hult De Geer, 1920.

gether to a continuous varve series. Thus the lowest varve of the uppermost part is marked by a line and a letter which reoccur on the corresponding level at the upper part of the following lower continuation of the measurement.

The limits between the single varves are marked with distinct short lines by means of a lead pencil on tapes of thick drawing paper. The tapes have to be 2 cm broad and about 1 m in length and the paper should be of a good, tough quality. Topmost on each tape is written: up, and the varves are marked along the one side of the strip. If necessary, the tape is turned upside down and the measurement continued along the other edge of the tape. If such a tape is not too much soiled by the clay, it can be turned over and the measurement continued on the back side successively along both edges so that, if needed, the length of 1 metre can be eaked out to almost 4 metres.

The character of the subbasement is marked, e. g. by: till, or: rock. From the base the varves are numbered, beginning by »1» just below the bottom varve summit. On an empty part of the tape is written: 1) the name and situation of the locality and a figure corresponding to the one denoting the situation on a map; 2) the name of the observer and 3) the date of the measurement. In the case of several tapes for one varve series the junction between each two of them are to be denoted quite unmistakeably by an easily recognizable sign and a corresponding letter.

Specimens.

The measurement completed, if possible also a series of samples should be taken out of the varve section. For that purpose we use boxes of zinc of a standard size 50 cm in length, 5 cm broad, and 2 cm deep, and with the 2 cm high edges soldered up in the corners. For an international exchange of specimens it is urgent everywhere to stick to this standard measure, as varying sizes will not fit into the cupboards especially built for the storing and exposition of such samples in the Geochronologic Institute and also else would cause trouble. When the sample is to be taken, the edges of the box are slightly pressed against the vertically cut, smooth wall of clay at right angles across the varve series. The impress will show if the wall is smooth all along, or if further smoothing is necessary. This being ready, the box is finally pressed against the wall, whereafter by means of a flat knife or the edge of the trowel an incision into the clay-wall is made tightly along the four outer sides, whereupon the box is to be cautiously beat in, whereby a small piece of board may be put along the bottom of the box to spread the pressure evenly. When necessary the pressure may be facilitated by repeated cutting around the walls of the box. When its bottom has arrived into the same plane as the clay-wall, a cavity is cut deeper into the wall all along the box, whereafter the specimen from all sides is cut free from the wall through oblique incisions, until the specimen is completely free from the clay inside, whereupon it is cautiously taken out by being leant backwards (Fig. 2).

The oblique inner crest of clay, now rising like a roof above the edges of the box, is carefully cut away in thin slices by a sharp knife, however not down to the very edges, as a reserve should be left for taking out small samples for special investigations, as e. g. chemical, for diatoms, and so on. If the clay is brittle, it is profitable to press it slightly with the thumbs, so as to get it well packed in the box, also because when drying the surface will shrink considerably. Of course this packing should not be done so as to disturb the layers.

On return to the laboratory the specimen gets a last finish, still leaving a minute amount of clay above the edges as a margin of reserve against shrinking. Thereupon the specimen is poured over with glycerine, which has to be done repeatedly, especially if the clay is fat, to begin with twice or more a day with gradually longer intervals, so as to extend the process of drying and counteract a too abrupt shrinking. If all the same the clay is apt to get dissected by fissures into separate portions, these have to be cautiously moved together by means of flat, steady knives (usual simple table-knives being practical) and the resulting empty space at the top or bottom filled out by some suitable plugging material, proper to be eaked out successively, as e. g. small slabs of thick card-board or wood, fitting the size of the box.

Before the taking of samples the zinc case is marked by a small notch filed into the lower edge and a figure engraved on the same side, corresponding to a figure in the pertaining description of the taking of specimens. At last a label is glued on to the lower side of the case with the same figure and the name of the locality, the date, and the sample-taker.

In the case of a continuous series of samples, every following box always must overlap the preceding one by 5 cm, which is the measure of the breadth of a box, easily remembered and followed. This measure is also quite satisfactory for identifying the varves common to both boxes.

For the transport to the laboratory the specimens are temporarily protected against drying by a cover of leaves, preferably of the coltsfoot, *Tussilago farfara*, which generally grows in abundance on clay, or by some other moist cover, and are wrapped up in paper tightly wound with twine, possibly also protected by a thin board of wood or zinc. For longer transports the specimens have to be packed up into wooden boxes, well protected with hey, excelsior, or other elastic material.

For avoiding transport risks it is desirable that a copy of the measuring-tape may remain with the despatcher and that the clerical material of measuring-tape, notes, and sketch maps may be sent apart by mail.

Finally it may be emphasised that the longer a varve series can be overcome, whether by measuring at one and the same locality or by a combination of several localities, the greater will be the possibility of identifying the variations of the clay varves with the general time scale.

Other methods of taking samples, e. g. with a plunging tube, also have been tried, but the method above described is, though in a way somewhat primitive, however so easily practicable, cheep and handy, that it can be used without great cost and circumstantiality, yes, even improvised when the measurer unawares comes across a favourable locality, if only a black-smith to make the boxes is not too far away.

Fig. 2. Cutting of specimens in cases of zinc 5 × 50 cm, 2 cm deep. Above: cutting all around the sides of a specimen-box, pressed into the clay-wall. Middle: cutting backside of specimen free from the clay-wall. Below: planning the clay-varve surface. Photo E. H. De Geer, 1930.

On clay-varve diagrams.

As denoted by the adjoined set of graphs, the thickness variation of a varve series easily can be made intelligible and adapted for comparison with varve series from different localities, if the measures of the single varves are put out horizontally from a vertical axis as a point of departure and from left to right at equal distances from each other with the lowermost varves downwards. For the Stockholm region the lines of thickness were put out with a distance of 1 cm, but as a rule 0.5 cm is used, as being more suitable for longer and not too strongly varying varve series. For publication the half, or 2.5 mm, are most preferably used (Fig. 3).

In this way the varve series is represented by lines in their natural succession from bottom to top, but for the sake of handiness the graphs are turned so that the vertical axis gets horisontal, as being generally the longest line, with the thickness lines rising vertically. Logically they ought not to be combined, but to enlighten a total view of the variations the tops generally are combined by lines, whereby the continuous trend of the curve is more easily grasped and the variations can be more clearly described.

Consequently of the above procedure the bottom varve comes to the right side and the succession of younger varves follows towards the left. For graphs of this kind this arrangement is as logical as any other one, the real starting point being our own historical epoch, which is relatively fix, while the graph series to be obtained are extended off into the unknown past, into remote geological periods, and always remain unlimited.

Sometimes a wish has been expressed that the varve measurement should be published not only in the form of graphs but also by figures. Though this wish partly may be founded on a misunderstanding concerning the registration in question, the figures named herewith are given, though necessarily they have to be introduced by a few remarks.

The very first varve measurements were executed by means of a millimeter scale, whereby the readings were noted down by figures. But soon enough this method was found to be neither quite safe against mistakes, nor time-saving, and was abandoned for the old, classical measuring method of the shoemakers.

Thus lead-pencil and paper-tape were used. Upon a carefully cut, vertical section of a varve series a piece of tape was fixed across the horisontal varves, and their reciproque limits were marked out with an acute lead-pencil. By afterwards moving the tape over a square-line paper, successively one step for every annual varve, the thickness of each varve was plotted by a dot, and by connecting those a clear general view of the thickness variation was obtained, whereby the height of the dots above the basis represented the thickness lines of the single varves. By using always the same distance, of 0.5 cm, it became easy to compare with one another the variation curves from different localities, and this little arrangement altogether included the possibility of the geochronology.

Comparisons between different localities, namely, are quite indispensable for the elimination, from this somewhat complex kind of registration, of such elements which have nothing to do with the climatic factor.

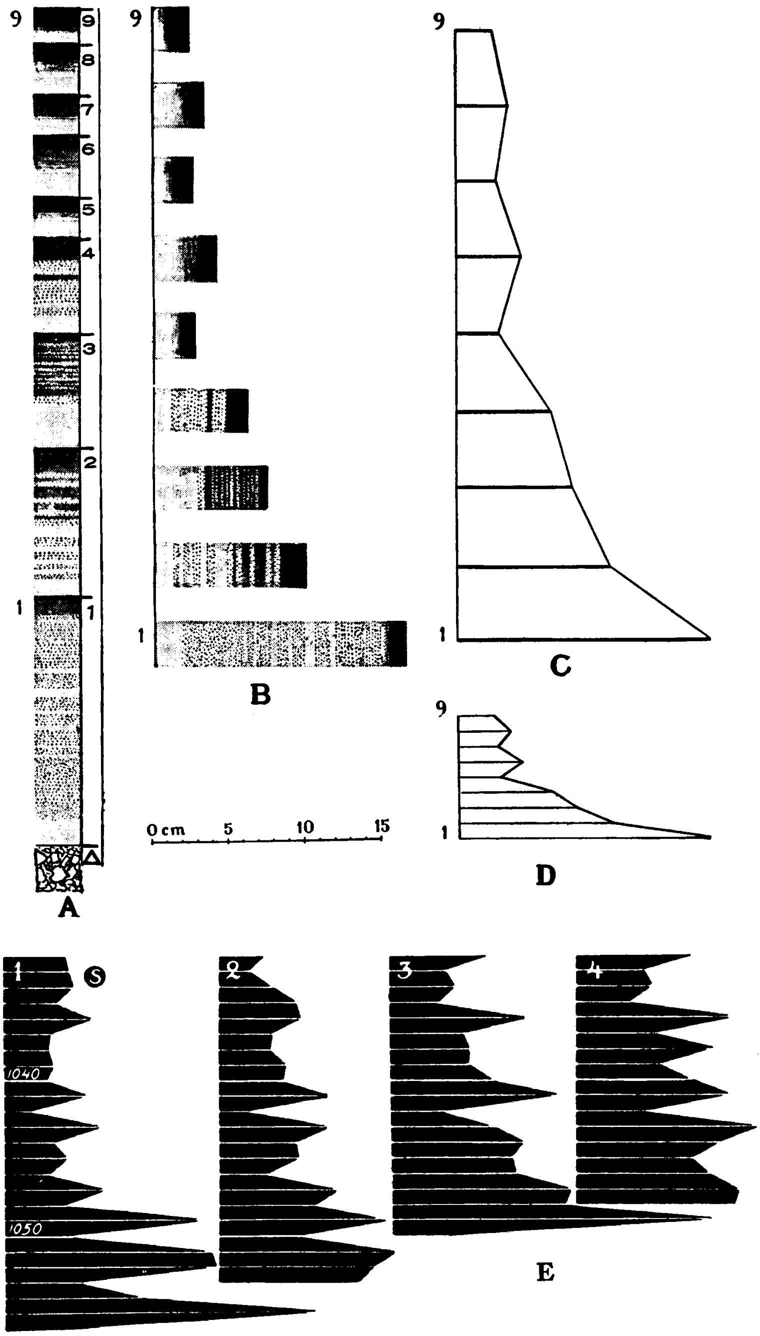


Fig. 3. Schematic view of varves measured and turned into a graph. A: a varve section reaching down to the substratum, here till, all alongside followed by the paper tape; markings: a line for each varve limit, with figures from the bottom upward. Below the base-line a triangle marking the till. B: varves turned sideways, at right angles from a vertical line. C: varves represented each by a single line, tops combined unto a curve. D: graph compressed unto a smaller, but always even distance between the year lines, as a rule just half a cm; in print reduced to half scale. E: first varve connections displaying ice-recession. Confer Fig. 23.

As clearly shown already by the published comparisons of more than 8,000 varves — see Plates 72–86 — the striking correspondence of the majority, sometimes amounting to 80–90 % of the whole number, quite as well between neighbouring as between most distant localities, indicates that the registration principally is determined by a common factor of universal nature, but likewise that this factor sometimes is more or less obscured by different local influences.

Since nearly sixty years having clung to the idea of a chronology and, since more than forty years, having had the opportunity of proving that it was performable, all since that time by a long series of detailed parallel measurements from all the five parts of the earth, I have been able to publish *Data* with undeniable proofs of the fact that for the last 15,000 years direct and controlled measurements are carried out and published.

Thus it was long since definitively proved that for all kinds of evolution, geophysical as well as biologic, there were now for the millennia most directly important to manhood, new possibilities of exactly determining the time factor. This being the case, it seemed at first rather striking that — notwithstanding many thousands of corresponding obervations forming a continuous net-work, everywhere interwoven by controlling parallels — there has still at some quarters been an open opposition or at least a scepsis. This was at first somewhat astonishing but may only be a new example of the ordinary *inertia* with respect to untrodden roads, especially where it would be necessary somewhat to deviate from the highroads of the official text-books. An additional difficulty is no doubt the linguistical one, and it will be of psychological interest to see how much time it will take before the time scale will be really rediscovered.

Sources of error by varve measurements.

The normal thickness of an annual varve can be influenced by several different sources of error, some ones depending of physical and other ones of observational causes.

Physical errata.

Physical conditions can give rise to one or another primary facies of the varves, already originated at their deposition; while secondary facies is due to different extra influences upon their normal sedimentation.

A. *Primary facies* may be caused by:

1. Changed distance of receding river-mouth, caused by the annual recession of the ice-border and also by the shifting of the river-mouth over to new fissures in the ice-border, sometimes sidewards one to several kilometers. When the river-mouth is regularly receding and the bottom-topography not too uneven, the varve deposit from year to year exhibits a more or less regular thickening in direction towards the river-mouth. In such cases this local thickening is possible to smooth out and reduce to variations around one and the same mean thickness, thereby better representing the real climatic curve. When the recessional element is too irregular to be eliminated, sometimes the proximal, most locally developed part

of the curve must be left out in the case of comparisons with other localities. The omitted varve number is to be noted.

2. The extra-glacial current direction was often varied from one year to the other as partly depending of changes in the direction of the river-mouths, thus causing, sometimes, annual changes in the axis of sedimentation and local extra thickness of the corresponding varve.

3. Hillocks in the bottom-topography have been found to give rise at their distal side to a thinner varve-deposit than at the opposite, proximal side, thus proving that the main mass of the sediment was carried out along the bottom. The same thing was shown by the occurrence of sand-layers within varves deposited some kilometres from the river-mouth.

The sources of error 1—3 are most accentuated in the neighbourhood of the river-mouth.

4. Extramarginal river erosion is especially met with where the ice-border was receding above the lake- or sea-level, so that the ice-river had to pass the distance between the ice-border and the shore as an ordinary land-river which by side-erosion of its shores, sometimes during a lapse of years (rather irregularly) could eak out its meltwater-sediment with extra material in a way, thus obscuring or concealing the more normal, climatical meltwater-curve by such accidental material for a number of years, until the material at each such stage was eroded away and a normal registration could recommence. Examples: Moen in Sogn and S. Halland.

5. Littoral erosion has added material to the meltwater-sediment near the original shores and where the water became shoaler by upheaval of land or by successive draining of lakes. Examples: Duchess Junction at Hudson River and several other places in New England and Poland.

6. Ice-dam draining in middle and northern Sweden not seldom gave rise to very marked single varves, sometimes more than 1 m thick, consisting below of currentbedded fine sand and upwards of silt in strong contrast to the long series immediately above and below of normal, often thin and regular clay varves. In the north Swedish coast region giant varves register the subglacial drainage of the great ice-dammed Lake Storsjön.

In the glacial lake of the Hudson valley such drainage or giant varves were to be expected from drainage of the great ice-dams along the south side of the Great Lakes. During our visit in 1920 Antevs therefore at my request made a series of varve-measurements in the region around and below Albany and established several interesting such varves, or rather varve-series of drainage, showing that those considerable drainings required several years before normal deposition gradually was restored.

7. Ice-river capturing, on the contrary, has sometimes caused a sudden increase or decrease of the average varve thickness at a certain place. Example of such a decrease: Espanola, Ont., the year 550 and upwards, and, on the contrary of an increase: to the north of Vimmerby at the year of 2455 and following upwards.

B. *Secondary facies*, caused by:

8. Sliding of many or single varves has occurred especially where the slope was steep and when a locality became elevated above the water-level and its counter-pressure thereby was annihilated. Sometimes the whole bunch of slidden varves has got their thickness falsified, sometimes the sliding has affected the lower varves only, while the upper ones have preserved their original thickness. In some cases a single varve has got its normal thickness obviously changed, probably from being more easily squeezed out than the others.

9. Disturbance by ice-bergs run aground. Thereby folded and squeezed varves were often afterwards covered by undisturbed ones and so on in several floors (series). Such disturbances are generally quite local, whereby a varve-measurement often can be carried around the disturbed portions. Confer Fig. 38.

10. Ice-raft deposition of till, till-lenses and till-beds, melted out from ice-bergs run aground if the substratum is deformed, or, if not so, quietly sunk when the till-laden ice-berg by melting had got the gravity of the water. Such ice-rafts, being extra deposits, should be passed over but annotated at varve-measurings.

11. Deposition of ose-talus does not seldom occur from gravel-slips along the sides of oses. Such slips sometimes simulate till and are to be passed over and noted at varve-measurements, as in the previous case.

12. Shrinkage by leaching and weathering of the upper varves, which thereby sometimes get their original thickness unequally reduced and, if measured, have to be designated by an interrogation mark.

Observational errata.

13. Deceptive bands simulating winter layers. If thereby one varve has been erroneously subdivided into two, it is called a *digraph* or, into three, *a trigraph.*

14. If an indistinct winter-layer has been overseen and thus two real varves erroneously joined in one, this is called a *monogram.*

15. Small faults along fissures or soil-cracks are apt to be overseen when the throw is small, and thus the fault is not very well visible on the section. When a measurement has passed over such a fault to an adjacent clay-block, it may be called *trespassing*; if it also comes back to the first one, it may be called *go-and-back.*

16. Inexact joints between adjoining measuring paper-strips sometimes have caused the missing or iteration of one varve. In the latter case the duplication is denounced by the iterated thickness.

17. Measurements on regularly sloping sections can be graphically reduced to the right thickness, while uneven sections must be cut plain before measuring, or, if the varves are thick, measured varve after varve, separately with a standard, the amounts being noted down.

18. Very thin varves can easily give rise to errors as to their thickness or even numbers. The best is to execute the measurements at home by enlarging 10 to 20 times on cautiously taken and exactly labelled varve-series in suitable cases.

Summary of errors.

Physical errata.

A. Primary facies from:
1. Changed distance of receding river-mouth.
2. Changed current direction.
3. Bottom topography.
4. Extra-marginal river-erosion.
5. Littoral erosion.
6. Ice-dam draining.
7. Ice-river capturing.

B. Secondary facies from:

8. Sliding of many or single varves.
9. Disturbance by ice-bergs.
10. Ice-raft deposition.
11. Deposition of ose-talus.
12. Shrinkage by leaching.

Observational errata from:

13. Deceptive bands, simulating winter-layers: *digraphs, trigraphs.*
14. Overseen, indistinct winter-layers: *monograms.*
15. Overseen, small faults: *trespassing* to an adjacent clay-block; sometimes also back to the first one: *go-and-back.*
16. Joints between measuring-strips.
17. Measurements on sloping or uneven sections.
18. Extra thin varves.

Correction of a few errors possible even at microdistal varves.

Microdistal varves deposited at a considerable distance from the land-ice coast are free from all local sources of error caused by unequalities of the bottom and other casualities near the mouth of individual melt-rivers.

1. Secondary errors. The microdistal varves, being very plastic, exceptionally have been somewhat squeezed out locally by sliding or pressure of superposing layers, what is to be corrected by control-measurement at some other place.

2. Personal errors. When microdistal varves sometimes are separated by whitish strips of very fine silt, they are easily measured, but when this latter is missing it is sometimes difficult to distinguish with certainty their faint limits, whereby errors can arise, which must be controlled by remeasurements.

As these two sources of error often may be possible to correct, the microdistal varves afford a quite new and very promising, mean registration of such climatical variations as can be found out from the annual varves.

The method of connecting varves.

Hitherto our geochronological publications have been rather strictly concentrated on the very results and have dwelt perhaps too little on several of such difficulties as had to be overcome. This is especially true with respect to the teleconnections or identifications at great distances.

An especially favourable condition for teleconnections is to have such a continuous standard line of reference as is available in the Swedish time scale with its continued filials in different countries.

But the identification and dating of wholly unknown, new-measured varve-series in many cases had not been possible to fulfil until after seemingly hopeless endeavours for weeks or sometimes even for months. Often it was necessary to take some characteristic part of the new curve for comparing it successively, first with that part of the standard scale which from geographical causes might be most probable and in that way to follow the comparison, until correspondence was found. But it could happen that the compared part of the new curve was locally developed and thus also unsuitable for identification. In that case another part of the new curve must be taken up for comparison. It may be easily understood that such repeated tests quite naturally must require as well time as patience. But when finally the real identity was found, the labour was richly remunerated, because though generally with intervals of less characteristic, locally developed varves, one constellation after the other with exactly the same intervals could be easily recognised in both curves consistently and generally along the whole of their length in such a way that every casuality was excluded.

It seems as if some critics who for their part have not tried or not succeeded with teleconnections may not have spent the time necessary for graph comparison, too easily taking some negative result as a definite one. More difficult it is to understand how they have been able to deny the identity of already teleconnected curves which, by long series of rather identic constellations are quite as closely tied together as any close-connected ones.

They ought to remember that every additional corresponding constellation which, after an exactly due interval, follows after the first identified one, is quite comparable to the stating of a prognosis. And it seems that the long series of such verified prognoses ought not to be met by mere subjective negations.

In this connection it must be laid stress upon the very remarkable fact that a great number of teleconnections with the Swedish time scale always has put the new-measured localities or meltwater-varves exactly in a regular succession, very probable for a natural ice-recession, while, on the other hand, other hypothetical parallelisations, founded only on assumed correspondence between certain terminal moraines or some seeming similarity between the utterly local rate of ice-recession in different directions has not succeeded to put forth that only real proof of identity which is to be had by series of correlated varves.

This is the more fatal, as nobody has dared to deny that in Sweden such a certification by varve correspondence always is found to accompany really identic ice-borders, e. g. along the rather extended middle Scandinavian terminal moraines. Where such a great number of intermediate close-connections are at hand, it seems sometimes to have been forgotten that already a close correspondence between the most separated points of this area is gained, which affords an excellent example proved of teleconnection, though in this case they are already tied together by closeconnections and by their relation to one and the same terminal moraine.

General and special control.

General. It was exactly quite a number of such well certified teleconnections in Sweden and surrounding countries which made it very probable that the normal variation of the Swedish time scale had a general cause and therefore also ought to be possible to identify all over the earth.

As may be known, this has now been verified in a great number of countries and in all the five parts of the earth. The majority of these teleconnections has been published in the Swedish journal Geografiska Annaler, Stockholm, in the years 1926—35 and often comprising rather long series of varves, mutually connected across distant parts of the earth.

Not seldom it has occurred that some or other observer has been obliged at some locality with disturbed varves to content himself with an estimate of the mere number of the dislocated varves, and that by teleconnection of those above and below the dislocated ones it has been possible for me to tell exactly their real number, which as a rule was found rather nearly to correspond with the estimated ones. It is obvious that this could not have been the case, if the variations and their intervals had not been really identical.

Special. It is very much the same with the geochronological dating of the Niagara canyon. The length of time believed to be required for its formation had earlier — from the actual recession of the fall by a considerable extrapolation and by different assumptions concerning quite a number of influencing but insufficiently known facts — been very differently estimated by different authors. Still the most elaborate of those estimates now were found to be about four times longer than the time directly indicated by the varve measurements. As one of the possible causes of the over-estimate named I suggested that a part of the canyon, just above the Whirl Pool, might have been eroded already before the last glaciation and afterwards filled out by its moraine material, just as the moraine-filled ancient part of the canyon north of the Whirl Pool. Later on, earth-borings, executed by W. A. JOHNSTON pointed out considerable masses of till along the bottom and sides of the canyon above the Whirl Pool, thereby confirming that a great part of the canyon during the Late Glacial epoch had not been cut out of hard rock material, but only and very much more rapidly had been reexcavated from the loose morainic matter. JOHNSTON seems not to have known my dating and my suggestion concerning a possible partial re-excavation of the canyon, but the very basis of the Niagara calculations being thus shown as quite unfounded, the whole of this time calculation no doubt should be a rather unpromising task after that it had been shown that the very length of the canyon was rather undeterminable. A word concerning this suggestion in beforehand, footed on the independent varve-measurements, therefore might here be in its place.

With respect to new theories it is a well known and to a certain extent no doubt useful fact that they are not accepted at once. In the case of geochronology, however, this latter does not represent a new theory, because it was rather well developed a couple of decades ago, and, further on, because it is no theory but direct conclusions from empiric measurements and their connections, repeatedly controlled in different ways.

Thus it may be allowed now to emphasise, how desirable it is to dispense with subjective criticism and to take up positive control in the field in as much this new method of investigation may get a wider chance of being a standard for Quaternary geology and other branches of natural science without hindrance of anticipated opinions. Very soon it will be found, no doubt, that exact time-determinations quite effectively will be able to fix many problems, hitherto subjected only to more or less vague assumptions. In the long run much time and many controverses would be spared, if a common, objective time standard as soon as possible be introduced.

It has been said that it should be difficult to form a definitive opinion concerning the scope of geochronology, before the whole of the observed material be published.

But concerning a material of this kind it can never be considered as complete, and this not only with regard to the earlier stages of the time scale, which still for a long time may be in a state of extension backwards. But even with respect to that part of the time scale which is measured in one continuous succession, new parallel measurements are desirable everywhere as strengthening the normal curve of the scale at such parts where the controlling measurements are few in number.

However, it is a quite legitimate wish to be certain that variations in the curve of the time scale do not occur in any rhythmical iteration which could lead to mistakes in the parallelisations.

For my own part, as having worked rather intensely with the time scale for so long a time, I know that real iterations are totally missing as well within the number of millennia already published as on the whole of the rest.

Fine-grained sediment versus coarse deposits.

Though it is quite generally admitted as a fact, well certified by detailed observations in Sweden, that the clay varves were deposited off the ice-border of the receding land-ice as a direct continuation of the same melt-sediment as the eskers, it seems as if this the finest and most regularly distributed Quarternary deposit elsewhere scarcely was generally admitted as a geologic formation worth of being confronted with its coarser and more protruding Quaternary associates.

From one quarter it was thus postulated that parallelisations between Quaternary deposits in different regions first must be carried out by means of so-called geologic evidence, while minor details afterwards might be possible to study by means of varve measurements. Hereby it must be emphasised that nobody has been able to indicate any other means of reliable teleconnections concerning terminal moraines in different countries than exactly the close correspondence of the varve series, while, on the other hand, several such assumed parallelisations of moraines without the testimony of pertaining varves have been found to imply serious mistakes exactly by overwhelming witnesses of this latter kind.

In other words, the attempts of correlating geological deposits more easily observed are possible to certify only by means of their associated varve series, which always afford the ultimate decision. The admonition to go the opposite way is therefore quite impracticable.

But for a reliable connection between varve series in different regions it is necessary to know well the varying sources of error and how to eliminate these or totally to reject such series where the normal variation is too obscure by local deviations. Such a control of the varved measurements often necessitates very minute comparisons, the omission of which would introduce often quite irrelevant and local variations which have nothing to do with the climatical curve and which would earnestly obscure or destroy reliable results.

The postulate sometimes emitted that the whole of the measured material ought to be published is therefore founded on an unsufficient knowledge concerning the detailed and time-craving, critical graph comparison and sifting which is quite necessary for discriminating reliable variations from misleading ones and for eliminating obvious errors. Variations corresponding with other measurements are shaded in the graphs, Pls 72—85, by heavy lines and in the tables by heavy figures, while more local ones are less strongly marked or even totally omitted.

Not seldom it occurs that the varve registration for a certain series of years has been affected by local deviations, which are of local interest exclusively and must be totally omitted in the case of teleconnections and other investigations concerning more or less universal variations. These latter generally continue after a certain number of locally developed varves, exactly coinciding with corresponding normal varves, as well as the similar length of the intervals, when repeated for quite a great number of such corresponding series and intervals, is of course a very good control of real identity. Also, as is easily understood, this quite as well can be certified already by the publication of well corresponding parts of the curves compared, when it is certified that all of the locally developed interstices do exactly correspond as to their length. This has sometimes been misunderstood, so that astonishment has been expressed, when at a preliminary publication of long varve series only the best, normal curve fragments were given, while irrelevant and quite local intervals were omitted.

Varve registration versus fossil witnesses.

The foundation of geology was the important discovery that the different fossils occur in a certain succession, whereby a kind of general relative chronology was made possible. The next step was the origin, about hundred years ago, of modern geology, when instead of the earlier, daring hypotheses and assumed revolutions, a gradual actualistic evolution was assumed as the leading principle in the story of the earth. But it was a story without years. Numerous have been the attempts to find out some means of estimating the rate of certain physical changes in the natural evolution, but always with very uncertain results.

The fatal difficulty was that in the really known part of some kind of evolution in nature — it may be erosion by waves or waterfalls, weathering and chemical changes, deposition of peat or other layers — always the time space observed was so short as to form scarcely more than a starting point with regard to the long stage to be estimated and the unknown rate by which the conditions might have changed. Furthermore even those rather uncertain estimates were quite isolated and gave no time scale.

In lack of real time-correlations geology was confined to correlations of fossils and to the assumption that more or less corresponding fossils also correspond in time, though this of course only could be a rather rough approximation. With respect to earlier geological periods the degree of uncertainty is scarcely determinable, but is no doubt very serious.

The appearance of certain fossils may indicate one or several more or less local migrations but affords no exact or reliable dating. As to the latest part of the Quaternary Period, this is very clearly elucidated. By means of geochronologic determinations it has become possible here accurately to fix the rate of the physical evolution and thereby really to date the different horizons of fossils. Thus we have got a very interwoven tissue of fossil remnants within a great number of locally different successions of years.

Even with respect to these layers there was often a tendency to idealise their succession as being supposed to be rather regular horizontal subdivisions, just as often has been done with respect to older geological systems.

Teleconnection and telecorrection.

But as to the Late Glacial Epoch here in question, we have got a striking illustration of what fundamental mistakes can arise from such abstract assumptions.

Since, in 1920, I had found in North America, at a great number of varve localities measured by myself and my companions during this first over-sea varve expedition, that the variation of the annual varves could be identified with corresponding varve occurrences in Sweden and always followed in the same geographical order, proving a corresponding ice-recession, I arranged for similar varve measurements in Asia by E. Norin within the Himalayas and in South America by C. Caldenius within the formerly glaciated region of Argentina and Chile, this latter investigation being essentially supported by the very valuable help of Dr José M. Sobral, then Director of the Geological Survey of Argentina.

As already earlier reported, at Lago Corintos, 43°10′ S Lat. and 71°20′ W Long. Gr., Caldenius had measured a magnificent varve section, comprising about 560 varves in the neighbourhood of a marked, double terminal moraine, which he suspected possibly to be corresponding to the great mid-Scandinavian moraines, which also often are double. Sobral and Caldenius sent these measurements to me for comparison with the material in the Geochronological Institute.

After some attempts and by the help of the assumption made by Caldenius, I soon found, in the neighbourhood of the mid-Scandinavian terminal moraines, quite a number of varve constellations, strikingly similar to those sent for comparison. Yet seemingly there was one drawback. The corresponding constellations in Argentina and on the northern hemisphere followed after each other in the same order and fitted marvellously to each other with exception of six annual varves which were not represented in the graph from Rio Corintos. Still all the others were so strikingly similar, that I was obliged to draw the conclusion that those six varves must have been overlooked by the measurement at Rio Corintos. Certainly this was quite explainable, considering the earnest difficulties by measurements in the steep barrancas of the high river sections, whereby small dislocations easily can escape even such an experienced specialist as Dr CALDENIUS. But, as to be seen in the graph here published, the very dominant majority of markedly conform varve variations simply forced me to believe in a real identity and to put this conviction in print, and it turned out that those overlooked varves really represented a most happy hit.

Somewhat later CALDENIUS, namely, had got the good luck of finding, at 46° 40′ S. Lat. near L. Buenos Aires, a corresponding section which exhibited all six of the missing links. In his next publication he mentioned that, of these six varves, five were found exactly at years enumerated in my publication, while he thought that the remaining had to be placed somewhat below the assumed year. Yet, by a close comparison I have found that also this varve may be rightly telecorrected.

These telecorrections, published in advance, at a great distance and from the northern hemisphere over to the southern one, and afterwards confirmed in nature, seem to be so conclusive proofs of undeniable teleconnections that their most important part has been reproduced on a special graph, Pl. 89.

Pl. 90 represents varves from 280 years between the years −800 to −1080, or seven years before −1073, or the lower limit of the Finiglacial subepoch. These years are represented by varves as well from the northern hemisphere: in North America (N Am.), Sweden, 1 and 2 (Sw. 1, 2), and Norway (Nor.) as from the Southern one. Teleconnected localities from the southern hemisphere are two, both from Argentina in South America (S Am.): the one from Lago Corintos (Co. 1), the other from Lago Buenos Aires (Bu. 2), the former, Co. 1, representing the measurement in 1926 sent over to the author for comparison, and the latter, Bu. 2, representing the later measurement of CALDENIUS, whereby he would confirm that all the six in advance advertised missing years, which were duly registered on the northern hemisphere, also existed on the southern one and had only been overlooked. The six varves, overlooked at the measurement Co. 1, on the graph are designated by vertical spears.

Underlining with a heavy line means similarity with other localities: an upper underlining, with the northern hemisphere; a lower underlining, with the southern one; a double underlining, transequatorial similarity.

Maxima of biennic variations are designated with round, black dots.

Triennic variations are designated by nooks at the top of light pillars.

From the very dominating occurrence of double, thick lines along the curves, at the first glance, it is easily seen how very dominating is the concordant similarity of the varve variation on both of the transequatorial hemispheres.

Very naturally there are local deviations in the amount of thickness, often caused by a different distance from the river-mouths, but the overwhelming and detailed similarity between such a great number of characteristic varve constellations seems already quite impossible to explain by mere casualities, and when the conformity is so dominating that half a dozen of overlooked varves can be exactly dated in advance from one side of the earth to the other and afterwards become refound in nature, it seems rather impossible to imagine a more definitive proof of real identity of those climatic variations, which have caused such a marvellous universal registration.

It seems rather unnecessary to emphasise the overwhelming number of single similarities, but for everyone who really wishes to get an unbiassed opinion concerning this world-wide registration of that sun-radiation which reaches the earth, it will no doubt pay the trouble attentively to study to what a degree such natural registrations in soft clay can be recognised and identified, in spite of different kinds of local deviations.

Hereby it is elucidating to remark, how often especially the biennic and triennic variations are well developed and recognisable at different localities, thereby forcibly confirming the identity of the transequatorial registration.

At several parts of foreign filials of the Swedish time scale more or less considerable gaps in the succession of years measured have been possible to fill out by help of comparison with the time scale in Sweden and in other countries, the regular amount of ice-recession interpolated in this way being a good confirmation as to the correctness of the teleconnection.

A further example of a direct confirmation as to the correctness of such a statement in advance may here be quoted.

During a reconvalescence from an ophthalmic eye-operation in 1928 I had proposed EBBA HULT DE GEER to try to date some varve measurements, executed in Iceland in 1919 by H. WADELL and E. YGBERG. After extended comparisons with the Swedish time scale she succeeded in dating the measurements in question, four in number, as corresponding, two of them to the years −974 to −1066, and the other two from −1095 to −1147.

Thus there was, between the two series measured, an interval of 28 years.

The conformity with the time scale is quite satisfying, but on my proposition at the publication of the results also curves representing the gap in advance stated were represented with the identified Icelandic curves.

Some years after this publication an Icelandic geologist, J. ASKELSSON, measured several varve series within the same southwestern part of Iceland, comprising also the gap between the varve series above mentioned.

As predicted in advance, the gap was now directly determined to comprise exactly 28 years. ASKELSSON's graph is here given on p. 224.

The measurement of ASKELSSON, being reproduced on an uneven scale, making it difficult to be compared with the time scale, soon afterwards was reproduced on the same scale as a dozen of other diagrams from the same epoch in Stockholmstraktens Kvartärgeologi, Fig. 30, where it is abundantly certified how reliable was also this teleconnection, also predicted in advance and afterwards confirmed in the field.

Already several years ago, when such a highly estimated meteorologist as W. KÖPPEN, had expressed the opinion that annual temperature variations could not be identified on the opposite sides of the Atlantic and that teleconnections by varve variations thus were hopeless, I made a careful comparison and found that being, as to annual means of temperature, a complete mistake, even concerning the mostly icecovered Greenland, where the annual variations also were strikingly corresponding, though inverted, as seen in Fig. 4. The mistake may have had its explanation in shorter temperature deviations, following the more irregularly passing barometric minima but compensated during the whole of a year.

This concerning the transatlantic conditions. As to the transequatorial ones, illustrated in Pl. 89, the conditions seem to be rather analogous. In the graph Fig. 5, are given the annual temperatures in question from northern Europe and Argentina, as being formerly glaciated latitudes, and thus comparable regions, namely in Cordova and Buenos Aires, as measured by thermometers, and from New Zealand according to tree-ring measurements by EBBA HULT DE GEER; and, for a comparison, corresponding annual means from northern Europe, in Stockholm and Berlin.

A close study of the graphs in Pl. 76 and Figs. 4 and 5 seems clearly to show that the variations in question all the same, whether they be registered by annual clay-varves, annual means of mercury reading, or by annual tree rings, do follow each other so closely that they indicate one and the same original factor.

Biennic variation.

Already at an early stage of these investigations it appeared that among the great number of different variations such ones of a certain kind were often returning, though with very irregular intervals. Still by continued comparisons these intervals were found to be, at different localities, always of an exactly corresponding length of time, with only quite subordinate exceptions, no doubt due to local, subshadowing causes. This concerns the biennic variations. It is to be remembered that the term biennic here is used in the sense of: »occurring on every second year», when speaking of biennic peaks; but in the sense of: »lasting two years», when speaking of the biennic cycle as a whole.

In order to get a clear oversight over this remarkable phenomenon I erected graphs exclusively showing the biennic variations by small keys, directed upwards for biennic peaks on odd years and downwards for even years. To emphasise the corresponding length of identic intervals those were sometimes represented by like-sided triangles (Data, 20, Pl. 4) for the years between — 1000 and Zero, or the limit between the Finiglacial and the Postglacial subepochs.

This so-to-say extracted graph, from which the more irregular and multifarious variations were left out, affords in a very clear and impressive way the constant and rather striking correspondence between connected biennic varve series at different localities in different countries even in different parts of the earth.

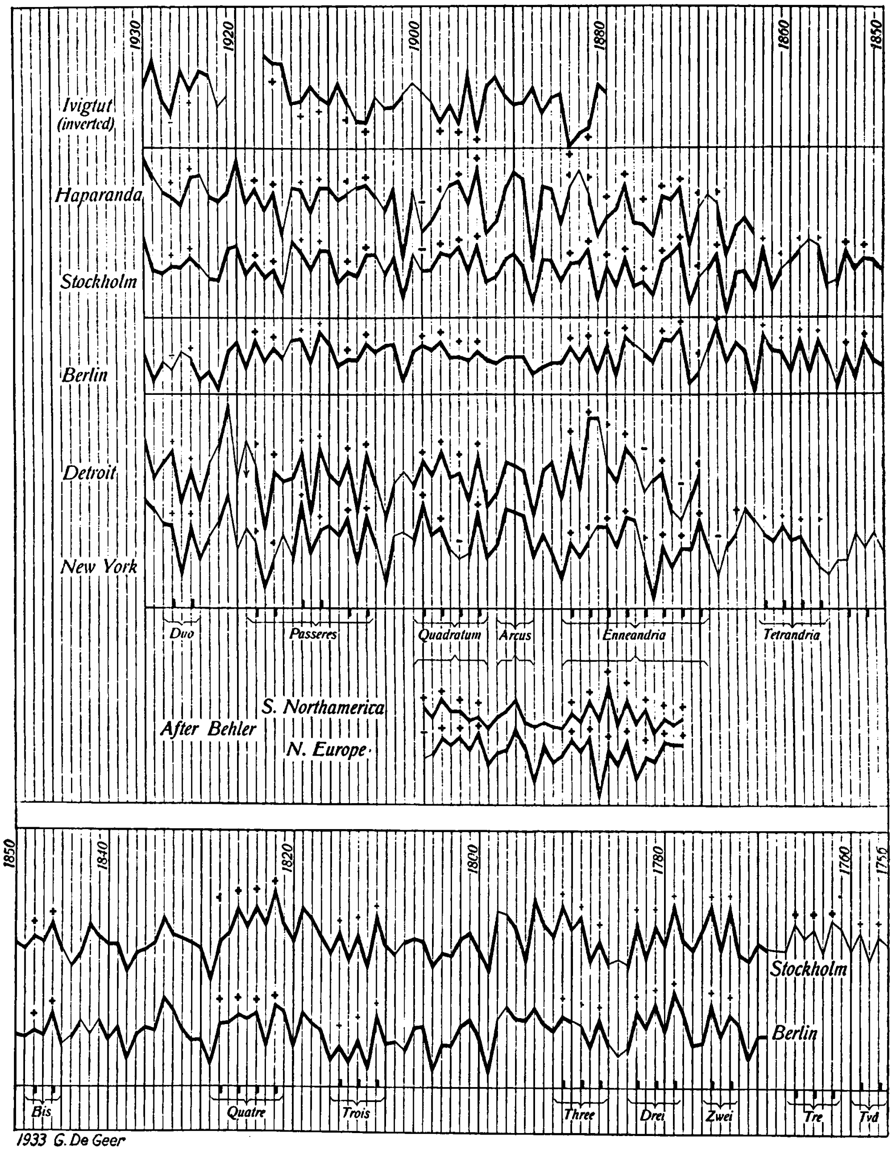


Fig. 4. Annual means of air temperature.

It is worth while to look through the details of such a graph carefully and thereby personally to state the undeniable, exact correspondence between the overwhelming number of biennic constellations and their intervals, decade for decade, century for century. It is easily understood that the relatively few and sporadic exceptions must be caused by an overshadowing majority of exact correspondence.

The phenomenon of biennic variations has been followed over practically all the directly measured parts of the time scale, hereby included the last one and a half century, the directly measured air temperatures of which showing quite analogous biennic variations. It is very remarkable that the same is the case with

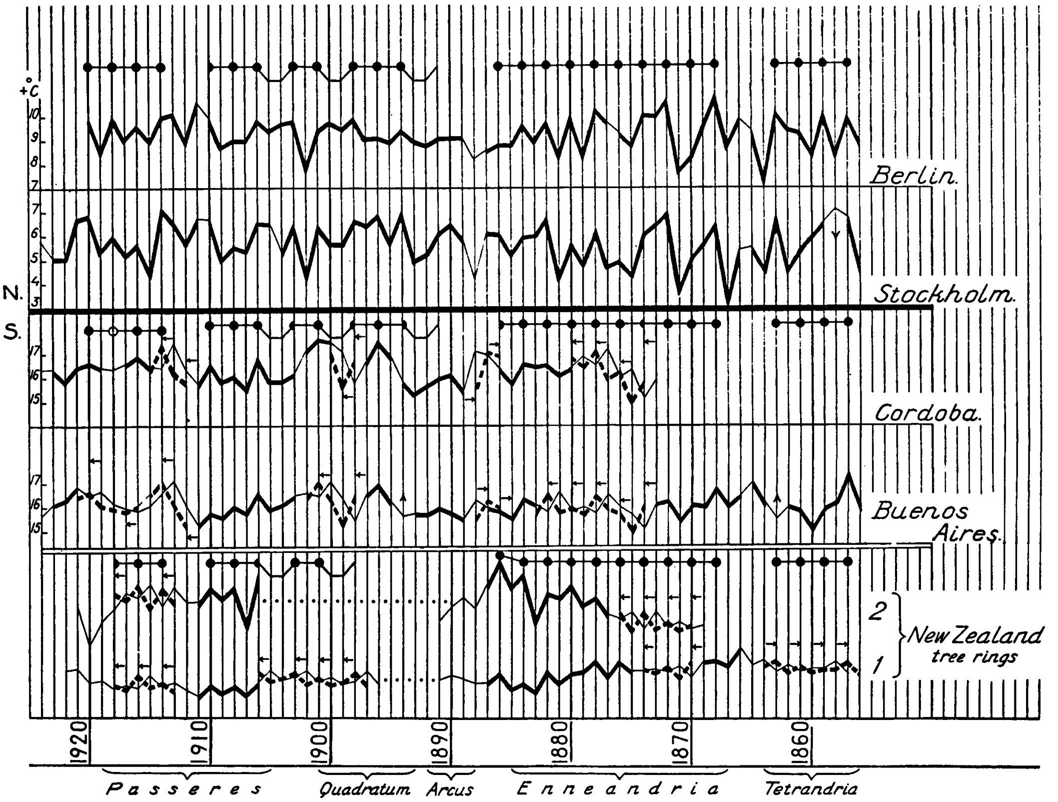


Fig. 5. *Annual Temperature teleconnections between N. and S. Hemispheres and tree rings from New Zealand;* 1: White pine = Podocarpus dacrydioides; 2: silver beech = Nothofagus menziesii. Years: A.D. Other signs mainly as in Fig. 1.

some newly published varve series, measured by C. CALDENIUS in Carbonian varves from southeast Australia and by O. KULLING in precambrian varves from north Sweden.

So far it could be presumed that my suggestion concerning the biennic varve-variation could point at a special shadowing effect of certain cloud-like circulating concentrations of meteoric, originally telluric matter at their conjunction every second year between the earth and the sun. More scarce triennic and quaternic variations might be caused by similar meteoric masses circulating in wider courses.

Biennic variations important for datings.

First of all, these biennic cycles have been of a special importance to the dating of new varve series of more or less unknown age.

Therefore, when a new-measured varve series is to be examined for dating, the standard graph of biennic constellations is to be used about as the sexual system of LINNAEUS and, when its place has been found, the whole of the corresponding variation will be recognised on the time scale. Of course the possibility of the comparison is depending of how normal the new-measured curve may be.

Earlier it was often a time-craving and rather difficult task by long continued tracing finally to hunt up the right chronologic identification.

Now this difficult procedure became utterly simplified. From the ordinary diagram of a new-measured varve series the maxima of its biennic variations were plotted upon a special graph on the same scale as the general biennic graph, and by such a comparison the possible similar combinations generally very soon were found, whereafter the real identity could be certified by comparisons of the complete graphs.

This meant a very important step forwards in making new identifications incomparably less difficult and more time-saving. Thus in 1933 a continuous graph of 4000 years with biennic variations was published in the report of the International Geologic Congress in Washington and is here given as Fig. 4.

Possible climatic indications.

As to the number of years representing the biennic variations during the sufficiently well represented parts of the late Quaternary period, the normal amount seems to have been about twenty percent or one fifth, especially so for the greater part of the very Postglacial epoch. Though no doubt it is unsafe to judge from such a limited material, the rather corresponding percentage of biennic variations during so different periods seems to make further comparisons very desirable as affording a new means of comparing the conditions determining the radiation from the sun to the earth during considerable periods.

So far we may presume that my suggestion concerning the biennic variations in the quantity of annual varve sediment and the corresponding amount of melt-radiation were caused by a shadowing biennic occurrence of cloud-like concentration of meteoric matter, circulating in a two years' orbit.

If this assumption should prove to be acceptable, it ought to be a consequence that the shadowing causing the biennic variations also should cause some lowering of the temperature on the earth, and from this point of view it may be worth while to throw a glance upon the curve on the plate named, exhibiting the variations in the percentic amount of biennic years, impinging upon the temperature caused by the ordinary radiation.

From the fact that biennic constellations seem to be more marked and constant than most other constellations it may be induced that their influence upon the radiation also may be noteworthy, though perhaps not always predominant.

During the Postglacial epoch it may be possible that the much discussed Mild Stage may have coincided with a minimum of shadowing biennic cycles some four thousand years after Zero.

Between five and, nearer to, six thousand years after Zero, or about one thousand years B.C., there were a couple of centuries with somewhat more than 25 % of biennic variations, and that may well have some connection with the bad climate reported from about that time.

A maximum of biennic variations amounting to somewhat more than 50 % of all the years occurs a little more than thousand years before Zero, or about at the time when, at the end of the Gotiglacial subepoch, the Final moraines undoubtedly indicate a cold interruption in the great ice-recession.

A lower biennic maximum occurs nearly a thousand years after the Zero year, when the land-ice was reduced to the northernmost mountain region of Sweden, possibly causing the Tärendö moraine.

At the midst of the Gotiglacial subepoch there was another biennic maximum reaching nearly 50 % of all the years and perhaps connected with the short stationary stage of the Göteborg moraine.

On the opposite, the glacier maximum with the important ice-extension at the beginning of the Gotiglacial subepoch is not at all connected with any high amount of biennic varves, which rather happen to exhibit a minimum. Anyhow, it is evident that this important glacier maximum must have been caused by another and mightier factor. Still these suggestions are at present only tentative.

Being certified that the ice-oscillations in question were synchronous everywhere, it seems that their cause must be sought in some astronomic event, of which at present we do not know any more than the very dating to about 15,000 years before our time.

Locally developed varves, a hindrance to mathematic calculations.

It is necessary to emphasise that varve measurements have to do with numerous sources of error. Thereby at several localities only some part or other of the entire varve series may be normally developed and thus really apt to register the general climatical variation, which is the main object of geochronology and its teleconnections. On the contrary there are not seldom quite a number of varves which, from different causes mentioned among the sources of error, have little or nothing to do with the normal climatical curve and are so much deviating from this latter, as if they were drawn in a quite arbitrary way. Of course it would be very misleading to mix up in a calculation such deviating varves with the really normal ones. Before we can expect any help from mathematical calculations, it will thus be necessary to bring about a considerably larger material, allowing a systematic elimination of all irrelevant figures.

Such an elimination is going on successively by means of careful comparisons of corresponding varve series, having started from a very great number of close-connections which had an indubitable proof of their relationship already by their geographic situation near to each other.

As will be shown by a close study of the numerous corresponding varve curves here published, this graphic method, which is the only possible one, is still quite sufficient for reliable correlations and all necessary controls.

In order to lay stress upon the essential difference between varves which, from the graphical comparisons, can be considered as more or less normal and other, quite local ones, the former are printed with bigger types and the other with smaller ones, as a warning against misleading confoundings.

From the very nature of the varve registration and from a rather long experience, it can be stated that there is a very fundamental difference between other relatively simple and homogeneous variations, out of which the dominating law can be extracted by mathematical analyses and, on the other hand, the rather complex variation of the soft clay varves, in which are implied so many different sources of error, that these are predominantly registered at several localities. At other ones, it is only by the evident congruence between more or less dominant parts of curves from different regions, that it is possible to make out a common, universal variation and, on the contrary, to state along which other parts this latter is concealed by irrelevant factors, which must not be allowed to obscure the great general phenomenon.

It was also not without hesitation that I published the numerical values from the measurements, but after the memento given above, it is to be hoped that the publication of also local figures will not do any harm, and they may even be of some use in the case of coming local, detailed investigations in the neighbourhood of localities with varves, showing local deviation. Sometimes also among the published series there occur some localities, exhibiting mutually corresponding variations, which evidently have overshadowed the normal curve, but still may be of use for continued studies concerning local climate or other local factors. Furthermore, in the very diagrams often there was not place enough to mark out all the zero lines.

Nature of varve deposition.

Introduction.

While the varves proper represented the finest deposit from the glacial melt-river, its more proximal sediment, deposited at a shorter distance from the river mouth, was more and more mixed with sand and ultimately also with gravel. At the very mouth of the melt-river the current was sufficiently strong to carry pebbles, and here in the very glacier vault heavy submarginal deltas were heaped up during every melting season of the ice recession, radially, thus giving rise to the renowned gravel ridges called oses or, at stationary ice-borders, transverse oses or marginal terraces.

Thus every annual deposit consists of one submarginal, ultraproximal part, more or less boulder-bearing and gravelly; one sandy zone of transition with current ridges; and one extramarginal, distal zone of a widespread layer, representing the clay varve proper with a distribution respectively proximal over to distal and finally ultradistal from the landice-border, and forming respectively macro- and microdistal varves.

It was by means of the numerous geochronological measurements that the whole structure of the melt-river sedimentation was followed up in detail and found to be one continuous complex series with a coarseness of grain gradually decreasing at the same rate as the carrying power of the melt-river (p. 260).

As will be mentioned below (pp. 85—95, 107, and 136—138), I observed such very thin layers or varves at several isolated and dislocated occurrences along the oses, but they were for a long while preserved in the collections as being not possible to measure like the ordinary varves. As evidently, no doubt, being deposited at a great distance from the proximal part of the varves, they were called macrodistal, or, when only possible to measure by magnifying: microdistal, or, when impossible to measure at all: ultradistal varves.

Earlier, generally different parts of that sediment had been considered as independent deposits and described separately, about as pre-Quaternary formations, in that order in which they were generally found and which was tacitly assumed as their relative age or order of formation.

Thus in the central parts of the glaciated regions, as e.g. in Sweden, the till was generally found immediately above the bed-rocks and at the bottom of the Quaternary deposits. Thereupon followed, at some places, the gravel and sand of the oses which, as being an important road material, is often exposed in special large sections and described as a special formation. As the next in the time succession generally was put the so-called glacial sand and upon this the glacial or varved clay.

A detailed study of numerous sections, and of one and the same section as extended from year to year, made it possible to identify and follow the same annual varves from their fine-grained facies over to their more and more proximal one, or the so-called glacial sand with more and more sandy clay-laminæ and finally with a rapidly growing thickness and coarseness uninterruptedly over into the very gravelly and pebbly ose deposits. All were found to be one continuous series of synchronous members of the same mechanical and glacifluvial assortment from the morainic raw-material.

The apparent stratigraphic succession of the different synchronous members in reality was caused by the rather regular recession of the land-ice border and the outlets of the melt-rivers, whereby more distal material was transgrediating over the more proximal one, seemingly forming independent deposits.

In the same way it was evident that the youngest till-beds could not everywhere be synchronous, but that e.g. the till-deposits in Germany were many thousand years older than the recent moraines in the Scandinavian highlands, not to speak of those in the polar regions. Hence it was a serious chronological lapsus to assume genetical subdivisions to be identic with chronological ones and to use such a definition as: »younger than the youngest till» of a certain region as being = postglacial. This was a mere word, but a misleading and narcotic one, which ought to be definitively given up and replaced by the purely genetic term: postglacigene.

In the same way, in lack of time correlations, it has been rather common to publish maps of striæ from the whole glaciated region as if they were contemporaneous, though the very diverging glacigene distribution of leading boulders long since has made it obvious that the flow of the land-ice has been much more complicated having changed considerably, exactly like the striæ.

Now, when the recession of synchronous ice-border lines from the last glaciation are possible to date and exactly to map out, it is also often possible to date the formation of corresponding striæ which, in supramarine regions are found to run at right angles to the ice-borders, here only determined by melting, while in subaquatic regions it is often possible by the angle between striæ and ice-borders estimating to what a degree the ice-recession has been determined by fracture. A systematic study of the origin of the striæ is not possible without a dating of the corresponding ice-borders.

To a certain extent the same is true of giant kettles and other water-worn markings of subglacial melt-rivers, when they can be distinguished from shore-kettles and other markings by wave erosion. Still, melt-water markings which earlier were mentioned as formed by hypothetical water-falls, piercing the whole of the ice-thickness and water-depth, are now referred to the submarginal part of the bottom-rivers, before these attained their ose-deltas and were still running too rapidly for deposition only leaving traces of water-wear. Those bottom-currents must have migrated sideways rather considerably, so as to be able to bring together all the material heaped up in the ose-deltas and which is often very much heavier than the till of the region. This explains also why the giant-kettles do not occur exactly along the oses, though generally in their neighbourhood, an occurrence, which earlier no doubt prevented their being put into connection with the oserivers.

In order to get a quantitative evaluation of the late Quaternary process of sedimentation it would be desirable not only to determine the original deposition of the glacial melt-sediment but also as far as possible to follow its postglacial redeposition as to the representative area here described. This could be tried in the following way.

The clay-material which during the land-emergence was degraded from the upheaved sea-bottom gradually, as unvarved, postglacial clay, became redeposited in the lower depressions which were better protected against the waves.

During the actual stage the results of this redeposition is to be found below the sea-level. It is very obvious how exceedingly plain is the bottom of the sea within as well the strait of Lilla Värtan as Brunnsviken. Considering the knobby topography of the region above the sea-level, the remarkable flatness below the sea no doubt is mainly due to the levelling effect of clay-sediments, as well late-glacial *in situ* as postglacial, redeposited ones. The thickness of the former one can be possible to determine from the varve-measurements, and it is also possible to get a minimum figure for the postglacial layers already by determinations of the total thickness of the clays below the sea-level. For this purpose it would be sufficient to execute soundings and borings through the whole of the clay layers. This would be relatively easily if made from the winter-ice by observers on skies, along the straight tracks of which it is easy to plot the observations accurately.

The number of the profiles of course will depend on the amount of thickness variation exhibited by the clay.

Oses.

Introduction.

Perhaps the most striking and fascinating Quaternary feature in the Swedish landscape is meeting the eye by the marked, long, winding, forest-covered ridges of gravel and sand which, as a rule, are following the bottom of valleys, or also passing out across the plains, lakes and rivers or even across meeting hills (Pls. 2—14, 54—58, 68—71).

Already from prehistoric times those smooth and dry ridges often were used as natural roads, just as the Indians in America used the deserted beaches from their glacial ice-dammed lakes.

From their importance for any easy communication through regions often rather stony or swampy, the oses often determined the foundation of new settle ments and very early must have attracted the attention of the aborigines.

But from a practical appreciation to a real understanding of the ose phenomenon it was a long way.

A good expression of the difficulty of finding a natural explanation of the ose-phenomenon is given in the following tale in the style of folk-lore from the plains of the province of Nerike.

»It was in the olden time of great dragons. The warm southern seas crawled of enormous sea-serpents. Once they were struck by a terrifying plague. Those who could escape, fled, struck by awe, towards the north and cooling waters. But so terrified they were, that many of them rushed up on land, before dying. There they became petrified. Their scales and bones were all changed into pebbles, and that was the origin of the long, winding oses, which really remind of some exotic, strange monsters, which have crawled up, invading our nordic landscape.»

The great pace-maker of modern natural science in Sweden, CARL LINNAEUS, already in 1747 said: »When shall our Swedes become as attentive as to describe all the oses of Sweden and thereby to lay a foundation for scientists with respect to the first emergence and origin of Sweden.» (CARL LINNAEUS, Wästgöta-resa. Reprint, 1928. Göteborg, 8:o. P. 14.)

Evidently LINNAEUS suspected that the pebbly deposits of the oses had some connection with the land-emergence, and this also was the assumption of several other scientists, who speculated upon the origin of the oses.

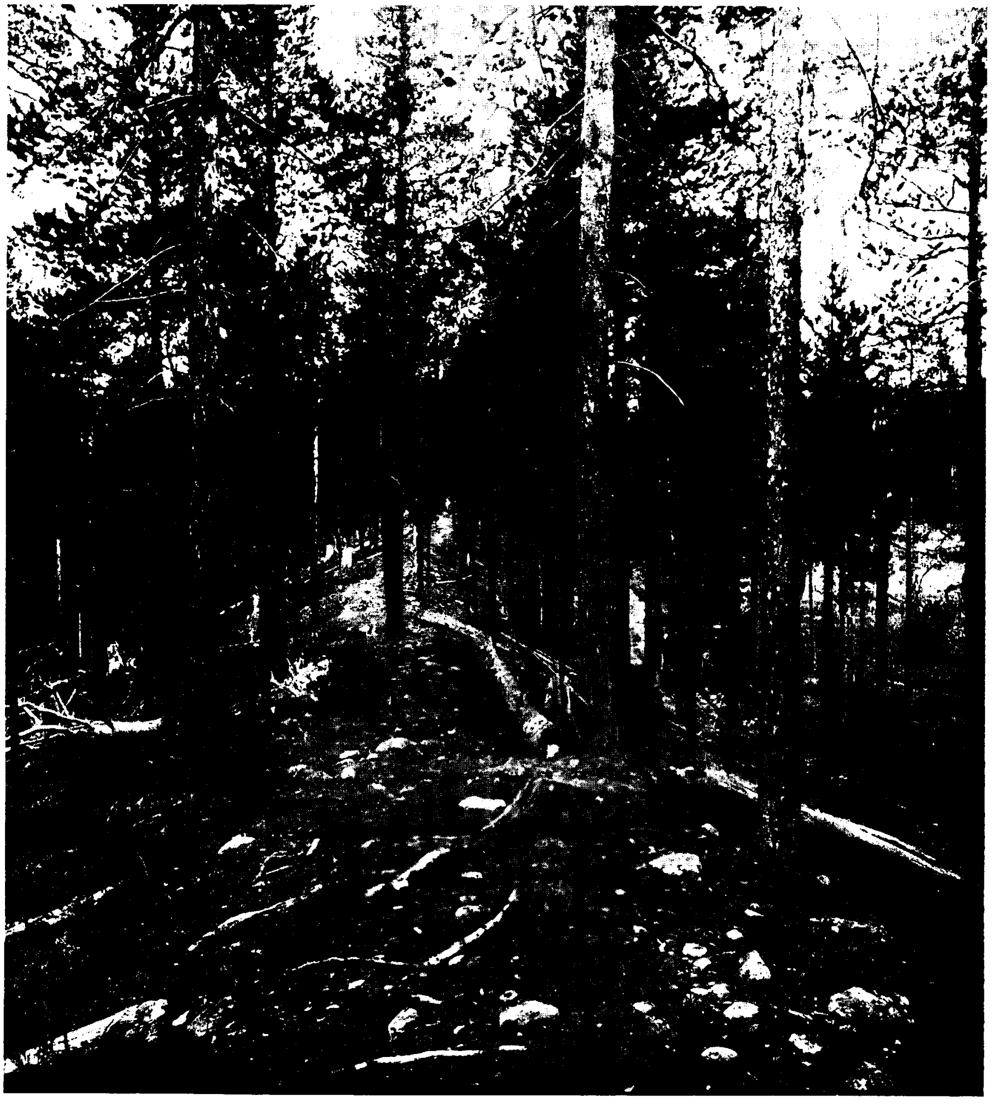
But during the childhood of geology, when careful observations in Nature still were very insufficient, it was a natural consequence that every attempt at an explanation of such complicated phenomena as oses must be rather hypothetical and that every hypothesis, having explained only some part of the phenomenon, must cede its place to some other explanation, until the series of tentative explanations could be substituted by direct, detailed observations, showing up all essential parts of the normal ose-anatomy and of its real origin.

By following, in the vicinity of Stockholm and Uppsala, the successive cutting of several great ose-sections by detailed levellings and measurings, I had the opportunity of gradually getting a large collection of facts, fixing as well the inner structure of the original ose-deltas as their actual, secondary, exterior shape.

What made it possible in this part of the glaciated area to discuss and illustrate more fully as well the formation as also the partial deformation of the oses, was that here they were deposited below the sea-level, whereby not only the coarser, real ose-sediment, but also its finer constituents of sand and clay were deposited close by. Here, consequently, the whole of the imposing annual phenomenon of late-glacial ice-melting could be studied in its totality, with its different parts completing each other, and here, furthermore, the later postglacial marine deposits clearly certified the secondary, partial degradation and ose-masking, which is necessary to bear in mind in order really to understand the great phenomenon of ice-melting which put an end to the Ice Age.

It appeared that the original ose-deposits were delta-like and flat-topped with current-bedding, having its general dip towards the distal, or here about to the southern side (Fig. 6).

Along both sides of the delta, and also around so-called *åsgropar* or sinkholes within the deposits there often occur dislocations, sometimes with a considerable throw. Thus along the west side of the ose at Uppsala I could fix in detail two faults, having together a throw of more than 9 m, indicating that along this



Ose ridge with steep slopes. Typical pine forest. Crest: ancient riding path. Right: olden road and coach. Supramarine deposition, spared from later wave-degradation, the slopes only adjusted by down-sliding. Loos, Hälsingland. Photo H. Hesselman, 1903.

Ose ridges winding across lake Storsjön and partly visible only as a row of small islets or shoals. Årsunda, Gästrikland. Photo Aeromateriel A/B, G. 189.

Ose ridge crossing river Dalälven. Hedesunda, Gästrikland.
Photo Aeromateriel A/B, G. 183.

Narrow ose-ridge, flattened by the road. Right and left: river Dalälven, here crossed by the ose. Hedesunda, Gl. Photo C. G. Rosenberg, Sv. Turistfören.

Flat ose-ridge passing out across the plain and marked by the olden high-road following its crest and a rail-road following its base. Clay fields covering the lowest part or real base of the ose-sides. Hille, Gl. Photo C. G. Rosenberg, Sv. Turistfören.

Ose ridge deposited in an ice-dammed lake, near the ice-shed and the high mountains. Handöl valley, Jämtland. Ice-lake shore-terraces in the back-ground.
Photo Nils Thomasson, Åre.

Fig. 6. Uppsala ose. Section at Asknäs, Ekerö, W of Stockholm. Primary distal ose lamination. On top: redisposited wave-rolled gravel. Photo J. Dylik, 1934.

side of the ose a subbasement of at least that thickness had disappeared, being evidently the ice-basis of the glacier-vault within which the ose-delta was deposited.

Not seldom such basal remnants of the marginal ice-vaults by a covering of ose-sediment were prevented from flowing away and could be covered by several tenths of annual varves, before they melted and caused a local sinking down and a considerable dip of the ose-varves. This is the reason why the varves in the exposures along the sides of the oses as a rule are so dislocated that their thicknesses are quite falsified. As the temperature of the water at the sea-bottom in those masses of melt-water must have been near the freezing-point of fresh water, it is easily understood that the melting of such imbedded bodies of ice must have required many years, as shown by the number of dislocated varves, sometimes amounting to more than seventy.

Besides the dislocations by melt-sinking also other ones, caused by slidings out from the original steep delta-sides are quite common. They commenced no doubt very often as soon as the delta shores of ice withdrew, and, as long as the sea-water was too deep to allow any wave movement at its bottom, the slope of the slidings may have been relatively steep, but, judging from the actual minimum depth in the most different parts of the water, at which fine sediment is left by natural selection without being transported farther off, it seems to follow that — the sea-bottom may be rising or sinking — everywhere in open situations no clay sediment will be left in peace at smaller depths than 50 m. Thus it must be assumed that bottom-waves at very strong winds must be able to carry away the finest sediment from more shallow parts of the sea.

Therefore it can be expected that, when the water-depth in closer situations had been reduced to some amount more or less below 50 m, some erosion by storm-waves may have shown its first traces along the easily eroded and still rather steep sides of the oses.

Hand in hand with the land-upheaval the eroding power of bottom waves increased together with the coarseness of the material washed down from the oses. When these finally rose above the surface of the sea, the ordinary shore-action in an often rather intense way put the last hand at the secondary deformation of the oses.

As I succeeded to show, in and after 1922, uncommonly heavy winds have succeeded to cut out even in coarse, pebbly ose-material quite distinct terraces of erosion at the special windward side of every gale.

After their first discovery about thirty such gale-terraces have been levelled and followed over the middle part of east Sweden. Some of them are marked on the adjoined map from a part of the ose-hill at Haga Norra or the northern entrance to the Royal Park of Haga, N of Stockholm.

On the upper, often more flat surface of the oses the waves were broken and, instead of cutting out terraces, have thrown up beaches, sometimes assembled to real beach-markets. On the adjoined map from Haga Norra such an example is given. Here the strongest waves have come from the east, and thus the beaches are often somewhat higher towards this side (Pl. 55).

The summit of the hill is 51 m a.s. and seems to have been planned off down to that level during the Postglacial subepoch and early Neolithic immigration to the middle parts of Scandinavia.

In the magnificent, great section in the southern part of the ose-hill at Haga Norra, the evolution of which I have followed during more than fifty years, the enormous postglacial degradation and redeposition of the ose material has been extremely well illuminated. In the lower part of the section the distal portion of the ose-delta has been well exposed, to the south with coarse, well-washed sand, sloping southward and in its northern part transgradiating into tails of somewhat more proximal, gravelly material.

Above a very marked, regular limit, characterised by more or less slidden varved clay, follows upwards a heavy bed of postglacial gravel to the south a few meters thick, but along a considerable part of the section rising to about or somewhat over 10 m, and all the way dipping southwards and towards the sides of the ose, in east and west, with the stratification often rather steep, or nearly as much as 30°, which is the normal talus-slope in the open air.

This means that during the postglacial upheaval of land a very considerable mass of the ose-material has been washed down by the waves from the higher part of the original ose-delta, which must have had its principal mass on the northern part of the actual hill and which, consequently, must have been considerably higher than the remaining hill, being at the same time originally limited by the steep walls of the glacier-vault.

By estimating the amount of that postglacial gravel which has been carried away by man for practical purposes and by adding a reasonable amount for that part of the whole postglacial denudation, which has occurred on the slopes of the hill, a fair idea may be had concerning the very great total of this amount of gravel and sand, which after the Ice-Age must have been washed down from the hill in question, which thus originally must have been considerably higher and have represented an imposing, steep-sided late-glacial delta deposit from about the years –1033 to –1031 before the end of the Ice Age, thus being a plurennic ose-delta.

It would of course be of great interest more fully to work out all the components, as well pebbles and gravel as sand and clay, of such an imposing melt-water-delta, but the hints here given together with the great number of measurements concerning the clay-varves may still give some idea of that very remarkable change in the radiation arrived from the sun, which has been so well registered in the melt-sediment from the recession of the last Ice Age.

Development of ose explanations.

Older theories.

A detailed study of the oses in the middle part of Sweden is especially recommendable not only because the oses here can be studied in direct connection with their finer subaquatic melt-sediment and because the ice-melting here was so considerable that the whole of the melt-deposits became uncommonly well developed, but also because the oses of this region can be directly followed over into their supra-aquatic continuation as well into the extended regions of Northern Sweden as across the supra-aquatic highland of the South-Swedish peninsula and down again to its formerly subaquatic slopes. In southernmost Scania oses also occur of the Danish and North-German type, partly covered with Baltic till and sometimes mistaken for terminal moraines.

The very marked oses in Middle Sweden early attracted the attention of the inhabitants who often used their dry and even ridges as natural roads, with their long, continuous trends and which with their common occurrence of natural water-fountains often had an obvious influence on the placement of habitations.

One of the oldest indications of an ose may be on an old map of Stockholm from about the year 1500 A.D., but a closer mapping did scarcely commence until in 1858 with the mapping work of the Geological Survey of Sweden, being probably the first detailed rational mapping of Quaternary deposits. All since that time oses have been investigated and mapped out over very considerable regions, and their origin has been discussed from different points of view, giving rise to a special literature. In 1897 the author tried to give a summary of these successive ose-theories and their different contributions to the knowledge of the ose-phenomenon, adding a new explanation resulting from his own detailed measurements and mapping work. This summary being given only in Swedish, may here be shortly reviewed.

The oriental traditions of a great flood, the *Diluvium*, for a long time were referred to as an explanation of several remarkable phenomena obviously indicating intense water-action. A natural descendent of such explanations was emitted by the Swede Sefström in his renowned theory: »*Om den stora rullstensfloden*» or On the great erratic deluge. By numerous accurate measurements all over Sweden he had discovered that the striæ radiated out from the mountainous centre of Scandinavia. This important fact he would explain thereby that the whole of the land, having been submerged, suddenly was uplifted, thereby throwing out boulders and other movable material towards all sides, in this way giving rise to the one-sided round-rocks with their striæ on the round sides and to the pebble- and sand-ridges of the oses. The radiating disposition of these phenomena was all right but the explanation which for some time arose much interest, was by and by abandoned as being too audacious and too little founded.

Some authors now tried to explain the oses as marine deposits, emphasising their water-worn material and their superficial marine shells, assumed to belong to their original mass. It was postulated that the oses should be old beaches, built up during a great subsidence of the land, but against this assumption was remarked that the oses do not follow the isohypses, but in the main are radiating about like the striæ, being not at all horizontal and not seldom following the bottom of enclosed valleys or sometimes also running across meeting heights. Furthermore the tributary oses, often adjoining the principal ones at great angles, were unexplainable to this theory. When the highest marine limit became finally fixed, it also became settled that numerous oses continue above that limit and that the origin of this phenomenon had nothing to do with shore-lines.

The fact that the oses were radiating and not parallel with the isohypses was at first disregarded. One author supposed that the material had been water-worn in high-level beaches and afterwards carried down as morainic ridges to their present situation.

A few authors tried to vindicate the morainic theory, postulating that the pebbly material could have been rounded by mutual interaction during the ice-transport, but were equally unable to explain the trend of the oses and their tributary oses often coming in at very great angles.

Still, the sedimentary origin being admitted and the trend of the oses better known from real mapping, a new stage in the explanation was taken by the assumption that the oses were deposited by rivers. Yet, to overcome the fact that the oses were passing across meeting heights, as across the whole of the Mälar valley and the heights to the south of it, the so-called erosion theory was proposed. Thereby it was suggested that the inequalities of the topography had been covered by thick layers of sediment upon the surface of which the oses could have been deposited within uniformly sloping river-beds. But this theory could not be applied to the occurrences in nature and was soon abandoned, because it would not explain from where such enormous masses of sediment should have originated, which would have been necessary to fill out the contra slopes not only to the south of Mälaren but even the northern slope of the South-Swedish highland, which also had been overrun by the ose-system, and how, after the deposition of the oses, it could have disappeared so completely without any damage on the very ose.

Thus this explanation was abandoned, still leaving behind the idea that some kind of rivers might be appealed to.

As a certain kind of general congruence had been found between the trends of oses and glacial striæ, the next step in the explanation of the oses was intended to combine running water with the ice-movement. But the first suggestion in this direction met earnest difficulties. It was, namely, assumed that the oses had been formed under long systems of ice-fissures which, from one or another cause, should have been formed and carried on in the direction of the ice-movement. Through these fissures it was suggested that local melt-water from the surface had fallen down, transforming the subjacent till into ose-gravel. The impossibility to explain the origin of such necessarily rather elongated, numerous trends of fissures as well as the obvious incompetence of falling water to build up so considerable ridges, gave a very short life to this theory. Still it had the merit of introducing into the explanation of the ose-sediment shores of ice, which afterwards disappeared.

The next theory assumed that the oses were deposited on the surface of the land-ice by melt-rivers which were assumed to have escaped from being captured by ice-fissures, the ordinary fate of actual melt-rivers on the surface of the land-ice. Therefore it was assumed that at the time in question the ice was dead, without any movement and fissures. This theory for some time was rather popular, but was still to be abandoned when, by the find of recessional frontal moraines, it was proved that the ice was not dead but pushed on during the whole formation of the typical oses. Furthermore it was proved that exactly during this time the region named as a rule was depressed below the surface of the Baltic.

This submergence, sometimes amounting up to 1—280 m lower than the present sea-level, means that the supposed surface-rivers above the levels named should have been able to bring together all their material. But with the general scarcity or even total lack of englacial morainic matter, this seemed utterly improbable. Further on the oses generally carry a great amount of gravel of quite local origin, and it was not explainable how this material could have risen so abruptly to the surface of the land-ice. Had the oses really been accumulated within river-beds on he surface of the land-ice, it was scarcely explainable how the underlying ice-masses afterwards could have disappeared without very serious dislocations in the whole central part of the oses. Consequently even this theory thus had to be given up, though it had introduced real melt-rivers with shores of ice into the discussion.

The next theory suggested that the oses along the whole of their length were deposited by bottom-rivers within long glacier-vaults at the very bottom of the land-ice. It was assumed that, though the ice was moving, the vaults named could be preserved by an equilibrium between the afflux of ice and the melt-erosion of the ose-river.

The explanation of the author.

Still, if this had been the case at all the deviations of the ice-rivers from the direction of the ice-movement, the morainic material following these latter ought to have been deposited below the moving ice. The definitive objection against the continuous deposition within long tunnels at the bottom of the ice derived from the new, detailed investigations especially at Stockholm and Uppsala, had fixed by maps and sections that the oses in question had a rhythmic composition with alternating centers of big cobbles, grading over to finer and finer gravel and sand and sometimes even to intervals without any sediment at all. Those rhythmical deposits I called centres and emphasised that they could not have been deposited simultaneously in one and the same river-bed as their rapid variation in coarseness required equally rapid changes in the transporting power of the rivers.

This was the main reason why in 1897 I published not a new theory but the results obtained by a long series of measurements and other observations. By these it had been possible in great sections directly to follow and to fix the continuous tectonics of quite a number of ose centers with their immediate extra-glacial continuation into the adjacent sea-water of local low stone-free sand-ridges, an earlier overlooked feature in the ose-tectonics, which I called current-ridges, and further on into less and less sandy clay, radiating further out into half-circular fans or aprons, gradually fading out and passing over into less and less sandy, ordinary clay-varves.

By these investigations it became directly proved that the ose-centres with their pertaining finer sediment must have been deposited successively at the very mouth of the bottom rivers, like their submarginal deltas at the same rate as the ice-border retired. This explained the rhythmical structure of the ose-material and even of such hitherto unexplained ose-hills as occur at the side of the general trend.

By the preceding theory it had been assumed that the intervals on the contrary of being secondary and eroded at the very mouth of the ice-river, which was assumed to have poured out violently, while it could have had a relatively quiet course below the ice, thus just the opposite to the results derived from my investigations. The rivers in question, namely, when opening into the still-standing sea-water, lost their cutting and transporting power and, on the contrary, must have deposited the heaviest part with which they had been overburdened as long as under the ice they had been forced forward under head from the melt-water in the fissure-system of the land-ice.

At numerous good sections it had been possible to fix by measurements, as a normal feature along the sides of the oses, marked dislocations registering the original situation of the steep ice-walls, once forming the very shores of the ose-delta and the sides of its glacier-vault. At some instances this latter may have been broken up by fracture and swimmed away, thus forming a local ice-bay, sometimes indicated by terminal moraines.

Very soon, off the ice-border, the current-ridges are characterised by a total lack of stones, even the smallest, in a striking way illustrating how suddenly the great power of the gigantic melt-rivers was subdued at the outlet into the sea. Still, as to the finest part of the sedimentation, or the varved clay, it has been found, quite recently, that its very finest particles have been distributed unexpectedly far into the open sea, at least more than 170 kilometres, still showing by sufficient magnification, a quite recognisable variation in thickness, permitting an exact dating. These microdistal varves no doubt form the very summit of this magnificent process of sedimentation, or so to say, »la crème de la crème», as being deposited far out from the coast and the different sources of error which must be taken into account concerning varves from more shallow waters.

In this way it has been possible by direct observations to trace and follow up the whole of the process of sedimentation from giant cobbles over one meter in diameter unto the utterly fine microdistal clay, and it must be emphasised that this is a relation of long continued direct observations made in a region where all the parts of this sedimentation can be studied in their mutual relations. It is therefore a misconception when certain authors are believing that my explanation is but a theory, the foundation of which can be discussed by confrontation with incomplete, locally developed or even more or less dislocated ose-deposits in other regions.

It would be more relevant first to study the phenomenon of ose-sedimentation where it is most completely developed and where its study long since from different points of view has been gradually developed and laid open as well by a considerable mapping-work as otherwise.

If this be done, it will be less difficult in other regions where the ose-phenomenon is not so clearly developed to perform such very detailed measurements, diggings and mapping-work as often seems to be necessary, if incomplete or dislocated ose-deposits are to be restored in a reliable way.

It is thus very natural that the founder of the subglacial theory himself has been led to the following conclusion: »at the same rate as you enter into details concerning the trend of the bottom-rivers, the difficulties augment with respect to a reliable conclusion; a judgement concerning the relative influence of the active forces determining the trend of the bottom-rivers, finally will be more and more unreliable. The same is true concerning the details in the tectonics of the oses, their height, their breadth, their interruptions. A solution of the problem, piercing into these ultimate details scarcely seems to be within the reach of possibility.» (Strandmark, 1885, p. 20; 1889, p. 110.)

Subaquatic and supraaquatic oses.
Radial or recessional, annual oses.

The ose maps of 1910 and 1940.

Towards the end of last century the quaternary studies in Sweden had proceeded thus far that it was possible to state how the knowledge concerning the origin of the oses had developed, step by step, to a conclusive explanation, building upon as well a considerable mass of observations and maps from a rather unparalleled ose-region as also new, special investigations.

By this discussion the possibilities for an ultimate solution had been thus far restricted that it had become possible by entering into very detailed mappings and measurements to find out and put together so to say the inner anatomy of the oses in connection with their feeding veins from the fissure systems by strong subglacial currents under head and to the extra-marginal currents spreading out the sifted, finer sediments of sand and clay, which have allowed a direct counting of the annual pulse of this great phenomenon of sedimentation.

In order to get an objective view of the ose-phenomenon I had prepared copies of the oses on a great number of the official map-sheets as material for photographic reduction to a reliable general map.

It being planned, some time afterwards, by the Geological Survey for the International Geological Congress in Stockholm in 1910 to prepare a schematical ose-map, the director of the Survey found it preferable instead to trust me with the publication of my ose-material and, by the care of the survey to get it extended until comprising the area so far covered by map sections. In order to emphasise the important difference between subaquatic and supraaquatic oses I published on the same map that highest limit of the marine, inclusive Baltic, transgression which at that time I had levelled and mapped.

By the use of this map it is necessary to bear in mind that the marine limit as well as the oses are formed successively at the same rate as the ice-border receded, so that they are strictly synchronous only along every identic ice-border, but still for every adjoining region showing the essential continuity and, as to the oses, how the outlets of the bottom rivers successively became registered by their deposits. Thus an ose-map does not give a map of the fixed trend of the melt-rivers but only of those successive delta-localities where the rivers named deposited such material as they had been able to catch during numerous subglacial displacements made necessary by the ice-movement.

As the map also gives a great number of glacial striæ, it affords a good means of sifting these as to the time of their formation by introduction of dated iceborder lines. These latter have been found not always to run at right angles to the striæ, whereas the recession in subaquatic regions has been more or less determined by ice-berg fracturing.

On the ose map here given, showing the finiglacial, recessional or radial oses, these are in a general way connected by iceborder lines, based on varve datings and making it possible to compare the synchronous proximal or ultraproximal melt-water deposition in different parts of the land. This concerns the dominating number of normal oses which consist of annual ose centres or submarginal annual rand-deltas, deposited during the ice-recession radially and successively in its direction.

Where the ice-recession exceptionally became stationary for some years, the ose material was choked up and deposited towards the sides in form of plurennial transverse oses, while at longer stops perennial oses or marginal terraces were built up (G. De Geer, 1909, p. 528, f., and E. H. De Geer, 1918, pp. 846, 849).

Ose centres (submarginal).

The dating of special parts of certain oses makes it possible to compare these with synchronous parts of other oses in different regions and thereby to get new aspects on the study of the ose problem and on the distribution of the proximal melt-sediments.

Especially in the late-glacial subaquatic regions where, by means of the occurrence also of the finer varved sediment, exact datings are possible, comparative studies of synchronous oses are very instructive as indicating the successive directions followed by the melt-rivers in the neighbourhood of their outlets. But even in supra-aquatic regions marginal and sometimes small, regular creeks of erosion may be helpful for estimating the local, annual ice-recession.

As also observed by C. MANNERFELT on the higher parts of Mt Städjan in Dalarna and by myself in Jämtland near Medstugan, the ose-ridges are sometimes rather regularly divided up into distinctly separated hillocks, which might represent annual centra and thus give some hints as to the rate of ice-recession.

Here it may also be remarked that in the more distal parts of the glaciated region of northern Europe, the oses occur in a somewhat different shape. They are often more or less covered by till, and sometimes rather dislocated. Several authors have assumed that they were deposited by melt-rivers in glacier fissures. But the sections published are generally schematic sketches only, and accurately measured, detailed maps and sections on a large scale of a representative such ose are much wanted, before this kind of oses can be satisfactorily explained. They may be distinguished as tilly oses.

By means of the varve-dated ice-border lines it has been possible to make out how within submarine or other subaquatic regions on the whole the structure of the glacifluvial oses coincides with the rate of ice-recession as expressed by their immediate continuation in the more distal varve sediment.

A greater degree of regularity cannot be expected, when it is the question of sediments deposited at the very mouth of a melt-river with varying and sometimes very intense strength of the current and further on not seldom with sudden changes of the whole river-mouth and of its ice-walls, reduced by the ice-melting or the opening of new fissures.

As a rule the deposits of such an annual ose delta·or ose centre begins with finer gravel, overlaid by a zone of maximum coarseness, often consisting of bigger, well-rounded cobbles, sometimes in a most obvious way bearing witness of the grand mechanic analysis, every year executed by the melt-rivers on the raw till-material produced by the grinding and transporting action of the glaciers.

Thus the long continued, detailed investigations and measurements which I have had the opportunity to bring about, especially in the Stockholm and Uppsala regions, have settled the fact that the oses, even where they are seemingly continuous on the surface, still in their interior consist of different centres rather sharply limited from one another. Each centre at its northern end consists of more or less big pebbles and even great cobbles, sometimes one half or a whole meter in diameter, and southwards more and more fine gravel and gravelly sand, often current-bedded with a general dip in the distal direction. Thus the oses were found to be composed of long series of individual delta-like deposits, consisting in the direction of their trend of a material so intensely varying in coarseness that a simultaneous deposition in one and the same river-bed evidently was out of question. Examples are also given by G. ARONSSON and A. BERGDAHL.

Ose river erosion and submarginal giant kettles.

On the opposite, now it was evident that the ose-material must have been laid down successively at the very mouth of the subglacial melt-rivers and thus as submarginal deltas deposited in the very glacier-vaults, by which the melt-rivers opened out into the still-standing sea-water, where their transporting power suddenly stopped up. Below the interior of the ice, however, according to my opinion, there was no deposition whatever, because here the water was forced forward under head from the masses of melt-water in the fissure system of the land-ice. This afflux of melt-water very often must have been more or less dislocated by the ice-movement and thereby it is explainable how, by such migrations towards different sides, the bottom rivers, even in regions with scanty bottom moraine, could bring together such considerable deposits as the oses. This evidently would have been impossible for a conservative river, always keeping the same trend as that of the actual ose. Now, on the opposite, the very ose registers only the succession of delta-deposits from always migrating bottom-rivers. These latter from their subglacial business only left traces of erosion and among these the most obvious generally are called giant-kettles (Fig. 7).

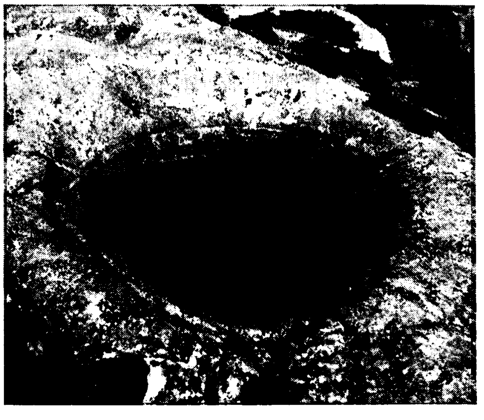
In olden time it was postulated that the giant kettles were made by giants, though they were not especially apt for cooking. Later on they were assumed to have been formed by the breakers along ancient sea-shores, and lately by cataracts falling through fissures in the land-ice.

But finally the really marine kettles were designated as shore kettles. Those formed within the reach of ordinary land-rivers were called river-kettles, while those not belonging to any of these groups, being somewhat more mysterious, retained the old common name of giant kettles. Yet, having often found that typical kettles are worn out by currents without any real water-fall and putting this together with the common occurrence of giant-kettles in the neighbourhood of oses, formed at the depth of 100—280 m below the level of the sea, I was obliged to conclude that such kettles were formed by eddies in the bottom-currents, as it seemed excluded that water-falls after having passed through englacial waters of the height named, still could have retained any force at all for boring out giant-kettles. Together with well developed kettles there often occur more or less water-worn rock-sides which are equally good witnesses of current action.

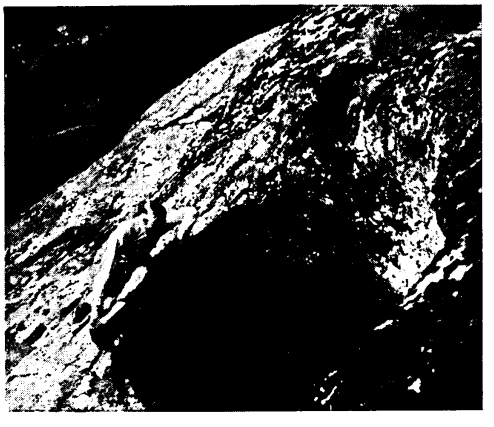
The seemingly sporadic occurrence of giant-kettles illustrates that the bottom-currents, sometimes with the exception of isolated, well rounded, spherical grinding-stones retained in the bottom of the kettles, generally do not leave any recognisable traces until reaching its very ice-border. Thus the giant-kettles' occurrence in the neighbourhood of the oses witness the migrating habitudes of the melt-rivers.

As already indicated, the late-glacial giant-kettles as a rule have not been formed out, as generally suggested, by vertical falls of melt-water from the surface of the ice falling through crevasses all the way down to the underlying bed-rocks. Such waterfalls were made impossible by the ground-water of the ice-body, everywhere within the crevasses standing so much over the sea-level as was necessary

Fig. 7. A. Giant-kettles near the sea at Strömstad. Photo Cl. Adelsköld.



B. Round kettle from the »Dead Fall», Döda Fallet, River Indalsälven in Jämtland. Photo Axel Fröberg.



C. At Steneby church, Dalsland, giant-kettle in a steep rock-side. Photo G. Lundqvist.

for making the outflow possible. Also the dominating occurrence in the neighbourhood of the subglacial oses speaks for their formation by subglacial currents.

Not seldom the kettles occur on the distal or lee-side of ice-worn roundrocks and in an attitude indicating whirls to have been caused by quite local conditions. Fig. 5 shows such a giant-kettle photographed at the NW side of the town Strömstad at the Swedish coast. This kettle was found to be 6.3 m deep, but it has been certified that even such vertical giant-kettles can be bored out by strong currents without any free waterfall.

Complex structure of the oses.

The oses themselves sometimes as exactly in the Stockholm region very obviously show that they were not at all continuous in the outset, but divided up into separate hills or centres, which sometimes are totally separated as well topographically as also with respect to their inner structure. The sections show clearly that this latter depends of their original deposition and is not due to later erosion. On the opposite, when several ose-centres have been deposited in a row, the one close after the other, they are often so well tied together and smoothened by the waves during the land-emergence that generally they were considered as quite continuous ridges. The inner structure of typical oses, however, when examined in good sections, always is found to be discontinuous and characterised by an inner cyclic structure (Pl. 9 b, 10) as to every individual centre, corresponding to the sediment in a certain clay varve, both these facies of deposition being corresponding parts of one and the same reassortment of morainic matter during one and the same year, both at the same time deposited in its delta. When STRANDMARK put forth his explanation of the oses, their inner periodic structure was not known, why he still believed that they were deposited continuously along the whole of their length, and that their interruptions were secondary and caused by erosion, while, on the opposite, it has now been shown that they are originally separated and explainable only by a successive, retrograde deposition at the very mouth of the ose-rivers in such cases where these had been captured, probably by side-fissures, and so melted out new glacier vaults.

What is said above especially concerns those extended regions which at the formation of the oses were covered by water and where thus the whole complex of melt-sediment can be studied in its mutual relations.

Supra-aquatic oses which generally are more or less separated from their finer sediment, flowing away with the running melt-water, need a very detailed investigation if the minute history of their origin is to be entangled.

Probably, in lack of standing water outside the supra-aquatic river-mouths, there will not, in this case, be so marked a marginal deposition as in subaquatic regions. In such cases it seems possible that gravelly material may be deposited also at some distance inside the ice-border and that much of the sandy components of the sediment will be spread out during flood time as ordinary river-sand, while silt and clay may follow the currents unto quiet water in lakes or in the sea.

It was especially the uncommonly subdivided topography of the Stockholm ose, having often from each other totally separated and somewhat to the side of each other situated hills, which led me to the idea of successively deposited and from each other totally separated marginal deltas, which had got their irregular situations by melt-river capturing through marginal ice-cracks.

Around the Gotiglacial Baltic ice-lobe with its iterated oscillations the oses, as already early observed in SE Scania and also at several places on the Danish isles and in north Germany were partly covered by till and even dislocated by land-ice pressure, but evidently these conditions require very detailed local investigations for a satisfactory explanation of the special instances.

But it is not at all the rule that the individual annual deltas of the oses to such a degree are divided up from each other, and, as this occurs exactly within a belt where earthquakes are supposed to have occurred, it seems not impossible that the capturing ice-cracks partly may have been caused by those very earthquakes.

Redeposition.

About at the midst of the postglacial bed of gravel mentioned on p. 66, several years ago I found remnants of somewhat weathered Baltic mollusca which, at this locality, as a rule seem to have been dissolved. Also on the great Uppsala ose on Ekerö island W of Stockholm I lately observed *Mytilus edulis* in postglacial beds of redeposited ose-gravel at the height of about 40 m a. s. (Fig. 8).

This considerable occurrence of postglacial redeposited gravel generally devoid of any subfossil remains and often in the section by its own secondary talus concealing its subbasement, several times by accidental visitors has been assumed to be ose-material in situ, and it is no wonder if the same also should have happened at other places.

Thus it has been described how, at Åbyfors near Gävle, a varved clay which with certitude is younger than the immediately adjacent ose, from which it contains laminae of downslidden gravel (Fig. 38, p. 153), is said to have been followed uninterruptedly by borings to the subbasement of the ose-material in a neighbouring gravel-pit. If this is right, the only possible explanation must be that this ose-material was not in situ, but transported and redeposited from the true ose-ridge.

On the whole the ose-deltas must have been deposited at the very mouth of tumultuous and rapidly changing melt-river deltas, which afterwards often have been seriously deformed by the postglacial waves.

This most proximal part of the annual melt-sediments is therefore often difficult to disentangle in detail without a series of successive good sections, but is, on the other hand, when followed in that way, of great interest for a detailed study of the uninterrupted succession from the most proximal and coarsest, pebbly and gravelly, submarginal ose-material, unto the finest microdistal varves, which quite recently have been found to be distinctly traceable for more than 170 km, while the very finest clay-material without visible varves evidently has a still wider distribution.

For chronological measurements the varves, deposited at a moderate distance from the ice-border, are those upon which the chronology has been founded, as being quite generally at hand and by their connection with the bottom varve at every place, exactly fixing the date of its ice-border.

Still the investigations during the last years have opened up new possibilities for utilising the more general registration of the melt-temperature, arrived from the sun, and no doubt most correctly readable in the very finest microdistal clay-varves, which are or can be made free from all essential sources of error.

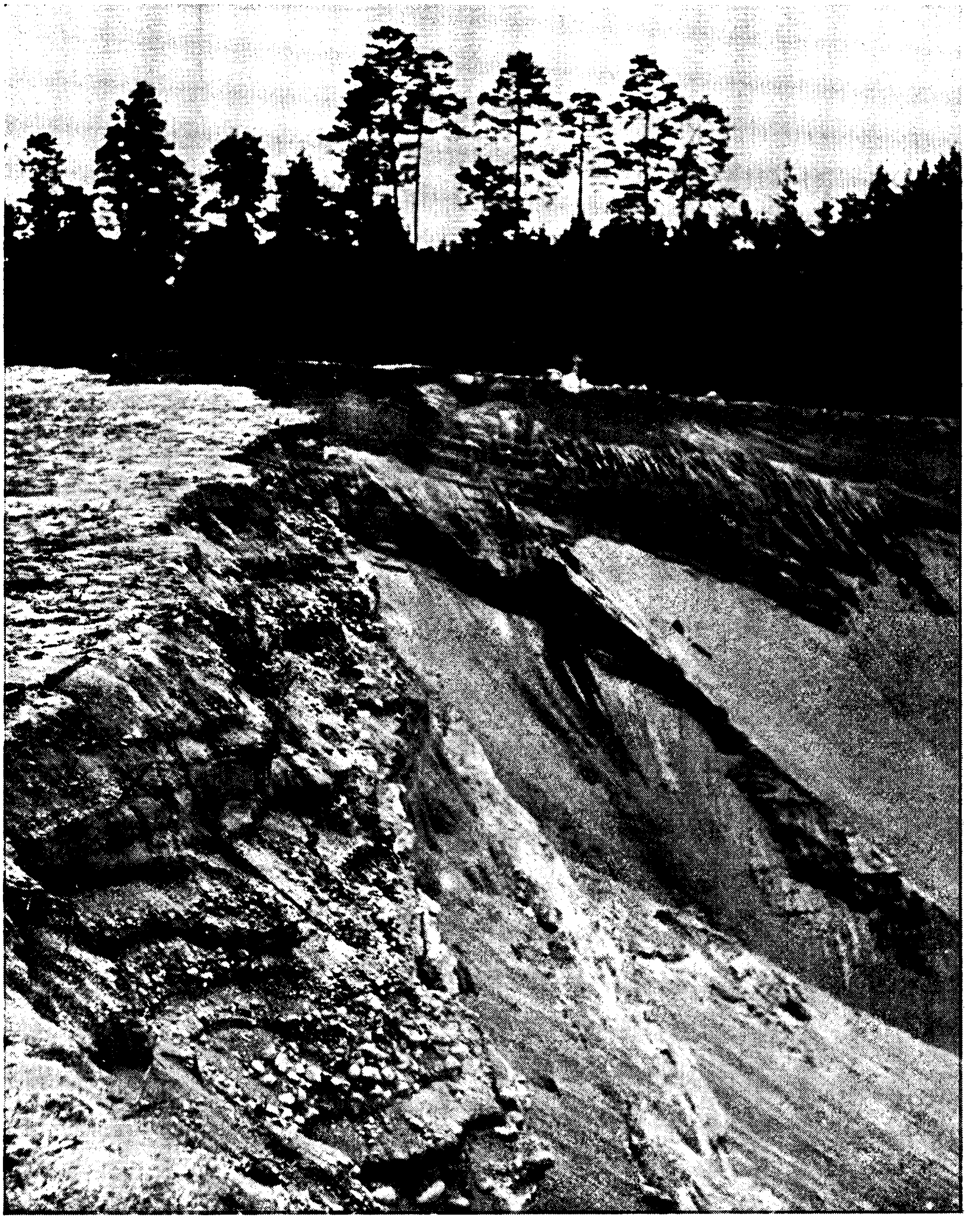


Fig. 8. Uppsala ose, Ekerö. Degraded summit covered by *Mytilus*-bearing redeposited ose-gravel and -sand. × *Mytilus*-shells. Photo E. H. De Geer, 1939.

The melt-sediments north of Stockholm.

Ultraproximal ose-varves or submarginal deltas.

Immediately north of Stockholm and its former northern custom-house, the Norrtull, and along the west side of Lake Brunnsviken runs a characteristic part of the Stockholm ose, which, by its situation near my home-town as well as by its marked morphology and its inner tectonic structure magnificently exposed in good and gradually enlarged sections, has been especially favourable for studies, during the last fifty years.

This region is here chosen as an example of the great Finiglacial process of sedimentation by the help of the adjoined map which, from several different, often considerably larger detailed maps, has been put together to the natural scale of 1:5000 being, on Pls. 56, 57, here reproduced on the scale of 1:15 000.

The very ose occurs here divided up into series of more or less isolated hills — Sw. *kulle*, pl. *kullar* — already thereby suggesting the explication proved by their inner structure.

For the investigation of these ose-hills generally hypsometric maps on the scale of 1:1000 with 1-m isohypses were used, though on the map in question only 10-metres curves are reproduced.

Ose hills at Ulriksdal.

The most pregnant features of our glacial landscape is represented by the ose. Exactly at the northern border of the map named occurs, at Ulriksdal, the most imposing ose-centre of the whole region. Evidently it was deposited by the subglacial melt-river in the northern continuation of the depression of Lake Brunnsviken. The summit of the hill rises to 42.8 m. a. s. (Pl. 8 b), and was earlier occupied by a windmill, in Swedish *väderkvarn,* thus here called *Kvarnkullen,* or the Mill hill (Pl. 54).

The southern third part of the hill is now cut away for road-material almost down to the sea-level. Had it not been for the ground-water, the digging probably could have gone down below sea-level. This it is evident that the melt-river here again used its old bed along the Brunnsviken depression after some ten years' digression towards its western side. No doubt favoured by its low situation the actual remnants of Kvarnkullen probably are the most heavy in the Stockholm region, amounting to not far from 50 m.

The ose-hill Kvarnkullen consists of at least two ose-centres though now, by postglacial wave-action, united into one hill. Still at the southern end of this hill two extramarginal current ridges are proceeding southwards. Of those the western and shorter one obviously belongs to the ose-centre which is now for a great part carried away. The other, eastern current ridge forms the so-called Polska Udden, pointing towards SE out into Brunnsviken and probably coming from a succeeding ose-centre to the NE of the former one.

The next ose-hill or the *Järvakullen* has been deposited with its south end a little to the west of the northernmost point of Kvarnkullen, well illustrating how the subglacial current by capturing has got its mouth somewhat changed. The Järvakullen was deposited with its western border against the neighbouring bedrocks, which appear at this side and rise to 46.3 m a. s., while the ose-hill in question attains 43.2 m. This ose-hill is sculptured by half a dozen marked gale-terraces.

The Järvakullen is distinctly delimited against the next ose-centre or the *Sydkullen* by a marked depression, probably indicating another small capturing back again towards the east. This ose-centre rises only to 22.3 m a. s., but its subbasement may at least at the north end go down somewhat below the sea-level as is evidently the case with the ose-dammed depression along its northeastern side.

The two ose-centres last named have short current ridges at their southern ends.

The low hill upon which the royal castle is built is probably due to a small ose-centre and this may perhaps also be the case with the small sand-hill at the chapel and to the north of it.

To the NW of the castle rises a more normal ose-centre, or *Nordkullen*, to about 25 m a. s., having on its summit an artificial excavation, may-be an old water-reservoir.

Towards NE nearly half a dozen gale-terraces have been measured.

Towards NW occur a series of smaller ose-centres, successively decreasing in height, and at the southwest side of the second one occurs the first of the annual frontal moraines, observed in 1889.

At this latitude it seems that the main deposition of the ose-river has been laid down in the depression of the bay Edsviken in the small islet *Kaninholmen*, from which now most of the ose-material is carried away, but which earlier was 19.6 m a. s. with an unknown surplus below the water.

The northernmost ose-deposit within this part of Edsviken appears as a low skerry of ose-pebbles at the narrow SE of Kasby bridge. At the opposite, eastern shore some giant-kettles remind of the whirling water of the melt-water. This last ose-centre in the Stockholm series seems to have been deposited during the year — 1016.

About at this time it seems that marginal fissures from the receding ice-border had commenced to capture melt-water from the bottom-river along the depression of Edsviken. Thus the next ose-centre at *Silverdal* is deposited nearly 1 km to the west of the pebble skerry last named. This ose-centre was scarcely of mean size and is mostly carried away.

Another kilometer farther NW the whole of the melt-river evidently has been captured in the new direction and here has deposited a very extended ose-delta in the region around and NE of Helenelund railway station.

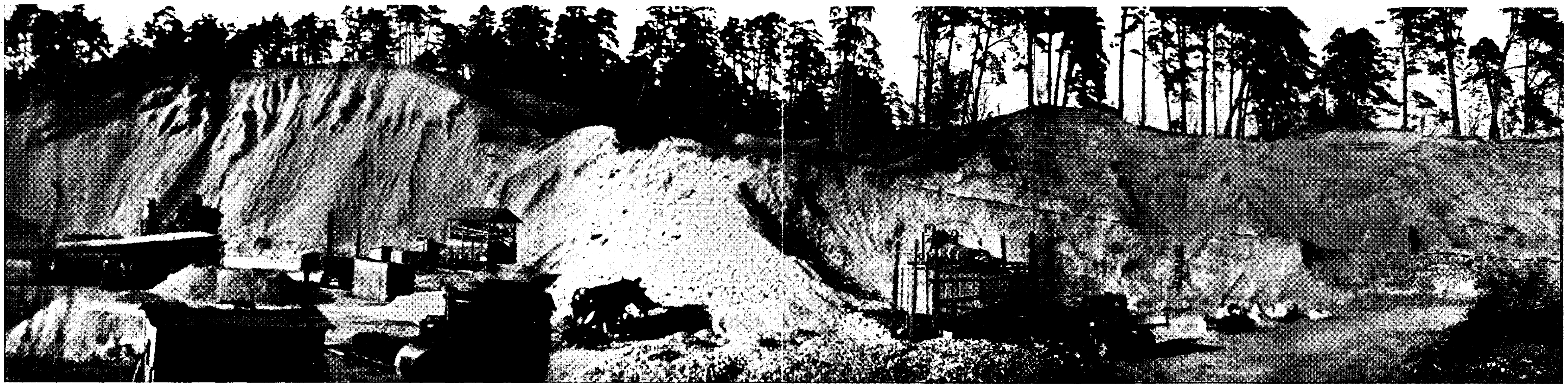
Ose delta at Helenelund.

The extended ose-delta at Helenelund rises to somewhat over 50 m a. s., or to a little more than the ose-centre above mentioned, but is scarcely of greater thickness. Its southwestern part west of the highway is mainly gravelly, while

W E

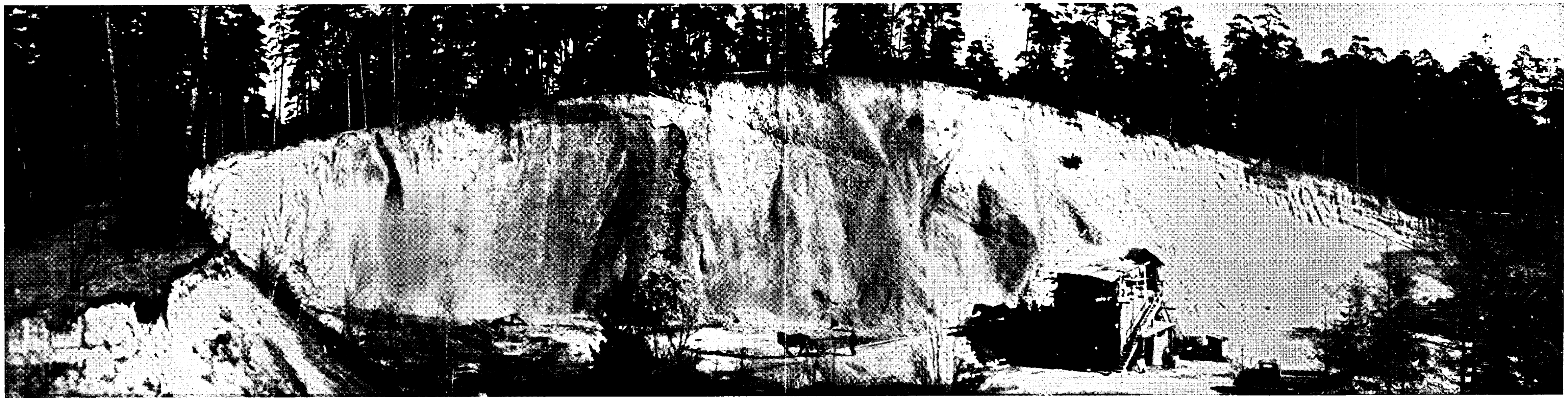
a. Stockholm S, Enskede. Cross section of a degraded ose, the surface being a level of abrasion. Photo H. Friberg.

NW SE



b. Stockholm ose at Ulriksdal. Sth. N. To the left: mainly ose centre. Right: ose centre dipping down below broken line and covered by thick, sandy varves, in right, upper corner clayey. Photo E. H. D. G.

W E



a. Stockholm ose, Haga, Linvävartorp. Typical segment of ose ridge. South end of Långkullen hill. Photo E. H. De Geer.

W E

b. Stockholm ose, Haga, Långkullen. Ose ridge perspective along the crest of Långkullen hill. Photo E. H. D. G., 1936.

most of the sandy sediment at the railway and to the west of it is now mostly taken away, thereby uncovering some parts of a frontal moraine, seemingly cotemporary with the northern part of the ose-hill in question.

In the northeastern part of the ose-hill, 100 m N of the main road, a great section shows to a depth of 20 m below the surface a continuous sequence of layers pertaining to one and the same ose-centre in this place. On different sides of the whole ose-deposition in question several marked shore-lines had been levelled, the most important one facing SW as a steep terrace, cutting right through this part of the hill at a height of 50 m with a series of beaches upon its flat summit up to a height of 57 m a. s.

The cut terrace named is fading out towards the east and grading over into a beach, indicating a western gale as its origin.

On the eastern side of the northern ose-centre there is also a marked cut terrace facing the east and situated, as to its northern part, 48.0 and southwards 47.3 m a. s. It may be possible that it can have been somewhat lowered by erosion, though certainly not as much as 2 m and, further on, it is facing east and not developed in other directions, why this terrace must be somewhat younger than the 50 m-terrace and may, as well as this one, owe its origin to separate gales. This is here noted because several facts indicate a possibility of a postglacial transgression or retardation in the land-emergence when the sea-level at Stockholm was situated at about 50 m a. s. Of the so-called twin-terraces at Stockholm the upper lies here at 42.4 m a. s. and the lower one about 0.8 m lower.

These two shore-lines were the first of the gale-shores which were identified at different places by means of their from point to point gradually rising absolute height and relative difference together with their corresponding situation, everywhere facing the west.

The detailed hypsometrical mapping of the Stockholm ose with its numerous original subdivisions in different deposits, often evidently caused by more or less considerable capturings, together with the well certified connection between individual ose-centres, current-ridges, annual clay-varves as well as moraines have directly proved that typical oses have been, year after year, successively deposited as submarginal delta-layers at the very border of the receding land-ice.

Thus the numerous different ose-hypotheses having successively delimited the ose-problem now may be said to have been replaced by direct observations. The outer and inner parallelisation between the Stockholm ose and all of its neighbours, namely, is so evident that no doubt it is possible to draw conclusions as to their similar origin, being all the coarsest components of the reassorted morainic material, the more fine-grained parts of which are deposited as current-ridges and varved sand and clay.

It is true that a considerable part of these sediments, especially the most fine-grained ones, were eroded away by running water and commonly by wave-action during the upheaval of the land and mostly during the last stages when the land surface passed the level of the breakers. At that time the very finest sediment or the microdistal clay was almost totally carried away, where it had not been protected by downwashed sand and gravel which especially was the case along the oses.

Oses in the Haga region.

This region affords several very good illustrations to the fact that the subglacial melt-rivers became captured and somewhat displaced under the indirect influence of the moving ice. Here, as at many other places, it is evident that the subglacial melt-rivers found their less difficult passage along valleys and depressions nowadays occupied by lakes, when their basins were extended somewhat towards the ice-margin or in the direction of the least resistance.

In this case this is indicated by a series of obviously waterworn rock surfaces along espceially the eastern side of Lake Brunnsviken. Thus they have been noted on the map at a narrow passage southeast of the lake, near the former Roslagstull, no doubt about at the place where at LYELL's visit in 1834 a real giant-kettle still was to be seen; further on at two places east of the narrow sound at Haga Castle and, also on the eastern shore, NE of the hill *Lingkullen*, here partly developed into a real giant-kettle.

From the position of the southernmost ose-hills it is evident that the melt-river still during their formation followed the lake depression, which at its southern end partly has been filled out by the ose sediment, as shown at the now almost totally consumed ose-hill *Tullkullen* by borings, going down 15 m below sea-level and also at its eastern side by the small pool, called Ormträsket, which is now totally filled out.

In 1882, when *Tullkullen* as to its western part still existed, I took a photograph and afterwards made a detailed survey, showing that this hill which, according to still earlier measurements originally had risen to a height of 36 m a. s., was built up out of two annual ose-deltas, of which the lower one seems to have had its proximal afflux from NW, where the restaurant Stallmästaregården now lies on a lower little ose-ridge and where a few hundred metres farther NW a beautiful giant-kettle was uncovered and is still preserved and accessible in a cellar under the county hall of *Haga Tingshus*.

Yet the upper delta of *Tullkullen* probably has got its material from the lake depression just like the headland of the hill *Bellevuekullen* and those three small hills which here are called *Kinakullarna* from the denomination of a building on the highest hill.

Probably shortly after the deposition of the deltas last mentioned, the mouth of the melt-river migrated somewhat more than half a kilometer towards the west, depositing, first, a lower delta, evidently in a depression at the south end of *Långkullen* and immediately to the north of a low rock plateau, at high-water partly covered by distal sand which, later on, when the ice-border receded, became diverted towards the east in a low sand-ridge representing what I have called a current-ridge.

The following ose-centres form a seemingly continuous ridge, which I have called *Långkullen* (Pl. 9), and from the east side of which two current-ridges have been mapped out. The older one of these is by far the shorter and is mostly covered by the younger one. The very overlapping part since a long time has been possible to fix at the western end of an extended sand-digging, cut all through the magnificent upper current-ridge and the subjacent one down to its rocky bottom and exhibiting a thin layer of dark grey autumn clay at the limiting contact with both of the current-ridges.

As to the great and higher northern part of Långkullen, it was not easy to tell how many annual deltas it represented. During the land-emergence shore-erosion had filled out such indications as originally might have marked the limits between different centra.

Therefore I tried by what I called a calibration to make out the number of transitions between coarser and finer cobble-material which could be observed at the surface and was leaving some hints as to the ose-material from which it had been washed out during the upheavel of the land.

For this purpose I got the help of eight students. We thus determined the size of the pebbles at the surface of the ose in the following manner. I followed a base-line along the water-shed of the ose with eight students placed along a number of lines, crossing the base at right angles. Every one had a cord, 5 m long, with a stone tied at its end by means of which the distances between the men were easily adjusted. At each cross-section every man had to write down on a register for his points the maximum diameter of the normal, water-worn pebbles concerning a space with a radius of 2 m. One section being ready, the whole troup moved on to the next section, and in that way the calibre of the surface pebbles was determined. Afterwards all the pebble-diameters were represented on a certain scale at their right places, and in that way the ose hill *Långkullen* was calibrated as to the maximum cobbles visible on its surface. In this case these registered only what had been left after the postglacial denudation by the waves. But even such residuary pebbles may give some hints of the original material, and here it seems to indicate the existence of at least two, but perhaps three ose-centres, though secondarily switched together and remodelled, whereby some fine pebbles seem to have been thrown up on the summit of the ridge in the last moment of land-emergence, while the coarser material at steeper ose-sides on the whole may be left in situ or be somewhat downslidden. Along other parts of the ose-sides, however, there may occur a harness of transported and redeposited gravel, covering the surface of the primary ose-material.

This calibre-measure may thus be a rather primitive method, but in lack of sections it may still be of some use as to long and seemingly continuous, narrow ose-ridges.

Storkullen ose hill at Haga Norra.

The next ose-hill towards the north, here called *Storkullen* or the Big Hill, rises to the greatest height in the environs, or to 51 m a. s. (Fig. 10 and pp. 48—49).

As affording good examples of many typical ose-phenomena, this hill has been especially studied since a long time and hypsometrically mapped out by Bennet Co on the scale of 1:1000, here reproduced by 1:3000 (Pl. 55).

As to the rocky subbasement of this hill, it may be mentioned that a short way from its southwest side the granitic bed-rocks are exposed close to the northern

Fig. 9. Stockholm N, Haga Norra. Total view of the ose summit with the main section, towards NW. Nearly half of its height is due to the redeposited material, eroded and wave-transported from other high parts, now destroyed. Photo E. H. D. G., 1936.

entrance of the royal park of *Haga* and the tramway station *Haga Norra* at a height of about 25 m a. s.

At both sides of the proximal steeper slope of the ose-hill bed-rocks are seen at a somewhat higher level or a little over 30 m a. s., probably being parts of a rock ledge running about W—E below the proximal part of the ose-hill, though probably here somewhat lower, thus affording the best passage upwards for the subglacial ose-river. Judging from the height of the moraine it may be a fair assumption that the subbasement below the main part of the hill may be something about 20 m a. s. Thus the remaining thickness of this ose-hill amounts to about thirty meters. But it is evident that such a deposit of loose sandy gravel in an open situation towards all directions necessarily during the land emergence must have been essentially lowered by wave erosion. This has also been amply verified by a really grand section which during the last thirty years has been carried on along the southeast axis of the ose almost unto its remaining highest part.

The successive situation of these sections are marked on the map with dotted lines and respective years. Thus I have had the opportunity to follow these sections during about half a century by the help of photos and measuring. Thereby it has turned out that a considerable part of the gravel-covering, which very easily could have been mistaken for a discordant upper ose-delta, in reality was a marine sediment consisting of redeposited ose-gravel with about twenty degrees dip in a centrifugal direction against the peripheral parts of the hill (Fig. 10).

Near the basis of the hill slope, between ose-deposits *in situ* and the superjacent down-wash remnants of downslidden dislocated proximal clay-varves were found.

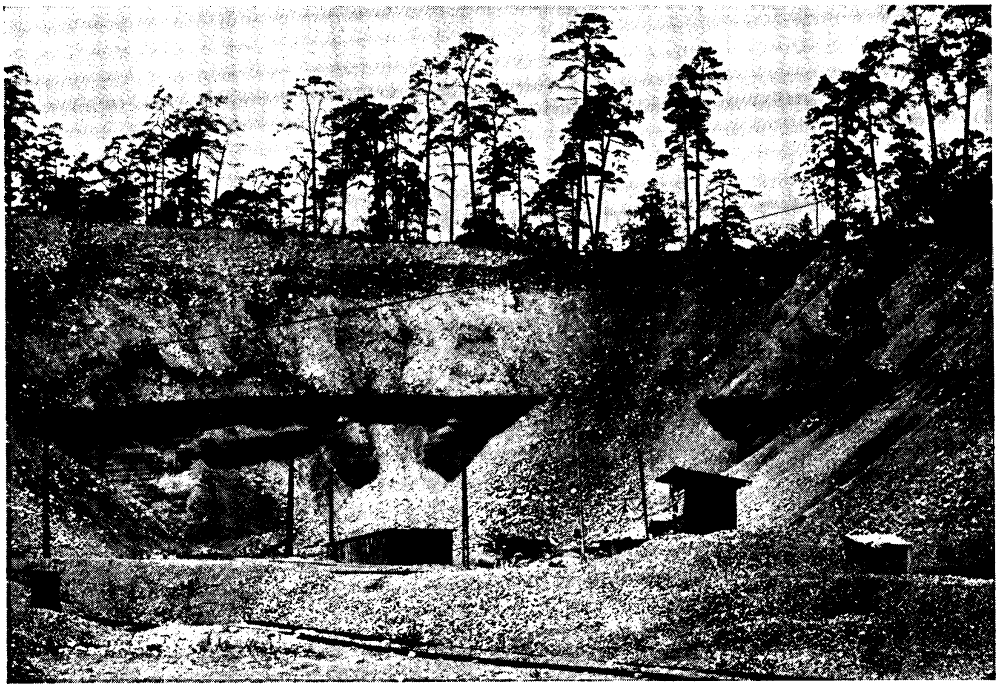


Fig. 10. Stockholm ose at Haga Norra, Sth. N. in 1919, NW wall. Sharply marked discordance between fine-grained ose-centre, below, and coarser material, above; on the summit real shore gravel, redeposited by the waves. Section at south end of the ose ridge. Photo O. Halldin, 1919.

Farther up and northwards this clay-horizon could be traced practically all along the section. At a certain division of its higher part only two small series of undisturbed microdistal varves were found, as it seemed resting concordantly upon the underlying ose-bed, and superposed by fine marine gravel, upwards more and more pebbly, this latter even at this height amounting to a thickness of somewhat over 10 m. This was at about a height of 35 m near the northwestern part of the digging in the year 1937 (Fig. 18) and observed at the SW side already in 1910 (Fig. 11).

Farther to the south, about where the surface of the hill approximately may have been some 35 m, I had found somewhat weathered but well determinable remnants of *Mytilus edulis*, *Tellina baltica* and *Cardium edule* in the postglacial downwash. As those shells were only weathering residuals, their original extension could not here be traced, but at other places in the region they have been observed to a height of somewhat over 30 m, this being still a minimum figure. Yet the shell-bearing postglacial deposits continue at those places as well as here in one continuous succession at least up to about 50 m a. s. Thereby it is certified that in the Stockholm region the postglacial land-emergence must have been at least of that amount, but at the same time no proofs have been found hitherto that it had been any higher.

No doubt there are indications in this region at about the height named, or some 50 m, of a special shore activity, possibly marking a small transgression

Fig. 11. Sthm. Haga Norra SW wall. Dark beds of micro-varved clay, covering the discordance between primary ose material, below, and secondary, marine above, dipping SW also containing *Mytilus edulis*. Photo G. De Geer, 1910.

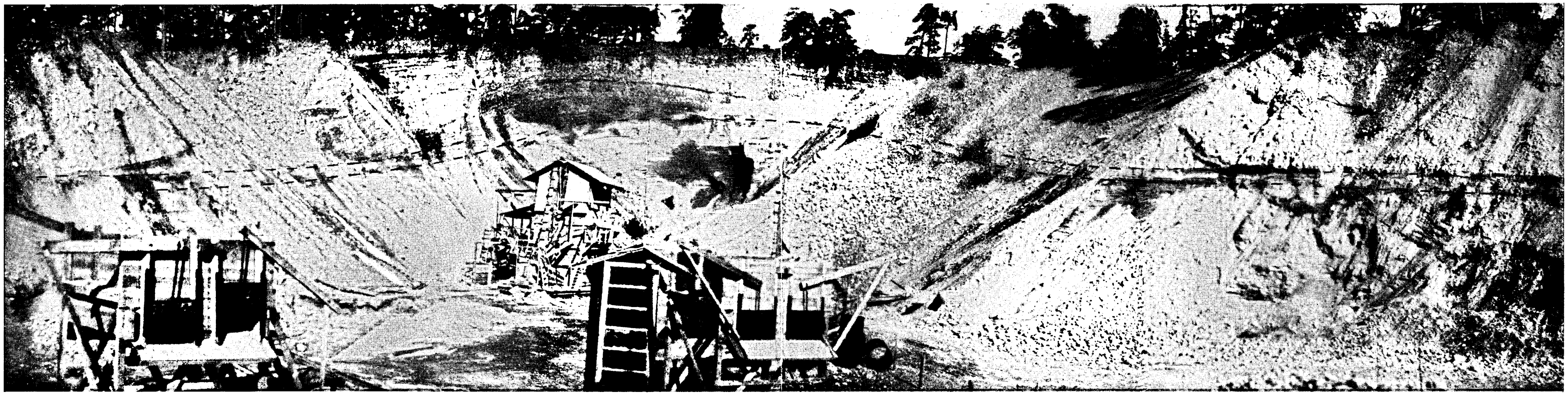
of the sea or a stop in the land-emergence, but this problem is not yet conclusively solved.

The very height of the ose-hill in question and the considerable masses of down-wash which must have been cut down by the waves until the hill was reduced to that height, may be explained by such a stop in the land-emergence.

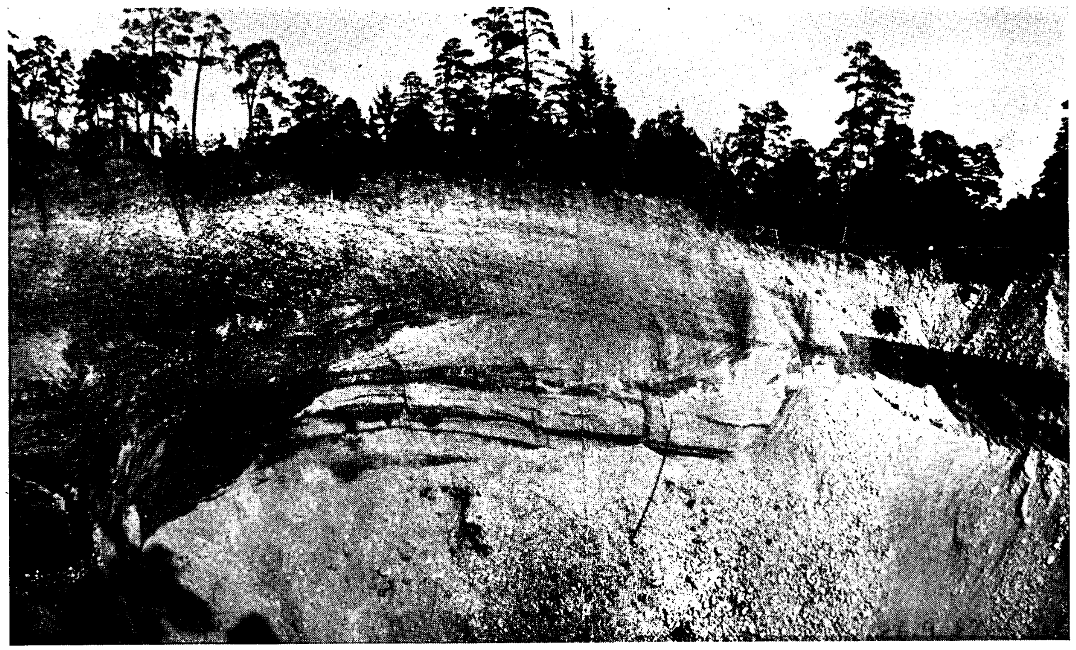
The great sections here mentioned, namely, show that along almost the whole of the inner part, being cut down to an almost horizontal bottom at about 24 m a. s., there is a magnificent cut all through up to a little more than 10 m thick such downwash, testifying a very considerable degradation of the original ose-hill.

The remnants of the original ose-deposits are rising to a maximum towards the highest part of the actual hill, here covered only by a thinner down-wash, as mostly accumulated along the more protected southern and western slopes. But the secondary degradation of the hill has been so very considerable that even a schematic reconstruction of the original delta-form would require quite a series of great diggings like those already performed. Within this latter the postglacial downwashed material may amount to about 11 m. Being assumed that this amount represents at least a fifth part of the corresponding down-wash along the other slopes which is probably a much too low minimum figure, especially when considering the finer sand-sediments carried farther away, it will be clearly understood to what extent the ose-hills of to-day have been lowered and remodelled by postglacial wave action. This must be emphasised as important to remember when studying subaquatic oses (Pl. 10).

In this connection it may be mentioned that in a great ose-section immediately to the south of Uppsala I had the opportunity of fixing by detailed measurements a series of big, marked faults with a throw of together not less than 9 m, evidently



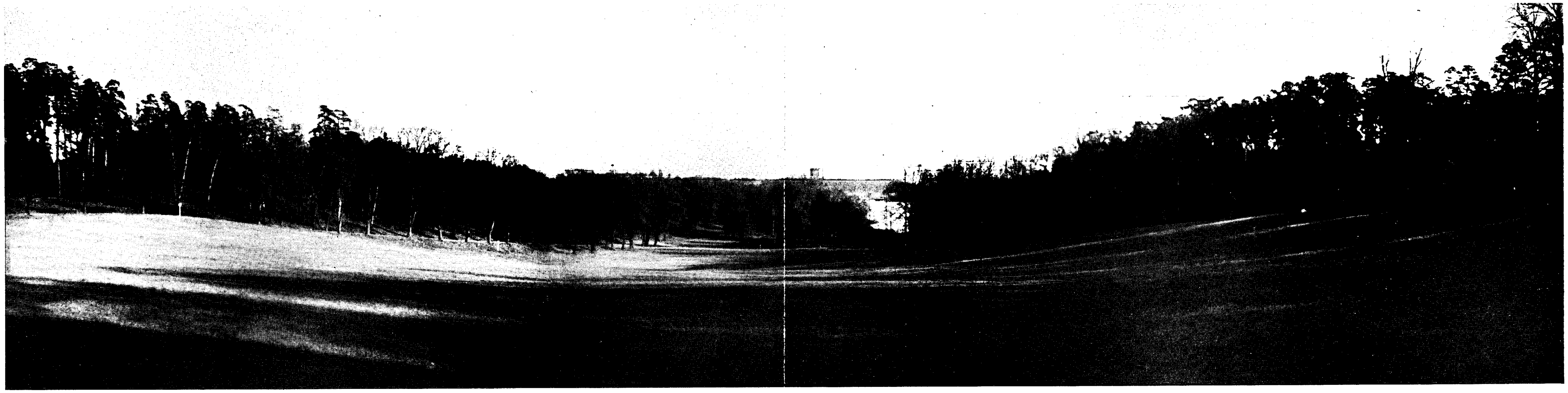
a. Haga Norra in 1936. Section prolonged still more westwards into the ose. a: Ose centre, primary deposition. — Discordance. — b: Glacial, varved clay. — Discordance. — c: Ose-gravel, in secondary position, downslidden. — Discordance. — *d*: Horizon of micro-varves, occurring more distinctly on southern side, and followed into the cirque of the back-ground. — Discordance. — g: Wave-transported, redeposited ose-gravel with *Litorina* and *Mytilus*.
From outer, left part of horizon d, SW, are derived the specimens of Figs 18—20, dated by micro-varves to the years c. -800 to -300 b.Z. Photo E. H. D. G., 1936.



b. Haga Norra: inner, western wall of big ose section in 1937. The microdistal discordant zone *d*, from Fig. 10 a. above fine ose-sand of distal type, probably upper part of the lower ose-centre, a. Thereabove, middle, a pocket of current-bedded, coarser sand, probably of next annual centre e, cut off and planed by discordance *f*. Wave-transported dip, g, towards NE. Discordance h, and shore-gravel, i.
Photo E. H. D. G., 1937.

c. Haga Norra in 1937. Closer detail of Pl. 10 b. Dots: discordance *d*, between ose-centres a, below, and e above. Broken lines: discordance *f*, between primary and secondary ose-material, the latter, g, wave-transported. Near surface: discordance h between the main bed of secondary ose-material, g, and the uppermost bed of littoral shore-material, i, with a harness of augmented bigger, rounded boulders.
Photo E. H. D. G., 1937.

N S



Haga Norra, Vasa plain. Smooth topography of extramarginal sand. Right: current ridge from Långkullen ose hill, of the year −1034. Photo E. H. De Geer, 1937.

Stockholm, Haga Norra. Natural ose-pond between ose-hills Storkullen (l.) and Långkullen (r.). Looking east.
Photo E. H. De Geer, 1937.

caused by a final melting away of imbedded remnants from the original base-ramparts of ice at the sides of the glacier-vault. Finally the wave-action has smoothened the ose-surface by at least the amount named but probably considerably more, or some 10 m of later sediment.

The relation between these faults and the actual surface of the hill, being degraded more than nine meters by the postglacial waves, is shown on Pl. 62, where the sandy, distal part of an ose centre is cut through by the faults. In the left, proximal part of the section I counted 500 cobbles mainly of local rocks with a diameter of more than 0.3 m.

The influence of the waves at Storkullen during the postglacial upheaval of the land must have successively remodelled the shore-material upon the surface of the down-wash already mentioned.

Upon the flat upper surface of the hill the action of the breakers has been marked by a series of pebbly beaches, the axes of which often exhibit a moderate slope from the eastern portion of the hill towards the SW, as being the less exposed side. The figures on the map, Pl. 55, indicate the height determined by levelling above sea-level of the beach summits above the isohypse of 40 m a. s.

On the steeper slopes of the hill no beaches could be deposited and no special lines of wave action as a rule are registered.

Cotemporary terraces from certain strong gales.

In 1922 I found by numerous levellings that certain terraces on the hill slopes especially along the sides of ose-hills are oriented in such a way that for every level they generally occur only in one special direction, from which had arrived the wind and the waves which had cut out such a terrace, while at the opposite or evidently the lee-sides of the same hill no special traces of erosion could be detected. This was verified at a great number of localities in Middle Sweden, and these one-sided shore-lines I called storm- or gale-terraces.

From their relatively restricted number of about thirty in east Sweden it appeared obvious that it was only during exceptionally strong gales that the pebbly gravel could be cut out sufficiently to leave distinct cut-terraces which could be traced from one hill to another, gradually rising a little in height in the direction towards the centre of land-upheaval, but every single one of such unequally upheaved shore-lines was always facing the same direction.

A big terrace facing the west, situated at a middle height of 40.1 m a. s., was the first shore-line which I succeeded to identify from point to point, thereby having a good help of its association with another, not much older terrace, facing a little more toward WNW and here at a height of about 41.0 m a. s. The upper terrace is here preserved only at the northernmost end of the lower one, while it is elsewhere cut away. These two so-called »twin terraces» were found to rise and at the same time gradually to diverge slowly towards the inland centre of land-upheaval and, further on, it was certified that other terraces at different heights and facing other directions everywhere represented a proportionate upheaval of land, which together with the individual storm direction in a high degree facilitated or made possible the identification of different localities with corresponding shore-planes.

Within the map region *Storkullen* is the only ose-hill of sufficient height to register several of the terraces named.

The next storm-terrace occurs about 33 m a. s., facing NNE on the hills *Storkullen* and *Långkullen*: the following at 31.5 m, facing SW; the next a little over 29 m, turned towards the east.

Northwards on *Lingkullen* some well-marked lower terraces occur (Figs. 12, 13).

Later on (p. 166) an example is given of how special shore-levels can be traced by means of such storm-terraces, whereby exactly cotemporary shore-levels can be fixed.

As the postglacial upheaval of land especially during its last part was relatively slow, it is evident from the small number of such storm terraces amounting to only about a dozen that it was generally but real, heavy gales which were able to cut in lasting marked terraces into the pebbly hill-sides, trom which the finer particles already beforehand were washed away.

The former gales thus registered represent the maximum of the last secondary sculpturing, which has essentially remodelled the genuine form of the flat-topped delta-deposits between the originally rather steep ice-walls.

This is necessary to remember when studying ose-deposits, but has often been neglected thus far that secondary downwashed marine beds of gravel and sand have been mistaken for direct glacifluvial ose-deposits. As pointed out above, such redeposited ose-material can be compared with a kind of ose-hide or harness, conceiling the very body.

Extramarginal current-ridges.

A new feature in the structure of subaquatic oses and their complement of finer melt sediment was first observed and mapped in this region. Already earlier, it is true, I had observed at Ed in the province of Dalsland on the surface of a plurennial marginal delta a kind of low current ridges consisting of small pebbles marking varying directions of the delta-building currents. But the current ridges proper here mentioned were observed a little later and are of a somewhat different character, being the connective link between the submarginal delta deposit of big cobbles, pebbles and coarse sand, deposited in the very glacier vault, and the widespread fans of finer varve sediment off the river mouth (Pl. 11).

On the map of melt-sediments north of Stockholm about a dozen of such current ridges are indicated. First explained was the biggest one, the trend of which extends on the east side of Långkullen, in the beginning supposed to be a minute real ose, but soon found to consist entirely of middle-grained sand without any admixture of gravel or stones and to exhibit an utterly regular surface with a most gradual slope toward SE, ending with a small but marked slope of accumulation.

To the SE of these ridges the slope of the subbasement became somewhat steeper and here no sand was deposited until on the more level surface at the base of the slope, where it seems to be a small continuation of the current-ridge, planted with an alley. Near the proximal part of the great current ridge this one is pierced down to its rock-subbasement by a large cut, exposing the uniform sandy material all through, at the western side resting upon another similar but shorter current-ridge, directed more southwards and found to be separated from the upper one by a thin layer of dark grey autumn-clay, marking the winter interval between the two current-ridges from the melt-summers.

Another smaller but well developed current-ridge occurs a few hundred meters farther to the south, running from the southernmost, lower part of Långkullen almost due eastward and having its end marked by a small step, here at the house of a park-guard. Even here the regular surface has been planted with an alley. The coarse, clean-washed sand of the ridge is cut through by a couple of small diggings.

An example of annual ose-sedimentation.

This current-ridge seems to have been deposited during the summer, following after the deposition of the winter-moraine from the year 1036, when the ice-border had receded sufficiently to allow the melt-current to escape in the direction of the ridge. A little earlier in the spring the melt-water evidently has overflowed the low, rocky ledge to the south and there deposited a sand-layer which scarcely can have had any other origin.

From the south end of *Storkullen* it seems that one current-ridge is radiating towards southeast, at the south side of its base blocking up a small ose-pond or *åsgrop* (Pl. 12), essentially filled up and, farther out, following the southern slope of the valley, until about 100 m from the shore of Brunnsviken it is ended by a small step of deposition.

The renowned fountain SW of the royal castle of Haga (*Haga slott*) no doubt gets its water from the sand layers of this current-ridge.

It seems that also along the south and west slopes of Långkullen a sand ridge is radiating into the cemetery with clean-washed sand a couple of meters thick, though the ridge-form is not quite distinct and the connection with a special fan of clay-material is not yet certified.

Farther to the north a current-ridge seems to radiate from the south end of the ose-hill *Mellankullen* (Middle hill) towards SE in a direction corresponding with the thickness curves of the annual clay varve from the year 1029, though it seems that when this ice-border had retired somewhat, the current and its sand must have been somewhat deflected towards the east by the opposite rocky hill.

A little farther north there seems to be a somewhat smaller current-ridge also running about SE.

From the ose-hill *Mellankullen* no more current-ridges appear at the surface and the ose-hill named seems to have a rather uniform structure, not being divided up into subordinate centres. Still, as the varve measurements indicate a marked axis of deposition, radiating about from this region, it may originate from the

Fig. 12. Brunnsviken, Ling's ose hill. Storm-cut terrace, 8.4 m a. s., looking NW, just NW of Ling's tomb.

two ose-centres *Lingkullen* (Fig. 12) and *Svalkullen* (Fig. 13), being probably of the same age and sending out a current-ridge, facing toward SE but afterwards probably by the west side of *Mellankullen*, diverted toward SW and the clay-lobe named.

The next, very considerable ose-hill *Kvarnkullen*, as to its main part reproduced on the map, Pl. 54, no doubt has its dominant current ridge forming the little cape of *Polska Udden* and running out into the depression of the actual lake Brunnsviken.

Kvarnkullen hill is nearly 43 m a. s. and was earlier crowned by a wind-mill, still marked on the map, as mentioned on p. 47. In its southwestern part great masses of gravel and sand have been dug away, showing that also here the subglacial ose-river had followed the depression of lake Brunnsviken and partly filled it out.

At Herr-Järva a subordinate little ose-centre was deposited.

Farther north, W of Beylon, two middle-sized ose-hills occur out of which the western, or *Innerkullen*, is the higher, being deposited against the eastern side of a rocky hill, and has a number of tumuli upon the short current-ridge at its southern end, while the northern hill or *Beylonkullen*, 42 m a. s., when judging from the ose-topography, seems to fill out a depression from the sea and to have directed its short current-ridge along the east side of *Kvarnkullen*.

The royal castle of Ulriksdal is probably built upon a small ose-hill protruding into the bay of Edsviken, and that seems also to be true with respect to the chapel close by to the southeast.

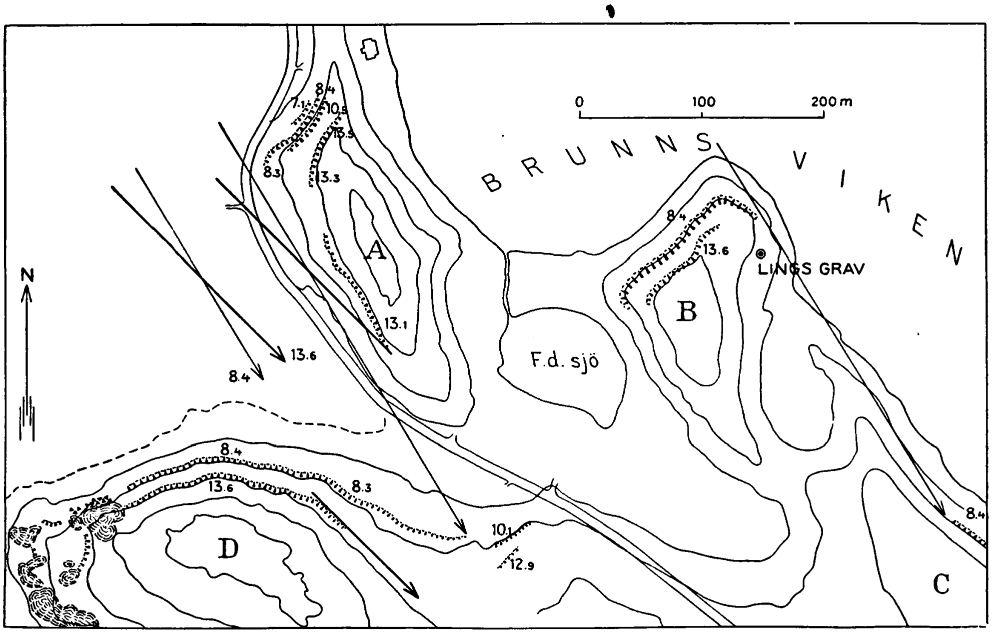


Fig. 13. Storm-terraces on the ose hills Svalkullen, A, and Lingkullen, B, as well as on the moraine-covered rock-hill, D.

Of more normal size is the ose hill *Park-kullen* NW of the castle with its smaller western neighbour. The northernmost ose-hill in the series here mentioned or the islet *Kaninholmen* was nearly 20 m high a. s., but its ose-material is now mostly carried away. Its low southern end most probably represented a current-ridge.

Outside this map, about 1 km farther NW, a small and low, pebbly islet in Edsviken bay, hitherto overseen, indicates another ose-accumulation, registering a considerable change in the direction of the ose-river, still more emphasised by a more marked ose-centre at *Silverdal* and a considerable ose-delta at the railway station Helenelund, showing that the ose-river, which evidently had followed the depression of Edsviken, now had deviated considerably as to the successive marginal direction of the mouth towards the receding ice-border.

The ose-series here described afford very good proofs why I could not adopt the ose-theory assuming that every ose represented a continuous and simultaneous deposit along the whole of its length while, on the opposite, I had found that the ose-deposition must have been successive and retrograde at the same rate as the ice-border receded, which is the only possible explanation as well of the inner, cyclic structure and the outer sometimes, as here, very incontinuous and capricious morphology.

As the oses represent that part of the melt-sedimentation which by its topography is most easily perceived, it has seemed appropriate to dwell in some detail on that very series of ose-deposits, which best illustrates their real mode of formation.

Ose centres and sediment isopachytes.

By these investigations it is definitively certified that quite naturally there is an uninterrupted connection between the coarser and finer parts of the melt-sediment from 1. every individual ose-centre or submarginal delta, 2. into its distal continuation in form of an extramarginal current-ridge of stone-free sand, in its turn 3. gradually passing over into an ordinary clay-varve, proximal and distal (Pls. 13, 14) which 4. ultimately has a very considerable microdistal extension before totally evanescing.

As the whole of such an assortment has a very great extension, it cannot be well represented graphically on the map with all its parts together.

Thus ose-hills and current-ridges can be mapped out, while the finer sediments or the varves as to their succession or the annual transgression of their proximal northern borders cannot be shown on the same map. Their relative thickness is to be given by diagrams and tables as shown in the atlas.

The thinning out within every single varve can only partially be reproduced by mapping and isopachytes or thickness curves. Thus in Fig. 14 (= 18 in Stockholmstraktens Kvartärgeologi — The Quaternary geology of the Stockholm region) they are given somewhat schematically on the maps, showing the thinning out of three annual varves as to their proximal parts.

Though the observations at that time were rather few, the general direction of the thickness curves seems to indicate a dominant southeastern flow of the bottom sediment.

More detailed mapping of that kind is given in Pl. 57, representing the proximal parts of two representative varves, showing their distribution of thickness as determined by the ice-border by inequalities of the sea-bottom and probably also more general currents in the sea (years –1028 and –1029 b. z.).

The ice-borders of these three years were extended between the great ose-hill Storkullen and the northern part of Lake Brunnsviken. Influenced by the main depression of this lake, the land-ice border here had projected by a lobe about half a kilometer south of its main extension in this region, transgradiating over a couple of the iceborder-lines from the preceding years (Pl. 56).

This projecting ice-lobe together with the opposed, rather dominating ose-hill *Storkullen* render the sediment distribution of these years especially instructive.

Thus Storkullen acted like a rather effective divisor of the bottom currents in question. On the other hand a protruding ice-lobe was followed in such an adhering way by the eastern wing of the clay transport that it seems to indicate an east-running current of the bottom-water, though this indication perhaps is not sufficiently supported by the south-directed western current-wing.

Still, as mentioned below, there are also other indications pointing at an east-going bottom-current.

The ice-border from the year 1030 evidently passes along the north side of *Storkullen*, coming from a moraine skeleton, having only a residuum of boulders left from its exposed position on a mountain-ridge, somewhat over half a kilometer

Stockholm S, ose at Sandsborg. Ose-centre, 1, with superposing proximal, sandy varves, 2, and distal, clayey varves, 3, to the right. Below the clayey zone is the varve of year −1073, when the Baltic ice-lake was drained and salt water entered through the passes N of Mt Billingen, causing a sudden change in the type of sedimentation. Cfr. Fig. 26.

Photo G. D. G., 1910.

Stockholm S, ose at Sandsborg. The same horizon of proximal, sandy varves as on the preceding photo, showing their mainly undisturbed structure with current-bedding. Only two varves disturbed, locally, by some horizontal ice-berg push, not affecting the other varves. Above, thinner clay-varves after -1073. Photo M. Zemaitis, 1933.

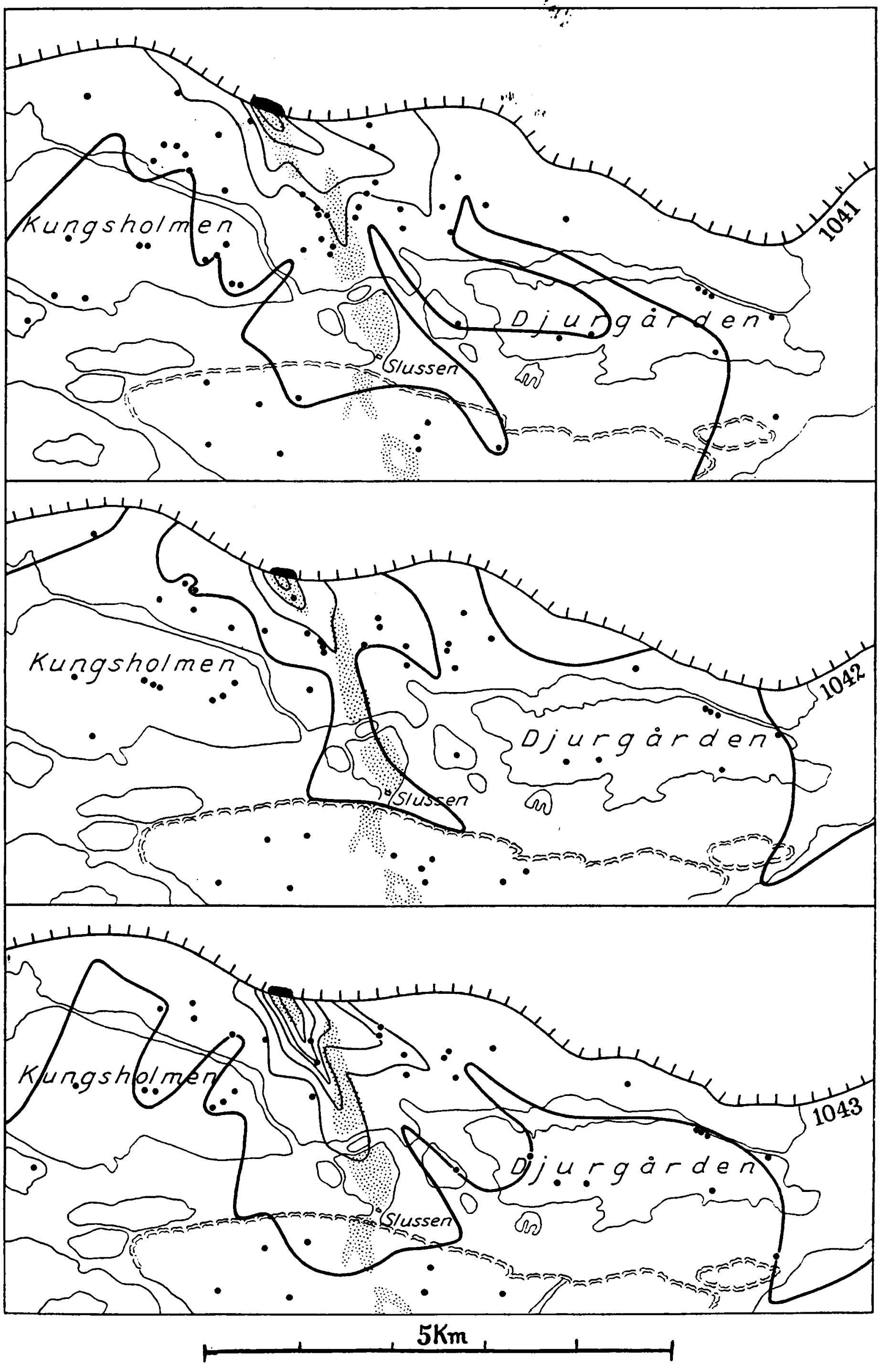


Fig. 14. Three annual varves: distribution of proximal sediment. On each map: northernmost: landice border, dated; black: river mouth; dotted: ose deltas of previous years; curves: in dm of the varve in question; single dots: varve measurings. The maps represent the years –1041 — –1043 before Zero. Confer pp. 74, 105—106.

NW of Storkullen. To the SE of this hill the ice-border in question is marked by a frontal moraine, touching the castle of Haga, from where the ice-border turns abruptly towards NE and, having crossed the *Riksmuseum*, it turns into its more normal direction towards ESE. As the clay-varve, having its north limit along this ice-border-line, is observed at relatively few places only, no isopachytes, or curves of equal thickness, are plotted on the map, this being reserved for the following two varves which in this map region are most fully represented.

As the trend of their ice-border in the main are parallel to that of the year 1030, it may be sufficient to refer to the maps, Pl. 56, 57, as to their general trend. The occurrence of frontal moraines and the varve determinations indicate where the ice-borders are more or less fixed.

Noteworthy it seems to be that these ice-borders are especially accentuated along the marked southwestern coasts of the strait of Lilla Värtan and along the ice-lobe, protruding over the northern, deeper part of Brunnsviken.

Both of the varves from these two years are, as already mentioned, along both sides of Storkullen divided up into two clay-lobes, like two wings, of which the eastern is extended about twice as far as the western wing, while the more proximal, coarser material of the year 1029 is dominant in the west wing, and the opposite is the case as to the year 1028, where the coarser material preponderantly is going eastwards.

Thus during the year 1029 the main part of the varve sediment passed like a western wing with its axis a few hundred meters to the west of Storkullen, being here nearly one meter thick and directed, first, towards SSW and afterwards with decreasing thickness towards the south, until a little south of the map it thinned out to less than 10 cm.

The eastern wing sent the sediment axis pertaining to this varve east of Storkullen toward SE and the Haga castle, where the thickness was somewhat less than 30 cm, being here divided up into two branches, when running about east and directed towards the *Vetenskapsakademien* (Academy of Sciences), from where the thickness of this wing gradually thinned out to less than 10 cm about NNE.

The other branch from the region of the castle evidently has followed the depression of the lake, sending out branches of about 10 cm thickness along its different bays.

The following year, 1028, shows a somewhat different aspect. Here a western wing, about in the same region as the maximum of the preceding year, shows no more than a fourth part of its maximum and is also less extended southwards, as being thinned out to less than 10 cm already half a kilometer earlier than the preceding varve.

On the contrary at the east side of Storkullen the varve 1028 still is more than half a meter thick and north of the castle more than 40 cm from where its axis is bent over toward ENE, being near Riksmuseum divided up into two branches, still of a thickness somewhat exceeding 20 cm. Here it must be once more emphasised that the varve lobe of this year has turned round along the synchronous ice-border towards ENE and that this varve-lobe has a considerable extension eastward before its thickness under-rates 10 cm. Also this varve sends a southern branch along the depression of Brunnsviken towards its southern bays.

As to the distribution farther westward of the two varves last named, they seem to be more gradually thinning out in this direction, though more material is desirable before discussing the details.

As to those parts of the varves which are thinner than 10 cm, they, of course, are more regularly distributed, but it will be most appropriate to describe their distribution in connection with a special memoir on the considerable material of varve-measurements from the very Stockholm region immediately to the south of that given on Pl. 56.

Concerning the possibility that the clay-laden bottom-currents from the melt-rivers partly may have been deflected eastwards, another phenomenon pointing in the same direction may here be mentioned.

In the Quaternary geology of the Stockholm region it was mentioned that the ose-river nearest west of the Stockholm glacial river, or that of the Uppsala ose, for a time by a bifurcation was divided up into two branches on both sides of the island Svartsjölandet. The eastern branch long since was known and mapped from the railway station *Tullinge* and northwards over the east end of island *Ekerön* and over *Malmön* island. But from the thick, proximal varves along the sound northward it was suggested that a subaquatic ose existed and perhaps could be mapped out by soundings about as far northwards as up to the region of *Riddersvik*, or the ice-border of the year 1025.

Recently I found that even close to Stockholm the varves seem to thin out rapidly just on the year 1023, and it seems very reasonable that the cause may be that the above bifurcation may have finished that very year by the capturing of its eastern branch, which became united with the western one. Thereby the contribution of clay-sediments from Uppsala river to the Stockholm region was essentially diminished.

If this will be confirmed, it may also be an indication pointing to a considerable eastward distribution of the clay sediment along the sea-bottom.

Remembering that the surface current quite certainly was directed towards the west, as shown by masses of Baltic boulders, carried in this direction by the ice-drift of the surface and now occurring in the late glacial varved clay, it seems well possible that this dominating westward surface-current possibly could arise a reaction current along the bottom.

Anyhow it is very probable that by continued detailed investigations of the dominating direction of the clay-distribution it will be possible to solve this question by making out whether the clay-carrying current, local influences being eliminated, really has a predominant tendency towards the east.

Annual clay varves.

Dating possibilities.

While the annual moraines represent a very conspicuous registration, they are only locally developed and are thus unable to furnish a continuous time scale.

Likewise the ultra-proximal sediment or the annual deltas or centres of the oses sometimes are very conspicuous, but, as deposited only within the ice-tunnel and by a strong current, often so locally developed and often so eroded, that they only very seldom and quite locally can be used as a registration of the ice-recession. It is only by the much more regular and continuous deposit of the finest melt-sediment that a trustworthy and all the way continuous time scale can be brought together. But this could not be done without several sometimes rather serious difficulties. In several cases these looked so earnest that it took quite a long time before the gaps could be overbridged. But finally it succeeded, by closer points of observation, by parallel lines of measurement, or by the discovery of long, connecting varve series, to fill out even the last gaps and to bring about a quite continuous Swedish time scale. This name has been proposed, because the very origin and the whole working out of this standard line were Swedish and because Sweden — by its extension as well as its widespread clay-fields and its general access of emerged clay-layers — is the only land, where it is possible in one continuous succession to follow up and measure the whole last part of the late Quaternary time, from the beginning of the Gotiglacial subepoch all the way past the whole of the Finiglacial and Postglacial stages, uninterruptedly down to the present year.

As time everywhere is the same, an important purpose at the working out of this time scale has been to bring about a measure of time, common to the whole of our planet and in order to attain all the advantages of such an exact correlation. Therefore also it seems important, and even necessary, everywhere to use the same zero- or starting-point, with the same years of reference and the same denominations of the different sub-stages, so as to avoid arbitrary changes without any geochronological foundation. The same principles ought to be scrupulously followed even with respect to a proposed and desirable building out of the chronology backwards over preceding stages of time. Only in that way we may be able for times to come to avoid such rather arbitrary, ill-founded and deceptive figures as hitherto have been encumbring the scientific literature.

Has it become possible at last really to identify and follow special phenomena of evolution on this planet, this possibility ought not to be spoiled by any local, quasi-Babylonian diversions.

A common, exact chronology is the necessary foundation, in the first place with respect to the physics of the glaciers and how to illustrate how different topography and other conditions exerted their different influence upon the recessional evolution on the different glaciations of our planet.

At the same time we get a possibility of studying how the vegetation took the new-born ice-free land into possession, how it was followed by the fauna, and sometimes even by man.

Hereby it will be especially important finally to get definite datings concerning the Palaeolithic evolution in different regions, while hitherto we have been confined principally to the evolution of the implements and accompanying zoological remnants from the meals. But, especially at greater distances, arguments are too much depending on migrations to be reliable as indicators of equal age. Reliable datings of Palaeolithic occurrences on the contrary will furnish a means of determining the ways which were followed by primitive culture.

Hitherto but one Palaeolithic occurrence has been connected with the geochronologic time-determinations, and that one was situated in British East Africa and belonged to the remarkable series of Palaeolithic remnants, which has been made known by the investigation of their discoverer, Dr L. LEAKEY, and put into connection with the corresponding lake sediments from quite a series of successive water levels, explored, mapped out and levelled by my former pupil, Dr ERIK NILSSON, who also succeeded to connect certain of those lake levels as well as some of Dr LEAKEY's Palaeolithic shore-caves with lake sediments which he supposed to exhibit annual varves.

Series of those varves he measured very carefully from three different horizons and handed over to me for comparison and eventual dating.

As already described in a special paper, it succeeded to identify all of those three varve series with closely corresponding series of the Swedish time scale. Of the two younger levels one belongs to the time at the very end of the Finiglacial and the beginning of the Postglacial stage.

The next older series corresponds equally well with varves from that epoch when the ice-border receded past the region of Sundsvall.

As to the oldest series, which corresponds to the Palaeolithic remnants, described by LEAKEY as of Aurignacian type, I had to search through, without success, almost the whole of the Swedish time scale until finally quite near the very oldest part of its hitherto definitively measured series, I succeeded to find a persistent and conclusive correspondence, showing that this Palaeolithic occurrence of Aurignacian type belonged to an epoch, very nearly 15,000 years before our century. But of course this does not mean that the Aurignacian stage everywhere was developed within the same epoch, and only by direct datings it will be possible to make out how far local evolution or successive migration have had to do with analogous occurrences of such primitive Palaeolithic types. Thereby it is especially desirable to study in detail the connection between such remnants and datable varved sediments as, for example, those in the Alpine valleys, where it may be possible to hunt up, in the varved glacial sediments, Palaeolithic implements from those early immigrants, who may have followed the late-glacial receding ice-sheets.

In the same way it will be important as closely as possible to investigate and measure earlier successions of varves and connectable remnants of different kind and in the same way varved sediments of Quaternary lakes, in order to get, finally, a reliable universal story, elucidating some of the main lines of evolution during the Quaternary period, when evolution was reaching its present summit.

At the same time as in this way it might be possible to shed some much needed, clearer light over the very origin of quasi-human culture, it will also embrace its environment as well in flora and fauna as in the inorganic nature with such changes of climate of which our own is no doubt but a changing stage. And further on, all those changes of level in the earth crust, in the currents of the sea inherited from the Ice Age, in the erosion of the water along the shores and rivers, in the laws concerning the rate of evolution of the tillable soil, only to indicate some of all those phenomena, which are subjected to the influence of time and for their understanding are in need of reliable time determinations.

At his important studies on the composition of the soil in our forests Dr OLOF TAMM has also taken into account the importance of the time factor, though hitherto he has not had occasion to get it applied more systematically and at localities of more different age, which, no doubt, will yield interesting results and possibly afford some hints concerning the evolution and possibly afford some hints concerning the evolution and nature of the procedure and how to learn it according to the interests of man.

As to the immigration of the flora and especially of the forest trees, a very important and comprehensive material has been brought about by Professor L. VON POST and the ever growing school of his cooperators concerning the succession of varying pollen contents, occurring in the peat-bogs and in other quaternary deposits.

By these scientists a very fascinating material of pollen analyses has been collected, throwing more and more light upon the immigration and successive distribution of forest trees in greatest detail performed in middle and southern Sweden, but also in surrounding regions.

Still the very nature of pollen spreading and preservation does not allow of any independent and exact datings. It is thus necessary to tie up observations concerning this rich material from as many points as possible with exactly determined ancient sea-levels which, in their order may be possible to date geochronologically.

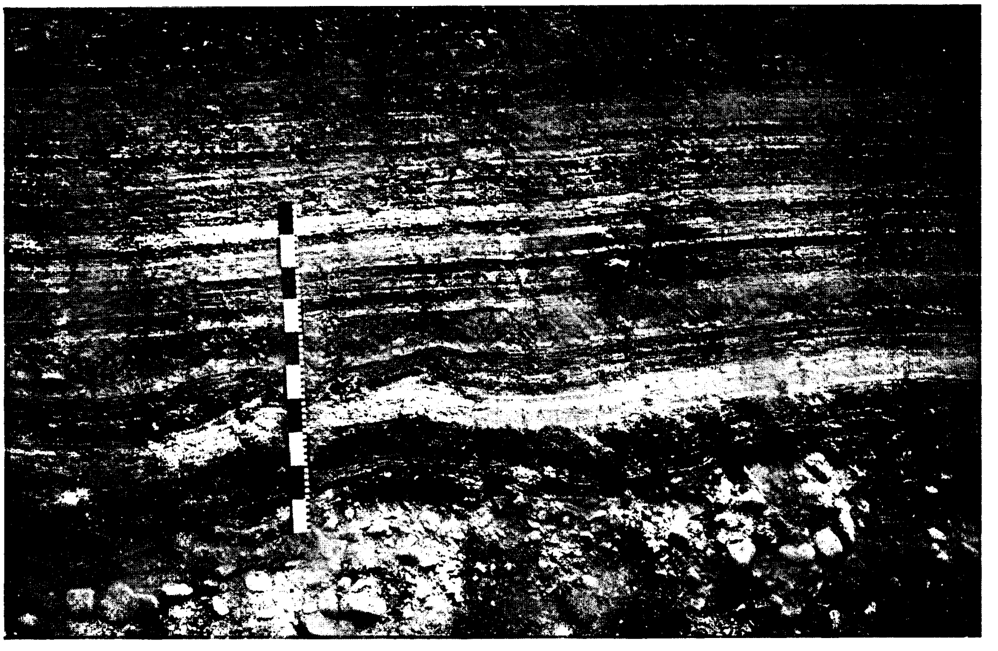
As to younger pollen deposits it is of course also effective to get connection with archaeological, really datable finds, but with respect to connection with earlier archaeological finds which are only conditionally dated, it is important or even necessary to try to get real biochronological datings.

In that way it is to be hoped that the story of the forest immigration unto Sweden and the surrounding region finally will be a unique example of how a quite desolate glacial *terra nullius* gradually has been covered with a forest vegetation in relative balance with soil, topography, and climate.

Character of varves.

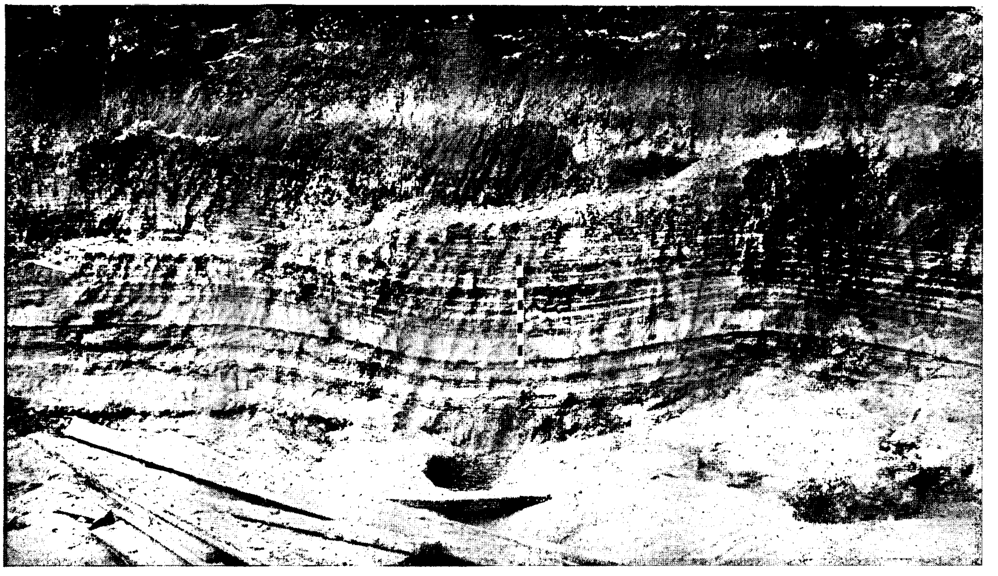
As mentioned above, p. 17, the appearance of the varves is very different at different places and in different parts of the country, depending of the contributing bed-rock- and morainic matter, on the transporting current capacity, and on of the distance from the mouth of the melt-river.

As a rule, the coarser the material, the greater is the percent of the summer deposit, while in micro-varves the autumn clay may dominate. Generally the distal varves are fine-grained, especially as to the autumn layers which as a rule upwards have a sharp limit towards the lighter and coarser spring layers of the next, superjacent varve, while there are gradual transitions within the different parts of one and the same varve. As generally the autumn beds are the darkest, the marked



a. Stockholm N., Roslagsgatan 45. Stockholm varve section. Bottom varve resting closely on the uneven surface of a thin till-bed. Photo O. Halldin, 1929.

b. Stockholm N. Proximal varves with interlamellation and current-bedding. Through repeated current-bedding of sand interfoliated with clay layers proximal varve limits often not photographically discernible and requiring great attention of the measurer. Bottom varve, thin moraine cover and bed-rocks. Triangles: Varve limits. Photo O. Halldin, 1908.



a. Stockholm N, Sturegatan 10. Varve section at Stockholm: varves upwards soon thinning out on account of the rapid finiglacial ice-melting. Bottom varve resting on bed-rock with a thin strip of till (left). Above: dark, redeposited and unvarved postglacial clay. Photo O. Halldin, 1929.

b. Stockholm N, Sturegatan 10. Detail of the preceding photo. Varve structure with augmented percentage of clay in each varve upwards. Thick sand layers = effect of bottom currents only in some five proximal varves from the bottom. Photo O. Halldin, 1929.

upper limit often clearly indicates, even in a small specimen, the difference between up and down.

The thickness and the coarseness of the varves depends of the distance from their source at the mouth of the melt-river and of the capacity of this latter. Thus at the very mouth the thickness is often 0.5—1 m, but can rise to a couple of meters, while at a distance of a few kilometers it rapidly sinks to a couple of centimeters only. At greater distances the thinning out is more and more gradual, and, as above mentioned, it has been possible to identify microdistal varves at a distance of more than 170 km off its origin in the river-mouth, the varves being here scarcely more than 1 mm thick.

Normal and local varves.

As to the rather considerable material of varve-measurements upon which geochronology is founded, it seems appropriate here to emphasise some very important points.

Even a rapid glance at the numerous sources of error mentioned below ought to make it obvious that varve measurements sometimes carried out by but little experienced observers can not be expected always to be infallible.

This has been illustrated within the great number of measurements in the Stockholm region, carried out by many different observers at localities in very different situations and in a most varying topography. Here it was only by a scrupulous comparison between all neighbouring points and consideration to the surrounding topography that it was possible to make out how the local conditions had influenced upon several observed deviations from more normal thickness variations, and furthermore which of the observations had to be rejected altogether.

In a great many instances it was found that even quite locally developed varve series could be reciprocally, and without any doubt, identified, though they were not at all normally developed.

Exactly in the same way it has turned out that very often, in such cases when all the varved sediment had passed the same way, it exhibited everywhere the same variation, though this one at the same time was not normal.

An opposite assumption must be considered as totally unfounded until it has been controlled by comparative connections with other regions, to what extent the varve sediment in such a valley may be normally or locally developed. Thus the long series of very valuable measurements executed by Dr E. Antevs in the Connecticut River valley has been found, by my teleconnections with the Swedish time scale, to exhibit, intermittently, rather normal and very local varve series, showing all the way strong variations, characterising the great meltriver of the valley named.

Thus, in such a case, the great number of control measurements no doubt can make the very observations quite valuable, while an evaluation concerning: local or not local ones, is possible only by means of teleconnection with other regions.

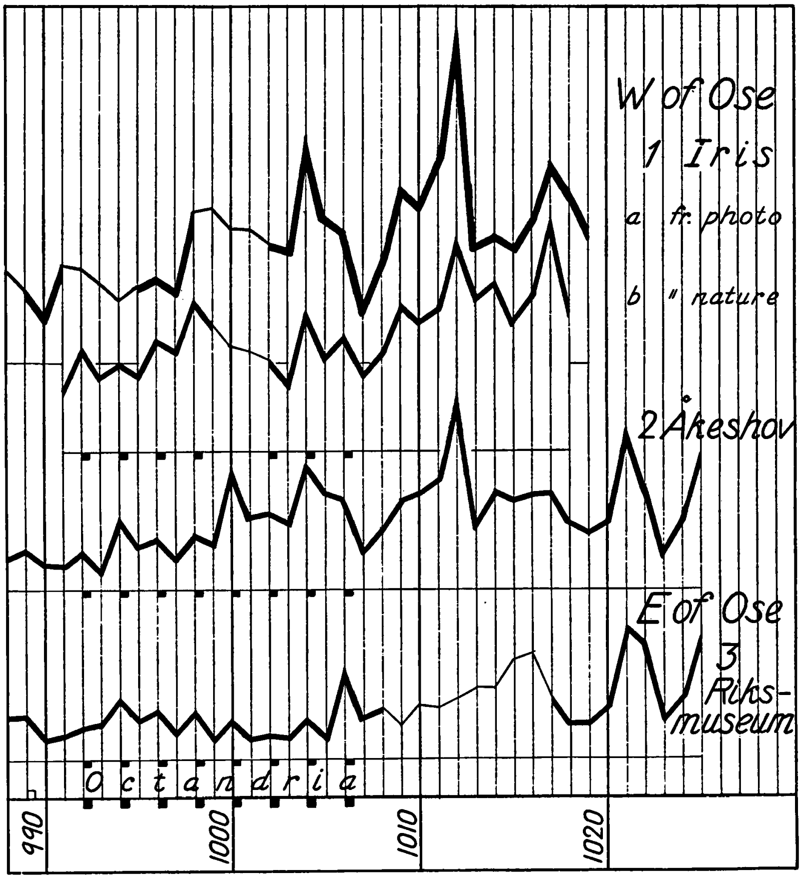


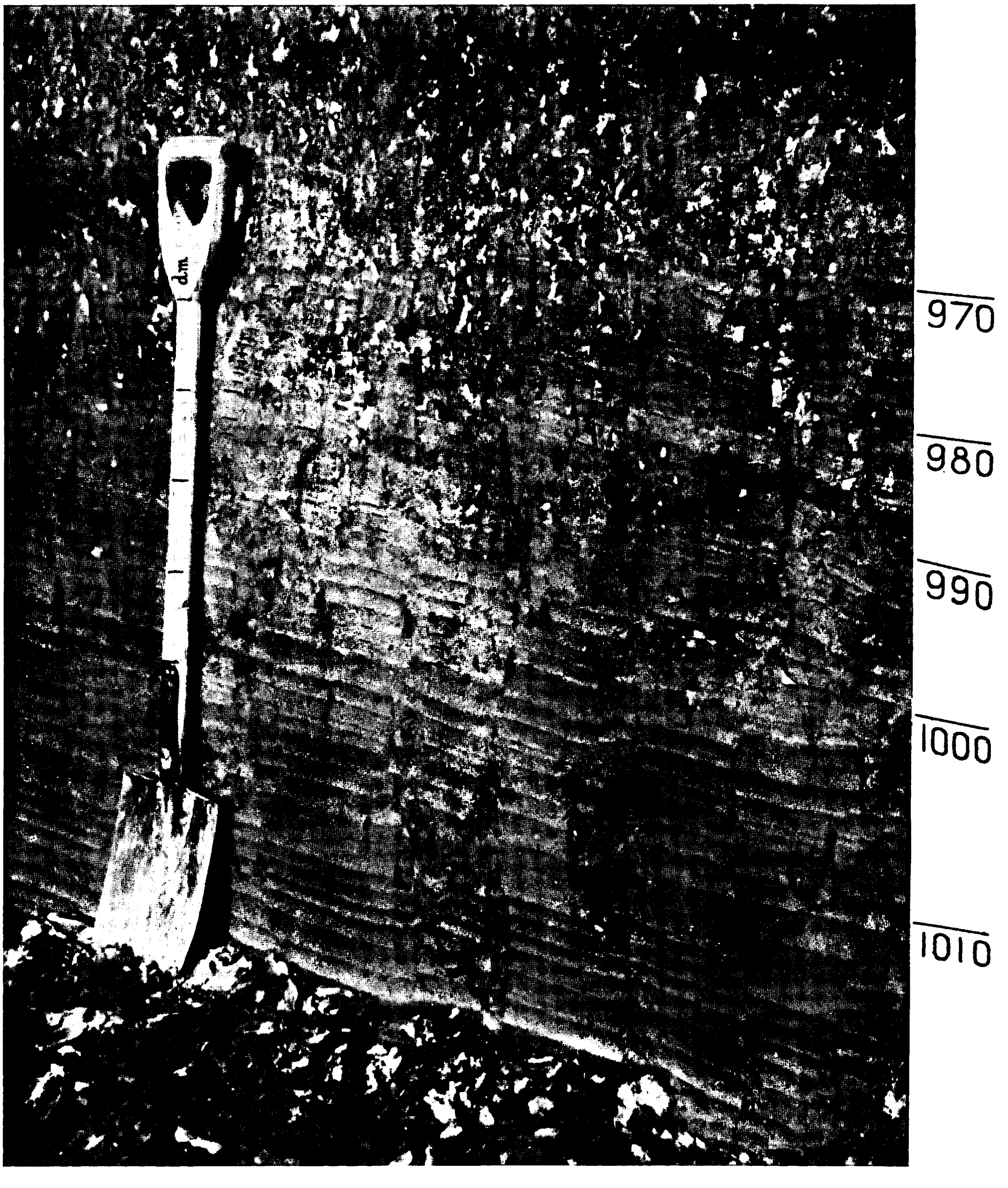
Fig. 15. Stockholm, Bromma Iris. Dating of the varves seen on Pl. 21. Sediment carried alternatingly E and W of ose, e. g. varves 1012—1009, 1005—998.

Short series of bottom varves.

It is easily understood that in an emerging region especially successive shore erosion first of all must hit the loose clay on the tops and exposed slopes of the hills, while at least the bottom layers were partly left at more sheltered places, now often covered by lakes, peat-bogs or by down-slidden sand masses.

Thus as the majority of clay-diggings, in order to avoid the ground-water, are excavated on hill slopes, generally the greater upper part of the varve series has been eroded away, leaving only the proximal varves and a few distal varves, and this has been the case at by far the greatest part of all the varve series investigated in middle Sweden. This was favourable only at the beginning of the varve investigation, when the main point was to fix the successive extension of especially the bottom varves towards the north and to avoid diggings deeper than necessary for getting variation curves sufficiently long for the identification northward of the steps of extension of the bottom varves (Pls. 15, 16).

This determination of the varve extension viz. ice-recession was necessary for fixing the standard line of the Swedish time-scale. But at the same time it



Stockholm, Bromma, Iris. Distal varved clay from Iris at Drottningholmsvägen Road. Varves −1019 — c. −970. Brittle zone above: thin-varved facies below the micro-distal varves. Bottom-varve at this locality −1043: lowermost visible varve −1020 is thus No. 24 above bottom and deposited when the ice-edge reached 6 km north (Spånga); varve −1000: 11 km (Tureberg); varve −970: c. 18 km northwards (Ekoln). Photo Börtzell, 1932.

induced several difficulties depending of the local conditions in the neighbourhood of the ice-border and the outlets of the melt-rivers with all their changes. From this reason it was often necessary, in order to ascertain the identifications, to make measurements with small intervals.

By and by localities were found where longer varve series with regular, more distal varves still were preserved, registering a more considerable lapse of the ice-recession and affording a good control of intervening close-connections. But the very thinnest varves could not be measured in the ordinary way, though it could be expected that they ought to represent still more considerable ice-recessions.

However, such thin, distal varves, which can be designated as microdistal varves, very seldom were observed *in situ* or in direct succession with the more proximal varves. At several places they were found as more or less isolated lumps at the oses, covered and protected by down-slidden masses of sand or gravel. Such isolated specimens of microdistal varves had been preserved in the collections of the institute since many years but were finally, some years ago, taken up for closer inspection.

Some varve datings from photographs.

Above the bottom- and proximal varves mentioned at the preceding lines follow the ordinary varves of medium size, which are of greatest importance for varve connections at shorter or longer distances, as well on account of their smaller thickness and therefore also greater number, as of their more uniform distribution over wide areas on the sea-bottom and more general registration of the annual amount of melt-temperature, irradiated from the sun. If in this respect surpassed by the microdistal varves, however the macro-varves are by far more available and always attracted the attention through their conspicuous cyclic character.

Some few examples of good varve series are given by the photos, Pls 17—19, each accompanied by a graph, Figs 15—17, showing how a varve photo can be measured and dated. They are not connected mutually, as each of them represents quite different years.

The photo from Iris in Bromma (Pl. 17) shows the varves, Nr 24—85 above the clay-bottom, or the years –1020 at the base of the photo up to –970, where the clay already becomes too brittle to afford a continuously measurable series. The basal varve of the photo is deposited when the ice-border had receded 6 km northwards, or to the region of Spånga; while the varve 970, was deposited when it had vanished 24 km, or a third of the way to Uppsala. This photo thus represents some 50 years of ice-recession across a distance of 18 km, or about 360 m a year (Fig. 15).

The rather distal varve series from S:t Erik brickyard in Uppsala (Pl. 18), represents the varves Nr 90 above the clay-bottom at the base of the photo to Nr 160 above the bottom, or the years –780 to –721 before Zero. These 70 varves are deposited while the ice-border receded from Skyttorp, 25 km north of Uppsala, to past Örbyhus, some 40 km N, which 15 km in 60 years gives a recession of 250 m a year. The graph, Fig. 16, shows their identity with those measured in nature.

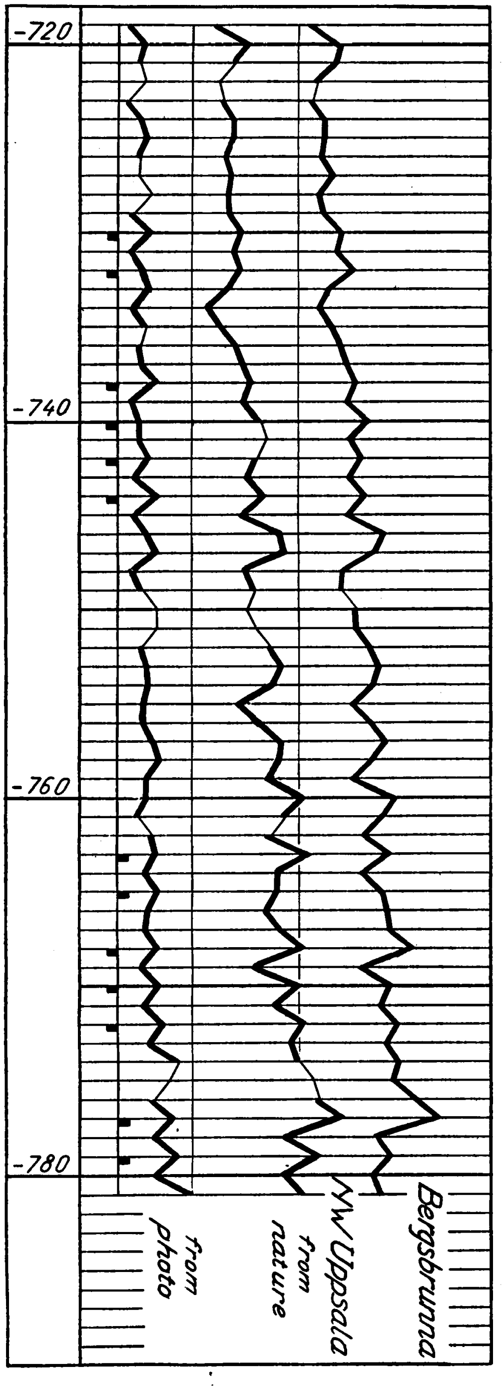


Fig. 16. NW Uppsala, S:t Erik Brick-yard. Dating of the varves in Pl. 22.

NW Uppsala, S:t Erik Brick-yard, No. 26 a of the Time Scale, Division M. Typical section at Uppsala, 1.5 m in height; very regular deposition of distal macro-varves, 70 in number and beginning, at the base of the photo, by No. −780 of the time scale, which is not far from one hundred varves above the bottom. When varve −780 was deposited the ice-border had receded as far as to the south part of Division P, and varve −721 at the top of this section was deposited when it had reached well past Örbyhus castle in Division Q, one hundred and sixty years after it left the place. Thus the mud of these varves was carried here from a distance of 25—40 km north of Uppsala. Graphic dating, Fig. 16, cfr Pl. 80.

Photo A. Reuterskiöld, 1920.

The very regular bedding of the Uppsala varves with unbroken, horizontal lines of demarcation points at rather regular conditions during the deposition of this clay as well as a great amount of mud, allowing macro-varves to be deposited for a longer time at that place than by the smaller Stockholm ose river. Also the ice-recession was slower through that part of Uppland than it was just north of Stockholm.

The two varve series mentioned, from Stockholm and Uppsala, both are examples of ordinary varves where the clay material is quite dominating, and also to their aspect rather similar, of a somewhat reddish colour, successively darkening towards the upper limit. Those from Iris are from the short *Yoldia*-visit, representing brackish water, while the Uppsala varves are greatly due to fine-grained calcareous rock material of which irregular concretions here and there are visible on the photo.

Pl. 19 from Loos at Voxna River, Helsingland, where the bottom-varve may belong to the year c. –250 b.Z., here represents the varve series –175 to 120 (Fig. 17), and thus from the clay-bottom: varves 75 to 130. They show still less a tendency of thinning out than the varves at Uppsala and are of a somewhat different character as being typical fresh-water varves with a light sublayer of sand in strong contrast to the dark, brown clay-horizon.

In spite of the irregular scar in the middle of the photo, an unbroken series of regular varves has been measured obliquely along the left side of the clear section. The graph, Fig. 17, shows a rather close similarity with Locality Gåsnäs in Ångermanland and also in the main with the two other series. A test like this shows the value of varve photos, especially if regular and well cut varve series are chosen, so that the best available varve series in great numbers could be preserved photographically and utilised for dating purposes.

Microdistal varves the summit of annual sedimentation.

During the last years I found that a hitherto neglected kind of clay-varves promised to afford a marvellous, rather universal registration of the general mean sedimentation by the most distant, finest sediment from the melt-water, deposited at a considerable distance from the coast and thus free from all the local sources of error, adhering to coastal deposition.

Already at the time of the so-called first clay campaign I had observed, at some places, in the Stockholm region, especially in sections along the slopes of oses, lumps of clay with a very thin lamination, the laminae being often less than 1 mm in thickness. They were all through grey, utterly fine-grained and uniform, but mutually separated by regular, lighter thin layers of very fine silt.

This alternating stratification was so regular, that it seemed evident, though the ordinary cyclic sequence of brownish and grey colours was missing, that all the same the interbedding in question should correspond to an ice-border far away towards the north, whereby every year only an utterly reduced part of the finest deposition still was spread out to the place in question.

These very thin, supposed distal or m i c r o d i s t a l varves could not be measured

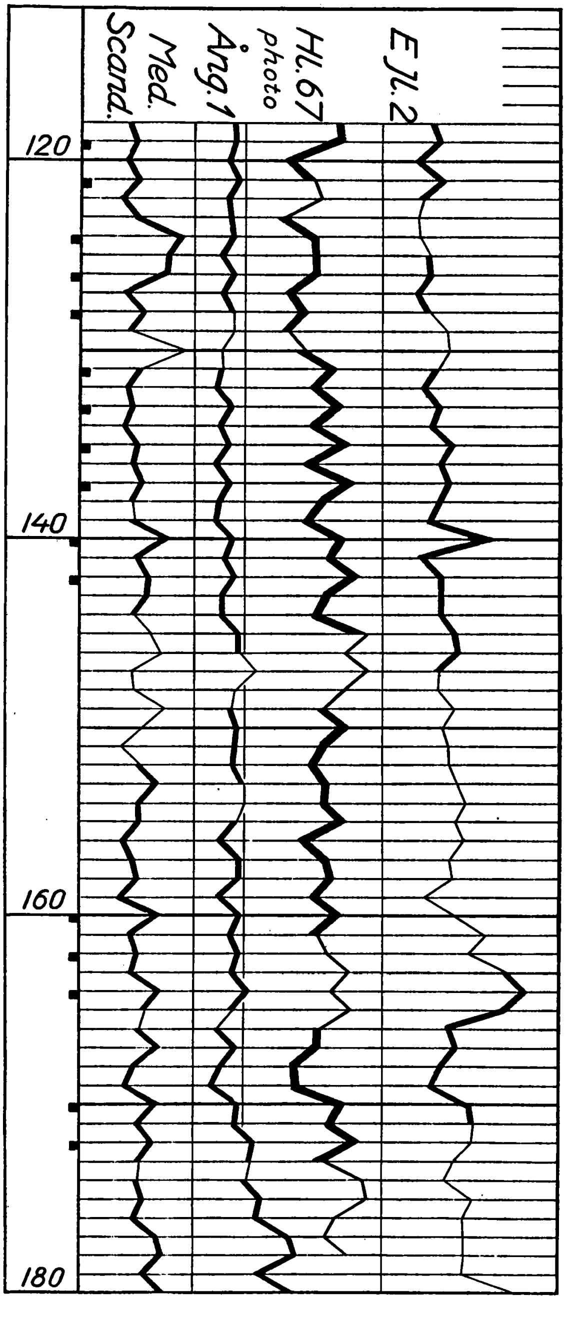
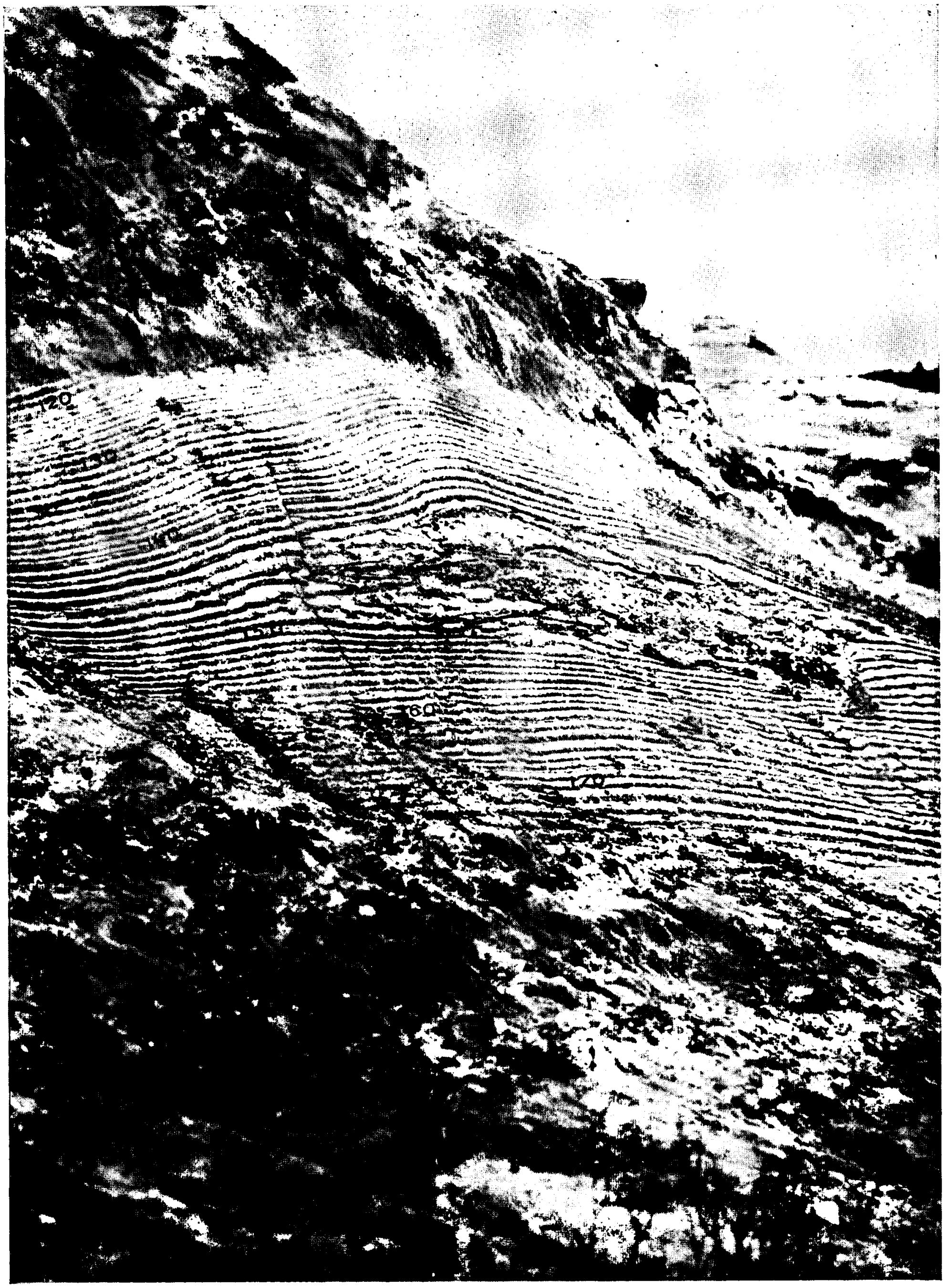


Fig. 17. Loos, Hl., Norrgård at river Voxnan. Dating of the varves in Pl. 23, as magnified c. × 8.



Helsingland, Loos, Norrgården. Natural clay section at River Voxna, representing the varves –118 — –175, according to graphic dating, see Fig. 17. Photo L. Wattenström.

and reproduced in the ordinary way. By direct comparison of regular specimens from Stockholm and Uppsala I found a striking and rather complete similarity but, thinking that at such a distance this might still be a mere accident, the whole question was put aside.

Thirty years have passed since clay samples with microdistal varves have been collected into our institute, and it has been certified that those micro-varves are thinning out upwards and gradually fading over into the utterly fine and plastic, so-called lower grey clay, in Swedish *undre grålera*, which generally under the name of Ancylus-clay, was assumed to represent a special geological horizon and subepoch, sometimes referred to the Postglacial epoch and separated from the late-glacial one by layers of sand, gravel and eroded parts of real varved clay.

The lower grey clay already by HAMPUS VON POST was described as the most fine-grained and fattest of all the Swedish clays. Later on it was called »the Ancylus clay», because shells of *Ancylus fluviatilis* and other temperate mollusca were found to belong about to this horizon. Therefore by some geologists it was referred to the Postglacial subdivision, and stress was laid upon its being seemingly separated from the varved clay by sand-layers interpreted as indicating an intervening upheaval of land.

Still the present author found that the clay in question in reality was an immediate continuation of the ordinary varved clay, the upper varves of which, whenever exceptionally preserved from erosion, exhibited, quite distinctly, a gradual transition into the fat, lower grey clay of HAMPUS VON POST, the lowermost part of which still exhibits very thin varves upwards gradually fading out into a seemingly homogeneous clay.

This uppermost continuation of the varved clay, being generally eroded away during the land-upheaval, is sometimes met with in sections along the oses, where it had been protected by downslidden or downwashed osematerial.

Not seldom down-slidden ose-material also simulates real sand-layers between different flakes of the varved clay which in reality are quite continuous.

Now the successive transition between the ordinary proximal varved clay and its thinnest microdistal parts has been certified at several places. The observed occurrences of sand, gravel and traces of eroded, proximal varves below the lower grey clay in question with or without its basal transition into micro-varves, in reality are caused by secondary slidings, being very common, especially along the sides of the oses. Thereby the most distal, fattest parts of the late glacial melt-sediment on account of their tough composition have special chance to be preserved.

When the last glaciation was retiring from Sweden, the lower parts of the land were still depressed below the level of the sea, whereby the melt-sediments every year during the warm season were extended over a considerable part of the actual lowlands. During the following upheaval of land the more exposed upper parts of this melt-sediment was washed away by the erosion of waves and rivers. Over great surfaces this denudation was performed so radically that the melt-layers were totally carried away and their subbasement of till and bed-rock exposed over wide areas.

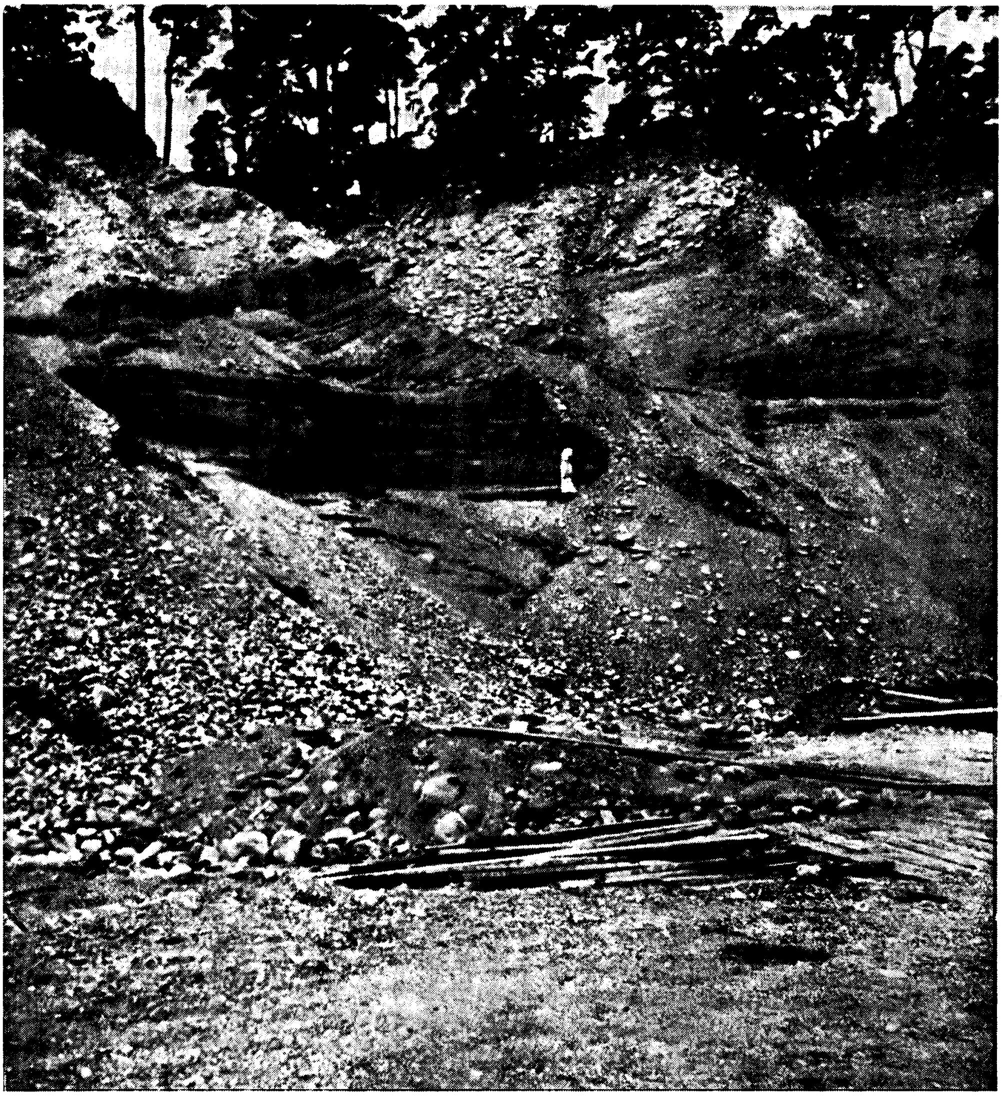


Fig. 18. Stockholm, Haga Norra, SW wall. Beds of microdistal varve clay deposited upon the primary ose-centre and covered by thick beds of down-wash gravel.
Photo Gerard De Geer 1937.

Thus the majority of actual clay diggings, being excavated on hill-slopes, are generally missing the greater upper part of the original varve series, and thus by far the greatest part of all varve measurements have been carried out on the lower or proximal varve series in question. Still, this was but favourable at the beginning of the whole varve investigation, which had for principal purpose the fixing of the successive transgression of the bottom varves, viz. the recession of the ice-border. At the same time it was convenient to have a relatively easy access to the bottom varves. Thus the denudation of the upper varves was helpful for the working out of the standard line, called the Swedish time scale. But at the

Fig. 19. Same clay-beds as in Fig. 18, forming two horizons separated by downslidden ose-gravel. Photo E. H. De Geer 1937.

same time this involved several difficulties, depending of varying local conditions in the neighbourhood of the ice-border and the outlets of the melt-rivers with all their casualities. In order to ascertain all the same the identifications it was often necessary to make measurements with but small intervals.

Sometimes localities were found, where longer varve series still were accessible, registering more considerable parts of the ice-recession and affording a good control of interjacent series of close-connections.

Sometimes very thin distal varves were found, which could not be measured accurately enough in the ordinary way, though it was to be expected that they ought to represent a still more remote ice-recession.

These tiny varves, which may be designated as microdistal ones, very seldom were found in a continuous sequence with lower, more proximal varves. Good examples of such a continuity are obtained at Uppsala, confer pp. 136–8. However, especially at the oses, isolated lumps or even somewhat greater remnants of such microdistal clay varves have been buried and protected against later denudation by downslidden masses of sand, and, by and by, a number of specimens from such series of distal clay-varves has been preserved in the collections of our institute.

As to specimens from several localities, there were no difficulties. Certainly the utterly fine clay material was quite uniform and without any visible periodicity in grain or colour with exception of the lower varves, which were passing over

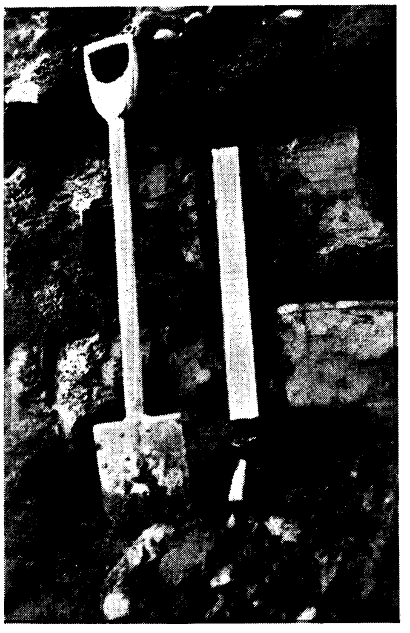


Fig. 20. A specimen of the two beds of microdistal clay, taken into one box, of standard length, 50 cm: Sth. mi 2 a, b, and 1 a, b, c dated to the years c. -330— -464 and -614— -780, Pls. 76, 77.

into the ordinary annual cycle of colours, characterising the proximal varves. But at the localities in question the limits also between the distal unicolour varves was pretty well marked by very thin layers of whitish, utterly fine silt. At some localities those silt layers were less distinct or almost missing, but generally it was still possible to discriminate the line of demarcation. Yet, at some localities and at some levels it was not easy, at first, to determine the true limits. But generally good results could be secured by renewed measurements, whereby self-deception was excluded by the uniform appearance of the varves.

Series of thus magnified microdistal varves were compared with the Swedish time scale, which is based on macro-varves. Thereby the comparisons of the two kinds of diagrams always have shown an often rather striking similarity between graphs of microdistal varves with the macro-varves of the time scale, often at a considerable distance towards the north, showing how far the ice-border and the melt-rivers had receded, when still microdistal sediment was deposited at the locality in question. Thus the microdistal varves in a splendid way have confirmed the belief that they could be expected to afford a very good registration of the annual variation. Some apparent differences disappeared after remeasurement, and some other ones depended thereof that in certain regions the macro-varves had been influenced by local deviations.

As the borders of the receding land-ice are now in the main sufficiently well located, it is at present possible to state that the microdistal varve sediment and its variations already have been determined at a distance of 170 km from the nearest point of the synchronous ice-border. Furthermore it is probable that such micro-varves can be discriminated even at still greater distances, when a special, closer study has been taken up concerning these new possibilities as to the extension and properties of distal sedimentation.

At Haga Norra two horizons were uncovered at the lower side of the ose, and they were later on found to continue discordantly upon the primary ose-gravel far into the extended, big ose-section. On samples taken from both of the horizons the microdistal varves were measured by a magnifying glass $\times 20$ and these rather long graph series were found to match very closely with certain centuries of the time scale above the tiniest distal varve series earlier dated (Figs. 18—20).

It will be very valuable when several parallel measurements will be gained for control.

One difficulty is caused thereby that the microdistal varves are so fine-grained and homogeneous, that their respective limits can be difficult to determine. Another difficulty depends thereof that such utterly fine and plastic material locally at certain levels by pressure from above has been somewhat influenced. But both of these errors may be possible to correct by repeated measurements in the neighbourhood or at different localities.

So far I have not had an opportunity to perform a sufficient number of control measurements, but still I found a very striking correspondence between microdistal varve series and their proximal counterparts, as being often identified at great distances. In order to promote further investigations I have inserted in the adjoined atlas several curves of microdistal varves at their due places, having their identified parts marked with heavy, black lines.

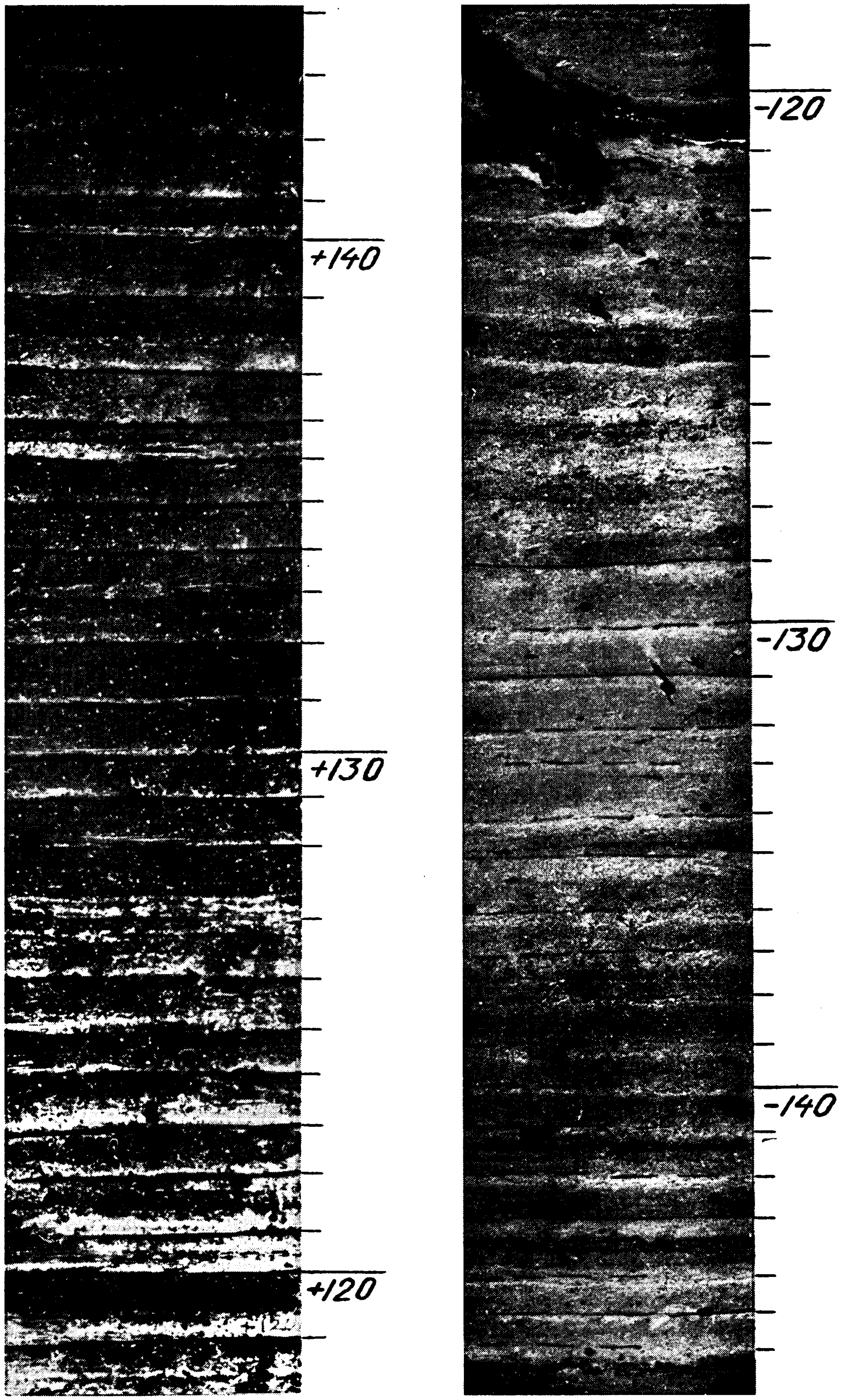
The very thinnest laminae were found in such relations to the ordinary varves that they must be considered as representing the most distal sedimentation, deposited at a considerable distance from the river mouth. It is true that only seldom they were found to be *in situ* as the uppermost part of a continuous section all the way from the more proximal, ordinary parts of the varves, which more often have escaped from later erosion and thus at a great majority of localities have afforded the material used for our varve measurements.

Generally by far the greater number of the upper varves and especially the uppermost microdistal ones have been destroyed and carried away by shore-denudation during the succeeding upheaval of land.

Their mode of occurrence has sometimes given rise to the assumption that such clay occurrences were separated from the ordinary varved clay by shore deposits from a special land-upheaval, while in reality there is an unbroken, continuous transition from the more proximal to the microdistal and its hanging, seemingly quite unlaminated, immediately covering clay-succession.

Still the upper varves were too thin to be directly measured and were therefore so far left out of the diagrams, though I pointed out that their horizon was a continuation of the varved clay and could not be separated from this one.

Finally, during November 1935, I made a first experiment by enlarging some of the thin microdistal varves mentioned by the help of a binocular glass, provided for the measurement of small tree rings and with a scale, divided into twentieths of millimetres.



a b

Fig. 21. Micro-varves from Högom, Sundsvall. Dating shown by graphs in the time-scale, Pl. 75, Me 2 mi. Here $^5/_1$. Photo Prof. E. Stensiö.

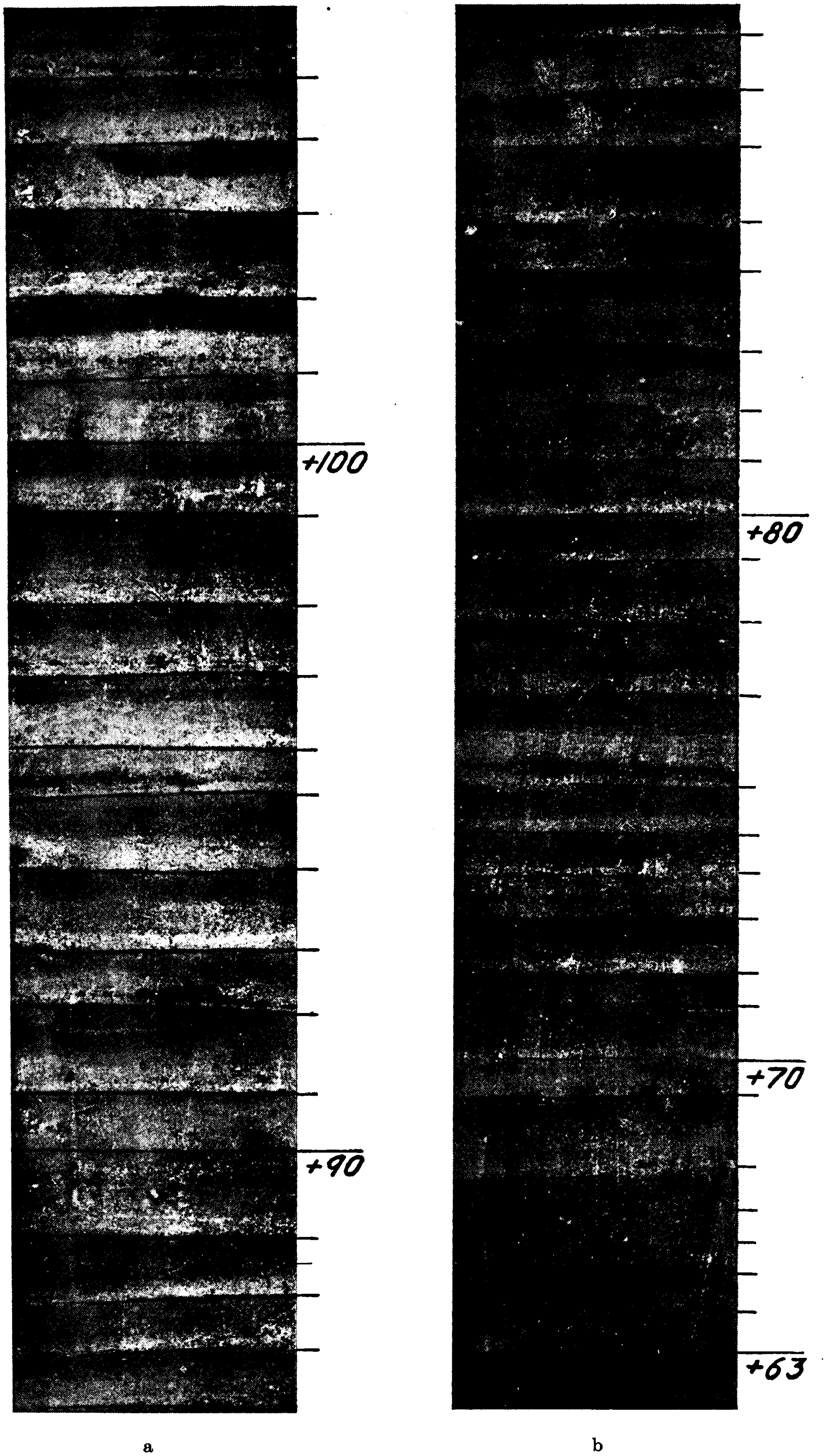


Fig. 22. Distinct micro-varves from Högom brickyard, Sundsvall, Me 2 mi, 5/1. Photo Prof. E. Stensiö.

The first microdistal varve specimen thus enlarged by twenty was taken immediately above what I called a moraine-raft, well exposed at the bus-station Iris a little west of Stockholm (Sth mi 4) and containing a great number of foreign boulders, which were supposed to be derived from a land-ice radius to the east of Gävle and the southwestern Botnic coast, because such rocks do not occur as bedrocks at any shorter distance. Thus I commenced a comparison of the graph representing the magnified microdistal varves in question with the time scale from the Gävle region.

With respect to the difficulty sometimes to discern the varve-limits or also to some small local disturbances by pressure from superjacent layers, it will be necessary at certain places and for certain specimens to make repeated measurements, but this new control will afford an excellent means of judging among different varieties of corresponding proximal varve variations.

Encouraged by this good result, I started analogous measurements on several specimens of microdistal varves, by and by brought together into the collections of our institute, principally from the Stockholm region and all magnified by 20.

In that way I succeeded in getting very good radial teleconnections between microdistal Stockholm varves and almost the whole series of ice-border varves from the centuries −780 to about −300 and, further on, micro-varves from the Sundsvall and Bollnäs (Hl. 54 mi, 125 mi) region at about the year −400 to a little below the Zero year, while Hälsingtuna at the coast covers the century −500 −600 by micro varves. Thereby practically the whole of the Finiglacial subepoch had been preliminarly registered also by microdistal varves, affording an excellent extra control of the time scale, and at the same time a new method of getting a highly improved registration of the solar variation as it reaches the earth. Dated microvarves from Högom, Sundsvall, magnified $^5/_1$, are shown in Figs 21 and 22. Graphs, Pls 76, 77. See also Tables, pp. 256, 262, 289–90.

The comparison was tried further northwards, but not until the century 300—400 before Zero at the end of the Ice Age did any correspondence occur. Here, on the contrary, a most striking similarity appeared and became still more complete by renewed measurements, totally independent of one another.

Notwithstanding reiterated, careful comparisons, this excellent correspondence with respect to a dominating sequence of characteristic constellations was verified, and no other one could be put in question.

At the same time it was as interesting as unexpected to be able to fix with certainty that real varve sediment, may-be microdistal, was spread out, reckoned from the nearest part of the ice-border in question, at least as far as 170 km, while ice-bergs with moraine rafts were carried out at least the same distance.

It is true that such distal sediment for the whole of a year was less than 1 mm thick, but still it allows of what can be called radial teleconnections over great distances as well as accurate determinations of, no doubt, very uniformly mixed sediment from the great number of melt-rivers, while the proximal varves, quite naturally, must be affected by several local sources of error.

Not being limited to any individual or to any special group of melt-rivers, the microdistal sediment thus must be considered as a natural medium sedimentation in general. Therefore, however, it is not possible to tell exactly how the sediment from one individual melt-river is fading out, when reaching the outermost limit of its distribution into the sea.

But in order to give some preliminary idea of that distribution I presented in 1932, p. 71, a diagram concerning the thinning out of the proximal sediment a couple of kilometers to the side of the late-glacial melt-river mouth at Stockholm, as communicated in the quoted publication.

In order to indicate in a general manner the more distal thinning out of the finest sediment, I have also given the observed thickness of that above mentioned microdistal clay varve at a distance of 170 km from the ice-border, to where it had taken some 150 years for the ice-edge to recede, and interpolated the intervening thicknesses which thus only in a very general way are giving a preliminary idea of the transition between proximal and distal sedimentation.

To get a more representative idea of this transition it will be necessary to work out medium figures for the thinning out of the proximal sediment at a sufficient number of localities, and that is only a matter of time and patience.

The principal thing is that now it has turned out how, by means of geochronologic measurements, the microdistal sediment can be identified and determined, even at a considerable distance out in the sea.

By the new investigations concerning the great extension of the microdistal varves new possibilities at the same time have been opened up for a study of such organisms, probably diatoms and pollen, which may have been deposited farther out from the icy shores. Being a quite new area of investigation, it is difficult to suggest what may come out of such a study, especially concerning the currents in the Baltic. As predecessors to the corresponding currents of to-day, they may be expected mainly to be southgoing on the Swedish side with its numerous melt-rivers, while the inflowing current mostly may have followed the eastern coast, thereby furthering the immigration of different kinds of plankton.

In this connection it would be of interest, if microdistal tube-specimens could be secured from the Botnic depression, where it seems, from the valuable investigations of Dr Stina Gripenberg, that in the regions named microdistal varves at several places occur without being covered by younger shallow-water deposits. As the microdistal varves even with the thickness of less than 1 mm can be quite measurable, it may not be impossible to get specimens representing quite a century and thus affording a chance of investigating its eventual plankton far out from the coast.

Micro-varves are also observed and mentioned as very thin varves, in a preliminary way by E. Granlund in 1931 and G. Lundqvist in 1926 and 1930.

Stockholm region.

Introduction.

Geochronology was born in the Stockholm region, and it was during the intense evolution of that town within the last five decades and with the accompanying innumerable different kinds of digging, that it became possible to bring together in the Geochronological Institute in Stockholm such a great number of detailed observations on late Quaternary data, that Stockholm will have a good chance to compete for the title: a Capital of Quaternary Geology.

It was here that it turned out that the land-ice, when it passed away, not at all was dead, as not seldom urged, but very active and exhibited a remarkable capacity in ploughing up and shoving together piles of big and rough boulders into marked frontal moraines, which, by intimate combination with individual connections between these latter with corresponding cyclical centres of the Stockholm ose, made it possible to demonstrate in the finest detail, how nature here has provided a most remarkable, excellent self-registration of the annual cycle of the climate, as expressed by the variations of the annual ice-melting.

For the possibility of investigating in the right moment a sufficient number of the plentiful but accidental and ephemere sections, it was necessary to live in their midst and to be at hand during a sufficient length of time.

Now it seems appropriate to give a summary of the pertaining observations from the Stockholm region as an introduction into the principles upon which geochronology has been founded.

Quaternary geology of the Stockholm region.

As geochronology essentially has originated and become developed in the Stockholm region and as this region is representative for a great part of eastern Sweden, where the Swedish time scale was followed up and worked out, it seems practical here to give a short review of relevant sides of its Quaternary geology.

At the request of the Director of the Geological Survey of Sweden I summarised in its publications, in 1932, the results of my studies concerning the Quaternary geology of the Stockholm region, illustrated by a map sheet on the natural scale of 1:50 000 together with illustrated special investigations with explanations in English.

This map is here reproduced on the scale of 1:150 000 (Pl. 58).

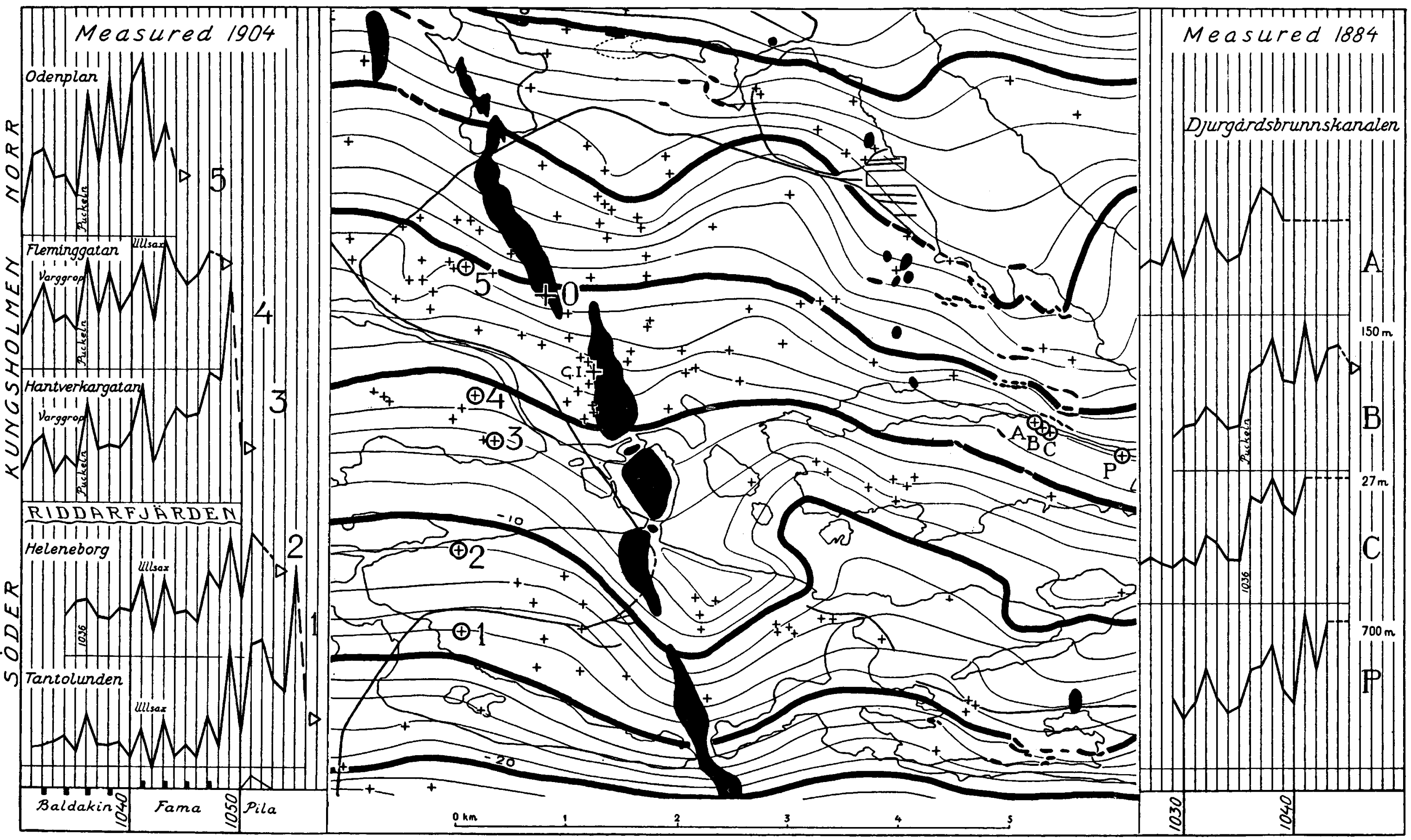


Fig. 23. First varve-connection and ice-recession at Stockholm. Map and Graphs: A—C, P, first connected clay-varve measurings; 1—5, first S—N varve connections reproducing the trend of ice-recession from S to N, also across a branch (or *fjärd*) of Lake Mälaren. Map: black, Stockholm ose; lines, æquicesses of ice-recession constructed from several measurements (small crosses); ± 0, temporary zero-year at Stockholm University, now replaced by the drainage varve of Indal River; G. I. +, the Geochronologic Institute.
Scale of map c. 1 : 60 000.

Quaternary rock surfaces and moraine cover.

On the Stockholm map rock-surface and moraine-cover were represented by a common mild blue colour. On earlier geological map sheets the rock exposures were marked with dominating, strong colours, hindering a clear view of the Quaternary deposits. Furthermore here, as in many other coast regions of Sweden, the rock exposures are so dominant that the common designation for the moraine covering and its gaps very often, just as in this case, signifies merely naked rock exposure. This is important to remember from two reasons. Partly because it indicates that the local, very striking occurrence of sharply limited groups of frontal moraines with an astonishing superabundance of big boulders demands a special explanation; partly because all these knobby exposures of the subbasement below the Quaternary sediments indicate how it has been possible at such a great number of localities to uncover and measure the series of glacial clay varves down to the very bottom, and thus exactly to fix the very year when, at every place, the land-ice receded and the registering varve deposition commenced.

This moderately undulating subbasement of the varve clays also occurs in the main southern part of Finland, but is in Sweden extended considerably more southwards, while in northern Sweden the varves are specially preserved and accessible in the great Norrland valleys. Another condition which has contributed to monopolise for Sweden the access to a continuous time scale was that along the considerable extension of the land in the direction of the ice-recession all along its eastern side, during late Quaternary time it had been depressed and afterwards emerged out of almost fresh water-bodies, favourable for the deposition of marked annual varves.

Frontal moraines.

The small but marked frontal moraines, first observed in the Stockholm region, delivered an undeniable proof that the waning land-ice was not, as earlier generally assumed, dead and motionless, allowing melt-rivers to develop on a surface without fissures. On the opposite, the regular intervals between those moraines gave the first indication of the rapidity by which the ice-border receded between every slight advance during the winter. Later on, this annual pulsation of the living land-ice was definitively proved by the intimate connection between those frontal moraines and the annual clay varves.

The Stockholm varves.

The varved clay in the Stockholm region was deposited under conditions making its investigation at the same time somewhat difficult and rather instructive.

The so-called Stockholm ose passes right through this town, thereby causing many of the irregularities occurring in the neighbourhood of a mighty current. Comes hereto the knobby topography of the bedrocks causing numerous deviations in the sedimentation. Also a rapid ice-recession caused a corresponding soon thinning out of the varves from the bottom upwards and a very strong Postglacial marine erosion by which the upper parts of the varved clay very extensively were destroyed and transformed into an unvarved, homogeneous horizon of Postglacial clay, deposited in all the lower parts of the district, so as to cover the original varved clay.

Still a very great number of diggings exposing varve sections near at hand and measurements carried on during more than half a century resulting in more than 700 measured varve series made it possible to connect almost all the measurements from point to point, and also to disentangle in detail the influence of even rather marked deviations (Fig. 24).

Numerous small layers of sand from the ose river make the varves often difficult to delimit on photos, though they are very well discernible in nature by their dark winter layers. Characteristic constellations of varves could be identified over the whole region and got occasional denominations, such as »the wolf hole», »the pillar», and so on.

The interference with the varve sediment from the neighbouring Uppsala ose-river to the west was one of the interesting data which could be fixed as well as numerous details commanding the sedimentation around the mouth of a large late-glacial melt-river (Fig. 25).

Thereby was also from first of certified that synchronism between different parts of one and the same varve did not at all imply such a schematical similarity as from some single observations once has been postulated under uncommonly regular conditions.

The drainage of the great Baltic ice-lake.

Considering the extension of the east-Swedish varved clay upon which the Swedish time scale mainly is founded, some explanations may here be given.

When in southernmost Sweden I commenced my tracings of the uppermost Baltic shore-lines, the impulse hereto was a visit during the preceding year, 1882, to Spitsbergen, where the vegetation could not conceal the very well developed late Quaternary shore-lines. In northeastern Scania I succeeded also to determine the said upper limit and its present attitude, sloping towards the south. As I found a rather corresponding slope in NW Scania, I supposed consequently all those shore-lines to be marine. Later on, as a consequence of MUNTHE's Ancylus discoveries, it became evident that the highest shore-lines along the Baltic side of south Sweden must have been formed along a great south Baltic ice-dammed lake. The south-looking attitude rather closely corresponding with that of the marine limit at the west Swedish side evidently was due to the fact that they were of the same age and had passed through the same stages of unequal uplift. The southernmost traces of water-erosion in SE Scania were thus cut out along the outlet of the ice-lake named and not by the waves of the sea.

Yet from our point of view this makes no difference, because at the recession of the ice in southernmost Sweden the level of the Baltic ice-lake must have been very little above the sea-level.

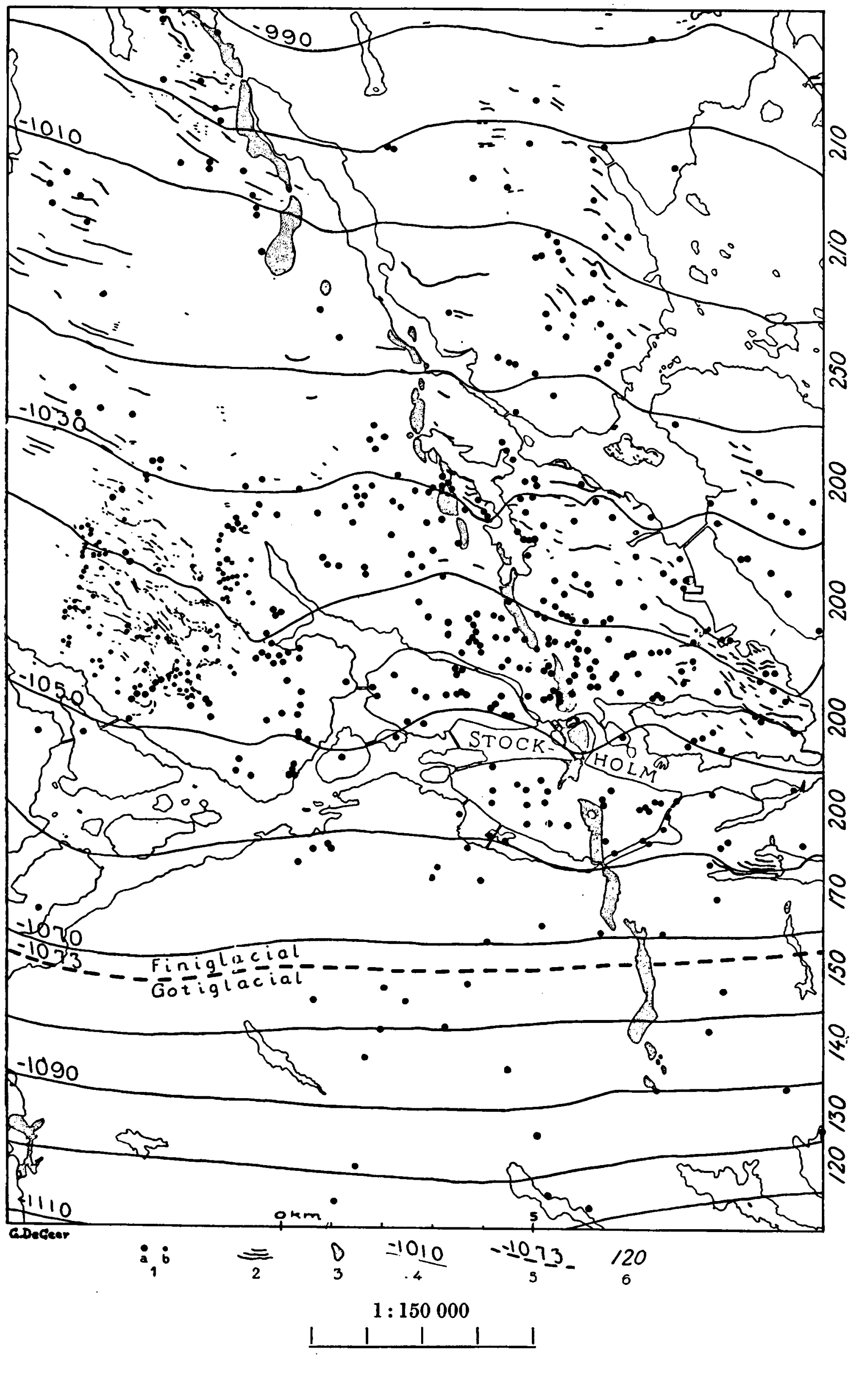


Fig. 24. Last ice-recession at Stockholm. 1. Varve measurements; a = earlier; b = recent. 2. Frontal moraines. 3. Oses (eskers). 4. Ice-border lines, years before Zero-year. 5. Limit between Goti- and Finiglacial ice-borders. 6. Annual recession in meters.

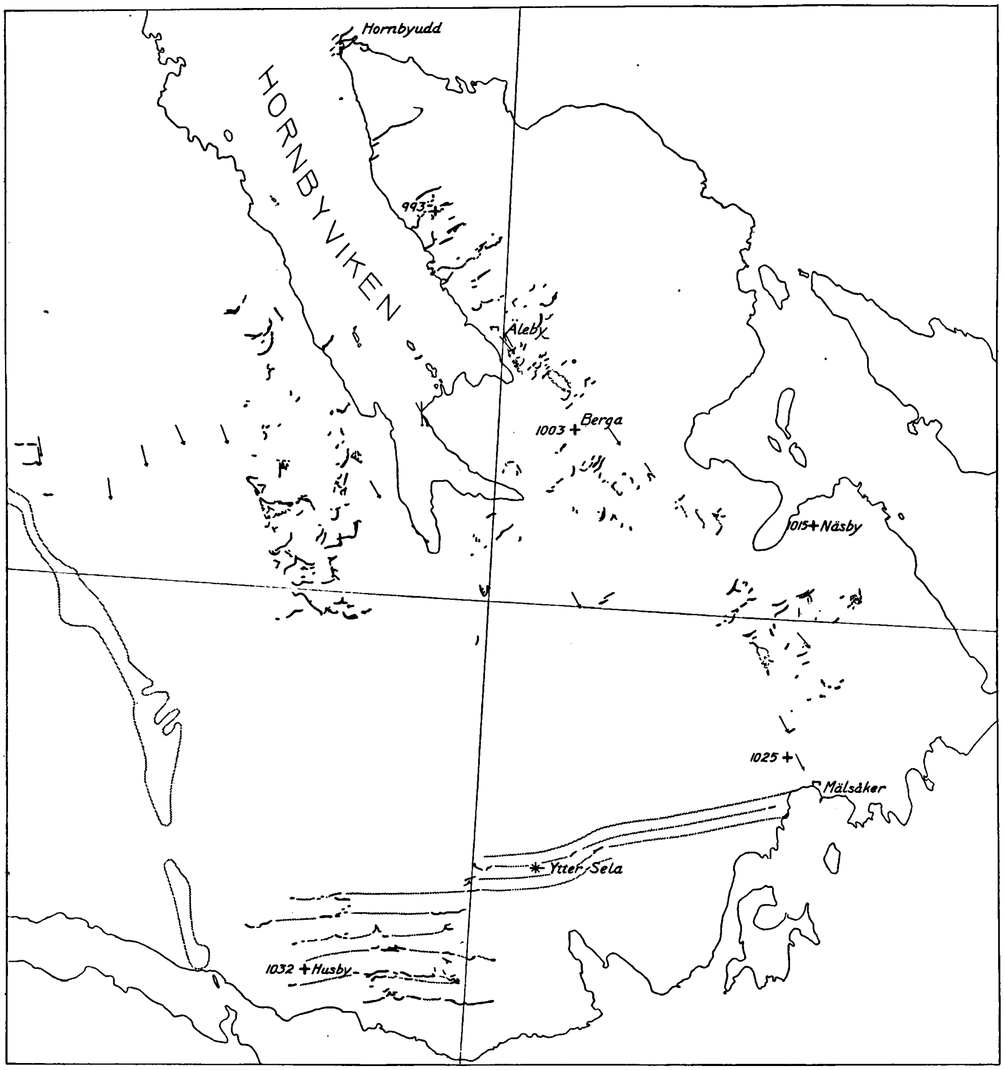
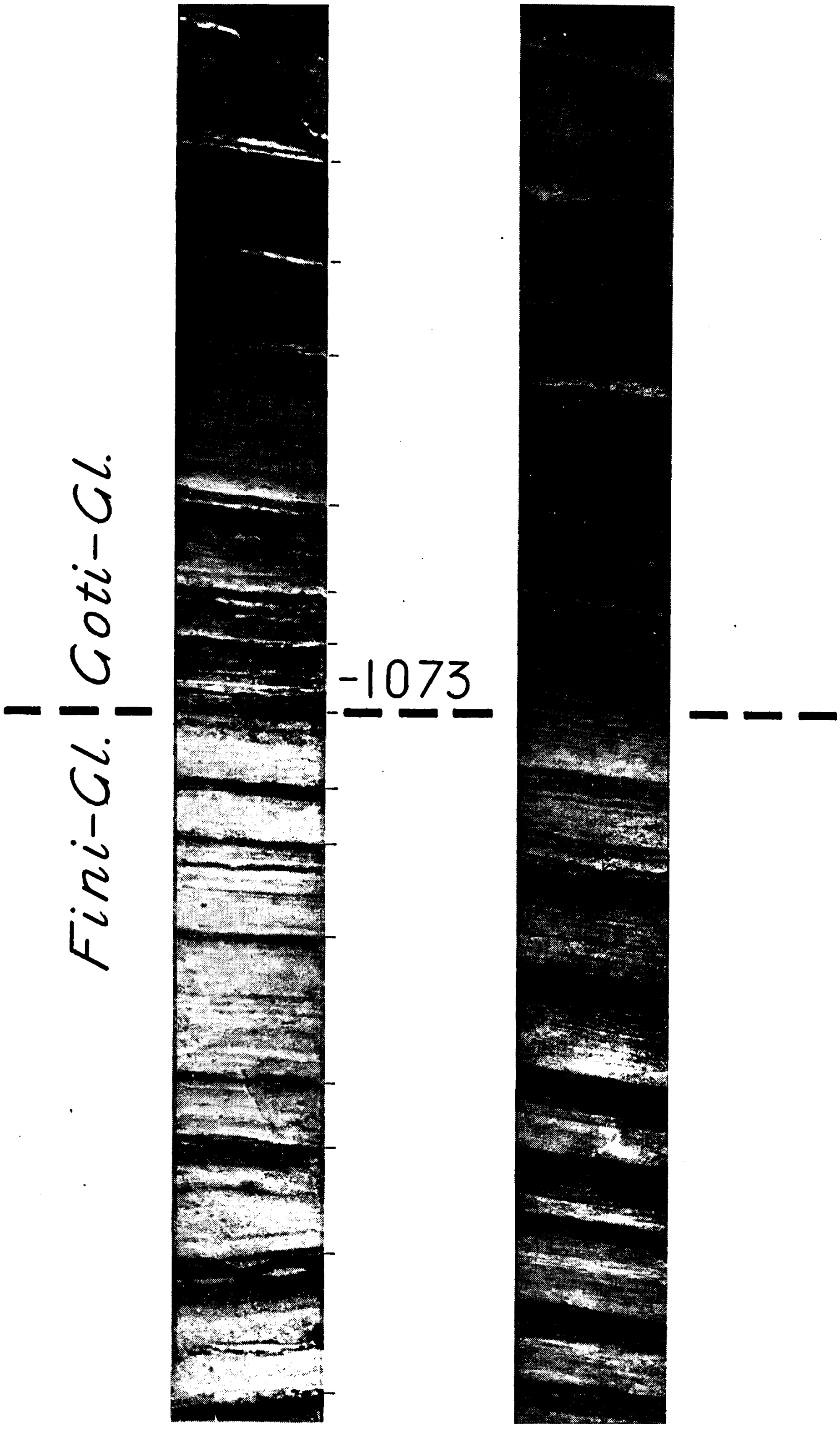


Fig. 25. Ice recession and moraines at Selaön, Mälaren.
c. 1 : 60 000.

But during the following evolution of the ice-lake named the land became gradually upheaved in so far that, when the damming ice-border retired from the last damming cape at Mt Billingen in the province of Västergötland protruding from the South Swedish highland, the shore-lines at both sides of that cape indicate that when the damming ice-border receded from the environs of cape Billingen, the great ice-lake must have been lowered down to the level of the sea with no less than 28 m.

This important lake drainage, seemingly the greatest known, has been registered in several ways. At the north end of Mt Billingen, as suggested by SIMON JOHANSSON it has left very conspicuous traces of erosion, immediately on their northern side followed by undisturbed frontal moraines of the annual type. Some



a b

Fig. 26. Baltic drainage varve –1073 before Zero. Varve specimens: a, from Skarpneck S of Stockholm; b, from Lina brickyard, N of Södertelje, Sl.

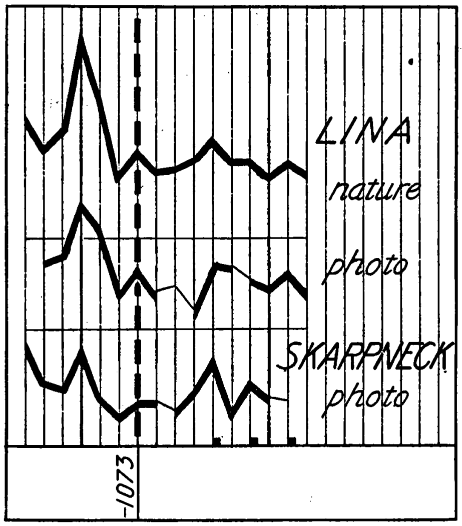


Fig. 27. Varve graph dating the draining of the Baltic ice-lake.

series of annual varves from the neighbourhood, measured by GÖSTA LUNDQVIST and the results being sent to me, were identified with other occurrences in Östergötland along one and the same ice-border passing the southern suburbs of Stockholm.

To the south of this ice-border the clay varves were more greyish and silty, while immediately to the north they became brownish and considerably richer in fat clay. From the coincidence of this very marked change in the consistence of the marginal varve sediment and that very ice-border by which this lake draining could be dated, it might be concluded that the inflowing brackish bottom current of sea-water has been caught in by all the outflowing melt-water as an east-going bottom current of reaction, causing, by flocculation, a more rapid deposition of the fine clay-material already near the ice-border (Fig. 26, 27).

The inflowing of sea-water is furthermore definitively witnessed by the appearance of *Portlandia (Yoldia) arctica* in the brown varves of the Stockholm region. These certainly rather dwarfed immigrants, (Fig. 28), — according to the varves — only paid here a very short visit during scarcely more than 100 years and probably did not spread farther into the Baltic region than to the east part of the Mälar depression as far as this one could retain sufficiently salt water at the bottom of the otherwise almost fresh Baltic inland sea. When the cooling ice-border retired but a little farther to the north and the finiglacial amelioration of the climate sat in, this ephemeric and local colony totally expired and came to an abrupt end. As of course they did not at all represent the high arctic *Yoldia* climate during that epoch of intense ice-recession, it may be somewhat misleading to use here the name of *Yoldia Sea* for a water so contrary to a real *Yoldia* climate.

Yet, as the late Glacial Baltic still was characterised by extended shores of

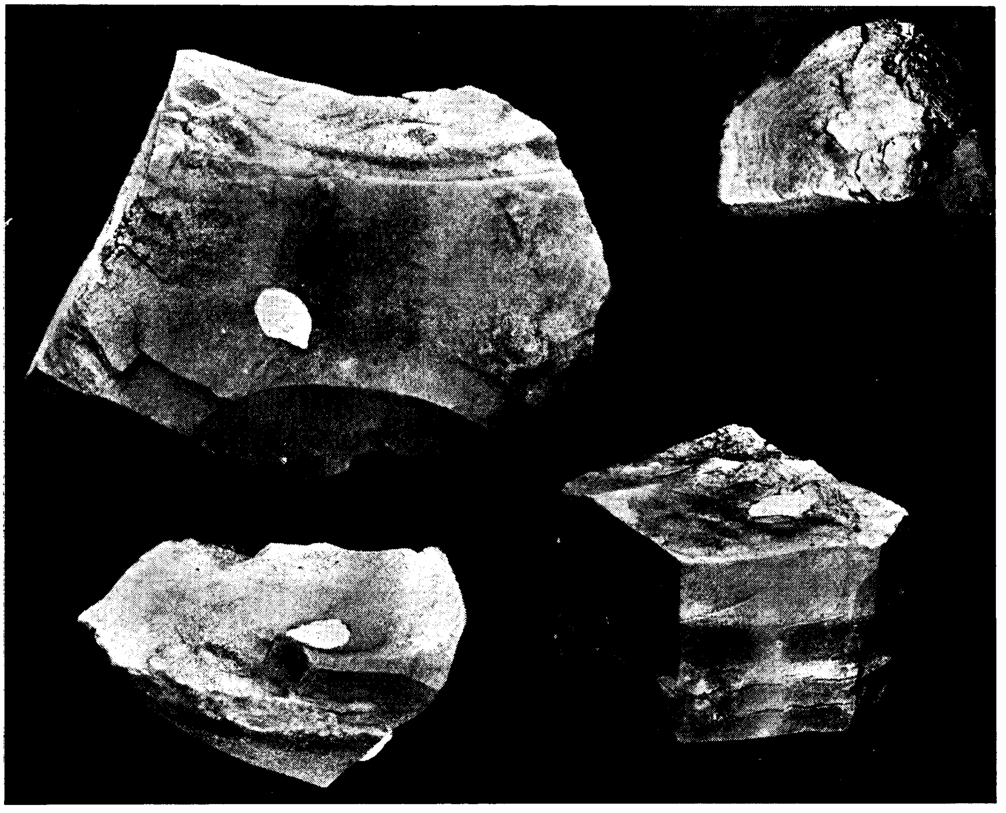


Fig. 28. *Yoldia arctica* in a clay-varve, most probably of the year –1020 b. Zero. Upper right corner: *Yoldia* magnified by 4 from the clay-specimen below. Photo Wahlberg.

land-ice, by immense quantities of melt-water and by drifting ice-bergs, this stage of the Baltic evolution perhaps could be named as that of the Finiglacial ice-sea.

Varves deposited in fresh and in brackish water.

This very remarkable, rapid transition of an enormous ice-dammed lake with fresh water into an almost equally large inland-sea in direct connection with the ocean also has been registered in a very remarkable and interesting way by a sudden change in the composition of the corresponding varves.

G. LUNDQVIST carefully measured the varves at the inside of the then cape Mt Billingen, and I succeeded to trace the same ice-border registering the influx of brackish water into the new Baltic domain of the sea extension, which was chosen as ending the Gotiglacial and commencing the Finiglacial subepoch of late-glacial time.

This influx of salt into the Baltic water in a very striking way has been registered in the composition of the corresponding clay-varves.

Already during my very first clay studies I noticed that the late-glacial sediment was designated as »*varvig lera*», or varved clay, as well in eastern as in western Sweden, though in the latter region for a long time I did not find any traces of varves, but in their place often glacial salt-water mussles, suggesting that a certain amount of salt might be a hindrance to varved sedimentation. This was assumed to be an example of the fact that presence of salt accelerates precipitation. Thus in the case of the varved clay the different parts of its ingredients in fresh water will be carried out unto successively graded distances, registering the balance between the deposition and the varying action of the current transportation.

In sufficiently salt water with a greater percentage of salt, on the contrary, the finer sediments of clay and silt are not deposited by coagulation but spread out far away with the current, while the coarser and more sandy material is sunk in the neighbourhood of the ice-border.

Thus at our west-coast the late-glacial marine clay does not show any lamination at all, as being deposited some way off the varying influence of the more sandy constituents, which had been laid down in the neighbourhood of the ice-border. Thus, when the ice was receding, such proximal, sandy deposits can be found for a few years varying with the finer, more distal sediment, seldom as much as half a dozen indistinct annual varves, representing a narrow, migrating zone, unhappily too local for connections.

These conditions explain why well developed varves are limited to fresh-water deposits in lakes or in bays with brackish water and corresponding mollusca; while deposits with true salt-water mollusca are not at all or only indistinctly varved.

Proximal varves spread out along the bottom.

Topographic influence on the distribution of sediment.

Already during the first varve investigations at Stockholm it was everywhere certified that a considerable part of the varve sediment with the cold and rather muddy melt-water was carried out along the bottom. Thus the varve deposits on the proximal sides of even small rock-bosses on the old sea-bottom, as at Norrtull station, were considerably thicker than the corresponding ones on their distal side, which would not have been the case if the muddy current had not followed the bottom of the sea, which was here about 100 m deep. This fact being definitively stated and well known already before Dr ANTEVS took part of my clay studies in Stockholm, it cannot be annihilated by a little experiment on a very small scale by which he proposes nothing less than to turn upside down this most essential process of the varve formation.

Later on this close connection between the bottom topography and the thickness distribution of individual varves has been certified in detail by numerous close connections of varves and by the minute topographic orientation of their thickness curves (Fig. 14, Pls 56, 57).

At several places some hundreds of meters off the ice-border and the glacial river-mouth small layers of real sand, sometimes current-bedded, occur in the clay, proving a transportation along the bottom.

As such a coarse, sandy material cannot be suspended but must have been carried in jumps along the bottom whirls, it is already in itself an irrefutable proof of a transport along the bottom.

On the other hand it must be emphasised that, at least a little distance off the river mouth this sediment transport along the bottom was so well balanced that, as a rule, no traces of erosion have been possible to find out on the subjacent varves. This is indeed a very important fact, because, if it had been otherwise, all those in finest detail corresponding connections would have been impossible. This is also the case at a few places, as near Mitau in Lettland, where beautiful clay varves had been deposited in an ice-dammed lake, so shallow that almost every varve had been intensely eroded by ordinary waves, so that the original thicknesses were not to be measured.

In some places, as along the deepest part of the postglacial Ragunda valley, where the current of muddy melt-water from the winter-snow on the highlands had its main passage, the well marked annual varves which by the action of the current were regularly undulated, had got their proximal side of these small current-ridges distinctly cut away, but always only partly, so that never the whole of a varve had been destroyed.

Along the sides of the valley, the varves were parallel to each other and afforded a good control of the number and of the true thickness-variation.

Microdistal varves of so-called Ancylus age.

By the great and numerous sections through the different ose-deposits in the Stockholm region it could also be closely followed up how the oses in their interior were found to consist of a kind of gigantic varves or individual centres of gravel which, by iterated direct observations, were found to transgrediate, every one in its turn, into sandy current-ridges, gradually passing over into a less and less sandy, normal clay varve.

The lowermost clay varves from the very bottom and upwards have been measured and identified at more than 700 localities in the Stockholm region, but their continuation upwards to a great extent has been eroded away during the later upheaval of the land. Generally it is only at the oses that some remnants of the uppermost varves have been protected against later erosion by downslidden or downwashed gravel- and sand-material.

Thus the Stockholm region offers excellent opportunities of studying the different elements of that gigantic mechanical analysis, which was executed by the torrent of melt-water, when assorting the morainic material. It is easily understood that it is mainly the finer parts of this sediment, as deposited at some distance from the turbulent current, near the mouth of the melt-river, which former, by its from year to year varying thickness, can afford a practicable registration of the melt-variations. See: Stockholmstraktens kvartärgeologi, 1932.

To illustrate the method which from first of I proposed for building up a time scale and which afterwards all the time has been used for these studies, Figures

12—19 with English explanations have been inserted into the paper named. In Fig. 30 there is, furthermore, given about a dozen diagrams, showing for different countries and parts of the world what a degree of correspondence which, of course with certain local deviations, can be expected from this universal varve registration as to those two centuries when the ice-border receded across the Stockholm region.

Already at an early stage of the geochronological investigations I found that the uppermost and thinnest, microdistal varves, which were very fat and homogeneous, gradually passed over into a quite similar, ultradistal clay, in which the last traces of limits between the varves totally faded out. This clay already by HAMPUS VON POST in his masterly and fundamental discrimination of the Swedish Quaternary deposits had been distinguished under the name of *undre grålera* — lower grey clay — as the fattest among the late Quaternary clay deposits. Later on, when *Ancylus fluviatilis* and other fresh-water forms were found in this clay, it was often called *Ancylus-clay* and as its deposits indicated an ameliorated climate, this clay was often referred to the Postglacial deposits. Still from the continuous connection with the varved clay, to which it formed an immediate succession, I found it more rational to put the limit between Glacial and Postglacial to the intramarine land-upheaval, which I had observed in southern Sweden and which at least in that region indicates a real break in the succession of deposits. It was in order, if possible, to follow this break further to the north, that I tried, by numerous levellings of different wind-directions, to fix the unequal upheaval of the land and thereby to find out and determine an eventual discernible continuation of the Postglacial limit.

Some authors have suggested the occurrence of two Postglacial oscillations within the southernmost parts of Sweden, but, as farther north as well as in Denmark only one such oscillation has been observed, this may be left as an open question.

Along the west coast of Sweden I had followed and fixed the transgression of the rich Postglacial marine fauna gradually rising from the actual sea-level very nearly to the outlet-level of Lake Venern. From there Dr R. SANDEGREN believed to have followed its all the way rising level towards the pass point over to the Baltic side. Here consequently the corresponding Postglacial marine limit must be expected to be developed at the same time, but very soon afterwards it was found that the assumed Postglacial limit along the east side of Lake Venern was not all the way synchronous and to the north less uplifted than assumed, whereby the synchronous, really Postglacial limit must be sought for at a lower level. In the Stockholm region its minimum height seems to be about 50 m above sea-level and not 60 m, as had been the consequence from the first assumed height on the Vener side.

Numerous levellings during 1922 and the following summer along different parts of about 30 of the named oragan lines proved that the upheaval of land had proceeded very regularly and, as a rule, everywhere at a remarkably proportionate rate, whereby locally missing shore-lines could be determined as to their height by a rather satisfactory, simple calculation from the heights of those developed at the place in question.

In the Stockholm description indications are given how to control the Postglacial limit of that region and to make out if, even at this latitude, there has been a transgressional limit or only a retardation of the upheaval of land. So far it seems as if in the Stockholm region the level of about 50 m a. s. should correspond to the highest limit of the postglacial marine transgression, the very marked height of which I have had the opportunity to fix in southern Sweden.

As will be mentioned below, I have recently found some chronologic holds concerning the epoch when some such postglacial phenomena seem to have occurred, at the same time delimiting the so-called Ancylus epoch.

The Stockholm moraines.

Previous and present mapping.

As already mentioned, out of the whole region which in Sweden has registered the Fini- and Postglacial recession of the last glaciation, the most thouroughly investigated part lies between Stockholm and Uppsala. This region also in many respects is very characteristic, wherefore a somewhat more detailed description concerning its melt-deposits may afford the best way of introduction into the whole phenomenon of that ice-melting and ice-recession which has afforded the basis of our geochronology.

Since the beginning of the eighties of last century the author has had the opportunity of studying the Quaternary formations of the Stockholm region. Thus he has brought together varve-localities, studying and measuring at the same time the successive, numerous and often very good sections, showing the inner structure of the oses, thereby as far as possible, by levelling and mapping, preserving shore-lines and other surface phenomena, before they were cut away.

With respect to the small frontal moraines which earlier had been overlooked, I observed the first of them in 1889, soon afterwards finding the whole group in the Bromma region NW of Stockholm. In the same year this find was shortly described in the journal of the Geological Society of Stockholm and, later on, reproduced on a sketch map in the Stockholm description of 1897, published by the Town Council of Stockholm, and partly on a more detailed map on the scale of 1:20 000 in my description of the Quaternary Geology of the Stockholm Region, in 1932, and, in 1936, in a paper on »The Aerodrome of Bromma during the Ice Age», published in the Proceedings of the Town Council of Stockholm.

In Pl. 59, a, b, here is given, on the larger scale of 1:15 000 the same moraine occurrence, but extended as well towards the north as southwards towards its southernmost end, where, according to my opinion, traces of seismic fracturing of the bed rocks seem to be most conspicuous.

With respect to the region immediately north of Stockholm which from several points of view is of special interest, it is reproduced as a map, likewise on the scale of 1:15 000, Pl. 57.

This map, namely, gives that part of the Stockholm ose from the annual deltas of which the main bottom varves in the very Stockholm region have been deposited like a succession of radiating fans.

Lake Brunnsviken region.

Within the region of the lake named, where the natural topography in general was not yet essentially changed by man, there were better opportunities to observe the original surface of the bed-rock as well as the frontal moraines and ose-hills than within the rather levelled area of the city itself.

Still, as there existed no quite suitable map for this purpose, it was necessary to bring together, from different sources, material for such a map.

For Lake Brunnsviken I used a sounding chart of 1841 with 1185 soundings, executed for the lowering of the lake, 1.9 m, down to sea-level, to which the soundings were reduced (scale 1:4 000).

The northern part of the lake was in 1920 minutely sounded from the winter ice by three of my students at the Stockholm University, T. HAGERMAN, S. LINDMAN, and G. ZIMMERLUND.

The basin of Lake Brunnsviken is situated at so low a level above the sea that, with respect to the actual amount of the land-emergence, it cannot have taken more than six hundred years since it was a bay of the Baltic. About a century ago it had been uplifted to 1.8 m a. s. and was a true fresh-water lake. The draining of this lake down to the sea-level, was executed a few years after 1841. Thus this lake, by the draining of its outlet at Ålkistan strait, now again has become a bay of the Baltic, after for about four hundred years having been a relict lake, the name of which — Brunnsviken = a bay of the sea — may be said to be well chosen. On the map a stipled line indicates the extension of Lake Brunnsviken before its lowering, within the Royal park of Haga. At several places this ancient shore-line still can be seen, sometimes well marked by rows of ancient alder-roots.

On the present map Pl. 56, Atlas, are only given isobaths for every 10th meter below sea-level, still being very well fixed by the 480 soundings taken.

With respect to the adjacent part of the sea, or the sound of Lilla Värtan, the isobaths of 10 and 20 meters have been constructed from a chart of Stockholm harbour on the scale of 1:15 000, issued by the Royal Sea-Chart Department (Kungl. Svenska Sjökarteverket) in 1928. Soundings some 2 800 in number.

As to the very ose ridge, the main part has been founded on a hypsometric map, issued by BENNET & Co in 1913—1914 on the scale of 1:1000 with 1 meter's isohypses for every m.

Other isohypses to the west of Brunnsviken bay mostly are derived from older military measurements from the earlier part of the last century with isohypses partly for every 10 and partly for every 5 feet. As to the coast region along the sea, the map was founded upon new, excellent official maps on the scale of 1:5 000 with 1-meter's isohypses; the region to the east, between Brunnsviken bay and the sea, is founded on official maps of N. Djurgården edited by the Commission for Ladugårdsgärde. Scale 1:8 000. Good isohypses for every meter.

For the northernmost region was used a map compiled by the Civil Office of Stockholm, Stockholms Stadsplanekontor, in 1929. Scale 1:4 000. Isohypses for every 1 meter.

Several details concerning roads and buildings as well as astronomic coordinates referred to the former Stockholm Observatory, situated 59°20′34″ N Lat. and 18°3′30″ E Greenw., are taken from the new »Map of Stockholm» with Environs by H. HELLBERG and A. E. PÅHLMAN, on the scale of 1:8 000.

The island Tranholmen is reproduced from a geometric map on the scale of 1:4 000 with 1-meter's isohypses.

Morainic material.

The subbasement of the Quaternary deposits, as I have suggested earlier, is in the whole of Sweden and surrounding countries a very extended sub-Cambric base-level plain which gradually became covered by Cambro-Silurian deposits. Along the western part of the Scandinavian peninsula these were, later on, intensely overfolded by the Caledonian mountian formation and along its eastern part more moderately dislocated. The protecting cover of Cambro-Silurian deposits generally was best preserved within the deeper depressions, as in the Baltic valley and on its lower surroundings. When, even here, the original protecting cover had been denuded, the flat subbasement of Archean rocks for a long time in the main has preserved its base-level character, though more or less knobby by pre-Quaternary weathering. In more upheaved parts of the land, where the covering beds earlier were denuded and the subbasement was more deeply dissected, the concordance between its highest summits generally affords a sufficient material for a hypsometric restauration of the original base-level.

Now these two phenomena, the occurrence of the base-level and its more or less moderate dissection has afforded a most favourable subbasement for a many-sided study of the Quaternary deposits in their varying attitudes towards the knobby bed-rocks.

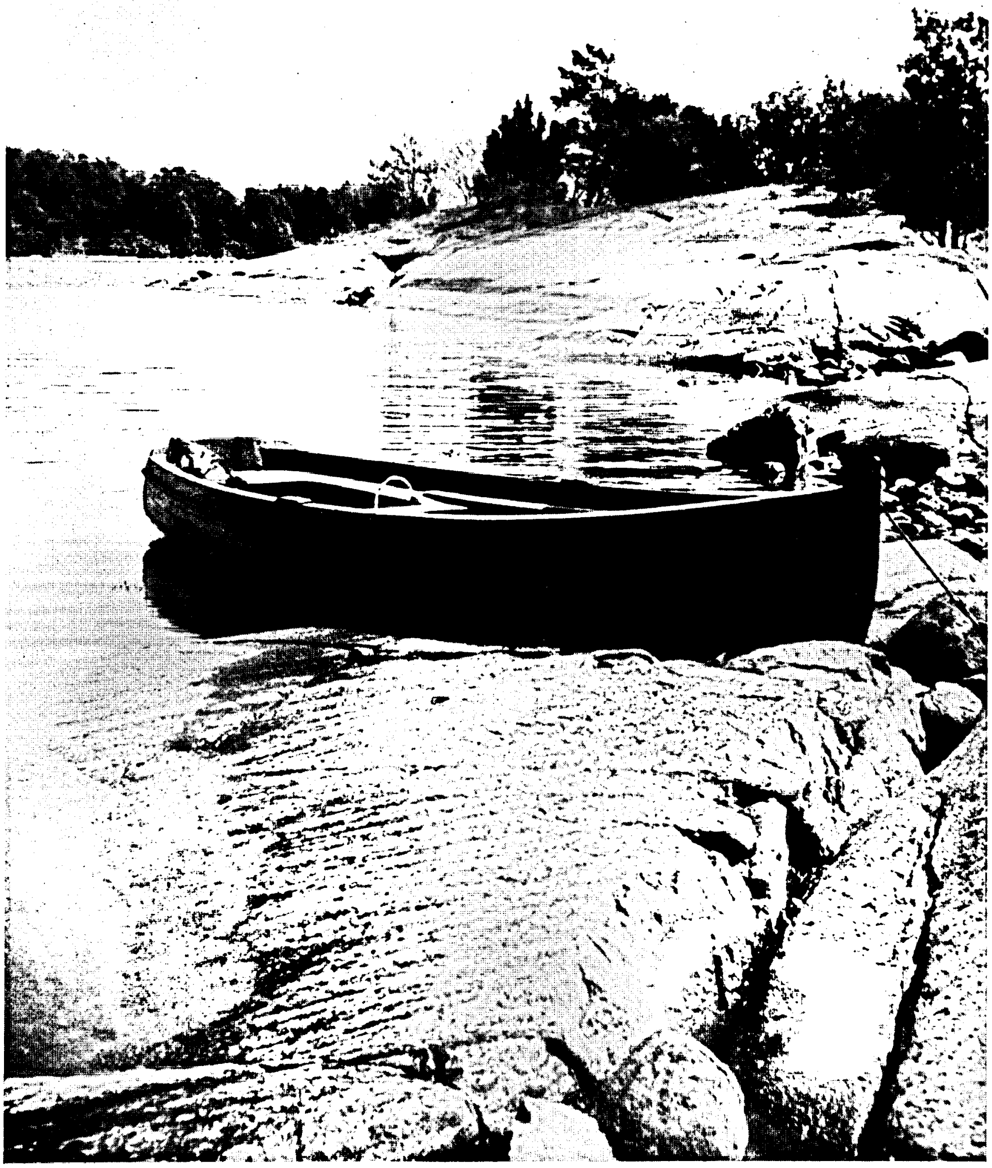
As the late-glacial sea covered a considerable part of the lowlands of Middle Sweden, its deposits now are accessible at a great many places almost everywhere, in the uneven topography being during the postglacial land-emergence more or less cut through by the waves, thereby giving easy access also to the bottom layers.

In some regions, especially within the higher parts of Northern Sweden and of the South-Swedish highland as well as of the more peripheric regions on the continental side of the Baltic, the bed-rocks are often more or less deeply covered by morainic deposits, while especially in the mid-Swedish lowlands these often are more scanty or almost missing.

Sometimes it has been assumed that this deficiency of morainic matter could be caused by shore-denudation within the region formerly depressed, but the naked regions do not coincide with those formerly depressed and do occur also above the former ones, likewise in regions so very flat that they cannot have allowed of any shore-denudation.

This local scarcity of morainic material is of interest from different points of view.

With respect to certain local rows of frontal moraines overburdened with



Stockholm region. Typical ice-worn rock-shields and striæ. Bare rocks even in wave-sheltered depressions. Photo O. Halldin, 1938.

innumerable local boulders occurring at the very end of the Ice Age in strong contrast to the surrounding almost total lack of boulder material, it requires a special explanation.

Furthermore the general scarcity of morainic matter in comparison with the rather considerable material in the oses which must have been redeposited from such material makes it evident that the ose-material cannot have been locally eroded along a single river-course, but must have been gradually brought together by subglacial rivers, intensely shifting its course and gradually depositing thereby collected material just at their mouth, wherefore the oses in these regions do not represent a conservative trend of the melt-river, but only the successive situation of its mouth.

Unequal distribution of till.

A phenomenon which has not been subjected to any special investigation is the rather unequal distribution of morainic matter over the subjacent bed-rocks.

Sometimes, as in western Dalsland near the Norwegian frontier, even above the highest marine limit, the bed-rocks are almost bare with only very little and scattered morainic matter testifying the supramarine situation.

Certainly in supramarine regions as well generally in Northern Sweden as on the South-Swedish highland the bed-rocks are generally covered by a considerable morainic material.

Still even in lower regions earlier covered by the sea, as in northern Uppland, the bed-rocks are almost totally covered by till. Yet in the southern part of that province, especially in the environs of Stockholm, the bed-rocks are almost totally devoid of a till-covering. This is also the case at localities between frontal moraines, proving that the ice here did carry morainic material which was richly deposited in the frontal winter moraines, but which had totally disappeared during the intervening summer retreats, marked by totally bare rock surfaces. Also these certainly had been covered by melt-deposits of varved clay, which easily had been removed already by a feeble wave action. But here this never could have been strong enough to carry away even the smallest stones of a till. Here it was also for a long time rather inexplicable how on the whole the frontal moraines had got hold of such great quantities of till and great heaps of partly quite gigantic boulders, when such material was almost totally lacking on all sides immediately around the morainic region.

As to ice-berg transport, it is also indicated by another phenomenon. On the surface of oses and in the pertaining, finer melt-sediment as well as their remnants sometimes occurs a material, obviously being redeposited till, which the drifting ice must have carried out from one or other ice-front and deposited at the outside of the ice-margin. Such drifted, secondary moraine beds may be called till-rafts.

Yet at the outside of this margin almost no such morainic matter here has been left, and this seeming contradiction may be explained by ice-fracture and till-transport by ice-bergs.

The formation of frontal winter-moraines as well as the pushed-up position of many among their boulders do show that during this epoch the ice-border moved somewhat forwards, being on the whole stationary, whereby the moraine material became deposited in the frontal walls and not carried away by ice-bergs, as was the case during the summer-recession.

Annual frontal moraines.

On a summer morning in 1889, when commencing an experiment with comparison of geologic mapping with and without special contours for rock exposures, I found, already on the very first day, to my astonishment a distinct, small, but quite regular frontal moraine in the neighbourhood of the royal castle Ulriksdal.

It gave a vivid remembrance of my first visit to Spitsbergen a few years earlier, and, this kind of moraines not being observed in our country before, I made the adjoined sketch of it (Fig. 29), using a fence as base line. Soon afterwards I found a few other similar till ridges in the vicinity.

But, when for the comparative mapping moving over to another place, I was still more surprised, because here I met with quite an abundance of the same kind of small, marked and indubitable frontal moraines. This was in the centre of the Bromma-parish, as seen on the map (Pls 58, 59).

Especially striking was the circumstance that those small and sharp frontal moraine-ridges did occur in rather regular rows with an interval of about 200—300 metres. In the transactions of Stockholm's Geological Society for the year in question I gave a short account of what I had found and suggested that the regular interstices between the till-ridges might depend of their deposition during the winter-pauses in the recession of the last land-ice, with the remark that this might be possible to decide, if it could be shown that one annual clay varve had its northern limit along every special till-ridge (Pls 21, 22). Several years later I could certify this in detail (Pl. 23).

In the mean time I had observed, at some places between Stockholm and Uppsala, the same kind of small frontal moraines, and I had the hope that it could be possible by careful mapping of those moraines and their interstices to get an idea of the time required for the last ice-recession past the region in question.

Later on I found that those annual moraines are confined almost only to certain rather marked, delimited areas and between those often are totally missing.

Thus it turned out that the determination of the land-ice recession has to depend exclusively on the gradual transgression of the annual clay-varves, which afford an omnipresent and thereby more exact record.

Yet the annual moraines from other points of view are of great interest. Thus, where they do occur, they exhibit an exact, obvious registration of the very ice-border line for considerable series of successive winters, very conspicuously illustrating any details concerning the physics of the land-ice, its recession by fracture, formation of ice-bergs as well as the deposition of boulders, ordinary till, melt-water gravel and -clay. Without their close relation to the ice-margin it would never have been possible in the same detailed way really to fix these and other pertaining phenomena (Pl. 23).

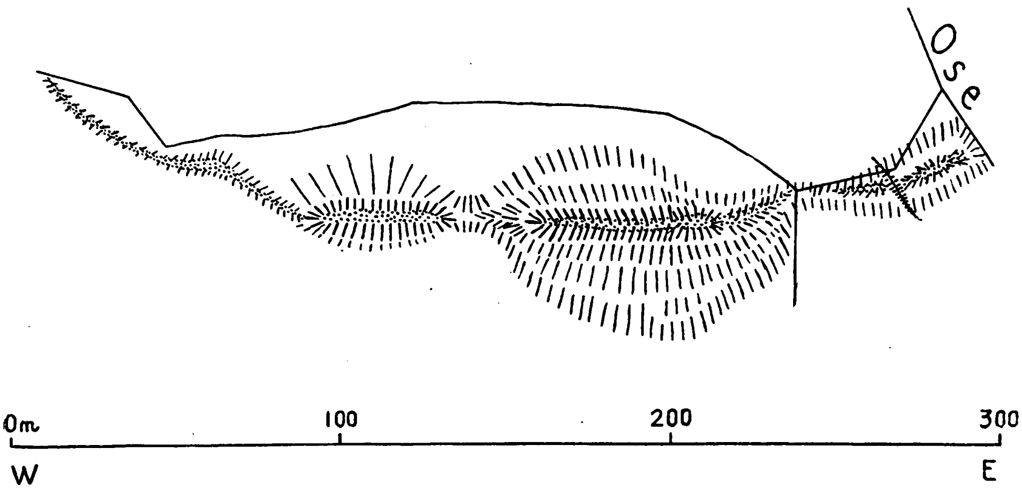


Fig. 29. Primus-moraine, Ulriksdal, 1889.

But, furthermore, during the last winter the very existence of these frontal moraines has suggested a quite new explanation, which, if it will be verified, may be of special interest with regard to the endogene processes accompanying the recession of the land-ice.

In the Bromma region, where the moraines in question are best developed and most carefully investigated, it seemed already from first of, as already mentioned, very remarkable that sufficient material here could have been left until the very end of the last glaciation, considering the long row of millennia during which the land-ice had swept away and exported loose material by its denudation.

At first I suggested as possible that when the ice-border receded, the movement of the land-ice had changed somewhat as to direction and thus got hold of morainic material which earlier could have been protected against ice-erosion by its situation on the lee side of the glacial round-rocks. But the continued investigation made it evident that, within the occurrence of moraines and especially on their distal or outer side, there appear rather formidable heaps of boulders, often a couple or several metres in diameter, while on the opposite, at the outside of the morainic belt, boulders in a most obvious way are lacking.

The seismic moraines.

After the first finding of annual moraines I observed similar occurrences at several other places in Sweden as well in the field as on the economic maps, which are showing the limits between cultivated field and — by very precise contours — small included strips of stony and generally wooded or shrub-covered patches, that is to say, generally spoken, between moraine and sediment.

Where such narrow strips exhibit a marked parallelism, not coinciding with the strike of the bed-rocks, judging from the geological maps, and approximately at right angle to the striæ of the region, it seemed very probable that they should indicate groups of the same kind of annual moraines, as was also ascertained in the field at several places.

At one place at least the phenomenon seems to be sufficiently well characterised already by the economic map. It is at the southeastern part of the province of Vermland and at the very easternmost part of the great Vener-depression. Here the surface of the land, as part of an old base-level plain, is very flat and for a great part covered by the lake. The peninsula and islands are very low and the bays are shallow with depths scarcely surpassing 1—2 m, which is also probably true of the peat-bogs and clay-coverings.

These conditions were favourable by obliging the cartographer to map out even quite small ridges in form of small islands and capes. Those of a somewhat greater order of magnitude were running about N—S, as evidently determined by the regular strike of the bed-rocks in this region. But in a certain, rather well marked part of the district there occurs, at about right angles to the last mentioned, broader ridges, a considerable number of quite small ridges, which could be assumed of being frontal moraines already from the total character of the occurrence and their marked parallelism, about at right angle to the general direction of the glacial striæ.

As this occurrence seemed to be quite an ideal example of the phenomenon, I paid a visit to the region in the year 1895, when the economic as well as the topographic map had reproduced this unique phenomenon. Such a concentrated association of moraines could be called a seismic moraine, or *seismic mora*, from the alpine word *mora*, meaning a heap of boulders, and possibly being the origin of the word moraine.

As to this special seismic mora, it seems that its delimitation can be taken out quite well from the economic maps, because in this extremely flat region even such small ridges as the moraines, generally but one or a few meters in height, may be practically visible on the maps, where they are not really missing.

Thus it seems fair to state that this mora begins a little south of Årås, situated at the mouth of the river of the same name, draining Lake Skagern, and about as far north as the two shallow bays, in this direction continuing the bigger Årås bay. The extension of the mora is about 5 km in W—E and 15 km in N—S. Its eastern limit seems to be rather parallel to the marked topographic fault-step which marks the eastern limit of the Vener depression (Fig. 33).

This sharp delimitation of the mora, by bed-rocks and topography are the same all around, and seems to be best explainable in the same way as the above described local occurrences of annual moraines in the Stockholm region, or by local earthquakes in connection with the late-glacial upheaval of land. At the Årås-mora, its parallelism with the faulted Vener-depression seems to indicate a local adjustment of the underlying magma, resulting in a corresponding shatter-belt, so markedly displayed by the land-ice oscillation.

It is desirable that systematic and detailed investigations of the mora-phenomenon at several other occurrences soon will show, if here we have got a new means of studying and dating the seismological effects of the remarkable and very considerable late-glacial upheaval of land. Certainly it seems to be a noteworthy cooperation between tectonics and annual ice-oscillations, explaining how, in regions with otherwise an almost bare rock-surface, an abundant boulder-material could be forwarded, for the formation of such moras, quite locally and within a delimited space of time.

The Bromma seismic moraines.

The northern, main part of the well defined mora in the Bromma region is so regular that the map seems to make a detailed description rather unnecessary and has had to speak for itself by help of some earlier publications.

But concerning the southernmost part of the mora in question it is so complicated that it has needed a great number of iterated visits and completing measurements until the very last time before it could be left to the printer.

Before this could be done, the detailed following up of the moraines exposed as well by nature as by successive diggings which also gradually made it possible to get the necessary number of varve determinations.

As shown by the map, as well the moraines as the extension of the individual bottom varves have shown definitively that the ice-border at this stage of its recession was splitted up into lobes and intra-lobes in a very striking way.

At first it looked as if the thinner part of the ice-border above the higher rock-surfaces had been especially fractured, thus causing several intra-lobes. This explanation is especially tempting at the Nockeby plateau which corresponds to the marked intra-lobe of the ice-border and, farther east there were indications in the same direction. But later on it was found that to the west of the valley at Nockeby there was a considerable intra-lobe found on lower ground lasting one single year, −1048, and proving that the rapid intra-lobe-recession of the ice-border must have had also another cause than the thinness of the ice.

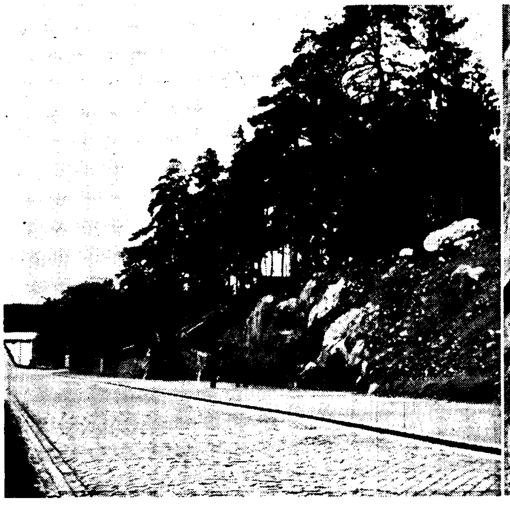
Then came the conclusion that the late-glacial earthquake was indispensable for the explanation of the striking superabundance of boulders in this very region. And if the bed-rocks here were splitted by an earthquake this must also have been the case with the superjacent part of the land-ice. This implied finally the explanation why the ice-border exactly in the region where the accumulation of big boulders reached its overwhelming maximum, had become so exceptionally and irregularly lobate and broken. But the cracks in the ice could freeze together anew and thus farther to the north the ice-border became more regular, while the broken granite remained splitted into boulders.

But exactly at the southernmost end of the morainic belt there is a striking contrast between the immediately adjacent, almost totally boulderfree region and the rather amazing heaps of boulders, often of gigantic size and heaped upon each other without any interjacent matter.

These phenomena are most easily observed in the close neighbourhood of the marked block-heaps of Olofslund. Immediately to the SE of it the ice-border from the year 1047 has reached the moraine of the preceding year and, as shown by Fig. 30, has been splitted up into small lobes with masses of boulders, gigantic indeed, while immediately east of the moraines there occur only somewhat splitted rocks. Some of the shaken and splitted rocks are shown in Figs 30—32.

Fig. 30. Stockholm, Bromma. Bed-rocks splitted by the Bromma earthquake. Left: proximal side towards the land-ice with polished surface still *in situ*; middle: intersected by fissures; right: split up and loosened unto a morainic train. Mimer's grove, S side of Drottningholmsvägen road of the year –1047. Photo E. H. D. G., 1938.

Fig. 31. Stockholm, Bromma. Same as foregoing, middle part: fine-grained morainic material pressed in by the land-ice, so as to stuff all the fissures, during the years from the earthquake in –1050 to the year –1047. Photo E. H. D. G., 1936.



a

b

Fig. 32. Stockholm, Nockeby. a. Some 0.2 km NE of Nockeby bridge, north side of Drottningholm Road: a breccia, dipping about 40° SW, being a couple of dm broad, but widening upwards and passing over into a moraine, probably representing conditions near the border of the earthquake. b. Detail of the fissure with its loose rock fragments. Photo E. H. D. G., 1939.

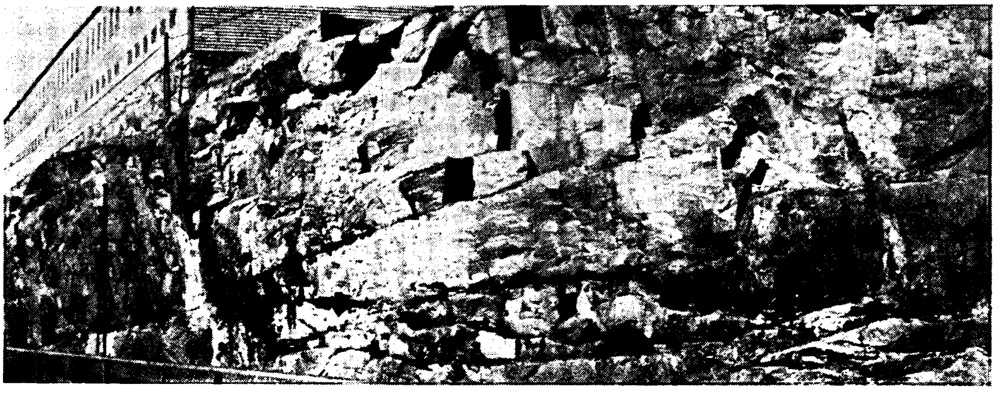


Fig. 32 c. Stockholm, N., Östra station. Horizontal zone in granite, slightly splitted probably by a Quaternary earthquake. Eastern railroad station, Djursholm Line. Photo E. H. D. G., 1938.

It seems as if the symbiosis between boulder-producing earthquakes and moraine-building oscillating ice-boulders commenced about at the year −1050 before the end of the Ice Age, or 9640 years before A.D. 1900.

Land-ice pressure and earthquakes.

Many years ago I observed along the road from Stockholm to Drottningholm not far from Nockeby an accumulation of big blocks at the foot of a bed-rock height.

But when preparing the Quaternary map of the Stockholm region, I found in the depression north of this boulder-train that the proximal limits of the varves were running about at right angles to the ordinary direction of the ice-borders.

This became certified by detailed varve measurements, made possible by numerous diggings for roads and buildings at the suburb colonisation of the region during the last decade.

Gradually it turned out that in the depression named at the last recession of the ice-border a very curious ice-lobe had lingered for a few years before a sufficient material was collected for a somewhat satisfactory presentation of this phenomenon, which has shown to be of unusual interest.

The lobate ice-borders in question have left the southernmost of the remarkable seismic moras or ranges of frontal moraines which I found in 1889 and successively have followed and mapped out. While the first publication was issued from the year named in the journal of the Geologiska Föreningen in Stockholm, I published facts on that mora in the work »*Stockholm*», issued in 1897 by the municipality and lately in its publication concerning the new aerodrome in Bromma.

Finally the southern, rather complicated part of the mora may now be possible to reproduce on a map (Pl. 59, Atlas).

In the last named publication I mentioned already that the local, sharply delimited occurrence of that morainic belt with innumerable, great, local boulders within a region of most uniform Stockholm granite and boulders made it very difficult to avoid the conclusion that the overwhelming occurrence of boulders within the mora may be due to a local shattering of the bed-rocks just where the boulder-belt occurs.

The difference is very striking indeed between the boulder-belt with its masses of big boulders, shoved together in hundreds, especially on the distal, outer slope of the annual moraines and the extreme lack of morainic material on the outsides of the boulder-string. Striking is also the abrupt beginning of the string at its southern end, like a gigantic boulder-fountain at the origin of the morainic flow. If it were not for their being mostly concealed by forest-vegetation they ought to have attracted attention long ago (Pls 24—33).

Last autumn (1937) I imagine having found, possibly, an explanation of how the abundant boulder-material may have been available at the formation of such markedly, local occurrences of frontal moraines. In view of the hundreds and thousands of great local boulders in the midst of an otherwise quite similar region, practically bare of boulder material, I felt it difficult to avoid the conclusion that the local boulder-belt might have been broken up by a tectonic movement in the bed-rocks. Certainly the recent earthquakes in Sweden are only rather inconsiderable, but they are unanimously attributed to the small but distinct and well-known remnants of the considerable upheaval of land which had its maximum exactly when the heavy ice-load of the last glaciation melted away.

According to the detailed and valuable measurements of RAGNAR LIDÉN in the Ångerman Valley, the maximum of that upheaval attained no less than 15 m per century and thus the respectable amount of 15 cm per year. Now the corresponding maximum rate of upheaval may not have been more than about a third of that amount but was, in that case anyhow fourteen times as intense as nowadays, and this scarcely can have occurred without considerable earthquakes and adjustments in the surrounding magmas.

The above described trend of boulder-moraines is only a few kilometers broad but about twelve kilometers long in NNW—SSE and forming an acute angle with the glacial striæ, which are running more N—S.

This boulder-belt has a counterpart some 10 km to the east, running along the partly water-filled depression of the strait Lilla Värtan, along the bay of Edsviken and Lake Norrviken with their old shatter-belts in the bed-rocks (Pl. 60).

Still both of these boulder-belts are radiating out from the north side of the broad horst of Södertörn, of which the probable earlier movements up and down have been suggested in the Quaternary geology of the Stockholm Region.

Yet the boulder-belts commence a little way to the north of the horst in question and about at the ice-border from the year −1050 before the Zero-year of the Ice Age.

Now it may be possible that the northern, more marked part of the horst may have been somewhat depressed in relation to its environment during the magma adjustment at the relievance from the load of the land-ice, and that subcrustal magma-currents may have been squeezed out in the direction of the boulder-belts, breaking up the surface of the overlying bed-rocks, thus giving rise to the local morainic material. No doubt there are several difficulties also with this explanation, but they may be possible to overcome by continued investigations, and at present it seems difficult to find out any other working hypothesis.

It being confirmed that the moras were caused by the glacial earthquakes, individual moraines and the accompanying varves will afford the possibility of dating and studying the tectonic adjustments accompanying the intense late Glacial upheaval of land.

The reasons why the local occurrence of boulders in the morainic train at Bromma scarcely seems explainable without the assumption of earthquakes, may thus be summarised as the following:

1. The bed-rocks are the same within the boulder-train as in its environs.

2. The boulder-train has a very marked extension with rather sharp limits on all sides, being about 12 km long and a few km broad.

3. Its longitudinal direction has nothing to do with the ice-movement and is extended from NNW to SSE, while the ice-striæ are running from N to S.

4. At its southern end the boulder train begins quite abruptly with most remarkable masses of big blocks, heaped upon each other almost without any material of morainic soil.

5. Exactly here occurs a very marked, almost straight little vertical wall along a quite open fissure in the bed-rocks, only concealed by moss and growing herbs (Pl. 34). This fissure line is about 120 m long, running nearly N—S, but forming an angle with the nearest frontal moraine in such a way that the fissure must have been filled out with morainic matter, if it had been formed before the moraine. This fissure seems to have been formed by an earthquake after the adjacent moraine.

Everyone who has seen this enormous heaping of great local boulders must allow it being quite impossible that this overwhelming mass of boulders could have escaped the long continued boulder transport during the whole of the Ice

Age. It seems scarcely more possible that the rather uniform land-ice could have been able to break up out of very uniform bed-rocks such a chaos of boulders without any especially favourable circumstance.

Further on it seems difficult to suggest any other such helpful circumstance than earthquakes.

Now the situation and direction of the boulder-stroke in question is radiating from the marked Södertörn plateau, which seems to be an old horst with separate movements as to the environs.

Assuming a moderate sinking in at about the year −1050 before Zero, or −9690 before 1900 A.D., it seems possible that the subjacent magma can have been pressed in below the boulder-stroke in question, thereby breaking up the superjacent bed-rocks as well as the land-ice.

Local symbiose between tectonics and glaciers.

In the beginning of 1936, when finally putting together my observations concerning the occurrence of frontal moraines at Bromma for a summary published at the opening of the new Stockholm Aerodrome in that region, I expressed the opinion to which I had been led gradually, namely that the extremely local occurrence of hundreds or thousands of big boulders of quite a special — and decidedly nonglacigene type — also required a special explanation.

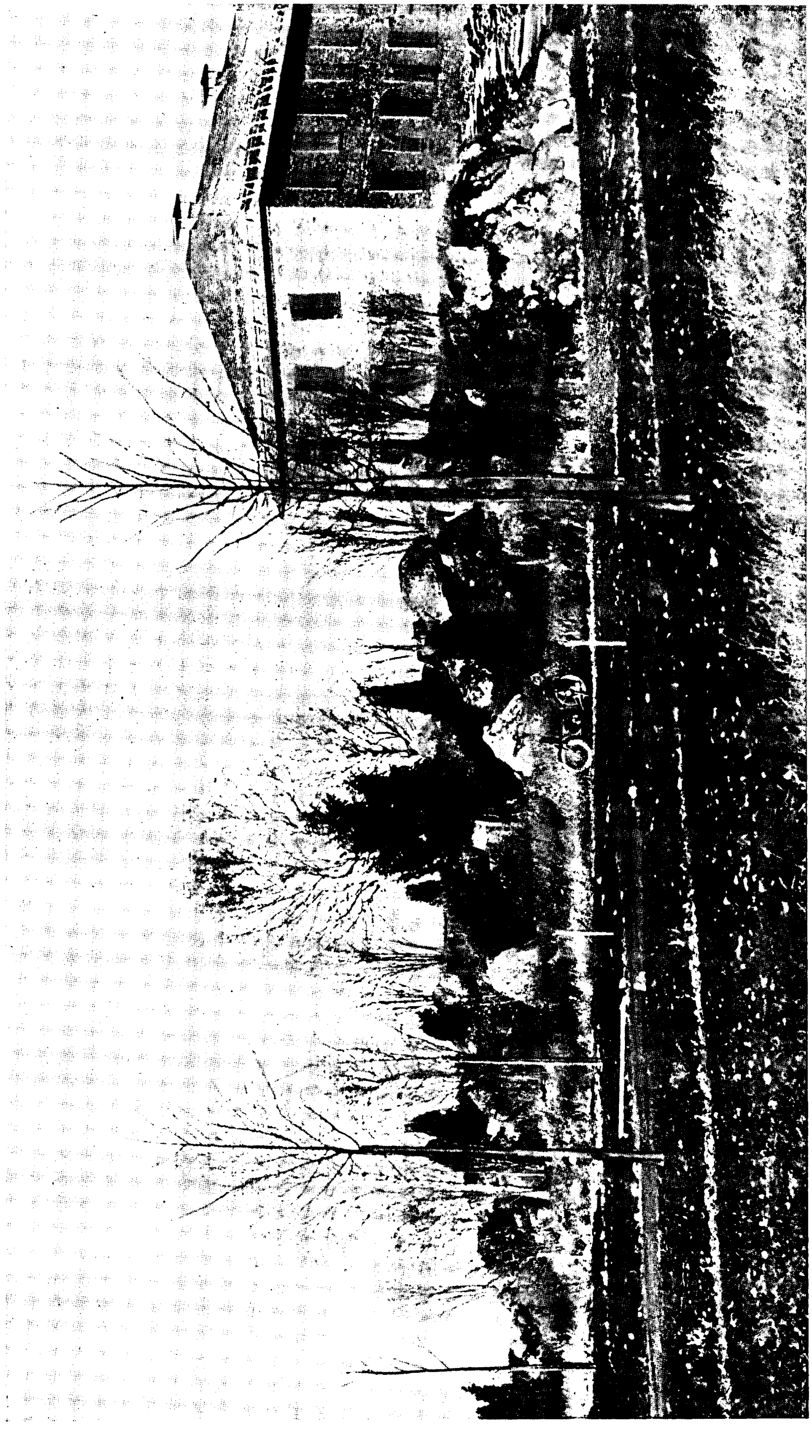
These huge rock-boulders consisted of the local Stockholm granite and gneiss they were as a rule angular and of great size, not seldom 4—6 m, and in one case 9 meters, while closely outside of the morainic belt as well frontal moraines as even isolated boulders altogether were lacking, though the bed-rocks were quite the same and no bearing explanation could be found why, at the very end of the Ice Age after the long-continued boulder export by the land-ice movement, such enormous multitudes of big boulders still could be at hand as building material for the boulder ridges of this morainic belt.

It must be pointed out that the morainic belt with a breadth of only a couple of kilometers is about twelve kilometers long, running from the Nockeby region with its axis in NNW. At the very south end this morainic belt begins quite abruptly with chaotic heaps of boulders piled upon each other recurring at different localities.

The whole occurrence led me finally to assume that rather effective earthquakes might have broken up the fissures of the bed-rocks and given existence to the boulder material at the same time being shoved up along the retiring ice-border during its small winter advances. It seems that the term exaration is quite characteristic for the ploughing action of the very ice-border which, especially during the summer recession, repeatedly was sharpened by ice-berg fracture. This also explains why annual moraines even in other regions predominantly occur where the ice-border had its termination in water and thus was apt to be sharpened by fracture.

That summer when, during a visit of Professor R. Speight from New Zealand, at the named south end of the moraine belt I demonstrated this probable symbio-

Stockholm, Bromma. Annual frontal moraine −1045, at 200 m. SE of Ängby Idrottsplats, before the town-planning. Just the crest of the till-ridge visible above the clay-fields. Boulders mainly on the distal side of the little ridge.
Photo Börtzell, 1933.



Stockholm, Bromma, Beckomberga. Frontal moraine cut through transversely by the road, showing the ridge form. Blocks heaped on the distal side of the ridge. Year −1041, confer Pl. 23. Photo Börtzell, 1932.

Stockholm, Bromma. Annual frontal moraines, E of Beckomberga, from the south. Regular winter-walls in rhythmic interchange with clay-covered fields of summer-melting; figures: years before the end of the Ice Age, (b. Z.) Photo Flygvapnet, 1936.

a. Stockholm, Bromma. Annual frontal moraine −1037 in the forest 500 m NW of Beckomberga hospital. Photo Ebba Hult De Geer, 1937.

b. Stockholm, Bromma. Annual frontal boulder moraine for the year −1036 at 500 m NW of Bromma church. Photo Ebba Hult De Geer, 1937.

Stockholm, Bromma. Annual frontal moraine wall for the year −1040 at Beckomberga Hospital. Length of the wall c. 1000 m, breadth c. 10 m. Totally bare of soil, it consists of boulders of considerable size, however somewhat rounded by transport. Photo Börtzell, 1933.

a. Stockholm, Bromma, Odinslund. Block grove in the forest SW of Djupdalsvägen and Gustaf III:s väg. Seismic moraine −1049, in snow. Photo E. H. De Geer, 1937.

b. Stockholm, Bromma, Olovslund block grove. Seismic moraine −1049, in snow. Photo E. H. De Geer, 1937.

Stockholm, Bromma. Splitted block from the Olovslund seismic moraine -1049. Photo E. H. De Geer, 1937.

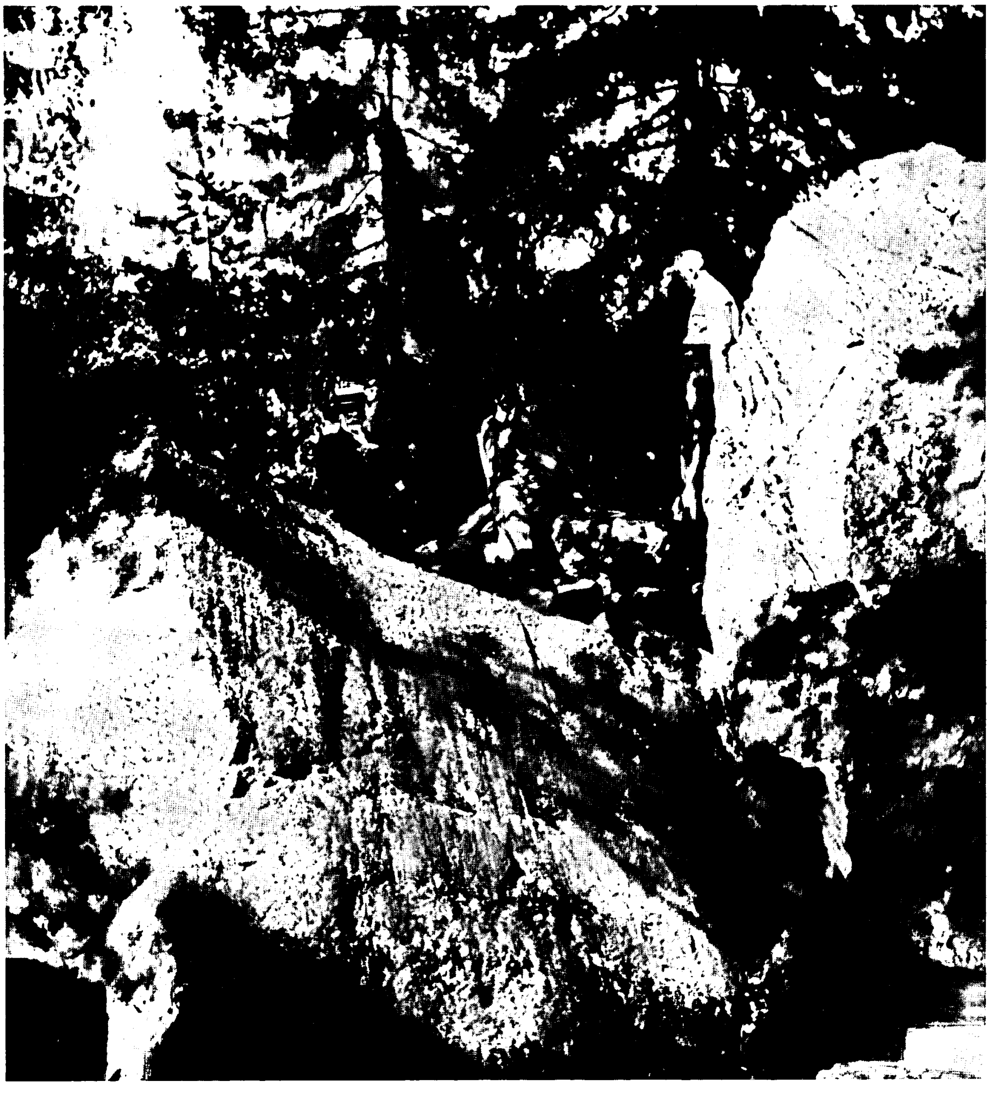
Stockholm, Bromma. Local rock-boulders »Dag and Delling» seen from the south in Mimer's grove. Frontal sides are ice-worn, polished and striated former rock-surfaces, now turned over into vertical or overhanging position. Splitting agent: earthquake; transport: land-ice push. Photo E. H. De Geer, 1937.

Stockholm, Bromma. Rock-boulder »Atletor», rock fraction upraised by the landice-pressure, 7 meters high. NW of Olovslund School, 120 m N of Gustaf III Road, from the south.
Photo M. Zemaitis, 1933.

Stockholm, Bromma, Torslunden block locality. Rock-boulder »Atletor» rising from the block chaos, seen from the west. Year −1048 b. Z.
Photo E. H. De Geer, 1932.

Stockholm, Bromma, Torslunden. Tor's bockar or »Atletor's Goats», from the west. Boulder »Atletor» in the background. Photo E. H. De Geer, 1937.

Stockholm, Bromma. Local rock-boulders near Atletor, in the block-chaos Torslunden. Photo E. H. D. G., 1933.



Stockholm, Bromma. Big blocks with striated surface from a split rock-fragment in the seismic mora of Olovslund of the year −1049 b. Z. Photo E. H. De Geer, 1936.

Stockholm, Ragnarök block locality. Volcanic fissure near the block chaos Ragnarök in Nockeby. Vertical wall proceeding 120 m, showing open fissures with parallel, split rock-slabs. Photo E. H. De Geer, 1938.

sis between late-glacial boulder formation by earthquake and ice-action, he observed a small, very marked, vertical rock-escarpment without any glacial striæ, why he suggested that it might be due to a continuation of the earthquake after that the ice-border had retired from this very spot.

Soon afterwards this escarpment was measured in detail by EBBA HULT DE GEER and myself, from end to end reaching 120 m and with its inbown ends enclosing like a crotchet the western basis of an adjacent rock-hill, evidently very closely following an earlier fissure-line, but cutting it sharply with a vertical step, not more than $^1/_2$—2 m in height. Where the basis of this step was cleared from moss and other vegetation, quite open clefts became exposed with vertical and almost exactly parallel, thin and plane flakes of the bed-rock, all evidently splitted up at the formation of the escarpment (Pl. 34 and Fig. 64).

The direction of this step was along its northern part very nearly N—S and thus about the same as the general direction of the glacial striæ in this region and, as the main, southern part of the escarpment was turned a little more towards the lee-side, the lack of striæ on the rock-wall seemed at first not to be a reliable proof of its later formation, though there seemed to be quite distinguishable limit between the upper, somewhat weathered, ice-worn surface of the rock step, if this had not been exposed afterwards. The same is true concerning the total lack of morainic material in the open clefts at the basis of the escarpment.

Several facts seem thus to corroborate the first impression of a geologist from the very land of earthquakes.

It seems that this earthquake fissure in the Nockeby quarter, arisen by a violent shock pushing up the earth-crust under the height immediately to the east of the escarpment, may be leaving as a result of the reaction a small fault, while the thin, flat stone-flakes splitted along the main fissure as to their upper parts were broken into slices and tumbled over on the immediately adjacent sea-bottom of those days.

Also in the surroundings the rocks are splitted at several places (see Figs. 30—32). The conditions which thus seem to speak for a cooperation between tectonic earth-movements as boulder makers and a glacial rearrangement of the boulders, heaping them up into frontal moraines, renders a new interest to the study of these latter.

Long since it had been suspected that the faint actual earthquakes of our time in Scandinavia could be caused by the slow secular upheaval of land in our days. But now we find indications of such more intense earthquakes at the very end of the Ice Age. At exactly the same epoch it is well-known that especially the central parts of Scandinavia have been subjected to a very considerable upheaval of land. Through RAGNAR LIDÉN'S careful and classical investigations along the Ångerman valley it has been shown that during the most intense upheaval at the very end of the Ice Age the maximal rate of the land-emergence was no less than 15 cm during every year. In the Stockholm region it may at the same time have risen to about a third part of the amount or some 5 cm a year, which is 14 times as much as the recent upheaval of 0.35 cm a year. Thus it is not unfounded to assume for the late Glacial epoch that earthquakes then were many times as powerful as those of our days.

Furthermore, those assumed at the morainic belt named seem to have been locally concentrated where their effects seem to be so prominent. This may be explained in the following way.

The seismic mora or morainic belt in question has its southern origin exactly on the southern, probably somewhat uplifted margin of the extended peninsula west of Stockholm. This margin forms the north shore of this narrow part of lake Mälaren, while its neighbouring southern shore is formed by the high and marked northern limit of the picturesque north slope of what I have called the Södertörn horst, assuming that its northern part earlier as a *Graben*-depression for a long time has preserved a part of that Cambro-Silurian covering which once was extended over probably the whole of the land. Later on this *Graben* may have been upheaved as a horst, from which the Cambro-Silurian cover became denuded down to the underlying Archean subbasement. Thus this latter had been protected against weathering with its numerous, small but straight and marked fissure valleys, while the surrounding Archaean rocks, having been much earlier exposed to the atmospherilia, had got their previous fissure-topography almost totally effaced by weathering. (Pl. 58.)

Now it seems possible that this Södertörn Plateau, earlier individually movable as *Graben* and *Horst*, during a certain stage of the great late-Glacial change of level has been subjected to a small sinking in of its northern part. Perhaps could it be possible that thereby semifluid magma could have been pressed out radially towards the north, thereby producing the assumed earthquake shocks, beginning under the named uplifted mountain-border.

What caused the mapping out of this southernmost part of the morainic belt in addition to the earthquake phenomenon was that the ice-border, when it receded past that very mountain-stroke where the earthquake phenomena had their southernmost outposts, became splitted up in a very singular manner. To begin with it looked rather chaotical, but through a long continued mapping out of gradually followed boulder-trains and bottom-varves it turned out that when receding over the mountain-stroke named, especially where it was more than some 30 m high, the thinner parts of the ice-border were rapidly cut away by ice-berg fracture, whereby rather inexpectedly marked ice-lobes for a few years were left in the depressions, retaining, however, a movement of sufficient strength to push up very impressive boulder slopes round their fronts. (Pl. 59.)

In analogy I am thinking of the magma currents described by J. VAN DE PUTTE in Guatemala, from where he has mentioned eight such more or less old magma currents by sunken parts of the adjacent Pacific former inland under the earth crust of the neighbouring coast region. Thereby the ancient magma currents could be traced on the surface of the land by numerous ruins of old buildings, while on the interstices buildings even from oldest times were still preserved.

This very interesting and instructive late Glacial landscape is so complicated that the more detailed description here must be excluded with a reference to the map.

It may only be remarked that to the north of the lobate series of ice-borders — about from a line Åkeshov—Ljudaren — their direction gradually became more regular and more straightly oriented at about right angle to the glacial striæ. Still an important exception may here be emphasised.

Exactly where the ice-borders enter the morainic belt, they are in a very marked manner bent over almost towards NW, though the glacial striæ show that the ice-movement also here was about N—S. This indicates that the ice-recession and the direction of the ice-borders were here determined mainly by ice-berg fracture, probably facilitated by additional ice-fracture along the earthquake boulder-belt. Especially along the eastern belt, passing the west side of the aërodrome field, the ice-borders seem to have been very much broken, while close to the east the ice-recession has not shown such irregularities but, on the opposite, on one occasion has been able to linger unbroken during several years.

The morainic belt in the Bromma region is no doubt an uncommonly interesting and instructive phenomenon, furthermore very easy of access as being situated in a suburb of Stockholm which, by the foundation of its hundreds of small homes all arisen during the last decade, has furnished an uncommonly great number of diggings and varve measurements, whereby the directly visible ridges of annual moraines afford a very convincing relief to the less visible but definitive testimony of the dating bottom varves.

Therefore the Bromma occurrence of annual moraines and annual varves has been specially described as a characteristic illustration to the ice-recession upon which the Swedish time scale is founded.

Quite recently, in the publications of the Swedish Tourists' Society, I published a short description as a guide for visitors to the Bromma region, especially with respect to the rather sharply limited occurrence of boulder moraines in relation to crushed bed-rocks and overturned, often gigantic, local boulders, the whole radiating out from a rather marked maximum at its south end, from where the earthquake seems to have originated. A great number of photographs were taken, and a few are reproduced in Pls 26—33. The boulders reach as much as 7—9 m. As a rule they are sharp-edged, and not seldom they exhibit great, ice-worn and striated parts of rock-surface in a secondary, upraised attitude.

Evidently there must have been very intense earthquakes to get such gigantic boulders more or less disclosed from their original position.

In fact there was a symbiosis between two mighty powers, that of the earthquake, from the interior, and that of the land-ice, along the surface, which together resulted in this classic example of exactly dated, so-to-say tectonic reactions immediately following the recession of the heavy land-ice and the corresponding, rapid upheaval of the earth crust.

Somewhat farther east along the eastern border of the Stockholm region there occurs another, seemingly analogous stroke of boulder moraines, which follows, rather closely, the southwestern shore of the lake depressions of Värtan strait and Edsviken bay with some ramifications, of which one along the northern part of Lake Brunnsviken. It seems that the boulders of these moraines are derived from old shatter belts, once determining the situation of the lake depressions named.

Both of these moraine-strokes have their southward origin about at the ice-border from the year −1050 and about at the same distance from the marked fault-line limiting the north side of the Södertörn horst which marks a characteristic aspect of the Stockholm topography.

This horst, having earlier exhibited tectonic movements upwards as well as downwards, also in connection with crustal adjustments following the disappearance of the land-ice pressure, may have undergone a slight subsidence which, in its turn, may have caused a radial dislocation at a few places of minimum resistance. Hereby may also be explained a real boulder chaos, distinctly marked by marginal moraines at Nackanäs, exactly at the outside of the named fault.

Referring to the Bromma moraines, Professor R. SERNANDER mentions from Uppland several occurrences of chaotically heaped boulders in connection with frontal moraines and by the inhabitants designated by the word *ulv*, possibly indicating earlier strongholds of wolves.

Another locality which seems worthy of a closer investigation I observed several years ago, in the neighbourhood of Hesselbyholm estate, northwest of Strengnäs at Lake Mälaren and a little south of a Mälaren fault line, the shatter-belt of which, by means of an earthquake, may have furnished the overwhelming multitude of monogene boulders which covered the moraines.

But also in the more peripheral and less upheaved parts of the country evident traces of late Glacial earthquakes have been observed.

The well known tourist-waterfall Djupadal due to an earthquake.

During a visit to Djupadal, Blekinge, in 1879, I observed a little to the SE of that fall a remarkable occurrence of gigantic boulders almost *in situ*, which evidently had been moved just a little, or about 1 m, in a direction rather opposite to the striæ of the land-ice which had smoothed the surface of the splitted bed-rock. This seemed so extraordinary that I measured a detailed, large sketch-map.

The bed-rock, consisting of the dominating gneissoze granite of the region had been splitted up along fissures, in N—S, W—E and NW—SE, into local, partly gigantic boulders, of which the largest was about 25×8 m wide and the next one 15×12 m. The steep, northeastern slope of the rock was ice-worn from about NNE. By sounding I determined a practically horizontal fissure at the depth of about 5 m. Along this joint plane the big boulders had been moved nearly 1 m about towards E from W, while the glacial striæ and the ice-wear, as coming from N, proved their *alibi* with respect to the displacement of the boulders.

Now, when late-glacial earthquakes have become known, the explanation seems quite natural. The bed-rock no doubt had been splitted and somewhat dislocated by an earthquake which was not sufficiently strong to throw the boulders out of their original places.

The common occurrence of big boulders in that region and their lack of arrangement in morainic lines seems to indicate that the boulder formation by earthquake here had occurred somewhat after the ice-recession. As this latter and the accompanying land-upheaval here was of a smaller amount than in middle Sweden, it seems to indicate that the earthquake phenomenon here was somewhat modified in comparison with the maximum farther northwards. Yet it may be possible that the coarse-grained gneissoid granite in middle Bleking has had a special tendency to become fissurated, which now ought to be closer studied.

Still the observed earthquake-fissures close in the neighbourhood of the fall of Djupadal, which is renowned for catching the whole of the Ronneby river concentrated within a straight and vertical fissure (running in NE—SW nearly 30 m, 1.5 m broad, farther south 4—6 m, and cut right through a horizontal ice-worn rock-surface without any traces of ice-wear on the borders), seems to make it rather probable that the fissure of this fall as well as the neighbouring fissures named are due to one and the same extraglacial earthquake.

A mora of annual moraines at Årås bay, Lake Venern.

Soon after the appearance of the topographical map-sheet Rosenborg the author observed, at the easternmost bay of Lake Venern, in the region between Årås and Visnums-Kil a considerable number of small ridges running at right angles to the glacial striæ across the cultivated fields and across the shallow bays as small islets or as points on the ordinary islands, which were extended in the main direction of the strike of the bed-rocks (Fig. 33), as described in p. 114.

At a visit to the place in 1895, I could certify that the small ridges were frontal moraines at Åråsviken, the easternmost bay of Lake Venern, west of Lake Skagern, or exactly at the frontier between the provinces of Vermland and Vestergötland. They represented a complete equivalent to those frontal moraines which the author a few years ago had found northwest of Stockholm in the region of Sundbyberg. At both localities the morainic ridges were rather small, but well marked and very uniform as well to their form, size, and intervals. It seems therefore rather probable that those periodical pauses in the recession of the land-ice, registered by these moraines, correspond to the most regular climatical period, or the annual one.

»The reason why the speaker did not consider himself capable of explaining the regular distribution of the moraines by Brückner's or other longer period was that the annual layers of the varved clay as to the recessional cycle of the land-ice within a certain region had given values of the same order of magnitude as the morainic intervals. Of Åråsviken and its environs a map on the scale of 1:20 000 was exhibited, from which it could be seen that the morainic lines, mutually parallel in the direction WNW and ESE, occur to a number, somewhat exceeding 100, narrow islets in the bay, here not more than 1—2 m deep, partly as low ridges on the flat land in the environs. This is delimited eastwards by a marked escarpment, probably representing one of the fault-lines which surround the main part of the Vener-depression. Near this escarpment, at one place was observed a transverse ose or marginal terrace which, judging from the topographical map, probably belongs to an ose-deposit, following the escarpment named. In the neighbourhood of this latter the moraines are missing or scarce. This is also the case concerning other regions outside a certain line along both sides of the moraine ridges, being seldom more than 5 km in length, while the whole morainic stroke in the direction of the striæ occupies a length of 15 km. This peculiar delimitation of the morainic stroke towards the sides may depend on local variations in the supply of morainic material. The individual ridges were often a few hundred but seldom more than five hundred meters long, some ten meters broad and a few meters high. The mean interval was about 170 m, as far as shown by the map without more extended investigations on the spot. Already when lecturing on the moraines at Sundbyberg, the speaker certainly had emphasised that the main interest of a closer study of such morainic strokes would be, thereby gradually to obtain a hitherto missing means of determining the length of the recessional stage. He had also, at his oral lecture, mentioned the figure, received on the basis of the single mapping, which is known before that now communicated, but had not, before sufficient material had been collected from different regions, wanted to introduce definite figures into print. On the other hand it was very desirable that several such corresponding morainic strokes, which successively had been observed, could be mapped on sufficiently large scale, as it was only in that way possible to obtain a somewhat reliable measurement of the mean intervals between morainic lines, which are often locally interrupted and not until on the map can be sufficiently overlooked.

»For comparison was demonstrated a map on the same scale as some twenty morainic lines in the Sundbyberg region and also a map on the same scale, showing the situation of the Åràs moraines in relation to those incomparably larger morainic lines which are extended through the whole of middle Sweden and which in many respects differ from the inconsiderable assumed annual moraines. On account of their situation towards the marine limit of the region these latter may have been deposited at a depth of about 100 m below the sea-level of that time.» (G. F. F., 1896.)

This morainic stroke is so well delimited that it fully deserves the special designation of a s e i s m i c m o r a. The adjoined map, which is a photographic reproduction of the official economic map, has only been made more readable by filling in the morainic ridges and leaving out numerous names, obscuring the phenomenon. The map has been diminished from the natural scale of 1:50 000 to 1:75 000.

In a very striking way the multitude of parallel, narrow ridges, which on the map evidently indicate multiple moraines, in the region all around, outside the mora, are almost totally missing. The rather marked limit is suggested on the map by a stipled line.

As no difference has been observed concerning the bed-rock, it seems also here difficult to avoid assuming a special cause for the production of this astonishing, local boulder-richdom at the very end of the long boulder emigration during the Ice Age. This special cause must have been able to provide the annually oscillating ice-border with the boulder-masses which the land-ice has shoved together along the annual moraines, and here, as well as in the Bromma region at Stockholm,

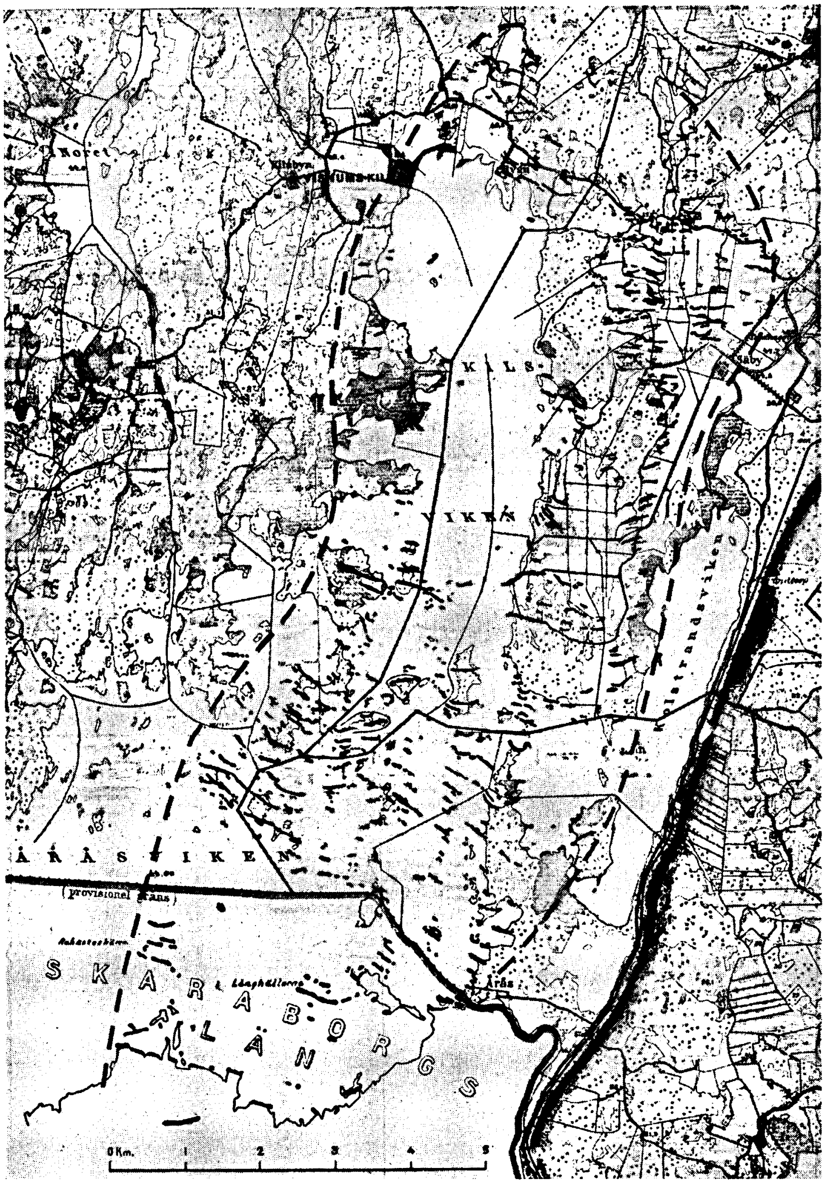


Fig. 33. Årås, Vermland. (Map.) A Seismic mora of annual moraines. Scale 1:100 000.

it seems difficult to find out any other factor than local earthquakes, having been broken and tossed up along joints and fissures above certain tectonic strokes.

As to the Årås stroke here mentioned, its parallelism with the probable fault-line along the escarpment seems to indicate a tectonic origin, probably in connection with a recovering of magmatic stability within the lower parts of the earth crust which ought to have been seriously influenced by the considerable late-glacial upheaval of land, following upon the disappearance of the extra heavy ice-load.

Various seismic moras.

By means of the detailed economic maps I marked on a general map of Late Glacial South Sweden, issued on the scale of 1:500 000 in 1910 by the Geological Survey of Sweden, together with oses and glacial striæ, all observed and assumed groups of frontal moraines.

From the new seismologic point of view it will be worth while to investigate more closely such morainic occurrences in order to find out their relation to or independency of tectonic features.

Besides the indication of the general map named during the following time, a few maps on a somewhat larger scale have been published.

In 1915 C. J. ANRICK published a map of the ice-recession and terminal moraines in the Odensala parish of Uppland, which, according to what he has told me, may form part of a mora. His map may indicate a rather straight western limit of the morainic stroke. Thus, by following up its limits all around, it may be possible to determine whether also here is an everywhere delimited mora, wanting its special explanation.

In 1916 GUSTAF FRÖDIN published a map on the scale of 1:50 000 of the Holmestad region in Vestergötland on the plain between Mts Kinnekulle and Billingen, just at the southern limit of the Finiglacial area, and some 50 km to the distal side of the Årås mora.

The Holmestad map, which is here reproduced, reminds in several respects of the Årås mora, and though it is not explicitly mentioned that the morainic stroke at Holmestad is sharply delimited against surroundings without moraines, it may be easily ascertained whether also here we have a marked mora, suggesting a local seismic boulder-production.

In this connection it may be allowed to remember of the neighbouring, very interesting and curious ice-border phenomena, which H. AHLMANN has described from Valle Härad between the west side of Mt Billingen and a marked fault-line, but this latter may only have had a purely topographic connection with that accumulation of ice-border deposits, being mainly glacifluvial.

Some 50 km to the NW of the Årås mora, or 25 km NNE of Karlstad, near Brattforsheden, N. G. HÖRNER found, in 1927, and mapped out on the scale of 1:30 000 the series of no doubt annual moraines which is here reproduced, diminished to the same scale as the other ones, previously mentioned.

HÖRNER estimates the annual recession or the intervals between his moraines in the southern part to about 200 m and in the northern one to about 150 m. He does not mention whether moraines are absent outside the mapped stroke, but if it should be so, it seems likely that also here we have to do with a local mora, suggesting a local boulder production, to be caused by seismic adjustment, following upon the great late-glacial upheaval of land.

Of course control will be necessary for the study of late-glacial seismology.

Most favourable for studies of this kind are no doubt regions which, as a rule, are poor in morainic matter, whereby local strokes of frontal block-ridges are especially suggesting an extra boulder production.

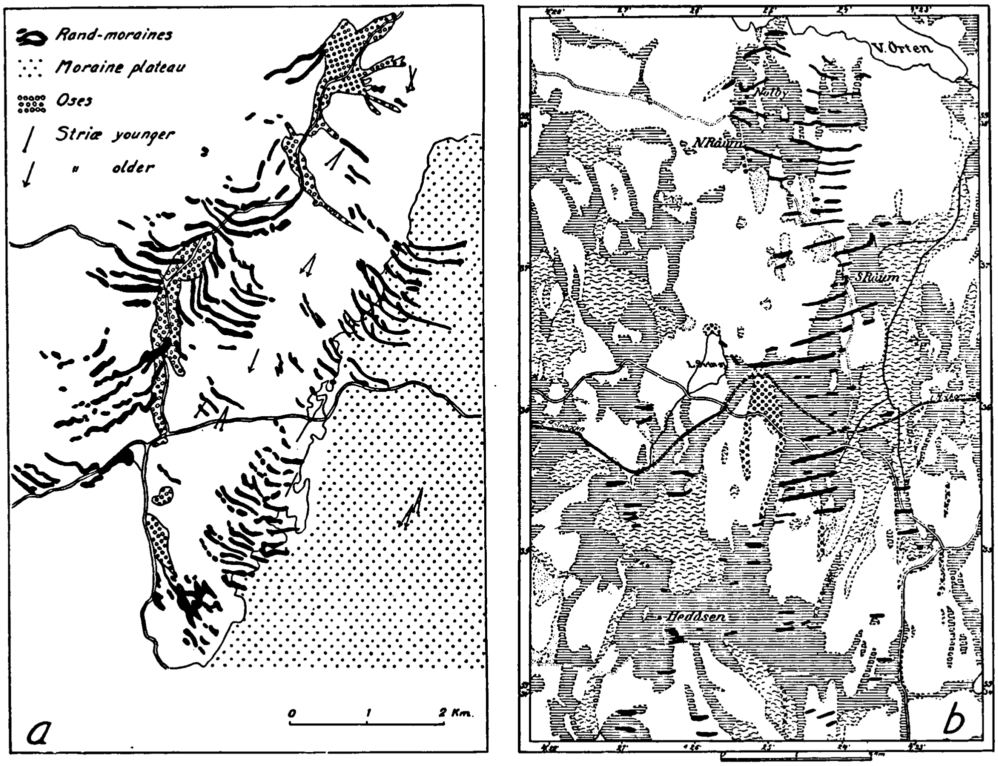


Fig. 34. Probably annual terminal moraines, 1 : 100 000. a, Holmestad region, Vg., G. Frödin, 1916; b, Brattfors region, Vl., N. G. Hörner, 1927.

In the higher parts of North Sweden the morainic covering generally is heavy, and thus normal material for the formation of frontal moraines also is at hand. Thus for an example I saw, in 1898, NW of Luleå, along the railway between Ljuså and Gransjö stations, a number of small frontal moraines, the intervals of which I counted and plotted by means of the telegraph-posts and cross-ruled paper to be about 100—200 m.

On the topographic maps of the inner parts of Norrland narrow ridges, partly perhaps representing small frontal moraines are very common, but for a great part they are considered by G. LUNDQVIST and C. MANNERFELT as being residuary till deposits within fissures in the very last ice-remnant (Lake Rogen and Mt Städjan). In any case new contributions to the knowledge of its distribution will be welcome for the continued discussion of this phenomenon.

No doubt it is always desirable to make out, by varve measurements, how many of the recessional moraines are true winter-moraines and thereby to control their chronologic value. As shown by the detailed Bromma investigation, it happens, where much boulder material occurs, that also subordinate ridges, which could be called s u m m e r - r i d g e s, occur between the more marked annual winter-ridges. Also by ice-berg fracturing irregularities can be caused, making a varve control desirable, where varves can be obtained.

A closer knowledge concerning the annual moraines will throw light not only on the problem of seismic boulder production in connection with the late Glacial upheaval of land, but it will also be very useful in the central supramarine regions of the land, especially where also varved clays from icedammed lakes are wanting.

In such regions the rate of ice-recession can be computed only by cautious estimates from recessional moraines and marginal rills and small deltas, here and there observed in such regions.

Changes of level and earthquakes.

Evidently in near connection with the recession of the last glaciation, quite recently it has been found probable that with the rapid and considerable land-upheaval also considerable earthquakes have occurred. It will no doubt be of great interest to follow up and more closely to investigate this phenomenon, but already so characteristic examples have been observed that it seems appropriate here to make at least a short presentation of the subject, the more so as it often probably can be put in direct connection with geochronologic datings.

In 1889, when I found the first small frontal moraines in Sweden, Fig. 29, from first of supposed and later on proved to be annual, I was much impressed thereof that they contained masses of boulders, often of considerable size, though almost totally wanting at both sides of the first investigated morainic series in the Bromma region, a little west of Stockholm. In the whole of the surroundings there, namely, was a most conspicuous lack of boulders.

This seemed rather difficult to explain, because the bed-rocks below and at both sides of the morainic stroke were identic and in this flat and regular region no reason was to be found why the uniform land-ice should have been able to pick up such considerable masses of boulders only along such a marked stroke.

Having appealed in vain to changes in the direction of ice-movement, it was not until a few years ago that I found myself obliged to the conclusion that along that curious boulder-stroke there must have occurred some special factor explaining such a local boulder-formation.

Not having been able to find out any other such factor than a concentrated strong earthquake, I suggested such an explanation in a short paper, published in 1936, at the opening of the new aerodrome at Bromma, close west of Stockholm, and close to the named annual moraines, which were briefly described in a presentation of the natural evolution of that region.

In the paper in question was reproduced a map of the central part of the morainic stroke at the formation of which the boulders had been shoved together into conspicuous rows. Already earlier I had published some parts of this morainic association, in 1897 on the scale of 1:25 000 and in 1932 on that of 1:50 000.

As the land-ice at that time was already retiring, the fissures were left open without neither ice-wear nor moraine-filling. As the region probably was still submerged, eventually deposited varved melt-water clay evidently has been washed away during the land-upheaval, and already earlier the Ronneby river found its way through the Djupadal-fissure at the bottom of the valley.

Still farther out towards the periphery of the region of upheaval where the movement of the earth-crust was of a smaller amount and probably also slower there are, as well at Mt Kullen in Scania as at the former shores of Gotland, late Quaternary shore pillars, which may indicate an absence of more marked, mentionable earthquakes.

It may be worth observing whether some of the downfallen grottos within the cretaceous region possibly have been destroyed by earthquakes.

Late Glacial earthquakes in North America.

If it is the case that the late-glacial land-upheaval has a tendency to bring about earthquakes, such a constellation may be expected also in North America. From my first visit to America, in 1891, I have some notes which may point in that direction.

In company with Professor N. S. SHALER I visited Mt Desert, the greatest island on the east coast of the United States. On the higher part of that island we inspected what Shaler called an overturned boulder. It lay really overturned in a direction opposite to the earlier direction of the last land-ice, which beforehand had smoothed and striated the almost naked granitic bed-rocks. I used the opportunity of measuring a small sketch map in order to show the present situation of the boulder and its original place in the underlying bed-rock. Shaler had assumed that the boulder, lying in a situation facing the open Atlantic, had been overturned by the waves of an oragan, but I succeeded to show that the late Glacial sea by far not reached this level of some 90 m a. s., as the sea never reached more than 64 m. In lack of more plausible explanations it seems now highly probable that this boulder has been dislocated and overturned by a postglacigene earthquake, whereby it seems as if the shock had worked about from SE, while the glacial striæ are running from N 25° W.

At another place, just a little above the highest marine limit, in the southeast part of the same island, at the very base of and close to a vertical cliff of horizontally benched granite, there was an angular pillar of the same granite, which had been considered as a shore pillar.[1] Yet it did not show any traces of water wear and was conspicuously twisted in a way scarcely explainable otherwise than by a moderate earthquake, acting in the same way as e.g. the twisted statue of Queen Victoria by the earthquake of Jan. 15, 1907, in Kingston, Jamaica.[2] Such moderate earthquake dislocations by which some part of a rocky pillar for a moment has been thrown up and eventually more or less twisted before returning to its subbasement, may be called *bilbouquet*-boulders and are reported from different places.

It is not impossible that even one or another so-called *bloc perché* can have got their position by earthquakes quite as well as by ice-transport.

Professor J. B. WOODWORTH was kind enough to show me some non glacigene,

[1] N. Shaler, The geology of the island of Mt Desert, Maine. U.S.A. Survey, Eighth Ann. Rept 86—87 p. 1021.

[2] V. H. Hobbs, Earthquakes, New York, 1907, Pl. XII, p. 168.

small dislocations within the Boston region which no doubt were due to moderate earthquakes.

Probably it is to be expected that in America as well as in Sweden earthquakes should have occurred in connection with the rapid late-glacial land-upheaval.

It may be emphasised that we have here to do with a movement of the very earth crust. It being probable that the earthquakes rather closely follow the ice-recession and the land-upheaval, it may be possible by close investigations to get more or less exact datings concerning such earthquakes.

In the Stockholm region there seems to have been an intense but local earthquake at Nacka in the year −1060 a few years later followed by earthquakes in the Bromma region and along the lake basins of Värtan and Edsviken in −1050 and may have continued for several years.

Farther west along the same fault-line and in practically the same year of ice-border recession, near Jakobsberg, there occurs a local boulder-heap, somewhat ice-moved, which seems to indicate also here some movement of the horst in question, though generally the direct witnesses may be concealed below water at the very foot of the fault.

Uppsala Region.

The Uppsala ose.

After having given some details concerning the ice-recession in the Stockholm region, it may be appropriate to do the same with respect to the Uppsala region. Certainly in this latter district no such long continued and extended mapping as in the former one has been carried out, but on the other hand the conditions in the Uppsala region exhibit such a marked contrast to those at Stockholm that they seem to be especially worthy of a continued comparative study for a fuller elucidation of the recession phenomena.

While in the Stockholm region the ice-border with its marginal depositions receded past a region with knobby topography, it was at Uppsala across the exceedingly even Uppsala plain, along the southwest border of which occurs a long, straight little step or fault line in the bed-rocks, which at the town of Uppsala determined the deposition of ose-material which latter farther southwards was following the same depression in the plateau named as the *Fyris* river.

Those as a rule clear and simple topographical conditions seem to be especially inviting for a detailed comparison with the already described conditions in a more broken region.

During my Uppsala studies about at the beginning of the eighties, as already mentioned, I gradually levelled and worked out the accompanying map with 3-m isohypses for the ose at and south of Uppsala down to the so-called transverse valley of *Geijersdal.* Farther to the south the isohypses are taken from a military map. My maps were measured on the scale of 1:2000 and are here given on 1:6 000. On the same scale is reproduced part of the ose at *Gamla Uppsala,* measured by Dr C. J. Anrick for the great and detailed archaeologic investigation of Professor Sune Lindqvist. To this map is added another one of the hill *Tunåskullen,* levelled and placed at my disposal by Dr Anrick. This map is also here given (Pl. 61) for the use of a desirable completion of the ose-topography between the two already mapped areas on both sides of the river depression where only the highest parts of the ose-hills are visible above the heavy clay-covering.

Yet in the Uppsala region I had no great opportunity of investigating that northern part of the ose, which was more subdivided into separate hills, but without any good sections.

The more continuous ose-ridge at Uppsala was southwards more easily accessible and could be studied as to many details, some of which are given in the adjoined map and figures (Pls. 61 and 62).

This investigation emphasised in a striking way, by considerable levelled dislocations, how the original ose-deposit sometimes had been lowered by erosion, even to an amount exceeding ten meters. At the same time there appeared that from first of more isolated ose-hills had been apparently connected by redeposited material, filling out the interstices between them. Also a magnificent cut all through the ose across the »big section hill» exhibited a rather complete section across the whole of an ose-centre, well illustrating the cyclic anatomy of the oses.

Several details, by the help of metric squares drawn on the natural gravel sections, transferred on square lined paper on a large scale, are here reproduced.

The ose-material being easily eroded and redeposited, has often in a very obvious manner emphasised the shifting conditions of postglacial sedimentation and faunal immigration.

Concerning the hypsometric ose-map which I worked out during my studies at Uppsala, it turned out that this seemingly continuous ose in reality was built up by a series of individual hills, indicated already by the hypsometry, but still more accentuated by the inner structure of the layers, magnificently exposed by a great cross-section, cut for the relatively new high-road a little south of the town and followed by the great sand-pit at its southern side (Pls 61, 62).

By following the recession of this section during several years, also after my Uppsala studies, a characteristic cross-section was obtained along the axis of such an individual ose-centre in the direction of about N—S. This is somewhat oblique to the actual trend of the so-called ose or collection of the delta deposition from the ose-river, here closely following the rather marked border of a step in the bed-rocks and the outlet direction towards the margin of the ice. The same divergence from the general train just mentioned is also well indicated by the south-westerly tail of the dominating hill of the castle *Slottskullen.*

The northernmost ose-deltas within the town of Uppsala, or the *Carolina-kullen* and *Universitets-kullen* seem to be deposited in the same direction, concealed by the buildings and by the situation on the very slope of the rock-escarpment, rising from the covering sediments of the plain.

The small depressions, marked by the old names *Gropgränd* and *Kamphavet* on the west side and *Odenslund* to the east, probably may indicate disappeared ice-remnants from the bordering sides of the glacier vault.

A very striking witness of such a former vault-basis, disappeared by melting, was found in the considerable faults at the southwestern end of the great cross-section mentioned.

By detailed measurements of the throw it was evident that along this side of the ose its marginal sediment must have sunk down more than 10 m. Thus before this took place the ose-hill must have been at least so much the higher. But, as here only the sandy, very thick bottom varve is left, the hill once must have been as much higher as the thickness of all the succeeding annual varves, or, probably at least some 10 m more.

Consequently the postglacial marine erosion during the land-upheaval here must have lowered the ose with its marine covering by some 20 m. Remnants of this denudation are found in the relatively small occurrences of postglacial sand with lumps of varved clay and the side covering of clayey postglacial sand. Furthermore, by far the greatest part of those very thick clay-layers which have been bored through near the foot of the ose east of the castle consist of such redeposited layers.

As well at the southwest side of the great section above named as along its continuation towards SE the ose is bordered by a marked depression, probably at least for a part marking the situation of disappeared bases of glacier vaults, but probably also the ose-dammed very interstice between the western plateau of bed-rocks and its original slope towards the great plain to the east.

Such ose-dams are not seldom occupied by lakes, and this has also here been the case, until it became drained by that little brook which has cut out the small transverse gulley, called *Geijersdal*, which again in its turn marks a depression between two ose-centres, mainly filled out by marine sediments. The height of the pass and the corresponding lakelet seems to have been about 18 m a. s. with some successive ox-bows occurring almost up to that level.

Near the north side of its outlet the lake entered into a marked hollow, no doubt left by the disappeared foot of an ice-pillar, or a so-called *åsgrop*, a sinkhole.

The Uppsala—Uppland varves.

Macro- and micro-datings.

Just as the Stockholm region affords a good example of varve deposition in a knobby topography, thus, on the opposite, the flat Uppsala region seems to afford excellent opportunities of rational studies of a more regular varve deposition.

This flat plain is furthermore enclosed by its contrasting and more knobby frame, especially on the western side clearly delimited by an ancient fault-escarpment, running ESE—WNW just west of the town of Uppsala (Pl. 61).

Through the Uppsala region are executed the measurements pertaining to the general standard varve line, Division M, and further on, several scattered varve measurements, longer as well as short bottom series. These are mutually connected and reproduced in Pl. 80 in order to facilitate continued varve investigations within the region.

Among the different varve localities the series at Bergsbrunna has been measured by the author and remeasured by several observers during a special control excursion in 1919. Furthermore it is controlled by other long varve series at the brickyards of Vaksala, E; S:t Erik, NW; and Röbo, N of the town. Bergsbrunna is especially valuable as giving a quite continuous varve series, comprising some 200 years from the bottom varve up to the transition over to the microdistal varve series, while there is a break of up to a score of varves not accessible in the else so valuable series of Vaksala and S:t Erik, as also in the more irregular series at Bäcklösa, Ultuna. Perhaps, by a continued watching of the diggings, the local geologists may be able to bridge the gap mentioned and find out, whether it depends of local slidings or other disturbances, or merely of the occasional location of the diggings.

Of course it would also be of great interest to complete the net of varve measurements by executing new ones in the interstices of those already known, carefully choosing the localities so that the bottom varves can be attained.

Thus the receding ice-border can be fixed and mapped out with the thickness distribution of the pertaining varve sediment, in this region no doubt affording a magistral example of proximal sediment deposition.

In Pl. 80 several small bottom series are obtained thanks to interested cooperators: AHLMANN, ANTEVS, FRÖDIN, GUSTAFSSON, HÖRNER, LAURENT (2—5), and by the very special and characteristic variations even those very short varve series seem to be fitted into the system, each at the only possible place. Also their dated ice-borders confirm the rather regular trend of the margin and recession to be expected in this regular plain. Some additional measurements farther west would be of interest for local studies to show whether the westerly fault-escarpments of Uppsala—Bergsbrunna and W of Läby rivulet might have caused any special adjustment to the topography and local bend of the ice-border.

The measurement of Locality 11 is made by the author on a photograph kindly taken in 1905 by K. WINGE at a digging for the new barracks NE of Grindstugan. It is drawn by thin lines merely to appear more clearly among the crowded curves of the plate, magnified to near natural size. From the perfect likeness this graph could well have been drawn by thick lines all through.

At locality 10, Polacksbacken, J. P. GUSTAFSSON in 1905 measured the series of bottom varves, 10 b, not further localised but probably quite near my own, first Uppsala measurement of 1882, at Polacksbacken, near to the [old] barracks, thus rather close to the ose.

In the left, upper corner of Plate 80 is given a continuation of the Uppsala varve curves in their very transition over to the microdistal series. The curves designated »$^1/_2$» show these varves as measured in nature or on the specimen directly, without any magnification. Quite naturally the curve soon becomes rather undecided for the measures of such small and scarcely conspicuous varves. On the opposite, the curves marked »*mi*» show these varves as measured by great magnification, here represented by $^8/_1$. In spite of ocular difficulties where they are not well conspicuous in this rather dark clay, the comparison with as well the microdistal series from Stockholm as the Scandinavian medium of macro-varves, both earlier chronologically fixed to these series of years, show quite distinct, individual variations, marking a real identity. The curves of Uppsala 6 *mi*, $^8/_1$ and $^4/_1$, are, namely, measured on a specimen from Vaksala, kindly presented by N. HÖRNER in 1938. Through the elaborate preparation it has undergone so as to obtain a quite plain and smooth, unfissurated surface, fitted for a scrupulous examining, it could not be measured until in the autumn of 1939, when all the graphs of the main time scale and the other special lines long ago were compared and drawn ready for printing. This specimen admits measuring of micro-varves, upwards more conspicuous, even to the year –450 of the time scale. From the year –500 upwards the clay is stuffed with whitish or light grey micro-boulders, well appearing in the dark clay-matrix, while in the lower series, down to the beginning macrovarves of –680, they are far more scarce and very small indeed. The upper micro-

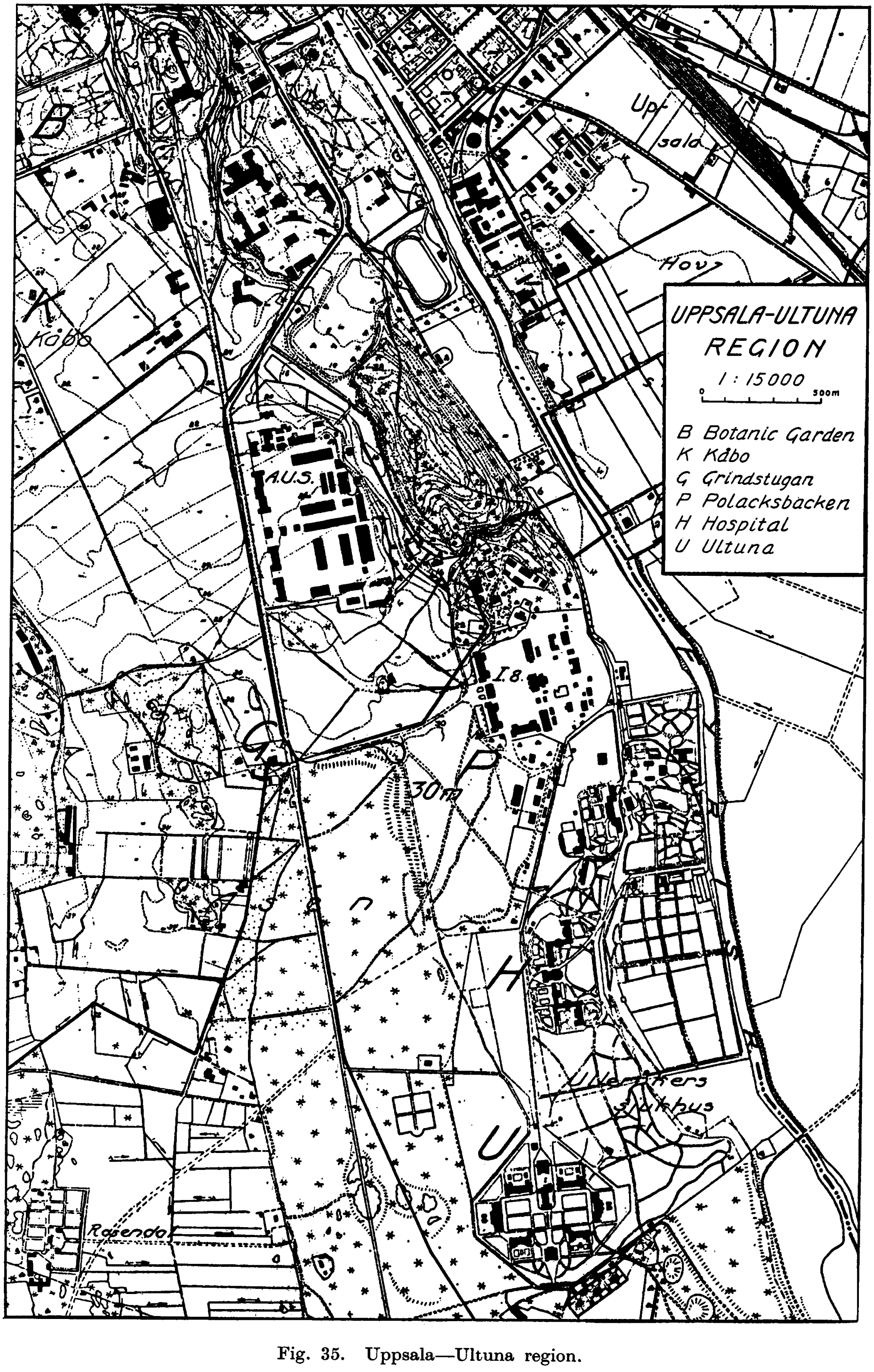


Fig. 35. Uppsala—Ultuna region.

series may be well compared with the micro-varves of S:t Erik and Hagaström, shown in the photo, Pl. 50, as also with those of Ovansjö in Njurunda and Hamre in Bollnäs, Pl. 47, 4 and 5. The measuring of those micro-series, as to thickness disturbed by the crowd of micro-boulders, however ought to be repeated several times before a fully reliable means could be obtained. The micro-varves of Bollnäs and Ovansjö have no micro-boulders and therefore are easier to measure by good illumination and a proper degree of magnification. The specimens from S:t Erik and Hagaström, Pl. 50, $^1/_1$, taken respectively by J. P. GUSTAFSSON in 1906 and G. DE GEER in 1911, had micro-varves sufficiently thick and contrasting in colour to come out on a photo and to be quite safely measured on a copy enlarged to 1 $^1/_2$ of natural size, with due consideration to the thickness disturbances through the multitude of boulder-nodulæ. Their graphs were not only mutually comparable, showing that they were for their main part simultaneous, although the Uppsala specimen was overlapping downwards, but also they showed, throughout over one hundred years, such good similarities with Ovansjö, as only to strengthen the dating of north-southerly Botnic ice-borders already obtained. Thus, in Pl. 81, to the Ockelbo Special, representing the line of varve measuring slightly north of River Dalälven, given by tiny macro-varve measurings on the scale of $^1/_2$, now also were added, below, the magnified micro-measurements from S:t Erik, Hagaström and Ovansjö, emphasising the same variations as come out in the smaller curves above. Here indeed the continuous, long micro-varve series have done good service by controlling the many combinations of short macro-varve series earlier obtained. In the graphs of S:t Erik and Hagaström also the micro-boulders are put out, by small triangles, for both series on their respective varves. Micro-measurement and dating by E. H. DE GEER, 1939.

Calcium nodulæ.

In Fig. 36 are photographically reproduced two series of half a hundred corresponding macro-varves, both representing the years −774 to −735, the dating of which is given by the curves of broken lines in the Uppsala special graph, Pl. 80, well exhibiting a close similarity. The one specimen is from S:t Erik brickyard, just NW of Uppsala, and the other one is from the brickyard at Bergsbrunna, 8 km to the SSE.

At several localities in the Uppsala region more or less clear, white pseudo-layers and lumps occur, especially at the base of the varves. In a part of the clay varves at S:t Erik brickyard the varves are intensely baked together by this white mass, which evidently is derived from weathering and dissolution of the upper varves and redeposition as a kind of infiltration in form of small dikes, irregular nodules, or even pseudo-layers. This secondary migration of the calcium carbonate no doubt can affect the analyses.

HÖGBOM made a very suggestive combination of all the analyses published in the descriptions to the geological map sections of the Survey, but as a great part of the varves did not reach all the way, it will be more rational to follow the composition of individual, dated varves now, when this is possible. Still it was

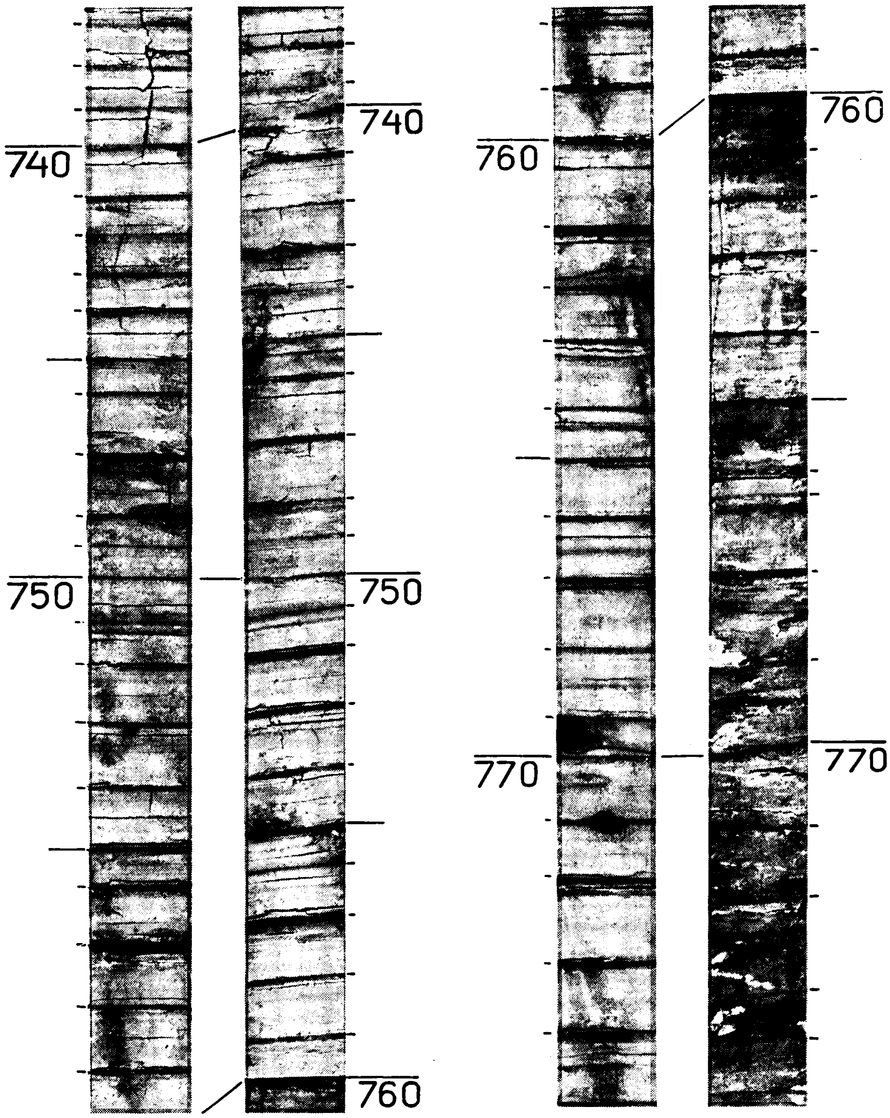


Fig. 36. Varves in NW Uppsala (S:t Erik brick-yard) and at Bergsbrunna, showing a great similarity of the single varves at both localities; see especially the varves 747—760. Nodules of calcium carbonate mainly in the specimen from Uppsala. Specimens taken by G. De Geer in 1906. Photo Wahlberg.

very suggestive to get a general view of the distribution of calcium carbonate within the whole of this region.

Varved marl, or distribution of calcium carbonate in the varves of middle east Sweden.

Long since it was known that varved marl occurred especially in northeast Uppland and adjoining regions.

Thus Professor C. E. BERGSTRAND in 1859 described in detail the lamination, colour, and amount of calcium and magnesium carbonate in the different laminæ as well as their specific gravity. This detailed and valuable investigation was also in 1869 reproduced in the description to the map section No. 31, Uppsala, of the Geol. Survey Office. Here are also published 8 determinations of calcium and magnesium carbonate in varved clay from different parts of the Uppsala region.

As to the amount of calcium carbonate in this region, Professor BERGSTRAND published careful analyses concerning the different parts of what is now called a varve, from Polacksbacken close SSW of Uppsala. He found for the different layers:

		$CaCO_3$
dark	upper	9.7 %
gray	middle	21.1 »
reddish brown . . .	lower	22.7 »
white	»	32.5 »

About twenty years later Professor A. G. HÖGBOM published some interesting papers, extending the knowledge concerning the distribution of the two carbonates in question over almost the whole of their occurrence by combining chemical analyses published in the descriptions of all pertaining geological map sections of the Survey.

He discovered that at the same rate as the distance from the Silurian limestones near Gävle augmented, the percentage of the more soluble calcium carbonate decreased, while the other, less soluble magnesium carbonate was relatively unchanged.

HÖGBOM'S analyses from Uppsala-Ekeby of 1889—92 thus are as follows:

	$CaCO_3$	$MgCO_3$	$CaCO_3$	$MgCO_3$
upper	18.5	2.5	19.2	2.5
middle . . .	21.8	2.5	25.5	2.1
lower	30.3	2.2	33.1	2.4
	1		2	

Ekeby, two varves: 1 above 2.

In order to explain the decrease of calcium carbonate from below upwards, HÖGBOM made the assumption that all the sediment had from the Gävle region been carried out quite a way into the open sea, whereby the bottom layers should have been spread out more rapidly during the melting maximum and the upper layers more slowly, thus being more deprived of its calcium amount.

But the sandy bottom varve sediment is much too heavy to be spread out a long distance in the open sea. Thus during the ice-recession over the Uppland plain no clay should have been deposited, until the ice-border had reached the silurian Gävle region; whereas the present author already in the field had directly stated, that the bottom-varves all the way were successively deposited out from the receding ice-border itself, thereby making the whole of the chronology possible. The successive partial dissolution of calcium had evidently already commenced in the subglacial melt-rivers.

After his lecture on the chemical composition of the marl varves I suggested that it seemed desirable also to determine if not the autumn sediment had been the richest in organic matter, whereby reduction could have given rise to sulphur of iron and the dark colour, while the abundance of mineral matter in the spring-season might favour occidation and reddish colour. Later on I noticed that the varves from the South Baltic ice-lake, which probably was rather devoid of organic matter, generally had brownish or reddish varves, may-be from a dominating occidizing, while in the Stockholm region at the transition from the fresh-water in the south Baltic ice-sea to the brackish sea-water with organic immigrants the autumn parts of the varves may exhibit its dark colour from reduction, while the brown spring layer may be due to occidation.

Farther northwards with growing immigration of organisms the brown colour generally has ceded to a grayish one, though exactly at the finiglacial change of saltness the conditions were more complicated.

Application of geochronology.

Early varve lines.

The Stockholm—Uppsala—Gävle line.

Preliminary varve measurings.

Originally, during a long time having been caught in the assumption that the performance of a geochronology should require at least a couple of generations, I had only made scattered, preliminary measurements, when, in the autumn of 1904, I happened to see an exceedingly good section through varved clay in a newly dug ditch at the outer, eastern end of the Djurgårdskanalen in the royal park Djurgården, just east of Stockholm. It was one km from the bridge across the canal, near its western end (Fig. 23), where exactly twenty years earlier I measured three varve sections and in 1884—85 described them, suggesting the possibility of bringing about »a chronology for the Ice Age».

By comparing my new diagram with those measured at the other point two decades earlier, I was struck by the remarkable similarity. It was like a flash from a dark sky. Now it was evident that the varve curves could be identified from one station to another, at least when the distances were not too large. The two identified localities were situated in the same direction as the probable former ice-border and thus had the same varve at the bottom. Now the problem concerning the ice-recession could be solved, if in the direction that the ice-border receded, or here towards the north, one bottom-varve was missing for every year that the receding land-ice had hindered the deposition of clay, which, as I had assumed, varve after varve ought to transgrediate in the said direction, like tiles on a roof. This very soon was found to be the case, and now the way lay open for geochronology.

I was astonished, indeed, that nobody else during this long time had taken up that idea expressly suggested in print, but probably no one had thought it at all performable.

Having hesitated, myself, during no less than twenty years, I found it now necessary to make a real spurt, in order to show to myself as well as to others that with practical organisation the work really could be carried out and that rapidly too.

At different diggings in Stockholm without delay I made measurements at some forty points and prepared a plan for a line of measurements across the whole of the Stockholm peninsula over the provinces of Södermanland and Uppland.

After having communicated my plan before the Swedish Academy of Sciences and got the permission of the State railway direction to use the railroad sections across the region in question, I enrolled some twenty students of geology, ten from Stockholm and ten from Uppsala, for measuring, each of them, a distance of 10 km with about one digging for every kilometer, with the assistance of line-men.

Being introduced into the measurements by previous exercise and provided with instructions, maps and instruments, they all started on one and the same morning in June 1905, having to return after five days, whether they had succeeded or not. The students from the two universities had to »compete in digging, as the students of Oxford and Cambridge compete in rowing», and the stimulus had a good effect. With but few and small gaps the whole line, about 200 km long, was ready in due time, and the single gaps, at especially difficult points, were filled out afterwards.

This was the first real clay-campaign. It had resulted in exact determination of the ice-recession during 800 years, and at the same time provided geochronology with twenty convinced and expert witnesses, such ones being, generally, rather wanted when new ways are to be tried.

In April 1905, two months before starting this clay campaign, the present author gave the following communication to the Geological Society of Stockholm, namely »A contribution to the chronology and the climatology of the Ice Age», in Swedish, here translated (Bidrag till istidens kronologi och klimatlära. Geol. För. Förh. 1905):

»On the basis of detailed explorations the author, in 1879, had arrived at the conclusion that the varves in question probably corresponded to the annual deposits of the glacial rivers. Before the society he had described a great number of different measurements, executed within different parts of the country and, finally, or 1885, some of them he had succeeded to combine with each other. Thereby he had emphasised that such a combination of a continuous series of measurements were necessary in order to perform a real chronology as to the late Glacial stage of ice-recession. The discovery of numerous small recessional moraines of the Stockholm type in 1889 was the next step to the solution of the question, as also these moraines most probably seemed to indicate the annual interruptions in the ice-recession, which occurred every winter. Thus there seemed to be a fair chance that this question could be soluble by an investigation concerning the annual varves of the varved clay within the region in question.

»During last autumn and winter the author finally succeeded within and around Stockholm to combine as well some of his former measurements as a greater number of new ones, or together about some forty different localities. Among other results he had hereby obtained full evidence concerning the assumption that every one of the annual varves of the clay towards the north is extended like shingles protruding a little above that immediately subjacent. Also these ribs of transgression as a mean have the same breadth as the intervals between the recessional moraines in the same region. By means of a map on the scale of 1:6 000 were demonstrated as well the moraines as, according to the measurements, lines designating the north limit of every clay-varve, thereby representing as many ice-border lines, by the author designated as *aequirecesses* or *aequicesses*. They also coincided exceedingly well with the frontal moraines in question as to their direction. For some of the thicker varves were also given on the map *isopachytes*, or lines of equal thickness, obviously showing that the essential deposition was derived from the ose, the different centra of which must represent different annual varves. Furthermore, the form of the isopachytes as varying from year to year indicated also the influence of the marine currents. Among other things were thus obtained a possibility, hitherto lacking, of a detailed study concerning the laws of sedimentation off the mouth of the rivers, which ought to be of interest to dynamic geology in general. Besides the map were demonstrated pictures of varve series in natural size and diagrams showing the thickness variation, by the help of which identic varves from different points could be reliably recognised.

»The varying thickness of the different varves suggested somewhat analogous variations in the water capacity of the ose river as well as of the ice-melting. Also the varying interstices between the aequicesses suggested changes in the annual temperature, influencing as well the melting as the fracturing. In that way, perhaps, it could be possible to get information, important for the study of eventual changes of climate, analogous to those named after Brückner nowadays.

»As a starting point for the late-glacial chronology the author to begin with used the Observatory of Stockholm and counted the annual aequicesses southward as − years and northward as + years. The annual ice-recession at Stockholm as a mean had been 250 m.

The first printed planning of a standard varve line.

»For the coming summer the author planned a more extended investigation of annual varves from the south end of Södertörn in the region of Nynäs, passing Stockholm and Uppsala across the whole of the Uppland peninsula and up to the river Dalälven. The work was to be carried out by some twenty participants, the half part of which from the University of Stockholm and the other half from the University of Uppsala. The whole line was about 200 km in length, and every participant had to investigate 10 km with one digging for every kilometer, in order to make the identification and combination possible from point to point. If 2—3 diggings were made every day, the main work ought to be executed in 4 days, notwithstanding necessary completions at localities where accidental difficulties were met with.

»However, the uniform, flat topography of the region and the rather considerable depth of the late Glacial sea, covering the whole region at the time of the clay deposition, as well as the very regular formation of recessional moraines and oses, was undeniably speaking for a rather regular recession of the land-ice across the whole of the region in question. In every case it would be possible now to discern, whether the recession had continued uninterruptedly or periodically, as is the case with now existing glaciers.

»The recessional moraines at the Venern bay Åråsviken by their time of deposition certainly indicated a somewhat slower annual melting than that occurring at Stockholm, or about 170 m against 250 m per year, but if for the moment the latter is taken as a starting point for the whole line in question, which comprises about a fourth of the whole distance from the south end of the country to its ice-shed, it should come up to about 800 years. Therefore the question is for the first time with respect to a geological epoch to perform a real chronology, expressed in terms of years, and, at the same time try to utilize an old climatological document, comprising perhaps more than three thousand years and in any case a lapse of time incomparably longer than that hitherto accessible for studies from this point of view.

»It is to be hoped that the cooperation and friendly competition which is imminent in connection with this undertaking between students in Uppsala and Stockholm, in addition to the direct scientific results may bring a development of a number of good observers, who in different directions could continue the investigation of associated questions.» —

The main part of the results is given in this publication, with the measurements as well in figures as in diagrams. Every participant had got his special part of the common line, marked with a letter, from the southernmost one at the coast of the Baltic near Nynäs with an A and the last or northernmost one with an S (later also T) at the opposite coast of the Baltic peninsula in the neighbourhood of the town Gävle.

Still, as this part of the *Geochronologia* begins with the Finiglacial subepoch, the parts here given commence with the letter E. That part of the line which passes the Stockholm region has been provided also with several measurements carried out earlier and later than those of the general line.

By means of this line-measurement it became at once obvious that a considerable part of the north European ice-recession past Sweden in reality was quite possible to determine and that in a very short time too. At the same time it became evident that the ice-recession along one line could be reliably fixed even by measurements at considerably longer intervals.

After the filling out of a few small gaps it was now certified that the ice-recession along the whole of this line had taken about 800 years.

The measurements had been carried out so closely, one after the other, that the ice-recession, as a mean, had been fixed about for every third year, and this part of the Swedish time scale is thus especially well fixed, leaving no place at all for extra oscillations of the ice-border. The direct observations confirmed definitively the predictions, founded upon the regular intervals of the annual moraines and the uncommonly regular occurrence of the oses, being nothing else than the visible, coarser equivalents of the clay varves.

An assumption was published a few years ago that a considerable late Glacial oscillation of the ice-border should have extended over the whole of the Gävle region at least.

This assumption, which of course has not been possible to verify by one single varve measurement, is in hopeless opposition to the uniform and regular passage of the oses past the whole of the region. Generally speaking that assumption of a special land-ice transgression from the Baltic valley was *a priori* rather improbable, exactly at an epoch when the Botnic glacier was subjected to one of the most rapid and considerable recessions of all glaciers known, exhibiting a catastrophic weakness, exactly where extra strength was postulated.

The estimate of about 800 years here given in advance for the whole line to be measured was somewhat longer southwards and shorter northwards than the results of the measurements here described, which still also gave about 800 years.

Yet the seeming identity between those two figures is only accidental, as the two lines have not a quite identic extension and the southernmost, gotiglacial part of the line measured in 1905 is here not described, and by its unexpected, locally very slow ice-recession would have essentially influenced upon the relation between the predicted and the directly stated ice-recession.

As to the normal ice-recession over the plains of Uppland with their very regular ose-deposits, representing the coarser constituents of the annual varves, it affords a good example of how very regular was the ice-recession in this part of the country, making it possible already by the help of very few measurements to predict at least the probable order of magnitude of the ice-recession.

Description of Divisions E—T.

Atlas, Pl. 72.

Division E.

R. Söderberg. Mean recession 128 m pro year.

This division is situated within the northernmost part of the Gotiglacial ice-recession, within the southern part of the Quaternary map of the Stockholm region, just north of the ice-border corresponding to the northernmost of the great Fennoscandic, so-called Final terminal moraines and a little south of the ice-border line, which has been chosen as marking the limit between the Gotiglacial and the Finiglacial subepochs.

Division E has been here included, though not being Finiglacial, as showing the variation of the nearest subjacent varves of Gotiglacial age.

Thus from measurements at ten different points, the northernmost from the points E 4—10 are here reproduced. They represent measurements about 1—2 km apart, and their relative situation is a good confirmation of the close-connections between the different curves of variation.

Biennic variations are dominant. Their maxima are marked by full or by half-dots, where only the half of the variation is normal.

Such parts of the curves as evidently are locally developed, are indicated only by thin lines.

Division F.

J. Söderlund. 6.0 km. Recession 120 m pro year.

This division, which comprises the decades just before and after the limiting year between the Goti- and Finiglacial subepochs, has been represented in the graph as well by the measurements executed in 1905 by J. Söderlund as by a few other measurements from the adjoining region.

As easily seen from those numerous measurements, they are almost without deviations but so well concordant that the true varve variation within this district seems to be very well certified.

Immediately above the Goti-Finiglacial limit the varves become thicker and exhibit at the same time a very striking change in color and consistence, which has been traced to that very point in the province of Vestergötland, where the land-ice border receded from the north end of Mt Billingen. This was the northernmost cape of the South-Scandinavian land barrier, which had been damming up the great South-Baltic ice-dammed lake. When the ice-dam thus became opened, the ice-lake was lowered by some 28 m, down to the sea-level, and an under-current of sea-water entered into the Baltic basin.

This catastrophe happened in the year –1073. Before that year the varves were rather grey and silty. Immediately afterwards they became thicker, brown and more rich in fine clay, probably because a greater portion of the sediment, when entering into the brackish water, at once became flocculated and deposited in the neighbourhood of the ice-border. Hereby it has been possible to identify the very ice-border of the Goti- and the Finiglacial subepochs.

By the varve measurements the quite unexpected fact was discovered that this very ice-border towards the Baltic valley did retire more rapidly than farther to the west, and thus reached up to the easternmost part of the Mälar basin and passed quite near the southern suburbs of Stockholm.

Division G.

G. De Geer. Recession 230 m pro year.

Already in the Divisions F—G are reproduced the earliest Finiglacial varves designating the influx of brackish water by their abundance of fine sediment, deposited already near the ice-border and giving a dominating, brown colour to the whole of the deposit. This appearance holds good for the whole of this region, which is also marked by lively variations. As seen from the graph, these multifarious oscillations have been favourable by fixing the connections within this division all through. This is, further on, already definitively confirmed by the above quoted, more comprising graph from the Stockholm epoch, as represented also by measurements from other countries, and different parts of the earth. In that graph quite a number of marked varve constellations have been designated with special names, alluding to the thickness variations in the graph, in order to facilitate and emphasise the identifications.

In the graph here representing Division G, the dominating, thick lines, emphasise the conformity of typical variations. One apparent exception, in the years 1043—1049, occurs at the localities No. 3 and the two measurements 5 and 6 close to each other from the newly exposed, rather wet bottom of the lowered Lake Hammarby. The apparent deviation, near the bottom of these measurements, may be due to some small, overlooked slidings, as, no doubt indicated by the remaining normal parts of the variation curves, even for the years named.

As to the certified biennic variations may here be mentioned of which the uppermost five maxima belong to a constellation, called Octandria, as having in all 8 maxima, of which the upper ones, above the year 1000, belong to the next division, H.

Division H.

G. DE GEER. Recession 330 m pro year.

The line follows the railway along the southern part a little west of the Stockholm ose. Farther north it being difficult to get good sections in the neighbourhood of the ose, two supplementary measurements were executed by R. LIDÉN, somewhat farther to the west. Though there were some difficulties, it succeeded to get a reliable succession also past this division, since it became evident that the ice-border in the region of Tureberg had made an unexpected deviation about in the direction of the railroad, approximately before the year 1000. This was evidently caused by the formation of a glacier bay, caused by ice-fracturing in the region between the clay-measuring line and the depression of the Säby lake which, later on, was found to designate the northern trend of the Bromma earthquake-line.

Division I.

G. A. LARSSON and H. STRÖM. Recession 300 m pro year.

This division follows the railway at a distance of 0.5—1.5 km west of the Stockholm ose. Almost all of the measurements go down to the till-bottom. From the neighbourhood of the ose the proximal parts of the varves are often somewhat locally developed, this being, however, amended by three later measurements, Nrs 3, 4 and 5, by R. LIDÉN, (broken lines). The upper, more distal parts of the curves, deposited when the ice-border had retreated somewhat, certify the datings by a good conformity.

Division J.

G. A. LARSSON and H. STRÖM. Recession 300 m pro year.

This division follows the railway and diverges, after a few km, from the ose which here continues in a more north-easterly direction. The measured line passes over the great plain in the region around Märsta and to its northernmost part, near Odensala church, it shows that the ice-border, about as was the case in the region of Tureberg, has deviated into a direction almost parallel to the railway.

Where the line passes the Märsta region, there seems also to be indications of deviations in the trend of the ice-border, which could deserve a local investigation, the more so, as in this flat region the occurrence of annual moraines could be well worth a combination with a special varve study.

Division K.

L. VON POST. Recession c. 350 m pro year.

This division follows the railroad about between the stations of Odensala and Knivsta. Along the greater, southern part the ancient ice-borders very closely followed the present direction of the railway, thus nearly in SSE—NNW, indicating that, to the west of this line, there had been formed a marked bay in the normal direction of the ice-border.

The variations of the varves is rather lively, but the connections are good and certify the unusal deviation of the ice-border. This furthermore was certified through a later measurement by R. LIDÉN, No. K 9, at the brick-yard, close to Knivsta station.

Among other good conformities two couples of biennic variations confirm the identifications among the marked characteristic bows in the upper part of the series.

A little more than 1 km NE of Odensala church Dr C. J. ANRICK published in Geol. För. Förhandl. in Stockholm of 1915 a paper with graphs and map of a couple of km, proving by frontal moraines and 15 varve measurements that the recession of the ice-border was here more normal than near the railway, thus running about in WNW—ESE, though with local deviations, caused by fracturing. The varves measured by ANRICK represented the years about 880—920. The variations are of the same character as those of Division K, according to ANRICK's graphs where all details are to be found.

Division L.

J. P. GUSTAFSSON, L. VON POST, and W. NISSER. Recession c. 360 m pro year.

This division passed along the railway and the east side of the great, flat forest region, limiting the southeast extension of the Uppsala plain. The close-connections between the single points is satisfactory, only at Point 6 b at the midst of the curve one varve must have been overlooked, as shown by the proposed correction.

Division M.

L. VON POST, J. P. GUSTAFSSON, and W. NISSER. Recession 350 m pro year.

This division had to cross over the great Uppsala plain, 2—3 km to the east of the railway, in order to avoid the region where it seemed probable that the thickness of the clay should make it difficult to reach down to the bottom varve, dating the ice-recession. Thus the division M passed over a region of the plain, where exposures of till and bed-rocks on the geological map section indicated that the bottom varves ought to be more easily accessible, while the even topography made it probable that the distribution of the varves should be uncommonly regular. This was also the case, and the varve variations at the different localities exhibit a very marked similarity as well with each other as with the curves from the preceding division L.

No doubt it would be a good plan to extend the measurements along the divisions L and M to both sides over a greater part of the Uppsala plain. Thereby it should be possible to get a unique example of an uncommonly regular clay-distribution from the proximal parts along the very ose-river and gradually out over the uncommonly even plain. This should afford a very desirable supplementing contrast to what is already known in detail from the Stockholm region with respect to clay distribution over an uneven and knobby topography.

With respect to the regularity of clay deposition already stated in the Uppsala region, it would, no doubt, be sufficient with a restricted number of well chosen measurements.

Some contributions to such an Uppsala investigation are to be found on the special map of the Uppsala region.

Division N.

J. P. GUSTAFSSON. Recession c. 200 m pro year.

This division has its south end about at the north side of the Uppsala plain and has, to the NE of Gamla Uppsala, been placed along the Uppsala ose, which here is divided up into a great number of small hills, following the same valley as the Fyris river which northwards is called the Vattholma river.

The connections within this division as well as with the adjoining ones to both sides were satisfying, though the knobby topography and vicinity of the ose had caused several difficulties in finding out suitable localities.

Division O.

O. SJÖGREN. Recession 250 m pro year.

This division practically all through has afforded good connections with regularly occurring, biennial variations, though the line follows the same valley as the ose along the Vattholma river. But the ose is here somewhat more regular than southwards, while the bottom-varves are rather thin, with exception almost only for localities in the immediate neighbourhood of the ose.

Division P.

R. LIDÉN. Recession 300 m pro year.

This division, with exception of the southernmost localities, follows the railway through a plain but knobby region at a considerable distance from the oses. The varve variations are small, but give good connections as well within this division as with the adjoining ones at both sides. Biennic variations are rather few.

Division Q.

A. BYGDÉN. Recession c. 150 m pro year.

This division begins near the railway station Knypplan and follows the railway up to the neighbourhood of Örbyhus. The line goes far from the oses, and consequently the varve series are rather regular, on the whole. However, in the southern part of the division, near Lake Vendel, there are irregularities, and the very bottom varves have not been fixed, while nevertheless this is the case with the connection with the adjoining division P, which is quite satisfying. From No. 4 the line runs NW, somewhat W of the railroad in the direction towards Tobo station.

As to biennic variations there are three constellations, the middle one between the years 700—713 with seven maxima and two other ones with three maxima each. At one of these latter in the Örbyhus region local conditions have masked a few of the maxima in question, which is indicated by small arrows.

Division R.

E. S. JOHANSSON. Recession 330 m pro year.

This division goes from Tobo station about in the direction towards Tierp

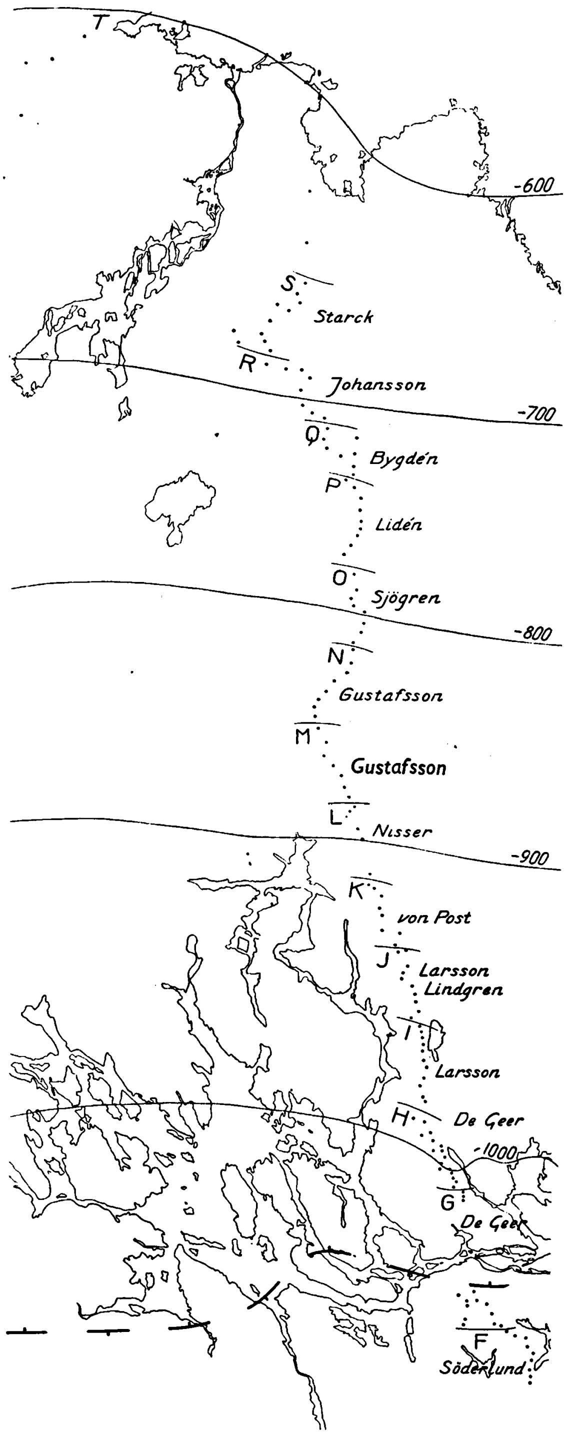


Fig. 37. Ice-recession through Uppland. Divisions of the Swedish time scale. (For T, localities here not complete, see Pl. 68.)

station, bending to the northwest, mostly over flat tilly ground with small clay fields, and thin sediment, deposited far from the ose, passing from the Vendel valley over to that of Temnaren river. Here the measurement met with somewhat complicated conditions, which could not be disentangled at once, why the campaign of 1905 here was ended.

Division S.

G. STARCK, 1906. Recession 250 m pro year.

The conditions which caused the interruption of the measurements of 1905 were the following. In the Tierp region we encountered a very heavy part of the Uppsala ose, surrounded by considerable sand-deposits, which made it difficult to find suitable localities for varve measurements.

This exceptional accumulation of rather coarse melt-sediment may have been caused by the contra-slope of the sea-bottom in relation to the melt-water current.

Somewhat to the east of the great ose it was possible along the valley of river Temnare-ån to carry out a series of varve measurements, forming the division S which ended 1.5 km NE of the Strömsberg factory.

Along the southernmost part of the district the neighbourhood of the great ose named was manifested by thick varves and vivid variations, still in good accordance with the upper varves of the division R, as seen on the graph R—S. Probably on account of the influence from a little ose river, following the same valley, the varve variations are somewhat irregular, but still possible to identify and indicating a rather regular ice-recession.

Some years later a few completing measurements were executed by Dr C. CALDENIUS and of these two were from Hals and Bredäng, 2—3 km NW of Tierp church and west of the big ose.

Division T.

District Vestland—Gävle.

G. DE GEER, C. CALDENIUS, A. BERGLUND, F. FOLKESSON, N. ZENZÉN, J. GRUFMAN, R. LIDÉN. Recession 400 m pro year.

Shortly after the measurement of the long line above described it was continued from its northern end at the region of Strömsberg, or the north end of Division S, towards the north, at first following the continuation of the named Temnare ose to a point 1.5 km NW of the Vestland church, and from there 7 km NNW to Sandby, and nearly 12 km NW to Älvkarleby at the river Dalälven, and further on WNW to the Gävle region, where several measurements were executed between that town and Lake Storsjön, and still farther SW to Torsåker.

The first of those measurements was executed by the author at Älvkarleby in June 1905, soon after the measurement of the long line.

In the great river section at Älvkarleby, about 130 varves were measured representing the ice-recession quite a distance at the north side of Gävle.

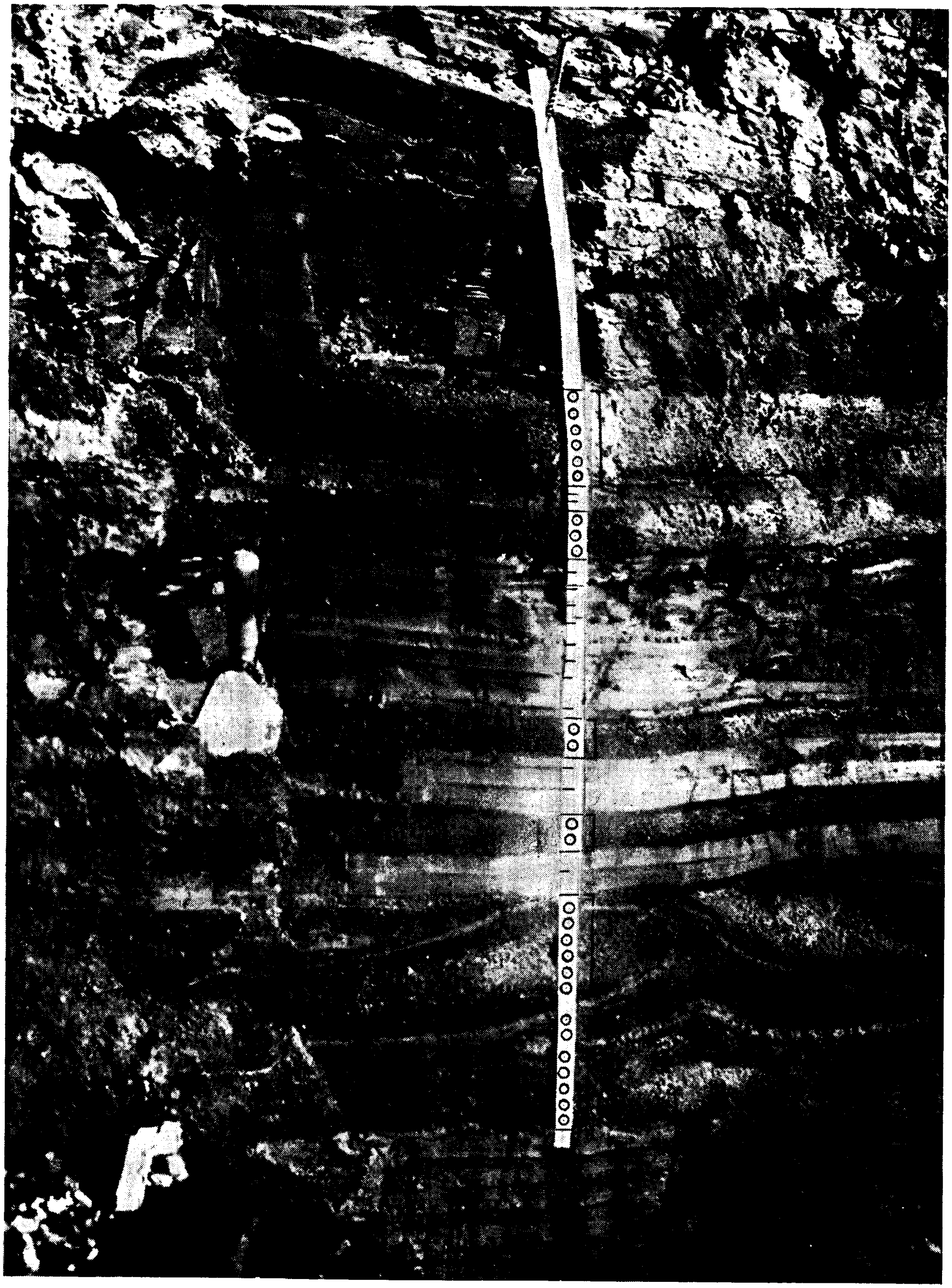


Fig. 38. Gävle, Åbyfors, G. L. Distal clay varves interbedded with layers of downslidden sand and gravel from the adjoining ose. In the lowermost sand typical disturbances from ice-bergs by a horizontal push, not essentially affecting the regular varves below and above. Below as well as above, deposition undisturbed. Photo E. H. D. G., 1930.

The following year I measured at Avesta in the high section of Dalälven at Månsbo a series of not far from three hundred varves.

Several of the measurements in the Gävle region were carried out in 1911 and a few years afterwards.

Thus there are good reasons for calling the whole of the measured varve line in question: the Stockholm—Uppsala—Gävle line, though it begins quite a way south of Stockholm and its very northernmost part just south of Gävle was completed or controlled a little after the start in 1905, though long before the mapping work in that region of the Geological Survey.

The varve measurements in the Gävle district with graphs and map are published in Geol. Fören. Förh. of 1938.

Stockholm—Uppsala—Gävle-line.

Divisions.

Designation	Years dated	Years of retreat	Recession distance in m	Recession pro year in m
	—600			
T		50	2000	400
	650			
S		40	1000	250
	690			
R		24	800	330
	714			
Q		22	700	150
	736			
P		34	1000	300
	770			
O		41	1000	250
	811			
N		49	1000	200
	860			
M		28	1000	350
	888			
L		22	800	360
	910			
K		16	600	370
	926			
J		34	1000	300
	960			
I		24	1000	300
	984			
H		30	1000	330
	1014			
G		44	1000	230
	1058			
F		50	900	120
	1108			
E		42	800	130
	—1150			

Norrland line measurings.

After the clay-campaign of 1905 the plan of following the ice-recession northwards, along the Norrland railroad, was partly fulfilled in 1906 by G. W. EKMAN for the stroke Kilafors—Bollnäs and in 1906 and 1907 by G. EKELÖF for the continuation northwards past Arbrå, as far as varved clay was to be found, or to the Tallåsen brickyard near Lake Hennan. Also in 1906 a special line along Lake Dellen was measured by O. VALLIN.

Further completions were gained in 1911, when E. ENWALL measured a part of a line through the region of Ockelby, south of Kilafors with which it was combined by some few localities measured by H. AHLMANN and C. CARLZON-CALDENIUS in the same year, while G. TÖRNBLOM at the locality of Råhällan measured a series sufficiently long to combine this northern line with the long, regular measurements at Avesta and Torsåker, well corresponding with the simultaneous ice-melting across the Gävle region.

The above mentioned measurements are represented by the special graphs *Ockelbo line, Bollnäs line,* and *Dellen line,* Pls 81—83, partly measured on the natural scale and partly by a magnifying glass with a micro scale.

Some long Dalecarlian parallels, mainly supplied by LIDÉN and CALDENIUS, from well developed varves of good distal size are well represented on the main time scale, giving a safe succession from the Gävle region northwards via Torsåker, Avesta, Gustafs, and Mora. On the Ockelbo line Pl. 81 the localities Smedjebacken and Gustafs show the connection with Råhällan and Ockelbo.

Micro-varves and giant-varves.

In the region NW of Gävle and mainly in Hälsingland, off the projecting Archean plateau, the clay is of a peculiar type, being micro-varved almost from the bottom. Still the measuring line could be carried through and further on, as mentioned, was controlled by numerous parallel measurements in Dalarna, the neighbouring province to the west. Here the varves were thicker as derived from softer rocks, and the accessible varve series also were longer, as deposited within valleys enclosed against later wave erosion.

This removal westwards of the main line of varve measurement was desirable, because the first measured line along the trunk railway was found to pass a region with exceedingly thin varves, the connection of which at first met some difficulties. It seems evident that the bed-rocks in that region had been poor furnishers of clay material. Still, finally, the connections did succeed even here, partly by the help of some remarkable, real giant-varves, being several or even a dozen of centimeters thick, while the ordinary varves were only 1—2 mm in thickness.

At the field measurements those giant varves were supposed to be due to quite local causes, while to me it looked more probable that they registered drainings of ice-dammed lakes in the highlands, what also may be the case.

Yet the comparative dating of these giant varves and the corresponding ice-borders has shown that almost all of those drainings were from the great Storsjö ice-lake, while a minority were derived from other ice-lakes.

The giant varves, as a rule, in their lower part consisted of very fine sand, often more or less distinctly current-bedded, upwards passing over into a fine silt or clay, or just what could be expected from a southward drainage of a great mass of water.

In the region between Lake Storsjön and the giant varves there occur a number of strongly eroded rills, having only the big cobbles left and probably indicating where the successive drainages in question had their way. By detailed mapping they should probably give further contributions to this interesting side of the great melting phenomenon.

The Finiglacial ice-recession.

Delimitation and significance of the Finiglacial Subepoch.

Having now got a view of the steady ice-recession from south to north, I intended, at first, to use the great middle Scandinavian terminal moraines as designating a limit between two subepochs of the Late Glacial Epoch.

But already when I first put together the Finnish, Norwegian, and Swedish parts of these moraines to one and the same synchronous line, I found that it was differently developed in different regions. Thus the ridge in some tracts was single, in other ones double or even subdivided into quite a swarm of smaller ridges, or sometimes, altogether missing.

Still, there was no doubt concerning its main correspondence and thus concerning its fitness as an approximate limit.

But with the further development of geochronology such an approximate limit could not be dated as exactly as needed in the time scale, it being impossible to date precisely those somewhat multifarious morainic strokes.

Hereto came that it was more natural to refer those marked moraines to the Gotiglacial subepoch as designating, by their stationary ice-border, the very maximum of the preceding Gotiglacial subepoch, characterised by its slow ice-recession (Pls 65—67, 68—71).

Very soon after the formation of the marked moraines in question there occurred the important incident, already mentioned, which was sharply registered in the very varve succession and thus well adapted to be used as limiting the Gotiglacial and the Finiglacial subdivisions. This incident was the rather catastrophic draining of the enormous South-Baltic ice-dammed lake down to the sea-level, described above on pp. 99—104.

This considerable lake draining, no doubt the greatest that has been registered anywhere, was described, as mentioned by Drs SIMON JOHANSSON and G. LUNDQVIST, while the corresponding change in the Baltic varve sediment has been followed by the author along the corresponding ice-border as far east as to the Stockholm region, and also by teleconnection to Finland, where the lowering of the lake surface is marked by the small, incontinuous, inner so-called Third Salpausselkä, which seems to have been developed only within the deeper parts of the former water-cover, where the lowering of the water may have caused a stop in the ice fracture.

This sharply marked difference in the varve sediment, indicating a considerable hydrographic event concerning the whole of the south-Baltic ice lake, seems very suitable for designating the limit between the Goti- and the Finiglacial subepochs.

On the maps the corresponding ice-border will be found a short way to the north of the great interfennoscandie terminal moraines and thus be easily refound in nature.

In this report the description of the measured varve series begins with localities along and just a little south of the limit in question, exactly as the Stockholm—Uppsala—Gävle line begins with Division E.

As the flat Uppland peninsula having an easterly counterpart in the flat Åland—Åbo, partly submarine barrier, the regular ice-recession over that part of middle Sweden afforded an excellent bridge over to the measurements of the corresponding ice-recession in SW Finland.

On the other hand, to the west of the Stockholm—Gävle line, over the adjoining plains around the lakes Mälaren and Hjälmaren, the same regular ice-recession was gradually followed, so that the æquicesses grow out from the supporting Stockholm—Gävle line like ribs from a backbone.

This great, flat region, rich in varved clay as well as oses, thus forms a kind of central region for the extension of the geochronologic studies over the whole of the north European glaciated region.

Especially as to the oses in middle Sweden and southern Finland, it will now be possible by comparison of synchronised parts to get a new means to their study and to a more rational knowledge concerning the hydrography of the flooded rivers at the maximum of the rather catastrophic melt-epoch.

The investigation performed had made it evident that practically all of the phenomena which characterised the last great ice-recession were most typical during its very last or Finiglacial subepoch, when the late Quaternary, rapidly growing temperature accelerated the rate of ice-melting. Therefore this epoch no doubt is most representative and best suited for illustrating the method of geochronology in general with respect to the coming exploration of earlier epochs, Quaternary as well as pre-Quaternary ones, whether already more or less explored or hitherto totally unexplored.

The ice-recession through Norrland.

Already from the first determinations in the province of Uppland of the varve-measurements combined with the direction of striæ round the southern part of the Bothnic Sea as well on the Swedish as on the Finlandian side, it seemed obvious that the land-ice, when receding over this region, was extended like a convex bow, projecting over the Åland archipelago. Later on, by the varve measurements of E. NILSSON in Åland, H. BACKLUND and the Finlandic geologists in SW Finland, the trend of direction of this bow became rather well fixed. Thus it seemed that this form of ice-border still continued, being accompanied westward on the Swedish side, by an embayment, so to say a Finiglacial predecessor of the Gävle bay of our days.

Towards the Finiglacial glacier-bay named the oses and their melt-rivers found their way in the direction of the least resistance.

Especially significant is the local direction of striæ and oses in that the Gävle ose in the environs NW of the city of Gävle as well as the Uppsala ose at the very coast is locally directed from SW towards NE, whereby the former already at the town in question is returning into its earlier direction, while the latter has its continuation concealed by the sea. Oses and ice-recession are given on the main map, Pls 68—71.

Somewhat farther northwards the north borders of the bottom varves as well as the striæ indicated that soon after the Gävle stage the ice had retired from the very Baltic valley, so that the ice-border became directed about parallel to the coast of to-day.

Now the problem arose to make out how the ice-border had receded from the direction ENE over the Åland Islands across the whole of the Botnic sea unto the direction parallel to the Swedish coast about S—N past the provinces of Uppland, Gästrikland and Hälsingland. See pp. 257, 3 × ×, and graphs, Pl. 79.

Professor M. SAURAMO with great skill and energy had extended the varve measurements over a considerable part of southern Finland and had the kindness especially to complete this very valuable material with a series of new measurements along the west coast of Finland in the environs of the town Kristinestad.

By plotting all the determinations available upon a sea-chart I had reconstructed the Finiglacial ice margins below the Finiglacial marine limit by help of its isobases.

Discovery of a gigantic ice-fracture in the Botnic valley.

The ice-border lines somewhat to the north of the Åland Islands indicated that they had probably been unchanged as to their direction about until the ice-border had retired unto a then water-depth of about 200 m.

Here it seems that the critical depth was attained where the lifting power of the water causes fracturing of ice-bergs.

Farther north the surface of the ice gradually must have attained a greater height, but at the same time the depth to the finiglacial bottom was deeper, thus favouring the continued existence of the critical depth and ice-fracturing, until the marked slope of the actual Norrland coast was attained.

Then, at once, the unusually rapid ice-berg formation became stopped.

Already in 1931, by clay measurements near the coast of Norrland, I found the main facts concerning this rather catastrophic ice-recession, but it was not until recently and especially through completing varve measurements near the coast of Hälsingland, executed by C. CALDENIUS, EBBA HULT DE GEER and myself, and later on also by J. ÖSTER, that the amount of this record of ice-recession was more definitely stated (Fig. 39).

It commenced about at the ice-border of the year –600 and finished about the year –500. The maximal recession along the midst of the depression thereby had been about 200 km, or no less than about 2000 m pro year. Thereby had been formed a broad, reentrant bight in the ice-border, no doubt limited by ice-cliff shores due to the ice-fracture.

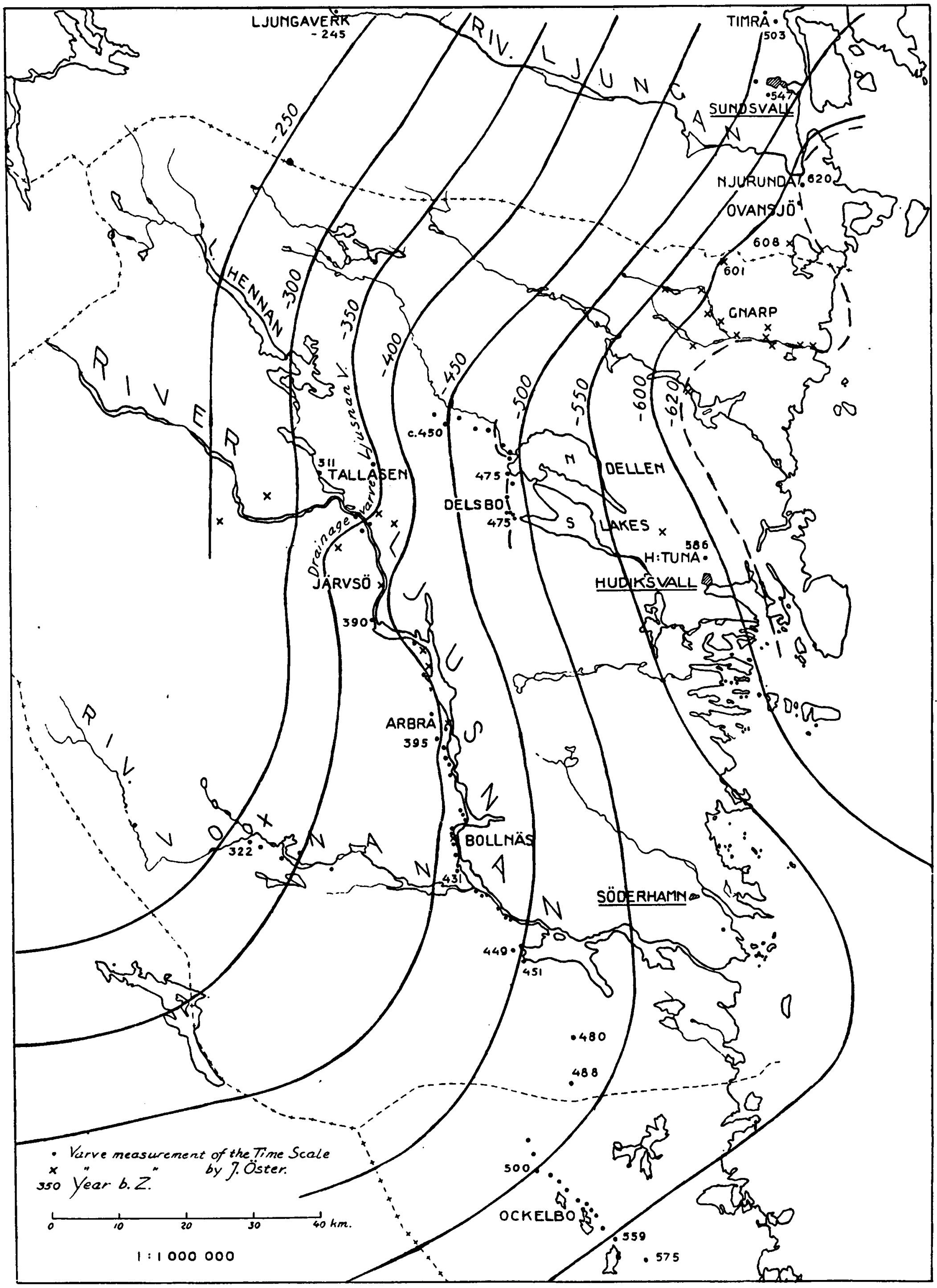


Fig. 39. Ice recession through Helsingland according to the line measurements (dots) of the Time Scale and supplementary localities measured by J. Öster (crosses).

When the fracturing of this ice-bay commenced, it may be assumed that the thickness of the ice was about 220 m, or an amount about one tenth greater than the depth of the water. This may be the first time when the thickness of a broad, finiglacial land-ice really could be estimated at least at its very border.

Assuming that the surface of the land-ice over the Botnic depression was but moderately rising towards the north and that the ice-bottom was sloping in the opposite direction in such a way that the critical proportion between ice-thickness and water-depth continued all the way unto the deepest part of the Botnic depression just off the Norrland coast, this may possibly explain the remarkable rapidity of land-ice fracturing in this region.

But this astonishing rapidity of ice-recession may also have been accelerated by a simultaneous sinking in of the sea-bottom in this region especially so near off the Norrland coast with the maximum upheaval of land.

Ice recession and Drift transport in the Botnic Sea.

Perhaps the most remarkable results from the new transgression of the micro-varves was found at Helsingtuna where the whole series of varves already from the very bottom consisted of micro-varves, so thin that they escaped ordinary measurement. Their number amounted to about 400 and they corresponded exceedingly well with the general time scale, certifying by the well defined bottom varve that the land-ice border had left this place already in the year –680 before the Zero-year..

This means that the corresponding ice-border, the continuation of which was stated at several places in northernmost Uppland, further north had deviated very abruptly, now following the west coast of the Botnic Sea. Already now I had reasons to assume that the land-ice border from the year –600 ought to have made a concave bow across the Botnic Sea, but now it was certified that the rapid ice-recession from that time in fact had been even more gigantic, so that the really catastrophic ice-recession over the Botnic Sea proper was performed in one single century.

From teleconnections of corresponding land-ice borders by means of identic bottom varves across the Åland Islands and to the north of these along both sides of the Botnic Sea and next north of these it was evident, as mentioned above, that the ice-border at these latitudes had crossed the sea-bottom about in the direction WSW—ENE, until it reached a depth somewhat over 200 m, whereafter an extraordinarily rapid recession set in. The reason must have been that the thickness of the ice-border here must have been about 230 m, in order to correspond to the critical proportion, when the lifting power of the water will commence the fracturing and launching of ice-bergs.

As the surface of the land-ice must have risen in the direction of the ice-centre, while at the same time in this very direction the sea-bottom was sloping down to the Norrland coast, it may be concluded that the critical proportion named occurred all the way until the neighbourhood of that coast, thus giving rise to this very remarkable, local ice-recession by fracture.

At the same time we obtain here at last some indications of the thickness of the Finiglacial land-ice here, where it obtained no doubt its greatest thickness for a considerable part of the remaining ice-sheet. This was true not only with respect to the very ice-border, but also to the inner parts of the broad and deep ice-bay which so rapidly was cut some 200 × 200 km into the north Swedish land-ice.

This considerable ice-recession by fracture is, with respect to the thickness and volume of the ice thereby carried away, no doubt the greatest hitherto fixed by any geochronologic measurement. It explains the remarkable occurrence of drifted till-rafts (Swedish: *moränflottar*) which are found over the late Glacial area all the way down to and past the Stockholm region (Fig. 40) as well upon the varved clays, upon the oses and the regions where till and naked rocks are exposed, though in these latter tracts the till-rafts may very easily be confounded with primary till, directly deposited by the land-ice. Still the till-rafts contain local collections of rocks often totally foreign to the region where they are found and generally mixed up with boulders from the Botnic valley with numerous specimens of pre-Cambrian and Cambrian sandstones as well as other Cambro-Silurian rocks among which the red Ordovician limestone is especially protruding.

These till-rafts are easily observed when they are rich in masses of big boulders and have been deposited on the even surface of the oses. During the subsequent upheaval of the land the fine material of the till-rafts has often been washed away by the waves of the retiring sea and the boulders of every individual till-raft represent a local collection of such rocks as occur along the land-ice radius from which its ice-berg has been derived. This makes a detailed study of such boulder collections very inviting and much more promising than the study of isolated drifted boulders.

By the combination of such boulder occurrences with special land-ice boulders we can expect valuable hints with respect to the northern limit of such sub-Botnic rocks which do not occur as bed-rocks above the sea-level and therefore must belong to the submarine geology.

Of special interest are some occurrences of moraine-rafts with several kinds of foreign boulders, among others of red and grey sandstones and red ordovician limestones, directly covered by microdistal varves, showing that the ice-raft had arrived at an epoch when the Swedish ice-border had already retired quite a way inside of the actual Swedish coast in North Sweden, where no such bed-rocks occur. This means that the moraine-raft in question must have arrived from that part of the ice-border named which was situated across North Quarken or the broad sound of the Botnic Sea and the Botnic Gulf. Thus the boulders in question must be derived from bed-rocks occurring on the bottom of the gulf named, as they are missing also to the north of it. A thourough search of morainic material on the islands in the sound in question will no doubt confirm this geochronologic conclusion concerning the occurrence of submarine bed-rocks at a distance more than 70 km from the measurement in question.

So far this may be one of the longest drift transports hitherto stated.

In the regions to the north of the Uppland peninsula and to the west of the Quarken Sound, or where the ice-borders were running at right angles to the Swe-

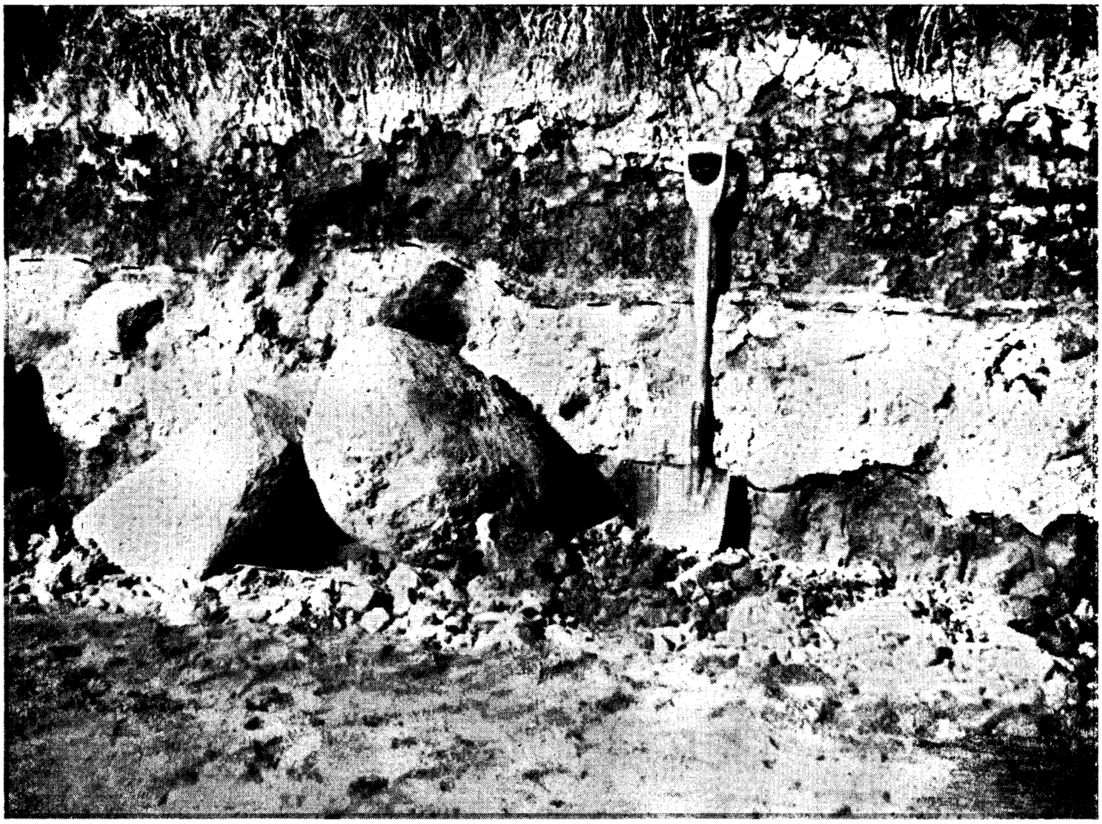


Fig. 40. Stockholm, Bromma, Iris. Till-raft, some 30 cm thick and 56 m in length, reposing on distal clay so as to form part of the till-raft (right). A section of thin varves is opened and smoothed (middle, right).

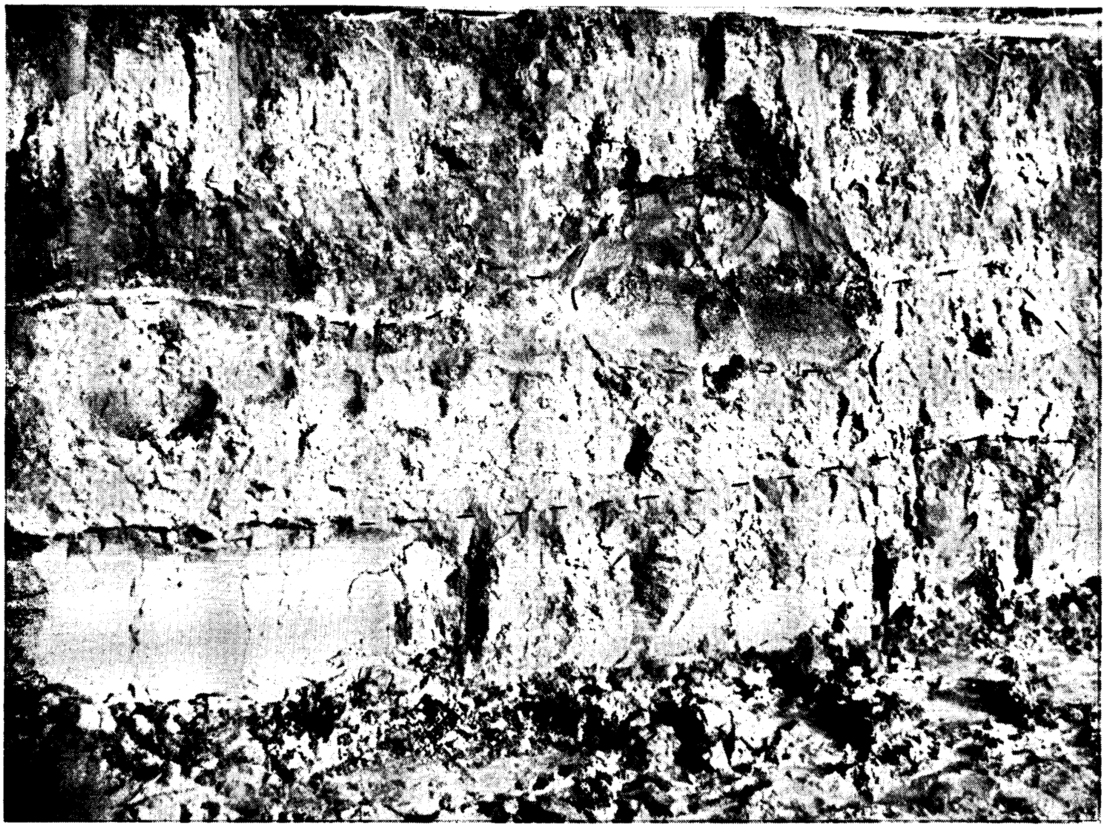
dish coast, a careful examination of the drifted boulders within the marine deposits will give valuable hints concerning the occurrence on the sea-bottom of such bed-rocks from which the drifted boulders in question have originated. Probably they have to be looked for especially along the Swedish side within the late Glacial marine area, because at other places, as in the Stockholm region, the drifted boulders have had a westerly trend, starting from the land-ice and deviating to the right. By determining the northern limits of the drifted boulders the north limit of the corresponding submarine north limits can be approximately determined by means of the trend of the corresponding ice-border.

By performing such a systematic investigation of drifted boulders in connection with the geochronologically determined ice-borders some hints concerning the submarine bed-rocks no doubt will be acquired.

The conditions around the Botnic Sea.

The conditions around the northernmost part of the Baltic valley hitherto are known only with respect to the principal lines.

As to the recession of the land-ice I succeeded, in 1915, to get definitive con-



varves and superposed by mainly microdistal varves. A lump of till is rolled together by the ice-berg push, A sandy storm layer of light silt all the way follows closely above the till raft. Photo Börtzell, 1932.

nections along a side branch up to the Polar circle of the Swedish time scale, the trunk of which was carried across the Scandinavian peninsula between Jemtland and the Trondheim region.

But, as mentioned earlier, on my numerous diagrams from the side branch named I had provisionally left out the hundreds from all the figures representing the years. Many years afterwards this abbreviation was overlooked, whereby the ice-border lines on some sketch maps got a too northerly deviation, though the very connections were all right. This omittance is here corrected and by connection with the northernmost varve measurements of SAURAMO, about at 64° Lat., it has turned out that the ice-border for the Zero-Year, representing the limit between the Fini- and the Postglacial epochs, passed across the northern part of the Quarken Strait, evidently forming an ice-lobe out from the depression of the Botnic Bay, being at that time up to somewhat more than 200 m deep (Pl. 64).

Varve measurements on the Swedish side of this region indicate that the depression named had accelerated the ice-recession about as at the depression of the Botnic Sea, this being indicated by the northeastern direction of the varve-determined ice-borders up to the valley of Lule River, or the most northerly region of the Baltic valley from which varve measurements have been obtained.

Farther to the E and SE it seems difficult to obtain varve measurements, though it should be desirable, especially with respect to the new, interesting investigations of the Finnish geologists along the remarkable valley to the east of this region, where no doubt a direct dating by varve connection should be of the greatest value.

At present it seemed appropriate to confine this review to the most accessible environs of the great Baltic depression, where the natural registration from the dominating great Baltic land-ice current was best recognisable.

The main ship passage past the skerry barrier of Quarken runs along the Swedish coast and seems not to be more than 15 m deep. Towards the east it is bordered by the long and narrow island ridge of Holmöarna. Due north of these, on the Swedish coast, it is continued by a low but mountainous ridge, which is rather marked towards the land-side, generally about 10 km broad and 90 km long, all the way followed by a road along its western foot.

This rock-ledge follows closely the bows of the coast and reminds evidently of the rock garlands along the Swedish side of the Åland Sea, being most likely of the same origin as broken off at the limit between the Botnic depression and the more uplifted land area. From the amount of dissection it seems probable that this tectonic procedure had taken place during late Tertiary time, thus in advance indicating the main Baltic depression.

Also the bottom of the Botnic Bay is rather flat, being generally less than 100 m deep. Some smaller parts, being a little deeper than 100 m, occur west of the midst and along the Swedish side in good accordance with the above mentioned coast garland.

Also concerning the Botnic Bay has been used the Swedish Admiralty Chart of Bottniska Viken of 1938 on the middle scale of 1:500 000.

Ice recession in Jemtland.

In the preceding pages together with the adjoined maps examples are given of the phenomena which characterised the last ice-recession past the lowlands of Middle Sweden. Of course there were variations and deviations from the normal rate of recession, but on the whole they were not at all essential and may generally without difficulty be explained by the help of what has already been elucidated in connection with a close study of the published diagrams as well from the line Stockholm—Uppsala—Gävle as from the general Swedish time scale.

When the receding ice-border left the Baltic depression and arrived at the slope of the north Swedish highland, the recession at once became slower, being when arrived above the highest marine limit, determined only by ablation, while ice-berg fracture during the recession across the deeper Baltic depression within Bottenhavet — the Botnic Sea — suddenly within the fjord valley was very much reduced.

In one region only, through the province of Jemtland, there is a relatively low passage past the mountain chain over to the Scandic basin of the North Atlantic ocean, and within this depression there has been a series of ice-dammed lakes with varved sediments which have made it possible in this single part of Scandinavia gradually to hunt up a series of varve occurrences which have allowed us here finally to determine the last recession of the land-ice as well from the Swedish as from the Norwegian side and to the tract where the ice first became bipartite, causing a great ice-dammed lake within the Storsjö depression to be drained off, leaving the actual lake Storsjön almost at its level of our days.

This drainage went through the Indal Valley, leaving there the thick drainage varve, which in this chronology is marked by Zero, as denoting the first bipartition of the land-ice and the limit between the late Glacial and the Postglacial periods (see p. 171).

On the Norwegian slope I have only succeeded to find a couple of measurable varve series and also on the Swedish side but a restricted number of corresponding observations, though still enough for indicating the mean rate of recession at the oceanic and the continental sides of the Scandinavian peninsula.

In spite of repeated attempts I have not been able to get any varve measurements from other central parts of the peninsula, though there had been ice-dammed lakes in the upper parts of almost every valley. But it seems as if the current of the meltwater here generally has been too rapid to allow a deposition of marked clay varves. At least it seems necessary systematically to hunt up especially favourable localities in former bays, sheltered against the stronger currents.

The bilateral ice recession from the eastern continental and western oceanic side dated by teleconnections.

In 1896, when trying for the first time to put together the principal lines of the geographic evolution of Scandinavia after the Ice Age, I used for the reconstruction of the former coast-lines a mathematic or geophysic principle in constructing for every marked and determinable stage of land-elevation, by the help of all levelled points of such a former geoid surface now deformed, a net-work of what I called *isobases* or lines of equal uplift for equally upheaved parts of such an earlier sea-level. By means of such a leading triangulation the corresponding coast-lines were successively worked out by help of the best available hypsometric maps. In that way a possibility was given for finding out and mapping lots of those former coast-lines from which our actual coasts have risen (Pl. 59).

Maps of this kind are not to be confounded with so-called palaeographic maps, which in reality are mere tentative sketches, suggesting probable migrations but lacking any real cartographic foundation.

The late Quaternary coast maps above mentioned are, of course, more or less reliable with respect to the amount of supporting measurements, and always open to improvements, though the main lines may be fixed.

While the evolution of the dry land from the sea-covering thus could be suggested in the main, the possibilities with respect to the successive recession of the ice-covering were at that time comparatively less favorable.

As the land-ice did not follow the laws of gravity in by far so simple a way as flowing water, the former ice-borders at the time in question could be reliably traced up and fixed only where they had left real frontal moraines, and thus almost only where it had been possible to trace and to map out the long mid-Scandinavian terminal moraines.

At other places there was scarcely any other possibility than to assume that the ice had retreated about at right angle to the glacial striæ, though it was obvious that where the land-ice reached out into a water basin fracturing of ice-bergs must have had an essential influence upon the ice-recession. Especially it seemed rather problematic only by such means to find out the simultaneous positions of the ice-borders at the opposite sides of the Scandinavian glaciation.

By geochronology the situation has been totally changed. Now it has become possible at every point where the basis of a sufficiently long varve series is found to determine the corresponding year when the ice-border receded from that place.

This to an essential degree has changed our knowledge concerning the whole recession of the land-ice. Now these datings represent a kind of first class triangulation by wichh not only the ice-recession itself is dated together with numerous ice-border phenomena, but at the same time also the state of land-upheaval at the different stages of ice-recession.

In this way it has become possible by teleconnection to obtain exact datings for the most distant localities without any consideration as to their reciprocal distances.

Furthermore along the lowest depression in the Scandinavian mountain range, between the Swedish province of Jemtland and the Atlantic coast at Trondheim, it has been found possible by and by to hunt up, to measure and to date quite a series of varve deposits, mainly from ice-dammed lakes which have allowed in the main lines to follow the two-sided ice-recession as well from the continental as the Atlantic side.

At this latter I have succeeded hitherto only at two places to get varve measurements. Thus in 1907 at the great land-slide of Værdalen near Levanger, NE of the Trondheim fjord, where masses of melt-water clay had arrived from the Swedish side, and further on at the Trondheim Technical Institute, which is built upon a marked hill, probably representing the stationary stage of the ice-border shortly before the beginning of the Finiglacial subepoch.

In 1922 I measured here the varve series given on Pl. 86. Though the very bottom varve was not exposed, the main dating was fixed, thereby explaining the occurrence of measurable varves along a stationary ice-border though somewhat farther off the water must have been ordinary salt-water.

P. A. Öyen has remarked that in the outer part of the Trondheim fjord the *Portlandia* (*Yoldia*) *arctica* occurs in its full, marine size, but farther in only by small specimens about as in the finiglacial relict colonies north of Oslo and within the eastern Mälar region.

This seems to be in good accordance with the dating of the ice-border at Trondheim. Thus at the beginning of the Finiglacial subepoch the ice-border evidently has left the Trondheim fjord free, and it seems rather probable that the Trondheim moraine has its continuation in the marked terminal deposits which have been reported from Stenkjær at the northeast inner part of the fjord.

It is, however, natural that with respect to the locality at Trondheim the parallelisation between Trondheim and the varves on the Swedish side was somewhat startling as showing no connection before reaching the ice-border in Sweden as far into the continental side as in the province of Östergötland. Here are, so far, only a small number of measurements at hand, but they exhibit, almost all over their nearly hundred annual varves, such a long series of corresponding constellations that the connection no doubt is definitively certified.

In 1907 I led an excursion of students to Jemtland, also visiting the known catastrophic land-slide at Værdalen, NE of Trondheim. The greyish clay was very thick-varved but utterly plastic, as being redeposited from originally palaeozoic sediment. New sections could not be cut in the very sticky and greasy material, but on the hard, dry surfaces of certain residuary bluffs a series of the varves could be measured and was also connected with varves on the Swedish side from the region of Vallby in the province of Östergötland about 14—1500 years before Zero. The bottom varves were not accessible but it seems probable that the ice-border was slowly receding around the inner parts of the Trondheim fjord.

This makes it probable, as just mentioned, that the ice-border deposits reported from Stenkjær correspond to those at Trondheim.

Still it is of course very desirable that this marked stage in the ice-recession also in this region may be further worked out.

As yet there has not been an opportunity of finding and measuring any more varve series to the west of the national frontier, but to the east of the water-shed conditions are more favorable because here, between the water-shed and the receding continental ice-body, ice-dammed lakes were blocked up in the numerous valleys between the mountain ridges, having their outlets over passes westwards. At the same rate as the ice-border receded, the higher ice-dams received new side-outlets towards lower passes over the main water-shed. In several such ice-lakes series of varved clay by and by have been found and dated, from where a number of measurements are given in Pl. 64 in order to give a general view of this interesting but somewhat complicated passage, more closely worked out by the map, Pl. 70.

On account of various difficulties some localities had to be visited several times.

Still being of great interest to fix as well as possible the main recession of this western border of the continental ice, it would be worth while to extend this investigation by an increased number of varve measurements in order fully to utilize this unique possibility of studying the important ice-dam phenomenon. Therein is also implied the unequal upheaval within this central mountain region by means of continued careful levellings of the marked, unequally upheaved shore-lines along the often extended, fjord-like ice-lakes. Already executed levellings indicate a general westerly dip, greater from the higher and older lines.

Thereby it will also be possible to fulfil the interesting endeavourings of GUSTAF FRÖDIN to reconstruct the surface slope of the land-ice from the continental towards the oceanic side.

As to the details of the graphs now at hand, they must be referred to the adjoining diagrams, Pl. 85, from the various ice-dammed lakes. And here no doubt it is desirable to complete and make full use of this unique material for studying at the same time the rate of the eastern ice-recession and the complex evolution of all these ice-dammed lakes in still closer detail.

A good example of such an ice-dammed lake is to be seen in the Bydalen region where the ice-border about 700 years before Zero enclosed the Oviken mountains, though no varve-measurements were obtained from that region.

Over the great plain east of the Oviken mountains and all around the town of Östersund the big ice-dammed lake of Central Jemtland was developed, no doubt mainly by ice-fracture and much more rapidly than by melting only.

The rate of this ice-recession is certified by varve measurements especially at Vålbacken and Frösön, and thus quite near the earlier ice-shed (Pl. 64).

The varves last named are definitely connected and their bottom at Vålbacken is thereby fixed to about 600 before Zero, or the same year as the eastern ice-border receded from the Botnic coast.

The varves at Vålbacken and Frösön afterwards have been overridden by an ice-oscillation from NE. After the land-ice had retreated past the fracturing ice-lake, it extended anew into the unprotected lake-water, leaving as witnesses moraine-beds upon the varves, and further on striæ and oses running NE—SW all over the former ice-lake unto the Oviken mountains and Järpen.

This irregularity in the last stages of the ice-recession seems to explain the migration of the ice-shed from its earlier, more easterly situation and towards the higher mountains in the northwest.

But in lack of observations we are here near the limit of the unknown. Farther east along the Baltic valley the conditions are much better known and allow certain comparisons of the mean ice-recession over the region to the west of the ice-shed.

In order to facilitate such a comparison the ice-borders for every 300 years have been marked by broken lines for every century, Pl. 64.

From this mapping it appears that the ice-recession was much more rapid on the continental, lower side with more sunshine, while on the west side of the mountains there were more clouds and snow and consequently also a slower ice-recession.

From the catastrophic Botnic ice-recession between the years –700 and –600 a gigantic ice-bay was formed just opposite to the Storsjö-lobe of the great ice-lake in Jemtland from the same time. Thus the shortest distance between these was reduced to about 140 km. During the following centuries it occurred several times that water was drained off by subglacial rivers from the ice-dammed lakes in Jemtland down to the fjords on the Swedish slope, where they became registered by rather gigantic drainage varves, occuring abruptly among the much thinner normal varves, being thereby exactly dated. Confer Pl. 51, at Indal, Jl.

North Botnic Finiglacial and Postglacial sediments.

Introduction.

Having certified the possibility of bringing about a chronologic time scale by means of annual varves, registering the retreat of the last glaciation, quite naturally I was anxious to find some means of tying together such a time scale with our own historical one.

In vain I scrutinized the postglacial marine clays in southern Sweden, but as a rule were they totally lacking any annual varves.

Thus in 1906 when, accompanied by R. LIDÉN at the inspection of the varve measurements through Southern Sweden, I found it very interesting to learn from him that he suspected to have seen something like varves in the high, postglacial river sections along the Ångerman River, where he had grown up. On return to his home, he sent me a very good specimen, exhibiting indubitable varves, and this was the first beginning of the very valuable, important investigation, by which he most reliably measured the length of the Postglacial epoch.

At first his careful, long series of postglacial annual varves was isolated as well from the main late-glacial time scale as from the historical one, but in 1919 in company with EBBA HULT DE GEER, I succeeded in tying together the two prehistoric time scales, — the standard-line and LIDÉN's varves. Later on, in 1933 EBBA HULT DE GEER succeeded — by teleconnection of Sequoia rings — practically to corroborate and more closely to fix the connection between LIDÉN's postglacial time scale and historic time within an irrelevant possible error of only a few years from varves possibly overlooked in the record.

Within the considerable, broad depression along the great Ångerman River LIDÉN worked out a very detailed and valuable map on a natural scale of 1:400 000, fixing the Finiglacial evolution of that region and affording a most valuable basis for his own studies, performed during a long sequence of years, also of the Postglacial evolution of this region.

By this exacting and monumental work LIDÉN has thrown a clear light upon the main sides of the natural history concerning the grand phenomenon of big rivers from the mountains in northern Sweden.

As in the beginning LIDÉN met several time-craving difficulties, I got the idea of possibly being able to promote the work by making another attempt.

The Ragunda region.

In the adjacent valley of the Indal River and especially within the thick sediments of the renowned former Lake Ragunda there seemed to be a possibility of counting and measuring varves up to a fix historical year. It is known that Lake Ragunda in 1796 by an accident became drained out and soon was deeply dissected into ravines with vertical sections, some 20 m in height, exposing its porous, loess-like, postglacial varved sediment. At Ravine Vikbäcken I found an ideal section, comprising, all from the basal till, first the glacial deep-water clay and thereupon, first, a zone of dark, thin-varved fjord clay, and finally a great amount of gray, postglacial lake varves up to the flat surface.

Here it might perhaps be possible to determine directly the number of annual varves up to what was the bottom of Lake Ragunda in 1796, by the varve deposited the preceding year.

Having made, in 1909, a preliminary estimate, I mentioned the result at the Geological Congress in Stockholm in 1910, with the intention as soon as possible to fulfil the investigation. This was also done the following year but with the result that the former Lake Ragunda was practically filled out with sediment a considerable time before the named drainage of the lake (Pl. 36).

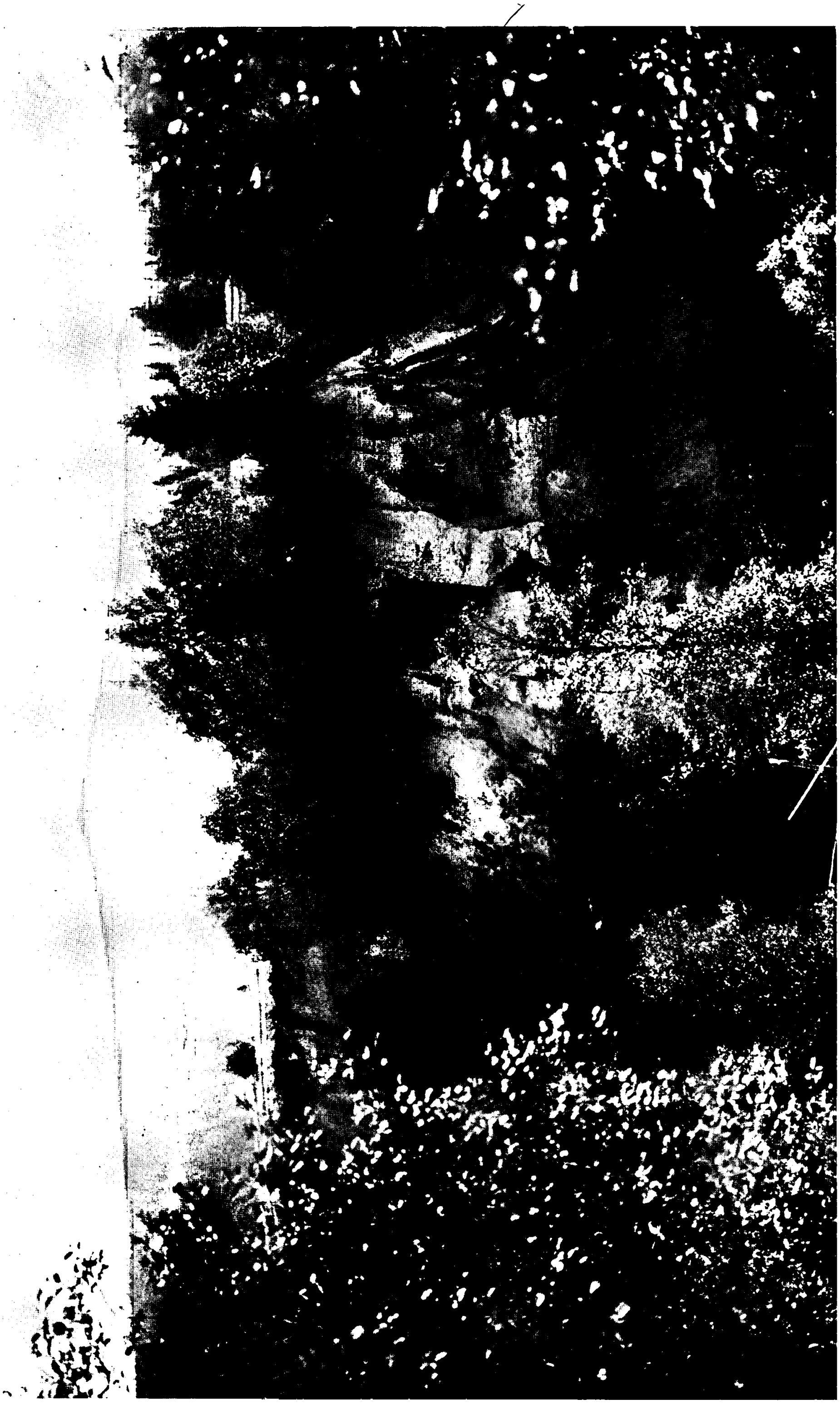
Yet along the midst of the Ragunda lake the current was so rapid that it deposited its sediment in form of wave-lenses or a kind of miniature deltas carrying some sand in the flood time and thereby at most eroded a little of the subjacent varve-knobs on this distal side, but without cutting away the whole of it.

In the winter layer often were observed vertical grooves as from shells and in one such groove finally a shell of *Anodonta* was found. In the summer-layer not seldom epidermis of *Anodonta* occurred, suggesting that during the winter *Anodonta* lived safe, bored down in the clay, while during the summer adventures generally it met its fate.

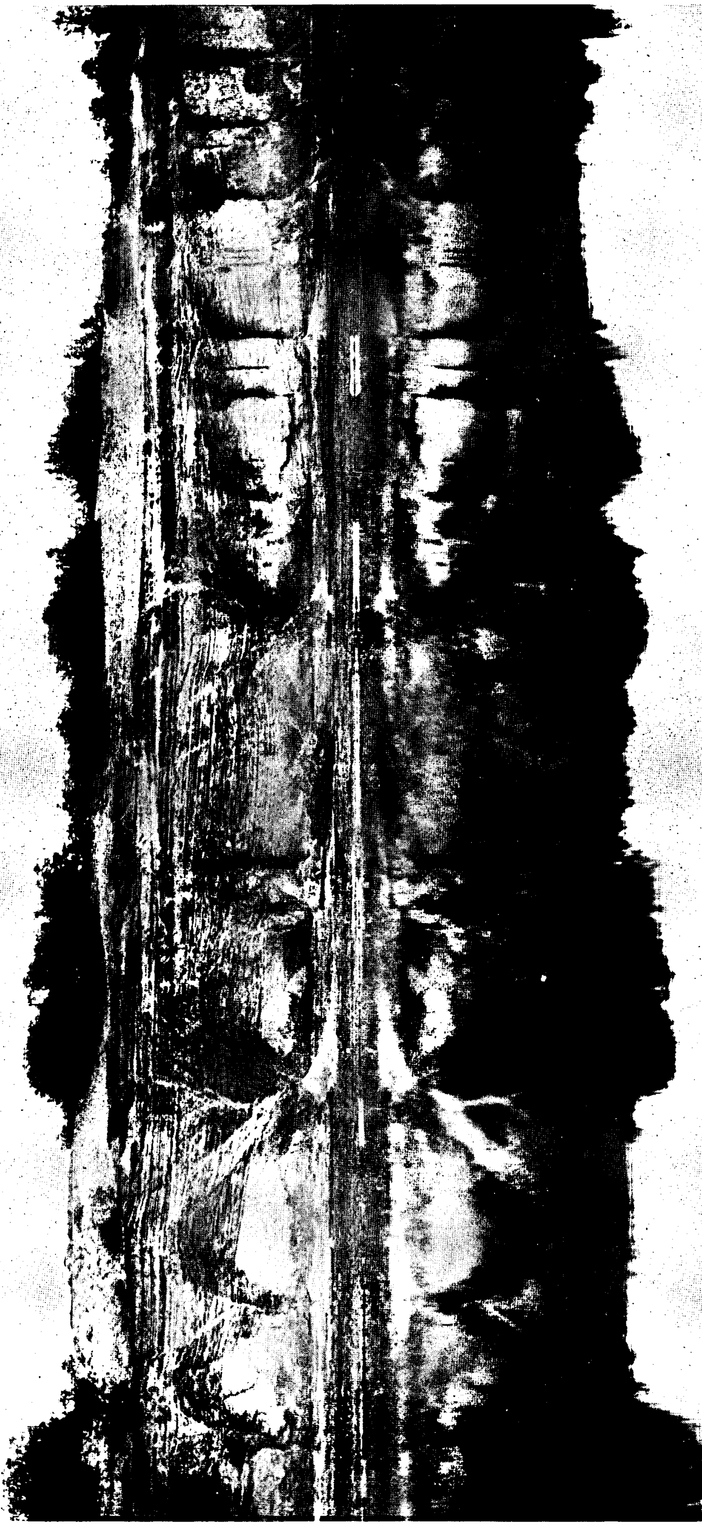
The wavy current varves were scarcely measurable (Pl. 37) but happily along the valley-sides the varves were regularly deposited in more quiet water and were all right, though their fine-sandy and silty composition made it necessary to be aware that locally some varves could have been less distinct by secondary infiltration.

The main results of the Ragunda observations were reported at the Geological Congress 1910 and demonstrated at one of its excursions. The whole history of this lake, its filling out with sediment, its drainage and dissection, seemed to be of such a great importance that it was highly desirable to continue the investigation of those interesting conditions. Thus I proposed to three of my pupils to take it up as a subject of a really detailed study from different points of view. Next summer, 1911, I returned in company with three of them, of which CARL CALDENIUS should overtake especially the continued measurements of the postglacial varves and the datings necessary for his comrades, while HANS AHLMANN had to investigate the Quaternary morphology and RAGNAR SANDEGREN had to bring together and prepare collections of the richly occurring plant remnants, which could be expected to furnish a prehistoric but accurately dated, unique standard series of herbaria from a long succession of centuries, illuminating the plant immigration to this part of the land, fixing the data from the peat-bogs.

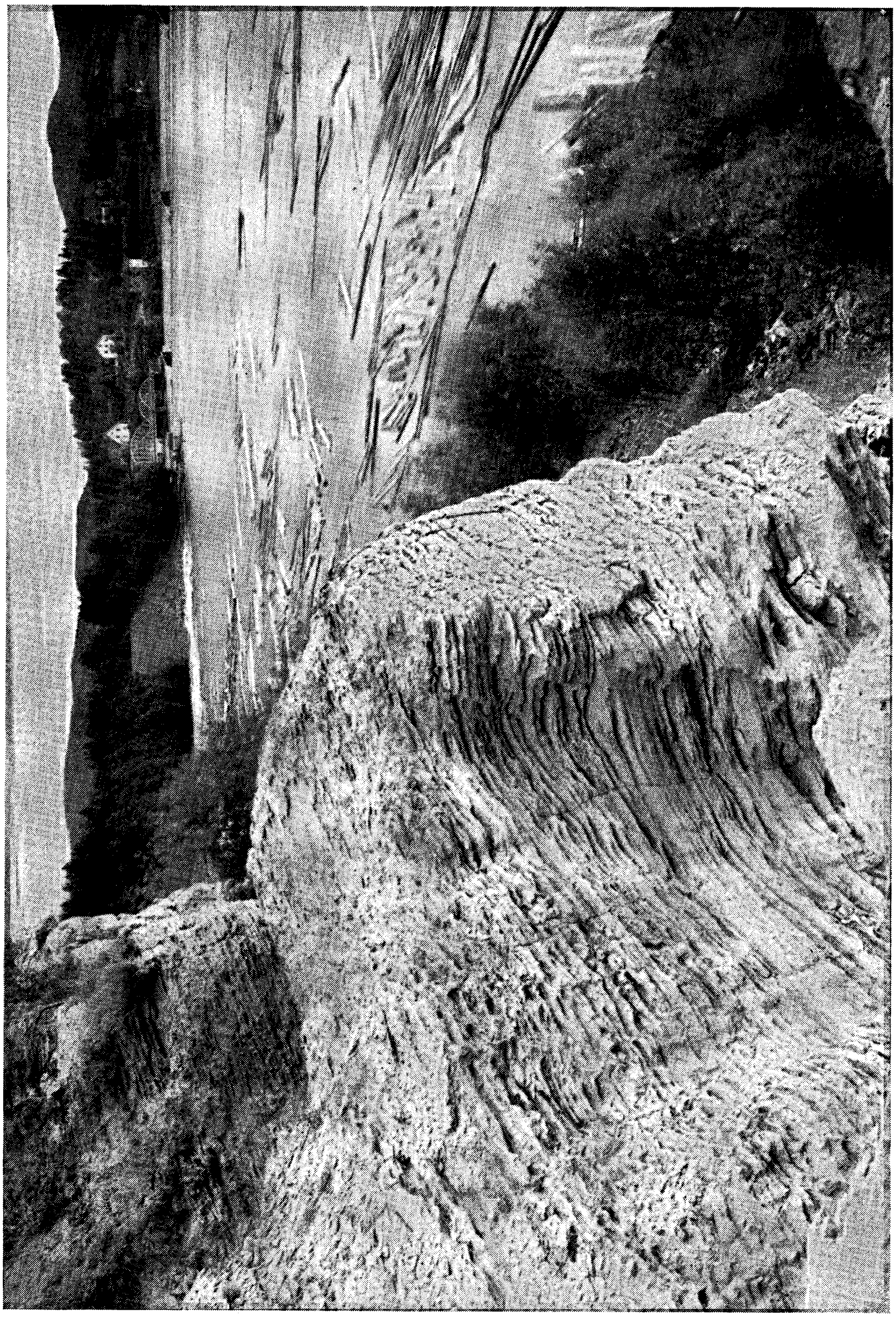
All three of them carried out their work in a most successful way, and the results have been published in Sveriges Geol. Undersökning, Ser. Ca, Nr 12. I, by H. AHLMANN, II, by C. CALDENIUS, and III, by R. SANDEGREN, the greatest part of this edition was destroyed by fire; re-edited with some corrections in the above publication, 1924.



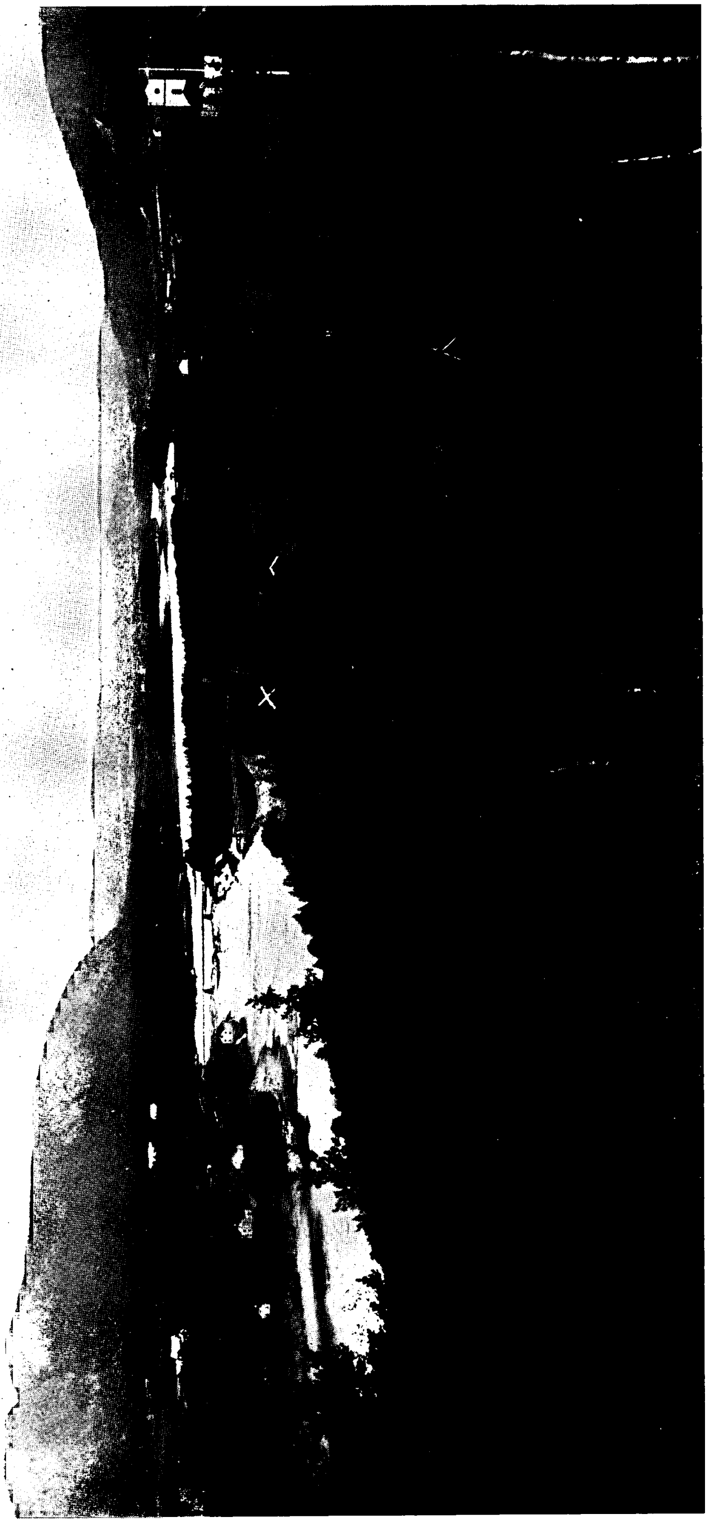
Ragunda, Jl. Vikbäcken ravine. Bottom: moraine; surface: the lake bottom of 1796. Section E Jl 2: glacial and post-glacial varves, measured from the ravine bottom to the surface by G. De Geer in 1909 and 1911. Photo O. Halldin 1910.



Ragunda, Jl. Escarpment Remmarna. Basal part, r., late glacial clay. Main section: postglacial silt. On top: dune-sand, also varved, a hundred tiny-varves counted by G. De Geer in 1911. Photo Karlström, Sollefteå.



Ragunda, Jl. Escarpment Remmarna, detail. Section of wind-eroded, sandy, postglacial varves at River Indalsälven. Background: Hammarstrand Hotel, and Section E Jl 4. Svenska Turistföreningen. Photo C. G. Rosenberg, 1933.



The Ragunda Valley. In the middle: Old Church (×) at the former lake shore. Thereabove: late-glacial fjord-bottom sediments. River sections: Late- and postglacial varve series. Photo H. Löfbladh, Hammarstrand.

The Zero-varve.

From investigations by RUTGER SERNANDER and GUNNAR ANDERSSON it was first made known that numerous plant-remnants were imbedded in the so-called river deposits along the Indal River near Ragunda. This together with the observation of RAGNAR LIDÉN that along the neighbouring Ångerman River annual varves seemed to occur also within the postglacial deposits, induced me to pay a visit to the Ragunda region in 1909, as mentioned above.

The observations quoted seemed to be of very great interest.

LIDÉNS postglacial varves finally promised to fill out a chronologic gap between the glacial varve chronology and the historical one.

Now at Ragunda, by River Indalsälven, there had been a lake which about 200 years ago, in 1796, was totally drained off by an accidental cutting through of a sand barrier. Here seemed to be a possibility of connecting the glacial melt-varves with our time by means of the named year of lake drainage. The postglacial varves were all right and became duly registered, but it was found that the former Ragunda lake had been practically filled out by postglacial varves long before the drainage year quoted.

Still about 3000 years of the Postglacial epoch were added to the time scale, and among those that very thick varve which registered the last ice-dam stage of Lake Storsjön down to its stage of an ordinary land lake.

This annual varve representing the first definitive bipartition of the land-ice and being in direct connection with the time scale was chosen as a very proper Zero-year, or limit between the Finiglacial and the Postglacial subdivisions of the late Quaternary stages. Thus earlier years are marked with *minus* and later years with *plus*.

The current of this giant drainage at some places was found to have cut away one or a few varves, why several measurements were necessary for definitive correction.

Generally the melt-water seems to have been so saturated with clay that it could deposit but not erode, and this must indeed have been a necessary condition for the remarkably exact adjustment of the varve thickness and thereby for the whole geochronology.

In the time scale, Pl. 75, the Zero-varve is given by a measurement from Indal, Me, for plus-years, and for minus-years by G. DE GEER's Vikbäcken, E Jl. 2, as well as one of C. CALDENIUS' long Ragunda-profiles, E Jl. 8 a.

The Zero-varve as well as other draining varves, deposited by extra strong currents, as easily understood, at different localities exhibit considerable variations in thickness, evidently caused by local hindrances in the bed of the current.

Thus in the most proximal locality of observation, or Storedan (E Jl. 8 a) in W Ragunda it amounts to 980 mm, at Vikbäcken 175 mm and Singsån 165 mm. Down the river, at Indal it was observed by G. DE GEER to 270 mm, while in a specimen taken by C. CALDENIUS, at 0.7 km distance, it was only 85 mm (Pl. 51).

It is, as always, the fine-grained clay-sediment, deposited in quiet water, which affords the dating possibilities by its far more regular and persevering variations.

The region of River Ångermanälven.

Varves.

It is already mentioned how RAGNAR LIDÉN was one of the most successful assistants of the first greater clay-campaign of 1905, how next year he followed me along the further extension of that line, and how thereby he came to the opinion that in the terraces of River Ångermanälven, when playing as a boy, he observed what might have been postglacial varves. Soon afterwards he sent me specimens, proving that he was right.

As further mentioned, this opened a possibility, long sought for in vain, of filling out the gap between our historical chronology and that of the Quaternary varves. Soon afterwards LIDÉN commenced his important investigation of the late Quaternary evolution of the Ångerman district.

This magistral investigation, skilfully planned, he successfully followed up in spite of different hindrances, and thereby, through mapping and measurements, he brought about a very instructive prototype for one of all the large valleys in north Sweden by a careful study of which much duplication can be made unnecessary.

His publication is rich in various valuable data and measurements, making the Ångerman Valley together with the Indal-Ragunda Valley to the foremost representatives of the Norrland valleys in general.

LIDÉN'S very careful varve measurements, published in 1913, comprise the years —500 to +247 of the Swedish time scale.

After several vain attempts at a connection of LIDÉN's varve series from Ångermanland with the main time scale, the present author in 1919 measured a section of regular varves at Gåsnäs in Resele, Ång., of which six specimens are presented here (Fig. 41) together with some varve series from Haileybury in Canada, taken by E. ANTEVS at our visit in 1920 from the section, Pl. 41 a, b. In the graph Fig. 42 are given the respective varve series, measured in the field as well as on the individual specimens from both localities. See also the Main time scale, Pls. 75—77, and tables.

Land-elevation.

Lately, in 1938, LIDÉN also published an important graph showing the rate of land-upheaval along the Ångerman Valley during the last 9 000 years and beginning with a maximum upheaval of no less than 15 m per century or 15 cm per year, successively diminishing until nowadays not quite 1 m per century, which may be the maximum upheaval of our days (Fig. 43).

In the same way it seems probable that the mentioned great upheaval, shortly after the melting away of the preceding ice-load, represented a maximum amount of emergence.

By systematic determinations of respectively delta- and sea-levels, corresponding to the successive proximal varve limits from the land-upheaval, LIDÉN worked out a very valuable curve of the land-upheaval in the Ångerman region, showing the regularly decreasing amount of land-upheaval, as mentioned above, which on the whole may give a good idea of this great and probably rather regular movement of the heavy earth crust.

T. F. JAMIESON, who observed that such land-upheavals always seemed to follow upon the melting away of glaciations, suggested that the causal connection was just the disappearance of the ice-load.

Furthermore it seems to me from certain stated facts to be probable that certain changes of balance in the earth crust at favourable places perhaps often may have caused such earthquakes as lately have been observed exactly at such constellations of circumstances.

RAGNAR LIDÉN not only discovered that in Norrland also the postglacial sediments as a rule have been deposited as distinct or at least quite measurable varves, but he executed also, by and by, in the Ångerman River a very manysided investigation of as well the late-glacial as the postglacial sediment and shore-lines in different conditions accompanying their formation.

By measuring also the postglacial varves at a considerable number of localities, at every place up to the very highest, he could, with sufficient accuracy, at every place determine the very sea- and delta-level at the corresponding stage of the land-upheaval.

Thus he succeeded to fix for nearly 9 000 years a detailed curve for this land-upheaval, a determination hitherto quite unique.

As might have been expected from the dimensions of the earth-crust, the rate of this land-upheaval has been very regular, exhibiting a rather parabolic curve with the most rapid land-upheaval in the beginning just when the ice-border had disappeared, and afterwards a rather decreasing amount until, in our days, the rising of the land does not fully attain one meter pro century.

In Fig. 43 is reproduced a fac-simile of the LIDÉN-curve, published last autumn, showing the successive migration downwards of the delta at the Ångerman river from its stand at Bölen, Junsele, at 220 m a. s., and successively a little before the Zero-year at the beginning of the geochronologic postglacial stage and down to the actual sea-level.

This sinking of the river-mouth or corresponding upheaval of the land, according to LIDÉN's careful and rather equally distributed determinations, has been so very regular that there seems scarcely, at this latitude, to have been any room left to deviations of any kind, whether isostatic or eustatic.

Eustatic oscillations of the sea-level ought to be omnipresent like the level of the ocean and thus occur at any latitude or in any region of our country.

Concerning the postglacial transgression, which by well characterised fossiliferous sediment is so conspicuous in the peripheral parts of Fennoscandia, it is more and more difficult to trace within the more central parts of that region. Generally but minimum figures of the corresponding level can be obtained by means of postglacial marine fossils and sediments in immediate connection with these.

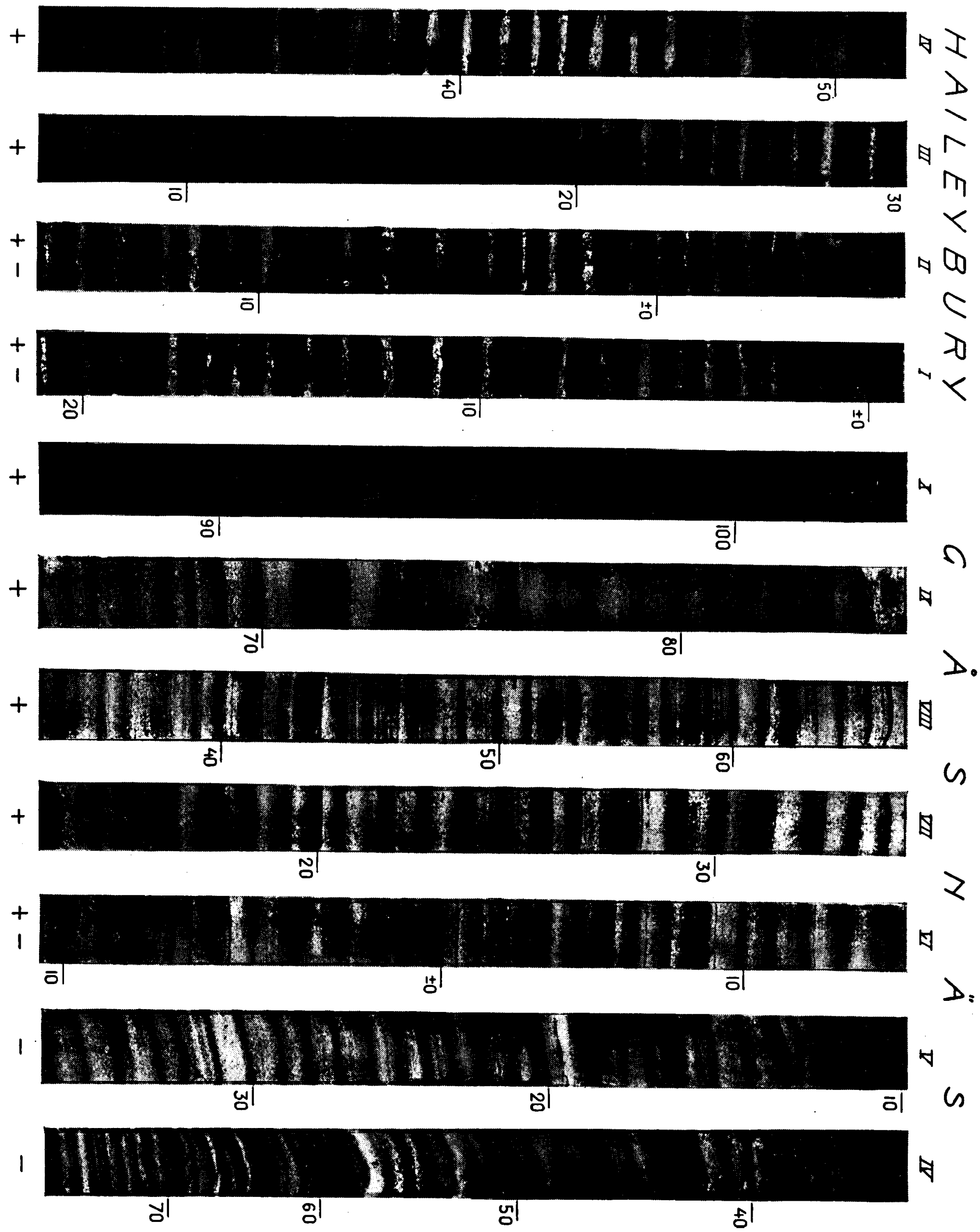


Fig. 41. Dated varves from Haileybury, Can. 4, and Gåsnäs, Ång. 1. Confer Fig. 42 and p. 222.

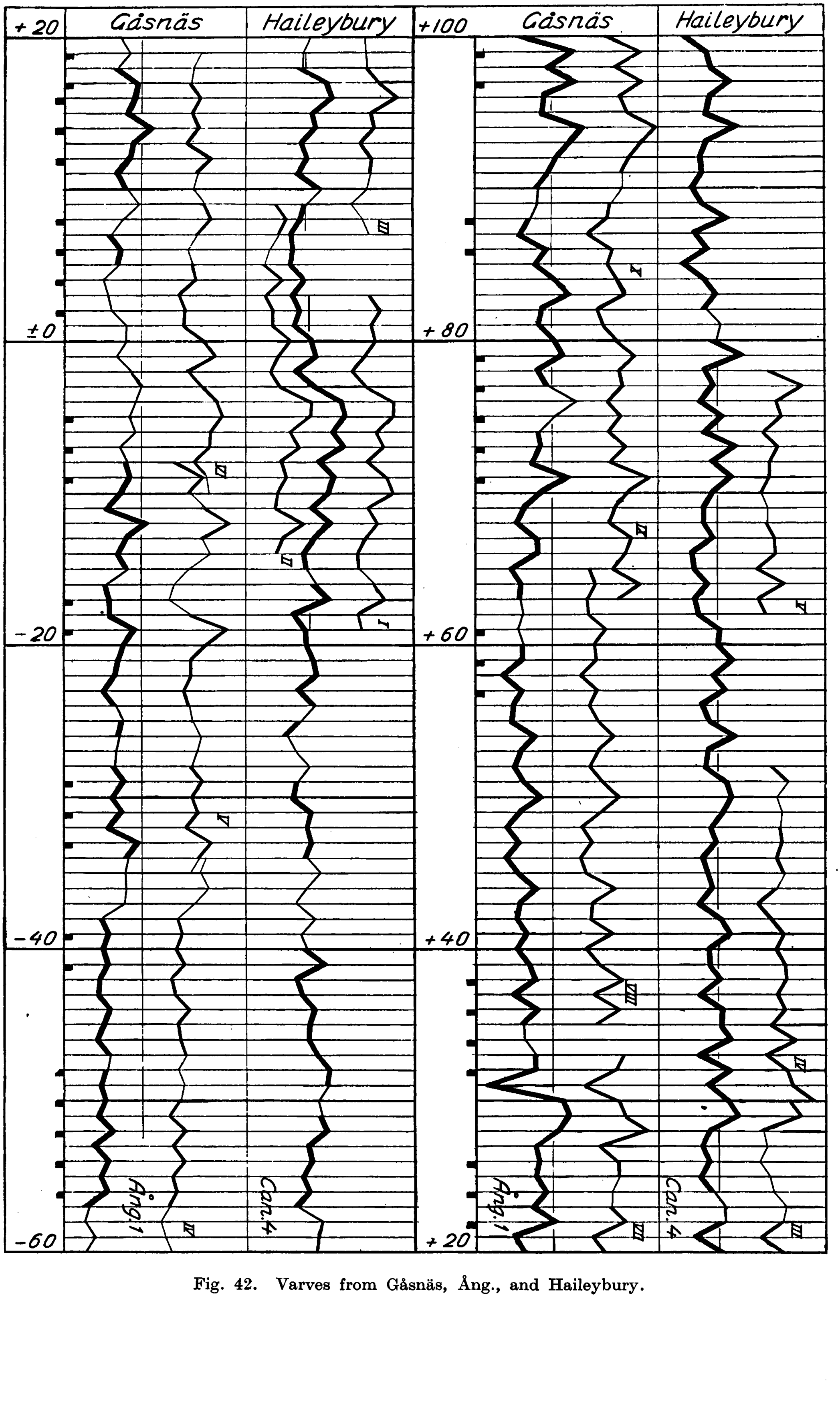


Fig. 42. Varves from Gåsnäs, Ång., and Haileybury.

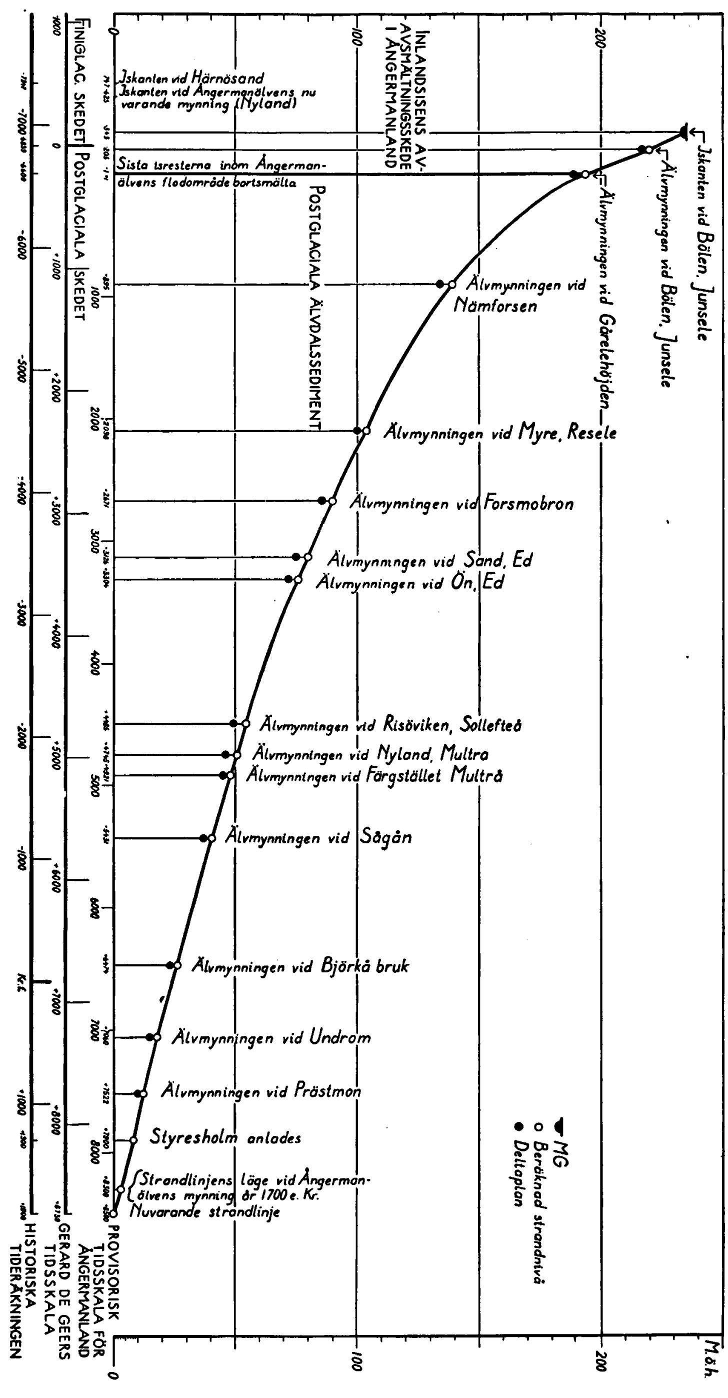


Fig. 43. Rate of land-emergence as determined by R. Lidén along the Ångerman river in North Sweden.

Of great interest is that the land-emergence followed immediately after the recession of the land-ice and at once reached its greatest observed amount of rapidity or, for a short time, no less than 15 m pro century, or 15 cm pro year.

This utterly rapid, rather catastrophic maximum land-emergence no doubt ought to have affected the balance in the earth-crust, why it was quite likely that in weak places of the earth crust magma-movements and earthquakes could arise.

In the foregoing as well as below, pp. 192 ff. and 206 ff., it has been told how, quite lately, some such phenomena have been discovered and how it can be expected that probably they will be found to be a normal consequence of rapid changes of level.

Extension of varve connections into Postglacial age.

In 1915, by comparing two long varve series from Älvkarleö at the Baltic, near the mouth of River Dalälven, and another one farther south at Örbyhus in Division Q, with a great natural section of the same river at Avesta (Pls 47, 76), some 85 km farther inland, I found that the same thickness variation of the varves could be equally well identified at long as at short distances, when the varves were deposited along the same ice-border and thus at the same time, and especially by means of long series of distal varves.

This evidently had nothing to do with accidental variations in one and the same melt-water or ose-district, but suggested a common and perhaps a general cause of a climatic order.

This opened quite new possibilities for geochronology and in changing it from a slow and time-craving walk, pace after pace following the tracks of the receding land-ice, into identifications at great distances, or what I called teleconnections.

This indeed implied an ability of flying or using a kind of wireless.

Together with Ebba Hult De Geer I started at once to test the new method, and it proved to be all right and quite practicable.

We measured and compared several long varve series generally at natural sections cut out at a number of the great rivers in northern Sweden, often with interstices of one hundred kilometers or more, whereby the localities were so chosen that some part of a long varve series could be expected to correspond to some part of the next one. It was a clear success, reminding of the giant Lunkentus in the saga, with boots taking lots of miles in one step.

In this way we got well corresponding teleconnections all the way from the river Dalälven past several of the greater rivers of north Sweden up to Vindel, Skellefte and Lule älv rivers.

Very often these big rivers have cut down magnificent sections through glacigene as well as postglacigene sediments.

Thus long varve series were measured at:

River Ljungan: Högom and Sundsvall,

River Vindel älv: Degerfors, Hällnäs, Juksån, and Strycksele,

River Skellefte älv: Kusfors railway station,
River Lule älv: Strömbacka, Överedet,

and shorter varve series at Lule älv: Boden, Hednoret, Bredåker and Åminne, as well as, farther south, at Örnsköldsvik, Hudiksvall, and Ljungaverken.

The long varve series from Vindel älv and Kusfors at Skellefte älv have definitively settled the early postglacial ice-recession in Västerbotten, and even the short series of rather proximal varves with great variations gained from Lule River seem to be quite reliably fixed to the former as well as to some Ragunda series.

Though sometimes the varve variations were influenced by marked *topographic* irregularities a careful comparison between these long varve series allowed all the way good and definitive connections, thereby fixing the main trend of the ice-recession.

Thus it was certified that the Zero-line, or the ice-border representing the limit between the Late Glacial and the Postglacial stages of the Late Quaternary Epoch, runs about in SW—NE, then making a bend towards SE and crossing the north Quarken Sound between the Botnic Sea and the Botnic Bay.

Farther east, according to the varve measurements published by M. SAURAMO from Ylivieska and other localities, that Zero-ice-border seems to make a crescentic bow around the ice-lobe pushing out over the flat depression of the Botnic Bay.

From the northern side of this bay no varve localities hitherto have been reported, but there are older striæ running from W—E, indicating that the ice, when it still filled out the Botnic Bay, moved in the direction named, while the younger system of striæ may indicate a later ice-movement, when the Baltic ice-obstruction was away.

Higher up, not far from the renowned Tärendö bifurcation, varves have been mentioned but not measured, which ought to be done, this being the northernmost varve locality, as yet reported from the Baltic region, just in the neighbourhood of the interesting morainic belt, indicated by K. A. FREDHOLM (Sv. Geol. Und., Ser. C, No. 83, 1886. Map.) and also on the present map, Pl. 67.

The chronologic Postglacial stage.

The nominations Ice Age, Pre-, Inter-, and Postglacial, no doubt were intended to express certain time-delimitations but, earlier there being no possibilities for real such delimitations, these terms generally have been used in a rather genetic or stratigraphic sense.

Thus the word Postglacial very often designated such phenomena and deposits as are superposed upon the youngest moraine of a certain region. Being a very considerable difference of age between the moraines in middle Europe and the recent ones in the high mountains, it is obvious that superposition upon moraines of so different age has very little value as a time-determination.

It was about the same with the other denominations, but this was rather natural as long as there were no possibilities of real time-determinations.

As to the Postglacial deposits in southern Sweden, originally I found it practi-

Fig. 44. Norrland, Vb, River Vindel älv. Big bluffs at Strycksele with postglacial varved sediment. Photo G. De Geer, 1915.

cal to use for their lower limit the discordance between the late-glacial transgression and the postglacial one, which I had found and followed around the South-Swedish Peninsula. But later on, when this land-oscillation not could be followed in the greater, northern part of the country, I found it necessary and at the same time more consequent to use, here and everywhere, an exact geochronologic limit.

After some consideration I thought it to be the best to put the beginning of the Postglacial stage when the greatest ice-dammed lake of middle-north Sweden, in the depression of Lake Storsjön became drained off by the bipartition of the damming land-ice along its Baltic side.

The uncommonly thick drainage varve namely was in direct connection with the time scale and easily recognizable in nature.

Along the northern part of the Swedish west coast I found a marked difference between the fauna in the late-glacial shell-beds and the postglacial ones, these latter being easily distinguished by an overwhelming mass of small *Rissoidæ* and a great number of newly arrived, southern immigrants and by having the whole shell-bed brown-spotted by *Cerithium (Bittium) reticulatum*. The upper limit of these postglacial shell-beds was gradually rising northwards along the whole of the coast and later on by Dr J. Alin was completed by a series of concordant shore-lines.

Yet, along the Swedish east coast it has been more difficult to determine the uppermost postglacial shore-line and to make out if also here it marked a transgression, a stationary stage, or only some level in a continuous land-emergence. The postglacial fauna of marine mollusca is here scanty, the few shells are often weathered away, and the upper limit of marine diatoms is not yet sufficiently studied in open situations, where its immigration was not hindered by the fresh-water from great rivers.

From the lower part of the great Ångerman River E. FROMM made careful analyses of pollen and diatoms from a dozen horizons, each representing 50—200 annual varves out of LIDÉN's unique collection. He mentions the difficulty in this way to date exactly the influx of salt water into the open Baltic, but from his estimate it should have been about c. 5000 years b.C., which is c. 1700 years b.Z. In the open sea, however, probably it was earlier.

Though the migrations of plants and animals are successive and thus not usable for exact time-determinations, they are of course of great interest and, being put in connection with physical time-determinations, they can afford a kind of gliding approximal time scale.

Still, for this purpose their rate of immigration must be studied in detail.

As to our shell-beds, their evolution up towards the end of the last century was totally unknown, with exception of SVEN LOVÉN's discovery that occurrences at greater heights had an arctic and at lower levels a more recent appearance. Some few existing shell-collections were labelled from localities but not from certain, fixed layers.

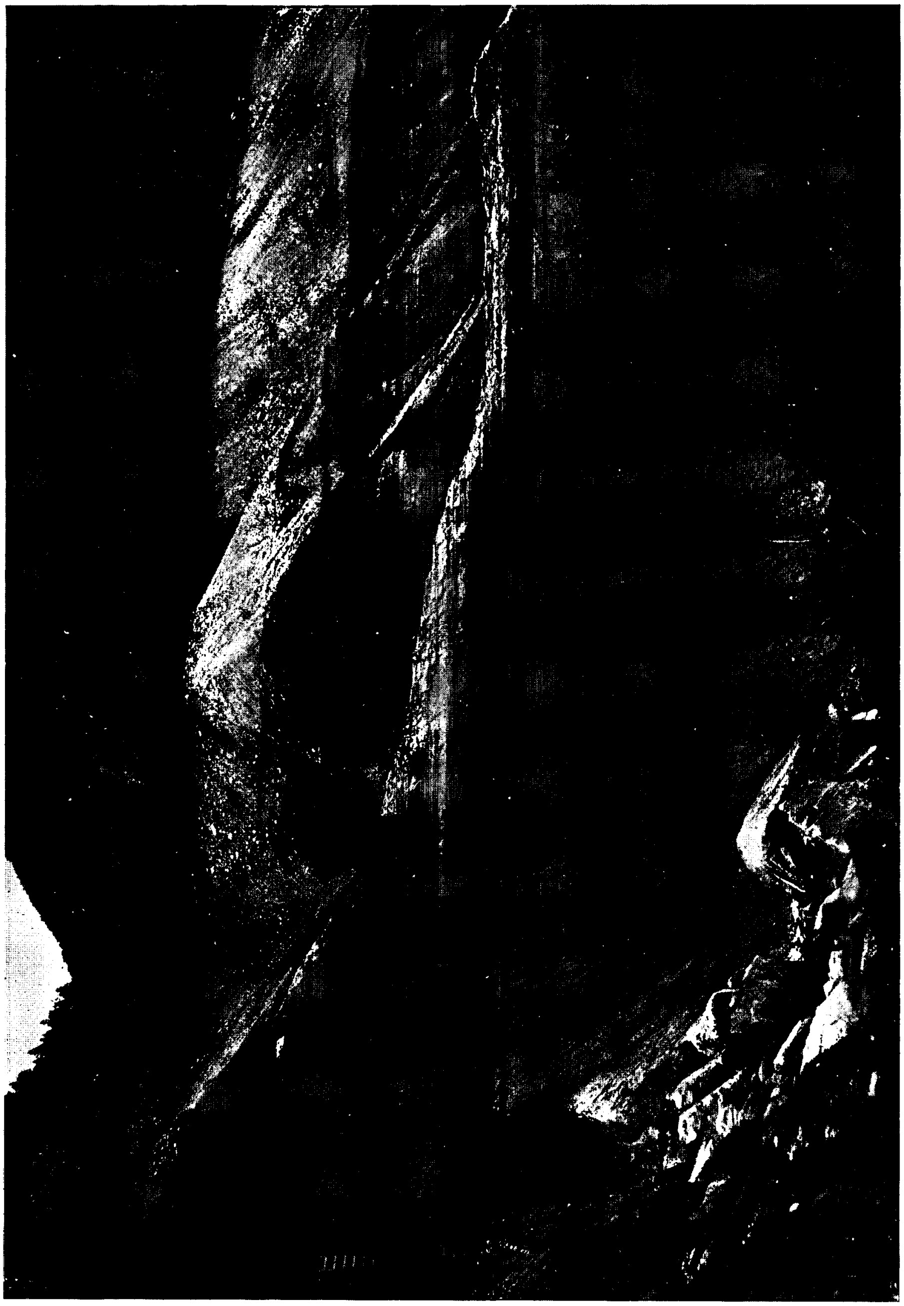
In order to find out the order of immigration of the different species in our shell-beds, sometimes more than 10 m thick, I began in the beginning of the 1880-ies to take unmixed specimens from complete successions of layers with an interval of half a meter. These specimens were weighed, carefully washed, assorted, determined and reckoned as to individually representative parts down to the smallest determinable pieces.

A part of these investigations were laid before the international Geological Congress in Stockholm (with maps and tables); another part was transmitted to E. ANTEVS as a contribution to his doctorandum thesis.

By a continuation of such quantitative statistical analyses in connection with the more and more close determination of the land-emergence the chronologic immigration of our shell-bearing fauna no doubt can be fixed in a rather satisfactory way, and, concerning the diatoms, to a certain extent the same may be true, but with respect to closer time-determinations such biologic deposits no doubt are too locally occurring and difficult to fix for dating purposes.

With respect to non shell-bearing plant-remnants Dr O. SELLING newly made an analogous experiment with a quantitative statistic analysis of plant remains in deposits at Lake Molken. Together with the detailed plant investigations of L. VON POST at Lake Molken and S. FLORIN at Vrå in Sörmland, the knowledge of the plant immigration will afford a valuable completion to the imposing amount of pollen analyses.

At the same rate as this material is completed, it may be possible to put it with necessary reservations in a certain connection with more exact datings as rather appreciable, where the latter are not accessible.



The varve terrace at Moen in Aardal, Norway. Delta structure analogous to those measured by Lidén at River Ångermanälven, with sandy varves passing over into light delta gravel beds on top.

Photo J. B. Rekstad, 1913.

Section of Moen varves with Rekstad's measurements. Photo J. B. Rekstad, 1913.

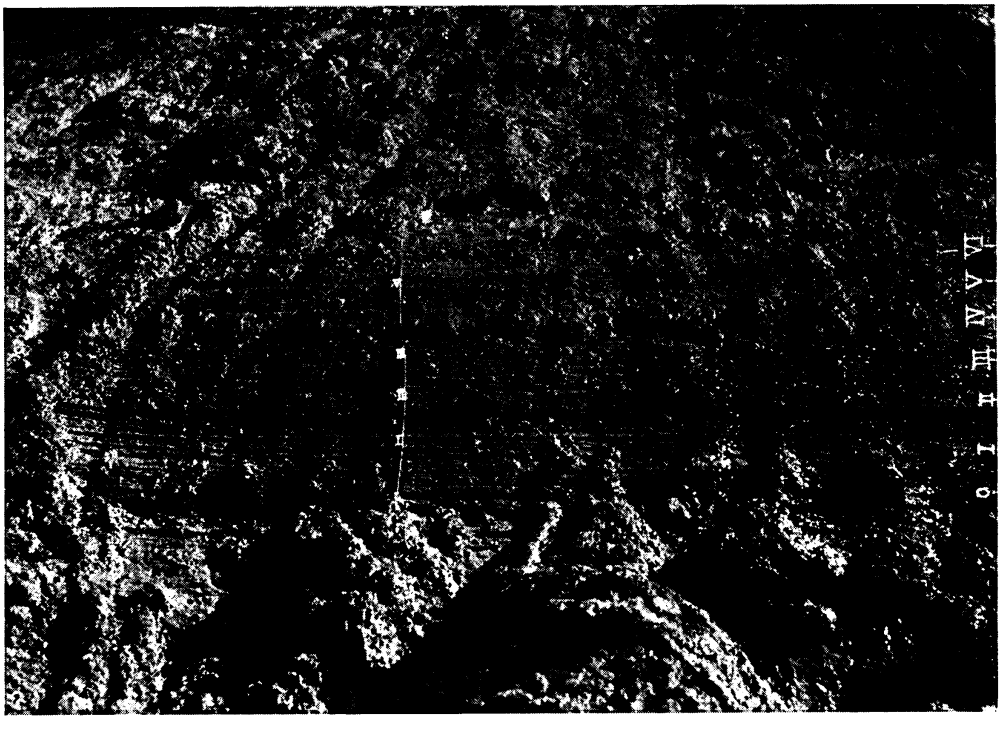


Fig. 45. Moen in Aardal, Sogn, Norway. Varve structure accentuated by wind-erosion. Photo J. B. Rekstad, 1913.

Neighbouring countries and Jemtland ice-lakes.

Sogn.

In the innermost part of the Sogne fjord, at Moen, somewhat inside Aardal church, the late Norwegian geologist J. B. REKSTAD found in 1905 and described in 1913 a late glacial delta escarpment, being more than 24 m in height and in the distal part varved. He first reckoned some parts of the varve series and estimated the whole number to about 6000. The big moraines at Aardal being assumed to represent the stage of the great Middle-Scandinavian Goti-Finiglacial moraines, the corresponding Swedish varve countings should have suggested about 2000 years. Rekstad decided to count and carefully measure the whole number and found almost exactly 2000 varves (2064). His long diagram being by the present author compared in detail with the time scale, also exhibited dominating long series of most striking similarity, as is well shown by the adjoined diagrams of the Time Scale, Pls. 73—78, Nor. 4. Between the correlated constellations there occur locally developed varves, no doubt due to extra material from meandering erosion of the melt-river between the ice-border and the sea.

Kvarstein.

In southern Norway the Finiglacial moraines, southwest of the well-marked stroke of the Raër, continue their trend somewhat inside the coast, diverging over a somewhat broader area. In connection with the retardation of ice-melting that they represent there also occur huge accumulations of varved deposits, somewhat analogous to those of Moen.

In 1932 Dr A. P. DANIELSEN had the kindness to measure several varve series at Kvarstein some 10 km to the north of Kristiansand in southernmost Norway, a little to the south of the great Mid-Scandinavian moraines. Though partly somewhat older than the Finiglacial stage, as deposited just outside the moraine-stroke, these varves are here reproduced as locating the southern limit of the Finiglacial area. One of his measurements is given on Pl. 78 as Nor. 3.

Scattered localities.

In the time scale is also given a varve measurement from Döli brickyard at Jesseim in Romerike, which is a region of heavy varve deposits, visited and measured by the present author in 1916 and 1917. In the middle of the section were two mighty drainage varves, consisting mainly of brownish sand, above and below which a score of normal clay varves were well discernible. From the lowest varve reached it was probably not far to the bottom.

At Oslo a good correspondence is gained by measurements at the brickyards of Bryn, Lillo and Nygård, of which the graph of Bryn is tentatively added to the time scale. The varve series obtained as yet in the valley of Glommen, at Tönset and Elvedal, however are very short series of thick and sandy varves with great variations.

In the colored plate (Pl. 51) is shown part of a specimen from near Fluberg at Randsfjord, kindly presented by Professor O. HOLTEDAHL, Oslo.

Trond.

At Værdalen, close NE of the Trondheim fjord, there occurred in May 1893 a great land-slide, visited and described by A. HAMBERG already the same year. He determined the thickness of the varved glacial clay to a minimum total of 27 m and reports single varves to be a fourth m thick. When, as mentioned above, in 1907 visiting the place, I measured in the remaining sections of varved clay a series which was correlated almost in one succession with two corresponding series in Östergötland, south of the Finiglacial moraines. The varves could be measured only on dry clay-walls, because the very plastic clay inside the dry crust could not be cut into measurable sections. Still the correlation was all right and especially valuable as representing an old stage of the Finiglacial ice-recession from the Atlantic side.

A still older stage of that ice-recession I found in 1922, as mentioned above, in Trondheim. It was at a digging close along the north side of the Technical High School in a quite open situation toward the fjord. But the institute in question is situated upon a marked hill, which may represent the same stationary stop in the ice-recession as the big mid-Scandinavian moraines; and thus it may be probable that sufficient quantities of melt-water here made possible the deposition of varves which seems not to occur in unmixed salt-water.

The dating of the varves points to exactly that epoch when the great moraines were deposited. Confer graphs, Pl. 86, and maps, Pls 63, 64, 70, text p. 323 ff.

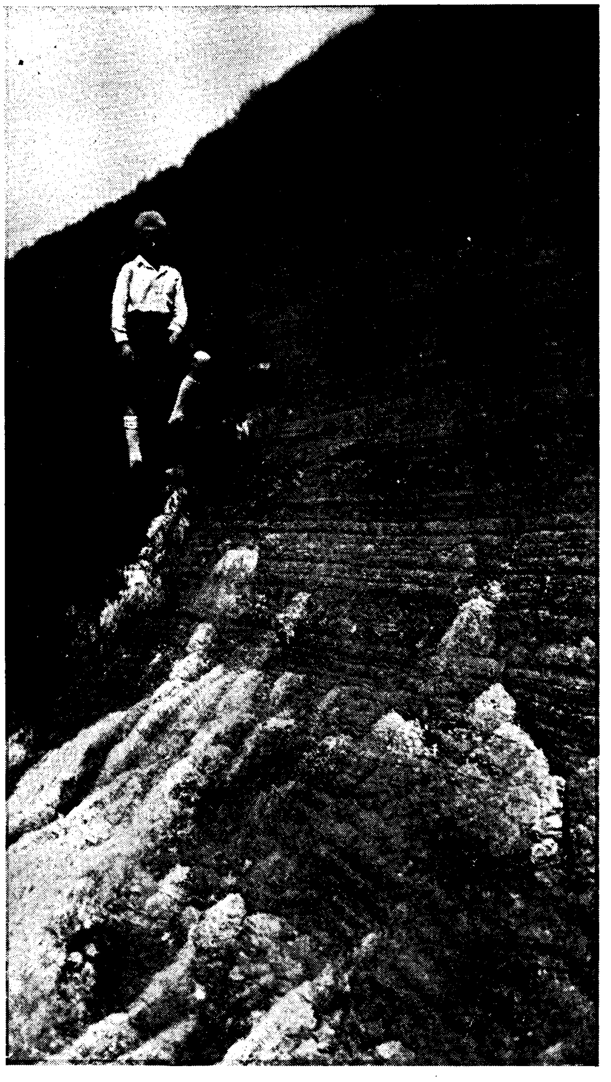


Fig. 46. Clay section at Kvarstein, Otra river, 12 km N of Kristiansand. D. Danielsen, 1932.

Jemtland ice-lakes.

East of Trondheim and Værdalen, and in the Meraker valley, I have no varve observations until on the Swedish side within the series of ice-dammed lakes in Jemtland, where varved clays have been measured at several places on the western side of the ice-shed. Thus at Medstugan some varve series were measured representing about the years —890 to —770, and at several places all along the road to Duved brickyard near the railway station varved clay occurs and probably could afford a detailed series of recessional measurements.

At the south side of Lake Ånnsjön, at Bunnerviken, not far from Handöl, a varve series was measured on the promontory formed by the ose, and some other series near Undersåker and at Järpen. At this latter locality it was noteworthy that the dated varve series was covered by glacifluvial gravel, indicating a readvance of the land-ice no doubt the same which occurred from the north side of the Storsjö depression, when its earlier land-ice tongue had been broken up by iceberg formation and the ice-dammed water had been considerably lowered.

This new local readvance of the land-ice from the northern highland is marked by numerous striæ as far as to the southwest side of the Storsjö depression and also by a few characteristic oses, running SW at lake Nälden.

Farther north we succeeded to hunt up a few varve localities, those in Ströms Vattudal reaching up towards and east of the very Zero-line or the basis of the Postglacial subepoch, though in need of control.

On the south side of Frösön island in Lake Storsjön, and at Vålbacken brickyard near its southeast end, there occur heavy deposits of thick varves, the definitive measurement of which made repeated visits necessary, certain parts of especially the bottom varves being almost of the same dark-grey colour all through. Still, by close inspection it was found that the winter layers could be quite well discerned by a faint but rather distinct silk-lustre. This was controlled by repeated measurements, and a good confirmation was found later on in the beautiful correspondence with the varve variation on the Baltic side of the cotemporary ice-border, being situated about in the Uppsala region.

All the ice-lake localities are enumerated on pp. 251 and 258. Confer also pp. 164—168, the maps Pls 63, 64, 70, and the graphs Pls 85, 73—77, with explanations, pp. 333—336.

Finland.

The ice-recession through the whole southern part of Finland has got its clay varves in an excellent way investigated and measured by Professor MATTI SAURAMO, who in a series of detailed publications has given a very thourough report of his craving and very valuable measurements. A few years ago I compared and referred his reciproque datings to the universal Swedish time scale.

Under such conditions it did not seem necessary in this publication also to introduce the very great number of diagrams from Finland which on the whole are very similar to the corresponding ones from Sweden.

Only from the westernmost coast of Finland a small number are quoted in connection with the remarkably rapid ice-recession observed on the Swedish side of the Botnic depression. In order to control the Finlandic observations named Professor SAURAMO had the great kindness of measuring particularly several new varve series near the coast at Kristinestad, thereby definitively verifying his earlier determinations of the last ice-border on that side of the Botnic depression.

Some varve series from Åland are reported on p. 158.

Confer pp. 255, 259, 265, 329—330; tables pp. 298—300, 308—311, 313; graphs Pls 77—79; and maps Pls 66, 68.

Changes of level.

Historic notes.

Even somewhat after 1830, when modern geology is considered to have its origin with LYELL'S Principles of Geology, there occurred several revivals of the great flood which earlier had been applied to as a licenced, general explanation of Quaternary deposits, and especially of those laid down in water.

Thus even the oses were considered by J. BERZELIUS and N. G. SÄFSTRÖM as deposited by a great general flood. Mainly by the occurrence of marine shells in deposits covering a number of oses at two levels, several of the leading geologists, who laid the foundations concerning the Quaternary studies in Sweden, were led to the assumption that the oses as a whole were a shore deposit and, as oses occur even in the higher parts of the country, they assumed that the whole of it had been covered by the sea.

On this stage we find as well E. SWEDENBORG, 1719, as CH. LYELL, 1835, H. VON POST, 1855, S. LOVÉN, 1861, and O. TORELL, 1873, thus all of them leading names in Quaternary studies. It was as well the widespread occurrence of oses and varved clay, even at high levels which for a long time postponed the fixation of a real marine limit.

As far as known, there are only a few and scattered localities where some geologists seem to have observed the highest traces of wave action. Thus G. LINNARSSON mentions that the eastern slope of Mts Kilsbergen in the province of Nerike does not show any marks of wave action higher up than to about 150 m a. s., while E. ERDMANN mentions from the south side of Lake Sottern that marine traces do not reach higher up than to 140 m a. s. From Mt Hallandsås D. HUMMEL mapped out a shore level at 60 m, which he supposed to be a marine limit, though afterwards it was assumed that marine deposits occurred even still higher up a. s.

Determination of the Marine Limit.

Having had the opportunity, in 1882, to make a close acquaintance in Spitsbergen with the arctic marine shore formations, which are exceedingly well developed all up from the present shore-level and not concealed by the scanty or quite missing vegetation, I determined, on returning to my mapping work in E Scania, to hunt up and as exactly as possible to determine the very marine limit, though it was here not seldom more or less concealed by vegetation.

Still it succeeded at quite a number of localities to fix the height of the uppermost shore-limit to a little more than 50 m a. s.

By trying to refind and follow this limit farther south along the eastern side of the province, I did not refind the highest traces of wave-erosion, even at quite open localities, at the same level, but always somewhat lower down; sometimes there occurred a very well marked series of beautiful beeches continued all the way down to the actual sea-level. Farther southwards, at Kivik, the highest wave-markings were at 32 m a. s., while at Simrishamn they were but at 19 m.

As all the localities were in an open situation and quite distinct, it was evident that they belonged to one and the same series of former water-levels which afterwards had been unequally upheaved.

As the region in question happened to represent the southernmost part of the continuous, great geologic unity, which later on by W. RAMSAY got the name of Fennoscandia, I was struck by the fact that in 1834, exactly at the opposite, northernmost end of the same region, by careful measurements of rather continuous rock-terraces, the renowned French physicist, A. BRAVAIS, had undeniably shown that also that district had been unequally upheaved in a very analogous way.

As in both of those districts the unequal upheaval pointed towards the centre of Fennoscandia and was sloping towards its circumference, it seemed to suggest the possibility that the whole of this natural region had been upheaved after the disappearance of the land-ice, like an immense bubble.

This seemed also to be in accordance with the approximal heights up to which the more widespread occurrences of sedimentary clay were found in a free situation as well as all that was known concerning the heights of marine shell-beds.

Still I commenced, as soon as possible during the following years, a series of investigations in the morainic, rather stony and forested slopes in a free position above the widespread clay-district. By these rather time-craving measurements I succeeded by and by to certify that the late-glacial unequal upheaval of the earth crust closely followed the main lobe-lines of Fennoscandia.

From the regularly varying height at which the marine limit was found very nearly where it could be expected, as well as from its generally very marked development, at first I came to the assumption that it might have been formed during a rather long stationary stage in the land-submergence.

From first of I got the impression that the land-emergence had not left its maximum depression until the central remnants of the land-ice had already melted away and given place to the wave-erosion.

Later on I found, at Dal's Ed and other places, that the upheaval of the land already during the ice-recession had proceeded gradually, whereby it was possible to date a successive development of the marine limit by means of its relation to the receding ice-border. The sharpness of the very marine limit was found to be due only to the marked difference between successively exposed, unwashed till and the highest intense redeposition by the contemporary wave-action.

Thus the present attitude of the marine limit is partly secondary and its successive evolution can be made out only by means of geochronologic datings.

In northernmost Sweden Professor A. G. Högbom made the interesting discovery that the highest limit of the sediment within the inner parts of the valleys did not occur at the same maximal heights as along a belt nearer to the coast.

This statement was confirmed by several determinations of the very marine limit, and thereby it was found that some marked terraces of glacial rivers had been mistaken as being of marine origin. The unexpected, remarkable sinking altitude of the marine limit from the coast region towards the interior of Norrland for a long time was assumed to be caused thereby that in this region the earth crust had been thus far upheaved, while it here still was ice-covered, so that the marine limit could not be marked by the waves, before the most depressed region already had been somewhat emerged.

Further on it was supposed that the maximum depression occurred about where the ice-load had reached its greatest thickness.

But it is true from what is now really known concerning the maximum and the final situation of the ice-shed during the last glaciation, that this, no doubt, was situated quite a way to the east of the water-shed, or about as far as the distance of the latter from the northwest coast.

But still there were no proofs at all that the ice really reached its maximum thickness sufficiently near the Baltic coast to explain the present remarkable attitude of the marine limit.

Successive development of the marine limit and distribution of varve sediments.

Isobases.

In order by and by to follow up the law of the land upheaval I combined already determined points of the highest deformed sea-level by marking it with lines of equal upheaval, which I called *isobases*. These lines were of good help when, from point to point, following the traces of this unequally upheaved, ancient sea-level, as a rule through rather broken and densely forested regions, and it was very satisfying thereby to find the great regularity which had ruled the whole of the land-emergence. The general trend of the isobases on my sketch map clearly indicated that the whole of Fennoscandia had been upheaved as an enormous individual bubble of the earth-crust. Soon afterwards I found that the prominent American geologist Grove Karl Gilbert already had used lines of equal deformation for representing the actual attitude of the almost continuous and widely visible deserted shore lines around the Quaternary lakes within the Utah region.

In 1891 I made a first attempt in N. America at hunting up and, by determinations in the field and publication of the results by maps with isobases, to discern the true limiting shore-lines of the Late Glacial Sea from erroneous figures derived from the so-to-say preglacigene drift theory. After about three decades of oblivion the main trend of these preliminary isobases seems to have been confirmed, through a great number of later shore-line investigations which have completed and considerably enlarged the knowledge of American shore-lines, marine as well as those of the ice-lakes. The synchronous extension of the glaciations here generally ought to be based on teleconnection as well with corresponding stages *inter se* as with other glaciations.

By the help of teleconnection the Swedish time scale has got quite a number of filials in different parts of the earth and been found to afford, everywhere, practically the same registration.

At first I thought of the possibility that the central part of the land-upheaval in Sweden could have failed to be registered by shore-marks through the still remaining, hindering bulk remnants of the land-ice.

Still the very marked difference at the marine limit between the zone of intensely water-washed material below, and the zone of till totally unwashed above the marine limit, gave the impression of a long-lasting water action at this level and that it might represent the very limit of a transgression.

Gradually it was found, and quite conclusively so, at the stationary ice-border of Dal's Ed, that the land-emergence undoubtedly was going on during that stationary epoch and probably also during other parts of the ice-recession, though a direct confrontation between the height and the location of the datable ice-border could be determined almost only at both sides of stationary ice-borders, where marked steps in the land upheaval were registered by distinct, built or cut marginal terraces. This I once called the step-theory.

In this way the marine limit at least approximately can be dated, one step after the other, though interpolation between the dated steps to a certain degree may be allowable by the help of determinations of the dated ice-recession.

On the more or less knobby bed-rocks of the lowland below the marine limit, in the depressions between the rock-bosses, varved clay very often occurs, except where the situation was too exposed to wave-erosion, whereby the till or even the bed-rocks have been exposed. But even at somewhat better protected places generally only the lower and thicker varves have escaped the erosion, while the uppermost, thinnest varves as a rule only are to be found in deeper depressions, covered by lakes or peat-bogs, or also as more or less dislocated remnants, protected by downslidden sand along the base of the oses.

Therefore the great majority of varve measurements have been performed on the lower or proximal varves along hill-sides, where ground-water is better drained away than lower down in the deeper basins with their more complete succession of varve series.

Within former bays and ice-dammed lakes clay varves may often be found somewhat higher up on the slopes, but on the other hand atmospheric weathering here often has destroyed the upper varves.

In the neighbourhood of oses which were successively deposited in the receding vaults of the glacial melt-rivers, the remaining varves often are too thick, too few, and too locally developed to afford sufficiently long varve-series for connection with other localities.

In arctic regions the discrete and rather scanty vegetation can not conceal the more or less marked traces of the Quaternary morphological evolution, and thus my early studies in the Spitsbergen region were from the beginning a very good help at the exploration of earlier, morphological and geological features in nowadays often densely forested regions of Sweden.

Also the next summer after my first visit to Spitsbergen I succeeded in finding out and determining what I called »the highest Marine Limit» in northeastern Scania in 1883, and by measuring its heights at different places I found, soon afterwards, that this ancient sea-level had been unequally uplifted, more so towards the north and less southwards. This being the southernmost part of the great continuous Archean block reminded me of the remarkable shore-line investigations, made, as mentioned above, by AUGUSTE BRAVAIS, in 1836, exactly at the opposite northern end of the same Archean block.

By his careful measurements BRAVAIS had stated that two marked shorelines along the Alten fjord were regularly sloping northwards from the interior of the fjord towards the sea, still afterwards as to the severe criticism raised from different sides against these results as unfounded, I got, on the contrary, the impression that I had found the same phenomenon and that the whole of the tectonic region in question was an old area of upheaval and denudation, which had been uplifted anew after the Ice Age. Besides by observations at the opposite end of that area this idea seemed to be corroborated by still more upheaved late-glacial sediments at the more central parts of the area in question and when, soon afterwards, I tried to control this assumption by hunting up and levelling the very highest traces of the wave-action over the widespread regions with marine sediment, I found that the height of this upper limit was so regularly upheaved that its present altitude could be represented by a rather simple system of curves, marking equally uplifted points of that surface, for which curves I proposed the name of *isobases* (see Bibl., E. H. D. G., 1918).

The isobases described rather ovale curves, conform to a combination between the region in question and the last glaciation, which I tried to explain as caused by a renewed movement of the old area of upheaval in connection with the unloading of the great ice-mass. After some time I pointed out that the central parts of that land-ice might have remained sufficiently long to prevent the erosion of the highest marine level at the time of maximum depression, not leaving access to the waves until the land-ice melted away and left the place free.

But because the highest marine limit was so well marked, I supposed at first that it might represent a stationary stage of land-depression and thus possibly to be everywhere synchronous.

Afterwards the geochronological datings of the ice-recession certified that the marine limit in every region was eroded successively, at the same rate as the ice-border receded, leaving free access to the waves.

The sharpness of the highest marine limit was due only to the sharp difference between totally unassorted till and such intensely water-worn material as at all localities with a free situation were testifying the highest limit of the breakers at every special locality.

The correlation between different parts of the marine limit thus became a special chronologic problem.

Still in such regions where the receding ice-border was parallel to the isobases and the trend of the highest marine limit, this latter must have been practically synchronous and, happily, this was the case along a considerable part of the Swedish coast west of the Botnic Sea, not to speak of shorter stretches in other parts of the late-glacial coast.

On the contrary north of the broad strait of Norra Kvarken which was crossed by the land-ice at the beginning of the Postglacial epoch proper, it is obvious that all moraines as well as shore-lines, even the highest ones, are Postglacial, and of course this is true also of all sediments, non-glacigene as well as all other ones, including oses, varved clay, and human relics.

At some places where marginal deltas or terraces have been fully built up to the level of the marine limit of any place, this limit can be independently dated by means of the corresponding varved sediments. In that way, by a careful interpolation, an approximate dating of the ice-border is attainable, also at neighbouring places.

With respect to younger shore-lines their dating is generally even theoretically more difficult. It is true that in 1922 and the following years I found in eastern Sweden at quite a number, or about thirty different levels, that mutually exact synchronous shore-lines had been formed by strong individual gales and thus practically on one and the same day and from a common direction.

Those old shore-lines from gales were found to be unequally uplifted and, while their cutting out was due to winds from respectively very different directions, still their sloping geoid-levels were found to be rather closely proportionate to each other, whereby no indication of any discordance was observed. The same was the case with the postglacial sediment which seemed to be rather continuous, while especially in southern Sweden there was a marked discordance between the late-glacial and postglacial sediments, at least partly dependent of their different modes of formation, so that with respect to the southern and middle parts of the land, the postglacial sediments were discordantly separated from late-glacial ones, inclusive the micro-distal and so-called *Ancylus*-deposits.

A Finiglacial hypsometric map.

In order to give some idea concerning the attitude of the land, over which the last ice-border receded, I used as skeleton map for the recession named a hitherto not published hypsometric map, which I constructed for the Stockholm exhibition of 1897. It was drawn on the basis of different ordinary hypsometric maps, but with their heights and depths reduced to the late glacial sea-level according to all available determinations of the marine limit from that time generalised by means of isohypses. As these isobases were not really synchronous but only consecutive, the same is consequently the case with the morphologic curves, but still these may correspond considerably better with the epoch in question than the hypsometric lines of our own epoch.

While it was assumed by EDUARD SUESS that the changes of level especially discussed with respect to Scandinavia were due to an eustatic rearrangement of the hydrosphere towards the equator, a great number of systematic levellings of the highest traces of marine action about at the same time had definitively shown that those highest traces did not at all exhibit a general slope southwards, but were, in a most marked manner, geographically arranged around a local center of upheaval about at the middle part of eastern Sweden, or nearly at the center of the whole region of late Quaternary upheaval. At the same time it was stated, that the extension of this region in the main seemed well to coincide with that of Fennoscandia, which must be considered as an old area of upheaval and denudation, though with some exception probably pointing to a secondary influence from the load of the last glaciation. This as well as the coincidence in the main between the center of the last glaciation and of the following land-upheaval were emphasised as speaking to the favour of the ice-load theory of T. F. JAMIESON, which earlier had been rather disputed and disregarded.

At the same time the new-found law for the late Quaternary upheaval of land in Scandinavia, which exhibited its local maximum at first when the central and thickest ice-mass had disappeared, consequently could not, as sometimes supposed, have been due to the local attraction of the land ice.

Along the southern rim of the upheaved area in northern Germany, Denmark and the Netherlands as well as in the region of Leningrad a negative movement of the earth crust was dominant, and the same has been stated concerning the bottom of the North Sea. It seems probable that it was the case in a still higher degree with the great area of depression within the northernmost part of the Atlantic, for which, at the geological congress of 1910, the special designation of *The Scandic* was proposed, comprising its two opposite parts, the Norwegian temperate and the Grönlandian arctic seas. It being observed in Spitsbergen that during the later part of the Tertiary period the main mass of this land had been upheaved by a considerable mountain-movement, evidently oriented from the Scandic depression, and followed by the original formation of fjord fissures, it was found probable that also the long continued extravasation of the Tertiary basaltic lava-beds along the Färoe-Iceland bank and the east coast of Greenland as well as the succeeding first origin of the fjord fissures were due to a marginal upheaval around the Scandic area of depression.

The same explanation was proposed with respect to a late Tertiary renewed upheaval of the west-Scandinavian mountain ridge, about in the same region as the long beforehand totally base-levelled Caledonian mountain ridge had determined the site and direction.

If this natural connection between the sinking in of the Scandic depression and the upheaval of the surrounding Scandinavian border-lands is right, it seems but fair to assume that the depression directly observed along the southern side of the late Quaternary region of upheaval also has been extended, and probably in a still higher degree, along its Scandic side, though direct observations here are difficult to obtain.

Land-upheaval and glaciation in North Sweden.

From the unequal upheaval of the Norwegian shore-lines, sloping outwards from the continent, it seems probable that the limit of the land-upheaval may be situated not very far from the outside of the old Archean region of upheaval.

Farther in over the upheaved region I constructed isobases of equal upheaval of the late-glacial or highest marine limit, though as to the central parts of the region it may be somewhat too low, because part of the upheaval already was performed when the land-ice laid this region open to wave erosion. Also from other causes the net of isobases in some regions ought to have had a larger subbasement of direct measurements. But anyhow, the hypsometric map of the late-glacial epoch affords, no doubt, a much better idea of the morphology of that time than the present attitude of the land.

As indicated on the map named of the hypsometry at the end of the Ice Age, the Scandinavian mountain ridge at that time was 100—200 m lower than now, and so were also the inner parts of the fjord-bottoms. The most important hypsometric difference in comparison with our time was to be found in the northwestern part of the Botnic Sea proper exactly off the most uplifted late glacial shoreline of the whole area. While the greatest depths here are nowadays somewhat over 200 m, they were at that time more than 400 m, while a depth of 200 m extended over a great part of the Botnic Sea and of the Botnic Bay and southwards almost down to the latitude of the Åland Islands.

In the same way the so-called Norwegian Channel also probably was more than 100 m deeper than now, and it is but natural that these greater depths must have exerted a marked influence upon the recession of the land-ice.

This considerable late-glacial depression of the region in question seems to have been preceded by an antecedent, rather remarkable, high elevation. Thus to the south of the middle and northern part of the great Baltic Valley there has not been found any erratic remnant, testifying the existence of such a depression during Tertiary or early Quaternary times. On the opposite, there are indications of a geologically spoken late sinking in of considerable parts of the depression named. Thus the whole assumption that the Quaternary glaciation was promoted by land-upheaval probably was not without foundation, though the geochronological teleconnections now have shown definitively that the great Quaternary glaciations, being everywhere synchronic, must have had a common and general climatic cause, though it was materialised as centres of glaciation only where the heights of that time rose sufficiently above the snow-line, while the ice-extension below that line was determined by melt-temperature and ice-berg fracture, so amply illustrated by the long series of recessional ice-borders.

The considerable upheaval of land from the late-glacial depression has rendered accessible for investigation the whole very extended and continuous part of the late-glacial sea-bottom, which has made a more detailed elaboration possible exactly here. And, furthermore, the unequal land-upheaval with a greater amount in its centre has tilted a great number of late-glacial lakes with their outlet at the distal end, so that their former lake-bottoms with varved sediment became accessible, thereby extending the possibility of varve datings also to the inland.

About at the midst of Scandinavia and between the two marked depressions, respectively at the middle part of the Botnic valley and near the Trondheim Fjord, the lowest pass in the mountain range was still somewhat lower and, facilitating the outflow of the ice towards the Scandic Sea, thereby caused the ice-shed to migrate eastwards about as far as the water-shed is situated to the east from the main west coast of Norway.

When this current of land-ice had melted away until its western border had passed eastwards over the water-shed, a series of ice-dammed lakes gradually came into existence along the receding ice-border, and in these ice-lakes a sequence of annual melt-varves, which have been dated by means of corresponding varve series in eastern Sweden. Hereby it has finally been possible to compare at least the main features of the cotemporary ice-recession on the Swedish and the Norwegian sides.

Though, especially at the Norwegian side, I have succeeded to execute only a few measurements, the observations are still sufficient to show that here, just as in south Scandinavia, the ice-recession on the eastern, continental slope, no doubt with more sunny and warmer summers, at several epochs was more rapid than at the opposite one, where the ice-slope probably was better protected against melting by fogs and snow at the meeting between the land-ice and the Gulf-stream.

An important cause of the difference named was no doubt also the different distance from the ice-shed on both sides.

Certainly a continued detailed chronologic study concerning the recession of the ice-border lines within different topography and at different latitudes will furnish the physics of the ice valuable new data concerning the varying behaviour of the land-ice.

Dating the origin of Scandinavia.

As long ago suggested, Scandinavia almost all around is limited by a system of regularly arcuated coastlines, which were supposed to be of tectonic origin.

That idea was carried further by a synopsis of the Post-Algonkian deformation of Fennoscandia.

This synopsis was principally founded upon a reconstruction of the Post-Algonkian baselevel plain, which was worked out by marking the very flat-topped summits of the Archean rocks in all parts of the whole region with summarised isohypses by 200 m intervals.

The only region hereby omitted was that western part of Scandinavia, where the intense Caledonian mountain-folding had too seriously, complicated the reconstruction of the base-level in question.

On the whole, and especially with respect to the Scandinavian peninsula, and its westernmost part, very significant features became obvious.

These former hypsometric lines, which I called eohypses, were constructed by the help of the best available large-scale maps and thus may give the named features in a rather reliable way.

Referring to the paper quoted, it may here only be mentioned that deep-borings through Palaeozoic deposits in Gotland, at Reval and Leningrad have indicated a rather regular, sub-baltic southeastern dip of the baselevelled Archean surface below the Palaeozoic beds.

These latter seem to occur up to the neighbourhood of the southeastern Fennoscandinavian coasts, where the Archean rocks are exposed without exhibiting any tectonic step.

Still, this coast-line may indicate a mild but very extended flexure, because along its southern side the submarine part of the baselevel plain in question seems to have a rather regular dip of about 1:250, eastwards gradually passing over to about 1:400.

On the present land-side of this flexure, or the very border of Fennoscandia, we meet at once rather extended and on the whole but moderately dislocated, Archean plains, which characterise a great part of southern Finland, of eastern Sweden and especially the eastern environs of the Botnic Sea and Bay.

Towards the western side of the Scandinavian peninsula our extended baselevel has been more and more dislocated and uplifted, within the Swedish frontier to about 1000 m, and within Norway to nearly the double of that amount.

According to the statement of V. M. GOLDSCHMIDT, the Archean Precambric subbasement is here very regularly upheaved like gigantic bubbles. Of these the southern one very gradually descends southwards to and is conform with the southern coast of the land and with the remarkable submarine circumcoastal depression, often called The Norwegian Channel with its Tertiary eruptives.

This uncommonly marked tectonic step on my map was designated as the 'south Norway fault'. No doubt the same tectonic line continues at least as far as the channel named, being parallel with the long Hjeltefjord, though the coast line is rather fjord-cut, when entering into the stroke of the Caledonian folding. The same is true concerning the whole remainder of what on the map named was called 'the fjord-cut west Norway coast', the main situation of which I thought, most probably, due to a tectonic origin as well as its immediate continuation along the Norwegian south coast, where such an origin seems undeniable.

Also at the other, northeastern continuation of the fjord-cut coast named where it leaves the disturbing zone of the Caledonian mountain-folding, it reveals its true tectonic origin by its continuation all around the great Kola peninsula, which all the way is limited by a marked fault-step.

Along the very west coast the Caledonian fissure formation and later fjord-cutting has made it difficult in detail to fix the original coast dislocations, which of course cannot be expected to occur exactly at the basis of present-day rock-sides, which, as was exemplified at Mt Hallandsås in NW Scania, must be expected to have receded more or less by weathering.

On the map (Pl. 63) 'Land-emergence during ice-recession in Middle and North Sweden', the hypsometry of which I worked out in 1897, several distinctly marked indications of submarine fissure-lines were indicated, and during the last year Professor O. HOLTEDAHL with good success, by series of systematic soundings, has taken up the closer study of such submarine coast-fissures.

In Spitsbergen heavy miocene beds have taken part in that considerable folding and continental upheaval which, most probably, also gave rise to the main contours of Scandinavia. Both of these plateaus are rising from one and the same submarine socle with a common, distinct but gentle slope down to the greater depth of the North Atlantic or Scandic depression.

The southwest side of Sweden and Fennoscandia is limited by an abrupt fault down to a couple of thousand meters deep and dated by basalts and probably early Tertiary beds.

Also at some scattered localities in Sweden and Finland isolated occurrences of probably Tertiary eruptives have been found. They may have originated as consequences of the same great earth movement.

The whole of the baselevel plain, which in Pre-Cambrian time was situated at the sea-level, by the probably late Tertiary continental upheaval of the two east Scandic plateaus has become most upheaved on the western Scandic side, parallel to which there are also indications of folds, according to the eohypses as well from western Norway as from middle and northern Sweden and, may be, also from Finland.

Especially along the southern part of the main Swedish flat of the baselevel plain along a certain line it has a rather marked, eastward dip of up to 1:10, on my map designated as the Alto-Botnic flexure, while a less pronounced step or rather fissure-line along the very coast was called the Lito-Botnic flexure. The former one, beginning at a probable marked fault-step along Mt Kilsbergen, can be followed more or less continuously towards NNE all the way to and along the Botnic depression, northwards gradually fading out.

Of those two lines the former is by far the most prominent and marks an important limit between the generally exceedingly flat and partly submerged, extended Uppland-Botnic plain to the East, but on the opposite towards the west to the much more dissected, higher main part of the land.

The real nature of this difference between the still quite flat and well preserved baselevel plain and the closely neighbouring, rather dissected and mountainous remnants of the same baselevel, being long ago explained, it was of interest to find that Dr B. ASKLUND a few years ago in a special paper pointed out the similarities between the Norwegian Strandflate and the east Swedish coast plain.

I think that the comparison is quite right, so that it may be the same baselevel plain which, at the Baltic side, lies near or below the sea-level, just as the Norwegian Strandflate, while this latter, quite in the neighbourhood, by the great Scandinavian upheaval has been brought up to the level of the mountain tops, a discessus which, though formidable and difficult to follow by small steps, still seems to be undeniable and important to follow up for getting a closer knowledge concerning the origin of Fennoscandia.

The main situation of the high Botnic flexure is fixed by the strike of Mt Kilsbergen and farther north by the direction of the long, straight railroad which closely follows the upper border of the great plain along the foot of the adjacent mountain region. Still farther north the Dellen lakes occupy a low angle, intruding into the border of the mountain region and including the wellknown volcanic occurrence of probably Tertiary Dellen-andesite, which thereby strengthens the supposition that the whole of the high Botnic flexure may belong to the Tertiary period. That was also in accordance with the impression of W. M. DAVIS, when I made him aquainted with the degrees of preservation exhibited by the east-westerly faults in the Mälaren-Östergötland region.

Nowadays the denudation as a rule has cut itself down to the underlying Archean rocks, leaving only some scanty remnants in a few depressions, such as those of Lake Mälaren and Lake Storsjön at Gävle with Eo-Cambrian sandstone and still smaller remnants of Cambro-Silurian rocks in some small depressions at Lake Erken in Uppland and the bight of Tvären at the coast of Södermanland.

At several points in the surface-fissures of the base-level plain small dyke-like remnants of Cambrian sandstone, sometimes with fossils, have been noticed, showing that the erosion has been stopped up about exactly when it reached the hard Archean rocks at the base-level below the former sediment-cover.

Above the flexure-line it seems that the weathering much earlier had reached down into the Archean and put its uneven stamp on the region.

In the sublittoral Baltic continuation silurian bed-rocks are observed, and on the Baltic northern part of the province of Uppland numerous Cambro-Silurian boulders are found just as on the Åland Islands indicating that remnants of Cambro-Silurian beds occur on the Botnic depression. At the Lumpar bight of Åland they were so numerous that neighbouring bed-rocks were suspected and also afterwards were observed.

On the west coast of Finland in the Björneborg depression Eo-Cambrian sandstone is found and farther north, east of the map region in the depression of the small lake Lappajärvi and farther east at Jänijärvi Post-Archean, possibly Tertiary eruptives occur together with several sandstone dykes of the named kind, showing that also in Finland inclusive Åland remnants of the great Botnic base-level plain sometimes are but slightly eroded.

It seems that the whole of the Botnic depression and its low, flat environs have been covered with sediments and a long time afterwards furthermore depressed and eroded, so that its tectonics and principal history have been more accessible.

In Närke at the foot of Mt Kilsbergen the small remnants of Pre-Cambrian Mälare-sandstone, mark the extended baselevel plain in question. At the western side of the Kilsbergen, at Lake Möckeln, the Visingsö-sandstone no doubt reposes on the baselevel in question, and the same may be the case with the whole of the Visingsö-series in the great fault-depression of Lake Vettern.

On the map, Pls. 65—67, are given by means of isobases the heights of the marine limit, which I determined principally in the 80:ies and 90:ies. No doubt they could have been more or less completed by later measurements, but they may be sufficient for the present purpose.

The levelled points of observation have been connected by isobases, showing in a general way the present attitude of the late glacial sea-level which they represent, with due consideration to their not quite synchronous origin.

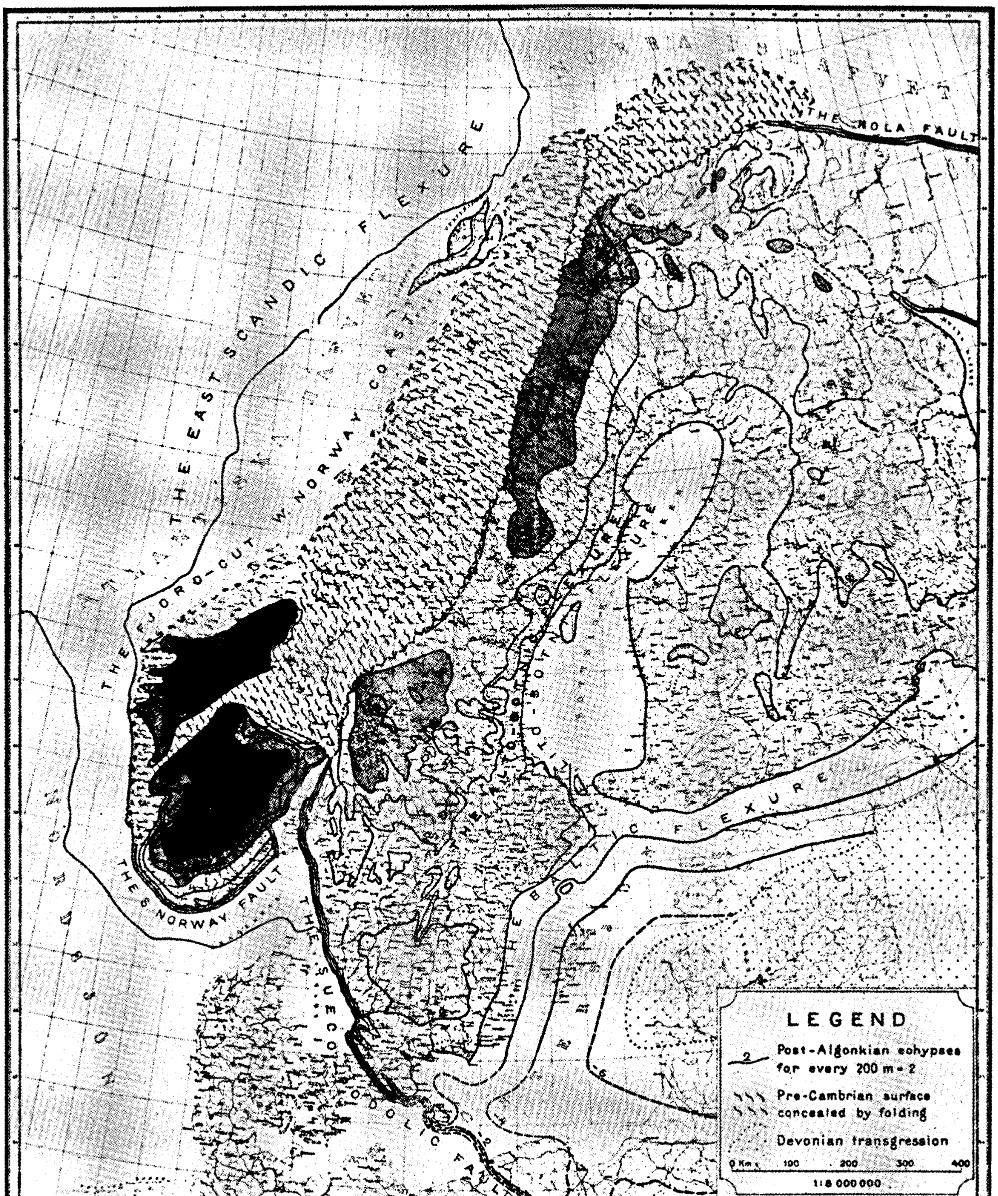


Fig. 47. Post-Algonkian deformation of Fennoscandia.

On the flat plains once covered by the late glacial Baltic sea, in lack of hills, sufficiently high, the marine limit could not be directly determined, but its former level has been calculated in proportion to the regularly rising heights of lower shore-levels.

In the provinces Gestrikland-Ångermanland the cost plain has become more and more narrow until it is restricted to the very shore.

Here, close NE of the town Hernösand there occurs a very remarkable landscape of rather Norwegian type. The bed-rocks rise very close to the coast 200—300 m a. s., being the only place of the long Swedish coast where such a bold shore topography is met with. Here also are observed the highest marine shore-deposits found in the whole of Scandinavia, reported by A. G. HÖGBOM to be uplifted about 284 m, or somewhat more than 280 m a. s. As the land-ice receded from this point about 9000 years before 1900 A. D. the mean annual emergence for the ancient shore level named must have been about 3 m pro century. As the recent land-emergence, which is the greatest in all Fennoscandia, amounts to about 1 m pro century, it is evident that the land-emergence, as beginning probably when the ice-border receded from this region, must have amounted to much more than the mean amount and no doubt quite as much as the maximum upheaval directly stated by LIDÉN and may-be even more than his 15 m pro century.

By such a very intense movement of the earth crust it is not astonishing that this rather suddenly upheaved region seems to show very obvious traces of earthquakes.

Certainly it would be of great interest to get a detailed hypsometric and geologic mapping executed in this so peculiarly protruding part of the land. At present we may refer to some photos placed at our disposal by the Svenska Turistföreningen, showing an intensely fissurated and broken topography.

This new-born and datable mountain-region could, perhaps, be called the Botnic Top-height of the Swedish coast.

Rather noteworthy seems to be the fact that right off outside this height there occurs the deepest, quite local depression in the whole of the smooth bottom plain of the Botnic Sea, showing a depth somewhat over 200 m. From this depth near the Swedish coast the deepest axis of the sea gradually passes over to and along the Finland side and, on approaching the somewhat higher, flat baselevel-plateau of the Åland skerries, turns along this one westwards, all the way a little more than 100 m deep. Having passed the western longitude of Åland, the 100 m isohypse joins a narrow, straight fissure-depression, which is widening out in the marked basin of Ålands hav, the Åland Sea, which latter is about 250 m deep with a distinct circuit without skerries, and, may-be, referable to the Lito-Botnic flexure or fissure-system.

By describing the gigantic ice-recession when the ice-border in one hundred years receded across the whole of the Botnic depression, it was mentioned as a possible explication that the ice-fraction may have commenced, when the ice-recession reached a cotemporary depth of c. 200 m, being evidently the critical depth of fracturing and that farther north the same critical proportion perhaps could have continued all the way to the present coast by a corresponding deepening of the sea and increased height of the land-ice.

In the mean time it must be emphasised that, according to my opinion, the main trend of the high mountain-step along the Norwegian west-coast in reality has nothing to do with shore erosion. There is an obvious lack of localities which could answer even to very modest demands concerning real shore-erosion. The rock-steps are not adjusted along the mountain sides like real shore-lines, but are cutting right through one and the same line, sometimes several hundred meters high and sometimes in the same continuation running out to nothing. Very often such steps continue unchanged from a quite open to an equally protected situation.

As to the so-called *Strandflate* or shore-plain, it has often been supposed to have been developed in connection with the present coast-step, though at a somewhat earlier date, but real proofs are totally lacking, and the very extended horizontality of the plain in question, especially obvious where it scarcely rises to the surface of the sea, directly emphasises that at least some depth of water is necessary for the production of eroding waves.

From the coasts of Norway as well as those of Spitsbergen I have come to the conclusion that the coast-plain phenomenon is one thing and the ordinary shorelines another one, necessary to be discussed apart. This is of course also true with respect to the renowned, marked but small notch-lines, by frost-action cut out along sounds and fjords in northern Norway and ice-dammed lakes in Sweden.

As already mentioned, the widespread remnants of the Post-Algonkian baselevel plain conclusively show that, once a time, it was extended over practically the whole of Fennoscandia.

From the scattered but widespread remnants of Cambro-Silurian deposits upon this baselevel it is evident that its age is Pre-Cambrian; but, as A. G. HÖGBOM pointed out, the interjacent occurrence also of Eo-Cambrian remnants indicate that practically the same baselevel, at least partially, had a somewhat earlier origin.

Thus the denomination Post-Algonkian may do.

The great continental upheaval, by which the plateaus of Spitsbergen and probably no doubt also that of Scandinavia practically obtained their present attitudes, may have occurred during the later part of the Tertiary period.

Still another possibility may be suggested in connection with the supposed earthquakes at the Botnic Top-height. That part of the Uppland-Botnic baselevel plain which is now depressed below the surface of the sea may perhaps precisely by its depression have caused the influx of sea-water and the stated, so rapid ice-fracturing. At the same time a causal association could be suggested between the Botnic Top-height and its counterpart in the neighbouring Botnic maximal depth. Anyhow, in connection with a local investigation this maximal depression ought to be very carefully sounded.

In any case, it seems obvious that the flat and extremely regular bottom of the Botnic Sea is a somewhat depressed part of the circum-botnic baselevel plain, and just as this one, judging from erratic occurrences, still exhibiting scattered remnants of a Palaeozoic covering.

No doubt, continued, systematic investigations on a chronologic basis will be able to shed new light also on several parts of the Fennoscandic geographical evolution.

The morphology of the Botnic depression.

For an approximate dating of the origin of the Botnic depression it seems important to have a look on its actual morphology (Map, Pls 65—67).

For the Stockholm exhibition in 1897, by the help of then available charts, I had put together two general maps, on the scale of 1:4 mill., of Fennoscandia and surrounding waters. One of those maps represented the actual hypsometry, the other one that of late-glacial time, constructed by help of corresponding isobases and best available hypsometric maps and charts. A photographic reproduction from a part of this latter map is here given in Pl. 63, which shows the main features of late-glacial hypsometry at the lowest depression of the Scandinavian mountain range between Trondheim fjord and the province of Jemtland, where the land-ice from the Swedish side at that time overflowed the lowest part of the water-shed towards the Atlantic side. At the recession of the land-ice its melt-water deposited, mostly in ice-dammed waters, at several places series of clay varves, which all since 1907 I have measured on different occasions. By comparison between these measurements it has become possible by and by to fix the main features of the last ice-recession in this region from as well the Swedish as the Norwegian side, though at this latter only a few usable localities were found.

This relatively easy escape of the land-ice through the Jemtland passage caused an important displacement of the ice-shed towards the eastern side of the water-shed of the mountain ridge.

Thus when the ice-border had passed over that water-shed, it brought about quite a series of ice-dammed lakes, having their outlets over the passes towards the Atlantic, and at the same rate as the ice-border receded, ice-dammed lakes at higher levels became drained down along the receding ice-border to lower, parallel ice-dammed lakes with lower outlets across the water-shed.

In the broad Jemtland depression there is quite an assembly of such ice-dammed lakes, often well marked by cut-terraces, and built deltas, giving their levels and extensions. Still more important are their varved sediments, by which their complex history can be made out and dated.

Hereby it has been very welcome at last to be able to fix the balance between the outflow of the land-ice through the Jemtland passage and, on the contrary, towards the continental side.

A closer study of the synchronous ice-border lines will reveal several stages in this balance which, without such direct connections, scarcely could have been expected.

Thus when the western ice-border was situated not far from Mt Åreskutan, its eastern counterpart was still in the region of Uppsala, reaching out over the whole of the Botnic Sea and the main part of Finland.

When the western ice-border reached the great depression of central Jemtland, there arose a considerable ice-dammed lake, greatly accelerating the ice-recession by fracturing of ice-bergs and giving rise to a non-climatic indentation of the ice-border.

The local balance in the ice-flow hereby disturbed caused a corresponding local extension from the ice-masses towards the northeast of the indentation in the ice-border. —

The following data are taken from the last Swedish chart of the Botnic Sea, on the mean scale of 1:500 000 along the 60th parallel. The length of the rather oval depression is about 350 km and its greatest breadth nearer to the southern part is about 250 km. The bottom is so regular and plain that evidently it pertains to the great precambrian baselevel plain, probably more or less covered by remnants of cambrosilurian beds from which masses of boulders have been carried by the land-ice to its southern environs.

As indicated on the map, the greatest depth occurs along the northwestern coast and amounts to very nearly 300 m within a crescentic area, about 60 km long off the towns Härnösand and Örnsköldsvik, or almost exactly off the most uplifted part of the marine limit.

Between the maximum depression named and the coast the 100-m curve gives indications of elongated hollows parallel to the coast and most likely originated along fissures.

The striking parallel association of the deep maximum named, with the most upheaved part of the marine limit in the whole of Fennoscandia and at the same time with a unique, exceedingly marked, rocky coast, not seldom rapidly rising more than 200 m a. s., seems to point at a causal connection.

The assumption seems to be near at hand that the sinking in of the sea-bottom immediately off the old tectonic line along the Alto-Botnic Flexure caused an extra maximal elevation upon the said flexure.

In the province of Hälsingland the Alto-Botnic Flexure seems to make a sharp angle towards the land-side around the depression of the Dellen Lakes, where the interesting discovery of the so-called Dellen andesite was made. This find of a young surface eruptive, probably of Tertiary origin, exactly along the flexure, seems to make it probable that also the flexure itself is of Tertiary origin. This seems to agree well with the state of downcutting of the surface topography above the flexure line, while, below, the extended, flat baselevel plain seems to be very little degraded. This difference in a general way is illustrated in the maps, by the late Quaternary transgression of the sea, though this latter generally has somewhat transgradiated over especially the northern parts of the somewhat older flexure.

Still thereby the mapping out of this transgression illustrates the fjord-like, dissected topography within the Swedish regions of moderate height.

This interesting maximal depression of the Botnic seems to be well worth a very detailed echo-sounding, as being probably one of our most recent tectonic phenomena.

The 200 m depth is situated along the coast side of a somewhat oblong depression delimited only by the 100 m curve. This latter encloses a long and narrow depression somewhat more than 100 m and with a breadth of some 30 to 10 km, following the west coast of Finland, but without any sharp limits at all. The slope of the bottom from the Finland coast is rather regular all the way and on the western side almost imperceptible. The maximal depth, which follows the longitude 20° E Gr., scarcely surpasses 150 m and seems to be southwards somewhat shoaler. About at the latitude 60° the maximal depth, all the time at nearly the same distance following the border of the Finnish archipelago, makes a bow towards SW and W, until 19° E Gr., SE of the lightship Finngrundet. Here it turns abruptly straight southwards as a marked, narrow depth, going straight down to the western border of the very marked local depression of Ålandshav, which slopes down from the regularly bowed coast of Väddö, characterised by its lack of skerries and going down to depths of more than 100 m farther out, near the Åland side reaching at least 270 m.

That part of the Åland Sea depression which is deeper than 200 m, follows the Åland side and seems to strengthen my earlier supposition concerning a causal connection between the depression named and the upheaval of the very Åland plateau.

This plateau forms the westernmost end of the rather extended Åland barrier, in its turn a direct continuation of the great Finlandian baselevel plain, gradually diving down almost below sea-level, so that only the tops of the innumerable, low skerry knobs are peeping up out of the water.

The causal connection between the very Åland plateau and the neighbouring depression of the Åland Sea, which I suggested after my first visit to this region, at present may be thus interpreted that probably in late Tertiary time a change in the tectonic balance may have caused the present attitude of those two closely allied neighbours.

Here may also be emphasised the very pronounced garland or uniform strip of islands, which for quite a length forms the border between the Swedish land and the Baltic depression.

Northwards this garland is divided up into several branches, diverging out towards the .shallow, submarine plateau off the Gävle coast.

As earlier mentioned, this marked and rather continuous series of long and narrow islands seems to represent a border of the continental crust, broken off along the adjacent, down-sunk part of the Baltic depression. This series gives an interesting indication concerning the simultaneousness between the sinking in of the Botnic and the Baltic depressions proper.

In fact the garland in question with the whole of its southern part faces the depression of the Baltic proper, the slopes of which according to the new chart is especially characterised by the isobath of 100 m which, coming from the Finland Bay, has been found on the Swedish side to be intensely dissected by a great number of narrow incisions.

This broken submarine topography is coarsely conform with the garland named, but approaches gradually its southern end. Exactly SE of this latter, almost precisely 20 km SE of the south end named and 30 km E of the light house of Landsort, there begins a very remarkable, steep submarine escarpment, which continues for some 40 km towards SW and S, exactly off the continuation of the intensely dissected 100 m isobath.

This very interesting, especially towards the land side very steep and straight depression, being no less than 450 m deep, is by far the deepest in the whole of the Baltic and is evidently due to a marked fault, no doubt in connection with the sinking in of the Baltic proper and the breaking off of the garland in question.

As the northern part of this latter is in the same way connected with the marked depression of the Åland Sea and thereby with the sinking in of the great

Botnic depression, the chronologic consanguinity of the whole of the Baltic valley seems to be rather probable.

The conditions mentioned may prove that just north of the Baltic proper the post-Algonkian baselevel plain rises from its cover of Palaeozoic beds about to the actual shore-line, but from that level by a moderate flexure becomes rather flat, forming the extended baselevel which ties together the great plains of SE middle Sweden with those of SW Finland, thus testifying that those two regions are connected not only by the sea but also in a fundamental way by a continuous baselevel plain, which at a geologically recent epoch became partly submerged by the shallow Botnic water, except for the Åland plateau.

Nordingrå superelevated region.

Exactly inside this deepest part of the Botnic Sea, near Härnösand in Ångermanland, there rises a remarkable, quite unique part of the Swedish coast. It nearly looks as if some part of the Norwegian fjord-coast suddenly had risen at this very point of the long Swedish coast, elsewhere for several thousand kilometers so very smooth and open; here on the opposite, in the region of Härnösand, Vibygge-rå, and Nording-rå, rising very abruptly and at the same time splitted into numerous small fjords and valleys with steep or even vertical sides.

The bed-rocks are splitted in the same way, often with open fissures, sometimes forming grottos and such masses of angular boulders that they seem likely to be caused by considerable earthquakes. This region no doubt deserves a detailed investigation at the place. At present only a few photographs, courtesy of the Swedish Tourist Society, can be presented as suggesting illustrations. They exemplify the exceedingly broken structure of this rocky plateau. The whole appearance seems to make it probable that this pronounced headland has been uplifted at a relatively late date and thereby splitted by severe earthquakes.

It is very remarkable that exactly in this region occur the very most elevated shore-lines from the last part of the Finiglacial sub-epoch, situated at the height of somewhat over 280 m a. s. and thus proving that, after the Ice Age, this region has been more upheaved than any other one in the whole of Fennoscandia. Furthermore, according to LIDÉN'S curve of land-upheaval the greatest part of this maximum upheaval has been concentrated to the time immediately after the ice-recession from this region, or a few hundred years before the Zero year at the beginning of the Postglacial epoch.

This datable last mountain formation of noteworthy dimensions deserves, no doubt, a special and rather detailed investigation in the field, also including the neighbouring, marked submarine maximum depression of the Botnic Sea basin in order to illuminate a geographically probable, causal connection between those two seemingly associated, marked phenomena. Confer p. 198.

Dating of the Marine Limit in northernmost Sweden.

At the northernmost shore of the Botnic bay I measured in 1898 two quite distinct sets of striæ, an older one running straight eastwards without any attrac-

Fig. 48. Fjord landscape, Nordingrå, Me. Sv. Turistföreningen. Nordingrå 46: E. Photo D. Lundgren, 1935.

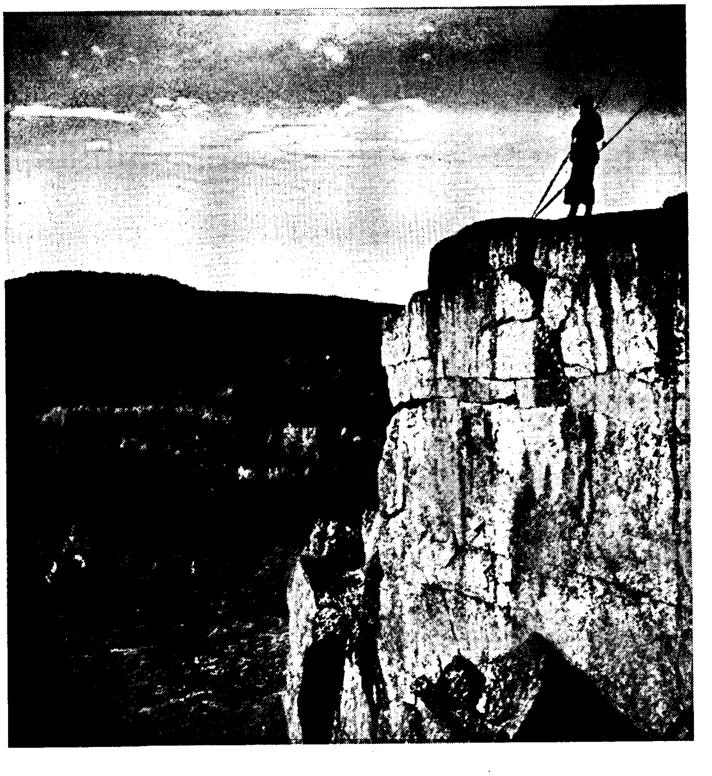


Fig. 49. Vertical bluff from earthquake movement. Sv. Turistföreningen. Nordingrå 48: C. Photo D. Lundgren.

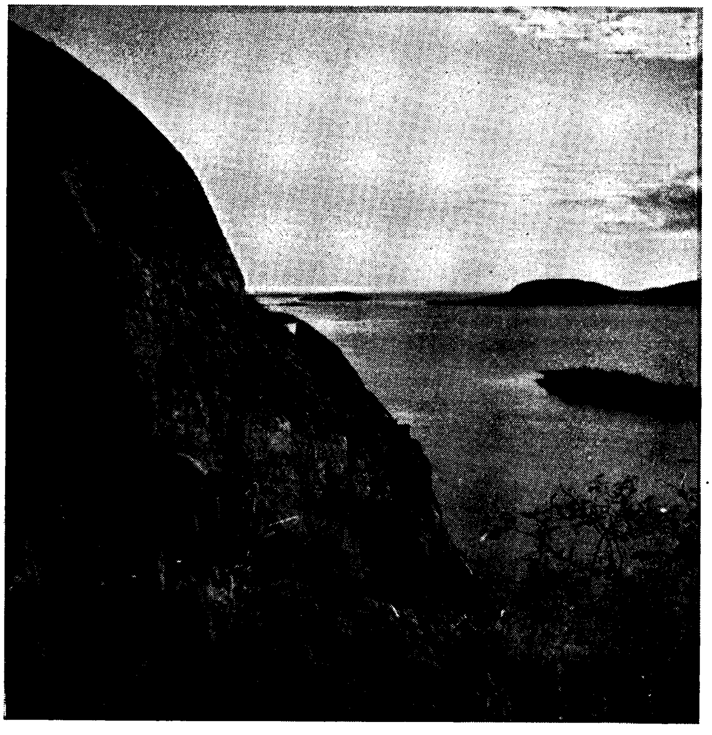


Fig. 50. Steep fjord-side. Nordingrå 53: A. Sv. Turistföreningen. Photo D. Lundgren.

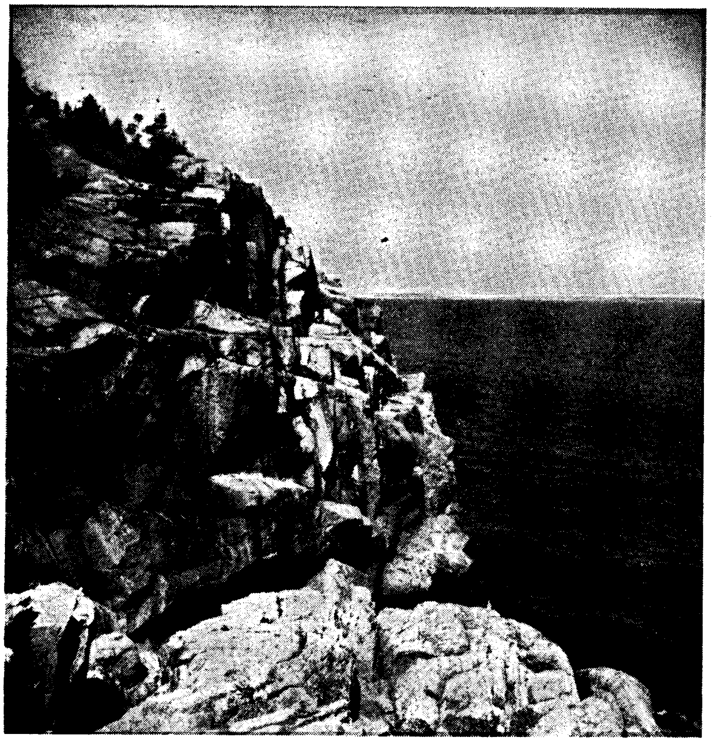


Fig. 51. Steep wall of fissurated bed-rocks. Nordingrå 21: D. Sv. Turistföreningen. Photo D. Lundgren.

Fig. 52. Earthquake-broken rocks with fissures and cavities. Nordingrå 48: F. Sv. Turistföreningen. Photo D. Lundgren.

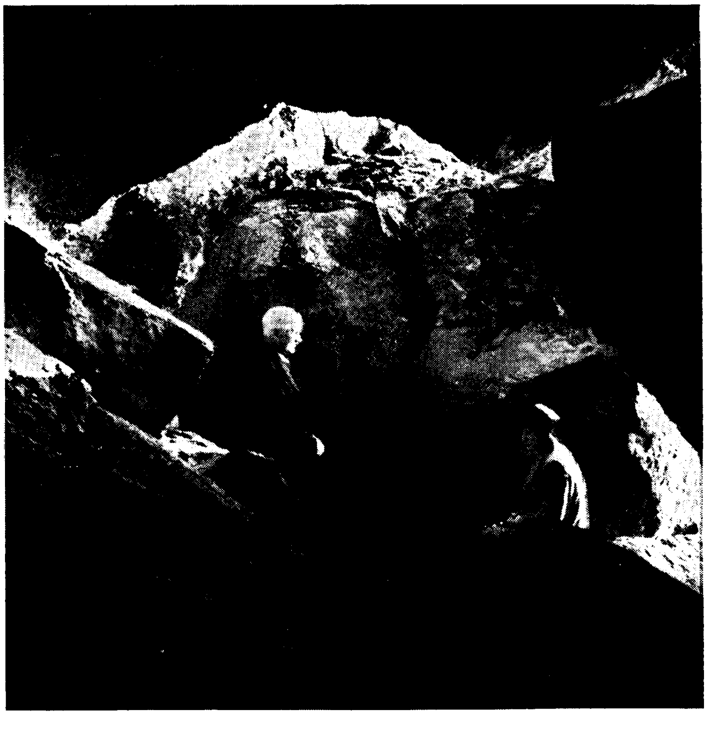


Fig. 53. A grotto in the rocks of Nordingrå. Sv. Turistföreningen.

tion towards a Botnian depression as then still filled up by the land-ice, and a younger set pointing southwards just in the direction of that depression, when this had become accessible. In the same way, in 1923, in the region of Ljusne, I found a lower, normal till and older striæ, running southwards along the Botten depression and evidently registering a great Botten glacier, and a younger set of striæ together with a considerable, true bed of big boulders, coming from NW or the inland, and getting out into this direction when the Botten glacier was broken up.

It is still an open question when the deep, Botnic depression originated. It may have been already during the century 700 to 600 years before Zero, thereby directly causing the rather catastrophic ice-recession, or it may have been somewhat later with analogous effect. In any case it would be very astonishing if not the depression and the maximum land-upheaval seemingly so well corresponding should not also be in a causal connection.

By fixing the ice-recession by means of varve measurements it has been possible to date the highest marine limit in all regions where varve determinations have been possible. This gives also the earliest time before which no immigration of man or any living beings at all was possible, though the climate in itself might not have been a hindrance.

Thus the flat regions around the northern part of the Botnic bay were submerged up to the marine limit in this region or to a height of about 200 m a. s., at about +500 years after Zero, or well within the Postglacial epoch, which is of importance to note with respect to the later on following prehistoric immigration of man to these regions.

Hereby the height a. s. and the rate of land-emergence also must be taken into consideration, which is here more necessary than in regions with less considerable geophysical changes in so recent a time.

Towards the north the axis of upheaval deviates somewhat from the coast, so that the isobase for 260 m still is to be drawn around the region of Trehörningsjö. Farther north the maximum of upheaval slowly decreases in height and depasses along the northwest coast of the Botnic Bay evidently some 220 m.

Still farther north, west of and along the Torne River, there occurs, as an earlier continuation of the adjacent bay, an extended, very flat plain, still with quite a number of small, isolated mountain knobs which at many places were not totally submerged. Yet the marine limit for a long time here was not fixed, partly in lack of reliable starting figures for levelling, partly from mistakes with glacial river erosion.

The first time I visited the northernmost part of the emerged Botnic region, in 1898, the height of its former extension was not yet determined. On Mt Lappberget it was found to be well marked at about 210 m a. s., but at some other points not well determinable. One-sided subglacial meltriver-scarps were mistaken for shore-lines. Still on a general map of the Quaternary clay- and marl-deposits, at this time published by the Geological Survey, the approximate height of the level in question consequently was assumed to be about 200 m. This was found to be a happy approximation, because of later determinations.

In 1900 namely Professor H. MUNTHE during geological investigations in northernmost Sweden had the opportunity of making several determinations of the uppermost marine limit, by which some earlier mistakes became corrected and confirmation was found upon the phenomenon first observed by A. G. HÖGBOM farther south, namely that the highest traces of marine action were less upheaved in the interior of the land than nearer to the eastern coast. MUNTHE published quite a series of measurements, plotted on a map with isobases for every ten meters between about 64°30′ and about to the polar circle, well illustrating his thesis.

This was further on certified by Captain G. SANTESSON within about the same region and nearly one degree farther north. Under favourable conditions and from newly measured fix-points he got in the main the same results as MUNTHE, and upon his somewhat larger isobase-map he could also indicate the approximate trend of the coast in question.

In 1924 Captain G. SANTESSON, namely, during topographic mapping work, started a great number of each other controlling determinations of the marine limit, obviously showing that here it was very regularly uplifted with a quite moderate slope from the coast region towards the northwest.

At the same time he delineated the highest former coast of the northernmost Botnic, which is here emerged to about 120 m a. s.

At that time it was but natural that both of those two authors overestimated the age of the marine deposits in this region, as indicated by the titles of their publications. Thus: Some observations concerning the Yoldia-limit within Norrbotten (Swed.) by H. MUNTHE and Investigations concerning the greatest extension of the late Glacial Sea within the district of Norrbotten (Swed.) by G. SANTESSON, while the geochronological datings have certified that within this region because of the still remaining ice-covering no marine layers could be deposited before well within the Postglacial epoch and a considerable time after that the last relics of *Yoldia* within the Baltic Sea were exterminated and even replaced by postglacial Baltic mollusca.

Yet along the western, Norwegian slope of the great upheaved region the shore lines have a distinct slope westwards, as was already stated by the classical measurements of AUGUSTE BRAVAIS, as being the first discoverer of the unequal land-upheaval which has now been followed in detail over practically the whole of the natural domain of Fennoscandia.

This flatness of the earlier geoid towards the inland, far from the outer coast, affords an interesting contrast to the above mentioned fold along the Botnic depression.

As remnants of varved clay seem to be scarce along these open coasts, the recession of the land-ice border has not as yet been determined in this region, but from the measurements somewhat farther south it is settled that ice-recession and deposition of varves, oses and other postglacigene sediments north of the sound of Qvarken all belong to the Postglacial epoch, certainly being glacigene but not even late-glacial deposits.

The Baltic fresh-water lake and its Ancylus stage.

The study of the Baltic fresh-water beds goes back to 1867, when FRIEDRICH SCHMIDT in Esthonia discovered in an open situation shore-lines with fresh-water shells which he called Ancylus-beds. Such beds were in 1884 refound in Gotland by H. MUNTHE, who thus established the startling fact that at least a considerable part of the Baltic had passed through a real freshwater stage. Also in Öland they were refound, in 1888, by G. HOLM, who — in his lectures in Uppsala — from his studies in Esthonia had predicted their occurrence also in Sweden and especially in calcareous beds, where these fragile shells might have been protected from total obliteration by weathering. (H. MUNTHE, 1886, 1887, G. HOLM, 1888.)

The principal aim of this publication being chronological, I have found it best at present here not to discuss the very interesting conditions described by the Finland geologists from the northeastern part of that country. Hoping that finally some varve datings there will be possible, as to that part of the region I have found it best to wait and see.

Concerning that remarkable fresh-water stage which followed after the very short and local *Yoldia*-episode, it may be appropriate to quote from the publication: Skandinaviens Geografiska Utveckling (1896) the following few data in translation (pp. 104—105):

»As regards the extension of this [Ancylus-]lake, there were in the beginning very few holds, because as such ones only were considered localities where fresh-water organisms had been found. Thus, as an example, the discovery of such fossils on the western side of Gotland was regarded as a proof that the fresh-water lake had been extended also to that side. This uncertainty also was quite explainable as long as only those two possibilities were suggested that either the region from Gotland to Esthonia had been locally uplifted with its shores of an old fresh-water lake to their present level, or that the Baltic at its southern outlet had been dammed up to the actual level of those shores.

»Certainly beaches with fresh-water shells also were discovered in Öland, and also here their upper limit was determined; but within the rest of the Baltic region fresh-water forms were found only in layers which could be regarded as deposited in the same great lake. Furthermore these are derived not from shore-deposits of the lake but from clay-layers laid down at a greater depth. And these finds, being very interesting from other view-points, have not afforded any nearer data concerning the shores of the lake or of its form and extension.

»It was only by the knowledge concerning the unequal but rather regular upheaval to which the whole of the Scandinavian region had been subjected that there turned up a possibility in another way to find out at least the main features of the greatest extension of the Baltic fresh-water lake.

»It was obvious, namely, on the one hand, that the Baltic never at its southern end had been closed up by any dam at all and, on the other hand, that the former lake-shores within the region Gotland—Esthonia certainly had taken part in the land-emergence, though not at all in a local one but in the general land-emergence which was extended over the whole of Scandinavia. Therefore it seemed probable that the limit of the Baltic lake in every part of the country ought to be in a certain relation to the whole amount of the corresponding highest marine limit at every place.» . . .

»Therefore it is necessary at as many localities as possible to try to fix the relative proportion to which the highest stage of the great lake had reached in comparison to the highest marine limit. From the height of the marine limit at other places, by means of the discovered law, it was easily calculated to what level the lake in question ought to have reached at every special place.» —

In this way a first sketch map was constructed of the main extension of the Baltic fresh-water stage.

As already mentioned, the geochronologic investigations some years ago stated that the datable, ordinary varved clay upwards quite gradually is passing over into very thin microdistal varves of an uncommonly fat and fine-grained clay, which earlier was called 'the lower grey clay' and later on often Ancylus-clay, being referred to the postglacial deposits, though afterwards found to be a direct continuation of the glacigene varved clay, now by micro-varves exactly dated.

It was in order to construct a first approximate sketch of the extension of the Ancylus level that I traced up the geoidic surface answering to the same proportionate relative height as the Svea pass in relation to the late-glacial marine limit (G. De Geer, 1890, p. 106; 1896).

The level of that pass generally was assumed as determining the origin of the so-called Ancylus Lake or Baltic fresh-water lake, but thereby some remarks may be allowed. No doubt it marked the origin of the great lake in question, but it may be remembered:

1, that probably much earlier the short, brackish Yoldia-stage within a small, local part of the great Baltic depression was totally overcome by means of the overwhelming quantities of melt-water from the receding ice-masses; probably after one or two centuries this melt-water must rapidly have restored the whole of the Baltic to a big fresh-water body;

2, that this great afflux of fresh but cold melt-water scarcely could be attractive to the very temperate Ancylus-fauna, which also seems to be missing north of the Baltic proper, and there are no proofs that it has immigrated before a considerable time after the upheaval above sea-level and the warping of the real Ancylus-water towards its south Baltic outlet. If so, the remarkable transgressional shore-lines perhaps might give an increased possibility of its closer dating.

At the mid-Swedish pass in Svealand between the Baltic and the Atlantic slope, where once it was planned to build a Svea canal, Professor H. Munthe discovered and together with Professor L. von Post even discussed the main traces of erosion by the water-masses from the Svea pass at its outer outlet from Lake Venern to River Göta älv, pointing out the importance of continued detailed investigations of these complicated phenomena. Thereby it may be worth while to observe whether also some finiglacial earthquakes had been at work by cutting up the bed-rocks along the old, jointed fissure valley of Degerfors. But as this research does not yet allow a really chronologic discussion, it may at present be sufficient to emphasise the importance of such a goal (H. MUNTHE, 1927, 1928; L. VON POST, 1927, 1928, 1929, 1937).

L. VON POST pointed out how, even long before the Svea pass was uplifted above the level of this fresh-water sea, its shores in that region were still at about 140 m a. s. marked by beaches with characteristic fresh-water diatoms of so-called *arenaria*-forms. The same fresh-water beds also were followed around the Vener-depression, indicating that the original fresh-water content of the Baltic had nothing to do with the Svea pass.

While this pass, as marking the outlet of the great topographical lake-basin seems to have been situated at about 105 m a. s., or 66 % of the marine limit, the summit of the really observed fossiliferous Ancylus deposits at Latorp in the same region seem to have their limit at about 79 m a. s., or at only 50 % of the marine limit. Thus probably they are not observed in that region before an epoch when the lake by the unequal upheaval of land had got its surface warped from its original outlet through the Svea pass towards the Danish sounds.

This warping resulted in a considerable transgression, the limit of which became registered by marked shore-lines along the southern parts of the Baltic valley. In fact it is exactly in the limiting beaches from this transgression that the Ancylus-fauna has been discovered and followed up.

If by continued investigations it should turn up that the Ancylus-fauna really is restricted to that southeastern part of the Baltic region which was reached by the lake-warping transgression in question, thereby it could perhaps also be possible somewhat better to date this remarkable Ancylus stage, the extension of which hitherto has been somewhat obscure. Then perhaps also the name of the Ancylus Lake could be restricted to the very stage of that Ancylus-transgression.

Since the lake in question by the unequal land-upheaval had got its former outlet laid dry after having found a new outlet through the south Baltic sounds, a peripheral new land-depression set in, or the so-called Postglacial one. The southern, best pronounced part of this Postglacial depression was first indicated in 1890.[1]

Along the west coast of Sweden the well marked, uppermost shore-line of this transgression at the same time was found to be the uppermost limit of shell-deposits, indicating a somewhat milder climate than the actual one and easily recognised by masses of *Rissoidae*, *Cerithium reticulatum* and many others. These shell-beds were followed northwards from the region of Göteborg at some 30 m a. s. to the Norwegian frontier at somewhat more than 40 m. Near the outlet of Lake Venern they seemed to reach about the same level, and farther up along this lake-basin no postglacial marine mollusca have been found. Yet for a short time it was still believed that shore-lines belonging to the limit of the postglacial transgression could be followed about to the pass-point between the Vener depression and that of the Baltic. If this had been the case, the necessary conclusion had been that the postglacial transgression also at the Baltic side of that pass had reached the same level, and it was tried to draw out the conclusions of this assumption.

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[1] G. De Geer, Om Skand. Nivåf. efter Istiden. G. F. F., 1900 (1888—90).

But a few months later it was found that the assumed postglacial transgressional limit around the Vener basin was not continuous and did not reach so high.

In lack of reliable marine fossils of postglacial age it has been difficult to fix within the Baltic region the exact limit which may correspond to the highest limit of the marked postglacial transgression in SW Sweden. Within its lower, eastern part it is true that the scanty postglacial fauna of towards half a dozen marine mollusca but seldom occurs, e.g. in the Stockholm region, where the postglacial sea may have reached about 50 m.

How far this limit, which in southern Sweden marks the summit of a transgression, farther northwards may mark only a stop in one and the same upheaval is not yet determined, and the same is thus the case with a definite dating of the stage in question.

The Postglacial epoch.

Botnic region.

Before any exact geochronologic subdivisions were possible I proposed to use the land-upheaval between the Late Glacial and the Postglacial subepochs, which I had found well developed in south Sweden, as marking the limit between those two subepochs. It was what I called the Ancylus emergence, and when the microdistal varves will be more thoroughly investigated, it will probably be possible more closely to trace up the limit between the Late Glacial and Postglacial subepochs. Still it seems as if the land-upheaval named at least in a general way should correspond to the Zero-varve, and thus be practicable for mapping purposes.

In regions where microdistal varves are available it may thus be possible as to their organic contents to obtain at least some limiting datings, concerning the biota of the succeeding layers of that time.

Consequently in his final Ragunda report of 1924 R. SANDEGREN gave detailed lists of all the remnants from a great number of different species, which he found in the long series of dated annual varves within three of the first postglacial millennia. This list embraces about 50 species of phanerogams and of cryptogams, about 130 of diatoms and some few mollusca and spongiae. This interesting occurrence of fossils was discovered by SERNANDER and GUNNAR ANDERSSON.

In 1938 ERIC FROMM seems to have shown that brack-water diatoms arrived into the then estuary of the Ångerman River about the year +1800, or about 5000 b. C., thus during the second millennium of the Postglacial subepoch, when the shore was at 120 m above present sea-level. As at the open coast they may have arrived even earlier, it seems as if the postglacial marine transgression in southern Sweden approximately corresponds to the chronologically dated Postglacial subepoch after the Zero-varve (a. Z.). Pollen grains and diatoms may be easily transported by currents to secondary localities, and thus it may be useful to find out also the witness of mollusca, though also these have their plankton stage.

In 1930 I found at Bergby in the parish of Hamrånge, north of Gävle, a few

Hamrånge, Gästrikland. Varved ooze-bed, dark, with postglacial mollusca. Photo E. H. D. G., 1930.

meters above sea-level, a vertical section of a postglacial marine gyttja or ooze with *Tellina baltica* and *Mytilus edulis*, exhibiting often quite distinct varves. Though perhaps already connected with the time-scale, the publishing of their date may be postponed until a definite control has been attained, the more so, as the corresponding ice-border will give the first indication of the late postglacial ice-remnants in the highlands.

Other analogous localities with postglacial varved sediments may perhaps be able to control and utilize these possibilities, e.g. the postglacial gyttja at Högom, Sundsvall, partly shrunk and dried up into pillars, hitherto not closely inspected.

During continued investigations concerning the postglacial deposits around the northern parts of the Botnic depression it will be of great importance trying to find out localities where the sediment exhibits measurable varves. So far, it seems evident that still at the beginning of the Postglacial epoch the North Kvarken, or the sound between the Botnic Sea and the Botnic Bay, as well as the region farther north still were occupied by postglacial sediment in this region. Thus it must be emphasised that archaeologic as well as zoologic and botanic remnants found *in situ* in this region no doubt are of postglacial origin. Further approximate datings may be possible by accurate determination of sea-level, occurrence of diatoms, and pollen analyses, when such studies have been carried up to these northern regions.

The occurrence of postglacial mollusca are of special importance at investigations of this kind, as their occurrence or non-occurrence is so easily stated in the field, but it ought not to be forgotten that as youngs they have their plankton stage, when they can have been transported long distances with the currents.

At present the lack of observations concerning the organic contents of the postglacial beds in the northernmost part of the Baltic depression scarcely allow anything else than hopes for a better future.

Postglacial conditions in Middle Sweden.

Relative synchronisation of postglacial sea-levels.

In 1922 I had the opportunity of identifying a specially marked cut-terrace on the side of different ose-hills but facing one and the same direction, while no traces of such one-sided shore-lines were to be seen at other sides of the ose hills. It looked as if these shore-lines were cut by the waves of a strong accidental storm, while ordinary winds were unable to cut such marked steps in the pebbly deposits. By continued land-emergence such a storm-terrace became upheaved above the sea-level, but after a certain lapse of time another similar terrace could be cut out by a gale from the same or another direction. By levellings at a great number of different hills I found, where the situation had been open to the breakers, corresponding terraces, but on somewhat higher levels in a certain direction, where the upheaval of land had been somewhat greater. At places where former islands had protected a certain coast-line against the storm-breakers, no cut terrace was to be seen, and by the situation of such wave-breakers sometimes it was possible rather accurately to determine the direction of the storm in question. This is examplified in Fig. 13, a sketch map of the ose hill Ling's kulle. In fact these terraces in all respects look as they should do, if they were cut out by individual gales.

After a thorough study I felt entitled to ascribe this kind of locally oriented, cut terraces to individual, heavy storms. As such storms often endure but one or a few days, the storm-shores make it possible to fix the present relative height of unequally uplifted sea-levels with a very great accuracy. Thus where it is possible by some or another means to date such an ancient sea-level at one point, the dating at the same time will be transferred to all parts of the corresponding shoreline.

It is evident that such cut terraces in the pebbly material of the oses only could be formed by exceptionally heavy storms or real gales, since merely about some 30 such terraces seem to have been formed within middle Sweden during the last 8000 years, which means one such storm during 300 years. Especially noteworthy is it that the differences in height between the storm-shores at different localities everywhere was found to be proportionate, though with increasing heights towards the centre of upheaval being about parallel to the axis of the land.

Needed connection of Postglacial terraces in East and West Sweden.

With the disappearance of the melting ice-sheet with its annual varves of melt-sediment the very best and most reliable means of geochronologic time determinations had come to an end.

Hitherto such melt-sediments had been followed for about two hundred years into the Postglacial epoch at Ragunda in the province of Jemtland.

As to southern Sweden postglacial varves generally do not occur and some single exceptions are isolated and do scarcely afford any means to a real time scale.

Now the storm-terraces mentioned made it possible even for the Postglacial epoch to obtain exact but isolated time parallellisations. In connection with the description of the ose-degradation it was mentioned how mainly on the oses there occur certain especially prominent such cut terraces at about thirty different levels, for every one oriented in a special direction in such a way that it must be ascribed to an exceptionally heavy gale, which has eroded on the wind-side, while the lee-side was left without any traces of special erosion.

Where the eroded ose-material was pebbly, it is evident that the slope of the terrace was adjusted at once in its present form, while at places where the ose material was sandy sometimes later local changes by rains or sliding must be taken in account, but generally the original terrace-foot can be rather exactly determined by levelling its mean height as representing the former storm-water level.

By numerous such measurements it has been certified that such storm-terraces can be identified from hill to hill, gradually rising in height towards the more upheaved central parts of the country.

Herewith a valuable means has been acquired for stating exactly the rate of unequal upheaval of the land at different stages of the last emergence.

Together with my wife I made, in 1922 and the following summers, quite a number of levellings on such storm-terraces, which we hunted up mainly in the provinces of Södermanland, Västmanland, Uppland, and Gästrikland.

At first I expected to have found a means of fixing, by these accurate measurements, eventual irregularities in the upheaval of the earth crust, but, on the contrary, a most remarkable regularity almost everywhere appeared. Thus from storm-terraces at different levels there seems scarcely to be much hope left for finding out sufficient general, exotic oscillations of such an order of magnitude as could have had any appreciable influence upon the whole of the oceanic level.

Undeniable facts are much needed. With a most striking regularity, while rising towards the centre of upheaval, these shore-levels everywhere retained as to each other a strictly proportionate height. This made it possible, where from some or other reason a certain storm-terrace was not developed, to calculate its height from other ones in the neighbourhood.

This was especially helpful with respect to higher storm-terraces which in lack of sufficiently high hills could not be directly determined.

The highest Postglacial terrace.

The main purpose of my investigation of the storm terraces being to determine the present attitude of those shore-lines in order to find out, above the most elevated postglacial shell occurrences, eventually some especially well marked shore-line which could be suspected to represent a stationary stage of the land-upheaval and thus to have survived several gales from different directions and possibly to be perhaps a fading continuation of the well marked limit of the postglacial transgression which I had earlier traced round the coasts of southernmost Sweden, I was naturally intent upon finding so to say all-round shore-lines, especially at some level which could correspond to the probable height of the uppermost postglacial shore-line within the regions in question.

Still I did not find any such dominating shore-line, though from the occurrence of postglacial marine shells I suspected for a time that the highest postglacial shore-line might correspond to rather well marked, though not quite all-round shore-terraces, the more so, as this level seemed possible to connect with shore-lines around the Vener basin, which by some authors for a time were considered all the way to represent a continuous stationary stage in connection with the postglacial marine limit along the west coast.

Soon afterwards I found this to be a mistake, and it seemed more probable that the highest postglacial sea-level in the Stockholm region may have stood about ten meters lower, or some 50 m a. s.

At this level the Stockholm region is characterised by a well developed shore-line, which possibly may correspond to the highest postglacial limit in southern Sweden. In any case it might be rather near to this level. Still, continued investigations are necessary. As a starting-level hereby can be used a marked shore-line in the Stockholm region, situated at 41 m a. s., here giving 50 m for the level in question and everywhere in the same proportion. Of this 41 m-shoreline at Stockholm and its unequal upheaval westwards over the eastern part of Lake Mälaren a synopsis is given on the map, Fig. 26, p. 78, in Stockholmstraktens Kvartärgeologi, Stockholm, 1932.

As an example of the land upheaval around the depression of Lake Mälaren during a later stage of the land-emergence the map in question gives a number of figures from one and the same shore-level, somewhat later than the shore-level of the renowned coast settlement at Åloppe in Uppland. In order to find the height of the shore corresponding to this latter, its height is to be sought everywhere in due proportion to the lower shore-line plotted on the map.

As already mentioned there are not more than some thirty well developed storm-levels which have been observed within the Stockholm—Mälaren region from the main part of the Postglacial epoch, or some 9000 years, and that would indicate about only one heavy oragan in three centuries. The size of the rearranged pebbles may give some hint concerning the strength of the waves in cutting out the terraces. Once cut, as a rule afterwards nothing has been able appreciably to disturb the horizontal line, registering the storm-level.

As far as known such storm-terraces hitherto have been in detail investigated only in mid-eastern Sweden, though probably as a rule they may be about evenly distributed all over the emerged area.

They might easily be confounded with less occasional shore-lines, but such ones must be shown to be really all-round and not cut out only from one single direction, if they shall avoid being suspected to represent a single brief gale rather than an oscillation of the whole of the ocean. Anyhow, the contradiction of the abundance of well certified storm-terraces and the great scarcity or almost lack of all-round terraces in eastern Sweden in opposition to seemingly quite contrary conditions in the western half of the country seems necessary to elucidate before this question can be considered as being solved.

Even the axiomatic eustatic general rising of the sea-surface which necessarily must have been caused by the ablation of the last glaciation seems hitherto not sufficiently studied, though this phenomenon ought to be a natural starting-point for such an assumption.

Of what hitherto has been found out by chronological varve series concerning the ice-recession during the Postglacial epoch there seems scarcely to be much hope left for finding out sufficient general ice-oscillations of such an order of magnitude as could have had any appreciable influence upon the whole of the oceanic level.

Undeniable facts are therefore much needed.

Method of measuring shore-lines.

A few words may be added concerning the measurement of shore-lines.

Pebbly beaches of some length and normally developed may be measured and represented by a normal mean height of their crest-line given in meter and decimeter, whereby the obtained figure may be somewhat higher than the corresponding mean storm level of the water in question.

This storm level is better represented by the base of well preserved cut-terraces, the constant mean of which showing that they are not slidden, which can occur when the material is too fine-grained.

As to stony material, the bigger stones which the waves could not sweep away sometimes are washed clean and shoved together at the base of the terrace, which thereby can be pretty well marked by a line of boulders more or less upraised, eventually by the winter sea-ice.

Storm-shores cut out upon low, morainic slopes can be rather well marked by long rows of so-to-say miniature shore grottos, washed out between the boulders and sometimes partly concealed by mosses, plants and vegetable mould.

By moving the levelling rod to several points of the terrace-foot the height of the shore-line can be determined with an accuracy of one or another decimeter, whereby it is evident that the terrace-foot cut by the storm as a rule has not been altered afterwards.

The heights observed thus are showing, as to the very wind-side, the highest storm-level of the sea, while farther towards the sides the storm-level can be about 1 m lower. Thus it is important to measure, at every locality, the mean maximum altitude in order to get due comparisons.

Often the storm-shores are well marked also in morainic matter, where the free-washed boulders generally are pushed up somewhat by the winter-ice along the foot of the terraces, as just remarked.

Approximate dating of storm-terraces.

RAGNAR LIDÉN in 1906, having assisted me in inspecting the measurement of the time scale in southern Sweden, returned to his home region in the province of Ångermanland in Norrland, from where he had the impression of having seen what ought to be postglacial varves. Now he could certify that his impression was correct and that an annual registration also of the Postglacial epoch, sought for since several years, now possibly could fill out the gap between the known part of the time scale and our actual chronology (confer p. 123).

With great energy he took up this important task and, in spite of considerable difficulties and with an everlasting perseverance, he carried this important and unique work through.

He executed his measurements along the great natural sections, cut out by the river Ångermanälven through those heavy deposits which before the recent stage of land-emergence had been laid down in the former Ångerman fjord.

By and by it has turned out that this considerable valley is the only region, not only of Sweden but of Scandinavia and probably of the whole of the earth, where a continuous registration by annual varves is accessible in one unbroken, continuous series from the recession of the last land-ice and unto the existing year.

LIDÉN has published some important preliminary reports concerning his investigations, and now he also edited a summary with a general diagram, showing the main results of his careful investigations concerning our postglacial history as registered by the magnificent deposits in the Ångerman Valley.

Along the lower part of the Ångerman Valley at about fifteen different, evenly distributed localities Lidén by and by performed accurate measurements of their varve series, followed right up to the uppermost varves at every place.

In that way proceeding down-valley, he found that the annual sediment upwards at every place became thicker, ending in the very delta deposit, when the sea-level and the mouth of the river were situated at the place in question. Thus by measuring the height of every such delta level with due correction and by the help of the whole connected varve series, he could quite reliably date the stage of the sea-level and the land-emergence, when the varve series at every place had been completed.

By connecting those successive stages of the sea-level Lidén succeeded thus to obtain a directly determined curve of the land-emergence at the Ångerman Valley or at about the northernmost latitude obtainable (Fig. 43).

The regular parabolic form of the curve seems to verify the great care exhibited at this long and craving work and at the same time it seems to be a good testimony of the striking regularity exhibited, seemingly without any appreciable interruption, continuously all the time from the recession of the land-ice and to our days.

This being in good accordance with the regular arrangement of as well the directly stated marine limit at different places as seemingly also with the arrangement of the storm-terraces, it seems reasonable to assume that the upheaval of the heavy earth crust in the Mälar region may have followed about the same law as in the Ångerman Valley.

It would be of great interest from another region of Sweden for comparison to get another and reliable determination of the land upheaval, equally detailed as to the gradual evolution of its rate. But in lack of such a comparison it seems to be the best at present only to introduce a temporary dating of the storm-terraces in so far that the age of every one is estimated to correspond to about a third part of the age of the corresponding delta-level in the Ångerman Valley, where the secular land-upheaval in our days is determined to be about 3 times as great as in the Stockholm region. This may be a reasonable reduction at the present state of things and, if marked with a *c* (*circa*), may indicate what a figure means and how it easily can be reduced back again.

Out of all storm-shore localities observed only a minor part hitherto have been published. But this being done and their number further completed, it will be possible to make out not only, as earlier stated, that the land-emergence everywhere seems to have been very regular and rather proportionate but also how the land-upheaval has been distributed along one and the same geographic line, thus distinctly reproducing the form of the crustal movement along that line. Thereby it would be possible to get a good comparison with LIDÉN's classical but hitherto isolated curve of land-upheaval.

It is easily understood of what value it would be in that way to get possibilities of generalising to a certain degree LIDÉN's remarkable pioneer work with respect to the late Quaternary crust deformation.

It goes without saying how valuable it will be, from many different points of view, to get at least some estimate of when different parts of our great plains emerged above sea-level, thereby opening possibilities of immigration.

Such irregularities in the land-emergence as have been followed up all around the Mälar depression makes it necessary to get quite a number of direct observations for somewhat satisfying reference-curves to the different values of emergence of LIDÉN's standard curve of land-upheaval.

Postglacial land-upheaval.

A postglacial discontinuity from first of was found immediately to follow the late-glacial land upheaval. At Ronneby in SE Sweden some sixty years ago by numerous earth borings it was certified that late-glacial deposits during a land-upheaval had been cut by a well-marked river bed and by a peat deposit with trunks of oak, the whole being covered by a thick ooze with Baltic mussels and diatoms. This oscillation was definitively certified, while another one, at first supposed to be older, was not confirmed. In the same way analogous deposits with oak-bearing peat and river beds covered by marine layers witnessed with certainty one postglacial land-oscillation within the whole of southernmost Sweden, while certain assumptions of more than one oscillation of that kind do not seem to be certified by the field geology. The same seems also to be the case in the minutely examined Denmark according to Dr E. MERTZ.

Also along the eastern side of the great upheaved region and may-be even along its western and northern borders there are traces of a similar land-oscillation, but they seem to disappear gradually towards the more central region. On account that to the south the continuous postglacial oscillation reached quite a way outside its original limit and that farther towards the interior it merged continuously over into the normal rate of upheaval, it seems scarsely possible to assume for this continuity any essentially other causes than those ruling isostacy in common.

As to those unique storm levels, already described on pp. 213—14, of which no less than some thirty have been observed in middle east Sweden, it seems that none hitherto have been stated in other parts of the upheaved region, though they ought to be, even there, quite common and necessary to take into account so as to get real order into the overwhelming multitude of different shore lines.

Transmarine and transequatorial varve expeditions.

Together with the great majority of measurements and diagrams here reported from Scandinavia, there are also a restricted number from other countries. Varve deposition has nothing to do with political limits, but it is natural that a representation of the Swedish time scale can be most fully exemplified in the land of its origin.

In order to emphasise that the time scale here exhibited really is of international bearing, also several examples of varve measurements from other countries and parts of the earth are taken up with the Swedish material. Such comparisons, here especially easy of access, may be the very best proof that the time scale really affords a reliable means of universal time determinations.

An undertaking with a special aim, requiring more or less extensive field-investigations, certainly may be called an expedition, even if carried out in countries in other respects long ago well explored and of a high culture.

As a matter of fact, systematic varve studies, and especially detailed varve measurements were not entered upon outside Fennoscandia before an initiative was undertaken from Stockholm.

Thus in 1920 the first transoceanic expedition started in order to investigate whether the Swedish time scale really could be applied all over the world and thus afforded a means of exact, universal time correlations.

North America.

Accompanied by my wife, EBBA HULT DE GEER, as well as my assistants, Drs E. ANTEVS and R. LIDÉN, I started in August 1920 from Sweden to New York, under the auspices of the American Scandinavian Foundation.

There a reception committee kindly took part of our plans, of which, together with Professor L. FAIRCHILD, I published a note in the »Science». It was determined that after the accomplishment of our field-investigations I should, at different universities and academies, give a series of lectures concerning this new branch of investigation.

After passing the imposing series of brick-yards with magnificent sections in varved clay all along the Hudson River, we first controlled my original varve measurement of 1891 at Essex Junction (Pl. 1), near Lake Champlain and the Canadian frontier.

Further we investigated a long series of varve sections at brickyards and river

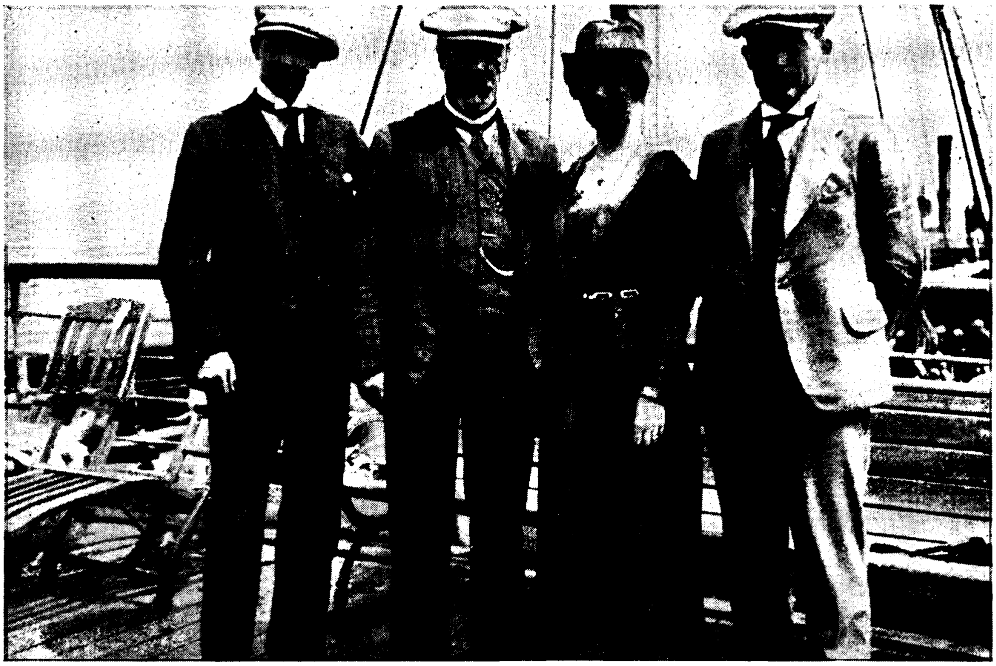


Fig. 54. De Geer's varve expedition of 1920 on board S/S Drottningholm.

Fig. 55. Clay-varve excursion to Dutchess Junction in the Hudson valley. De Geer speaking to Professors Kemp, Douglas W. Johnson, and students from the Columbia University. Photo E. H. De Geer.

escarpments mainly along the Great Lakes as well on the Canadian as on the American side.

In the valley of Lake Timiskaming we found at Haileybury an important varve series connecting the postglacial varves of the Hudson Bay slope with those along the north side of the Great Lakes, where LIDÉN found and fixed a magnificent section near Espanola at Spanish River, which by some 1100 varves bridged over a barren region northwards, devoid of clay, now firmly connecting the southern clay-fields with those of the Timiskaming Valley. (Haileybury, Pls 42, 74; Figs 41, 42.)

When in November heavy snowfalls commenced, hindering the field-work, we finished investigating the main clay region around the Great Lakes, having brought about detailed varve measurements at some 60 localities, whereafter the planned lecturing took place.

The last members of the company returned from New York on Dec. 30, arriving at Stockholm on Jan. 10, 1921. After three weeks of close comparisons I found and certified the first exact teleconnection across the Atlantic, between Essex Junction and the region just south of Stockholm, and as soon as this was done, adjoining localities now could easily be correlated; the same soon being accomplished with practically all of the measurements.

Dr ANTEVS, who had got a stipend from the Swedish-American Foundation in order to follow my expedition and afterwards to continue the studies at an American university, did so and, being by the expedition introduced among the leading geologists, later on got favourable possibilities of continuing our varve measurements as well in the same region as in adjacent or other tracts around the Great Lakes and in Canada. Thereby he added a very considerable material of varve measurements.

His detailed reports show that especially in New England the time at his disposal only at a restricted number of places allowed reaching down to the bottom varve necessary for the fixation of the rate of ice-recession. Though having failed to follow the evolution of geochronology from being only the very registration of the local ice-recession over to a means of extended reciprocal datings all over the world, ANTEVS still with great assiduity brought together a considerable material of measurements which precisely by the disputed but fully controlled teleconnections became integrant parts of the universal varve registration of time and climate.

This is true even of his last varve measurements in Manitoba which, though assumed to speak against teleconnection, were found to be all through a brilliant proof of its validity. Confer G. DE GEER, *Data*, 9 and 19.

Himalaya.

A great number of successful, indubitable connections between long series of varves in Sweden and North America, always placing the latter ones in the same order as the former and at analogous intervals, indicating an analogous ice-recession, can be expressed as making possible a kind of telemapping of the transatlantic rate of ice-recession by means of teleconnected varve measurements.

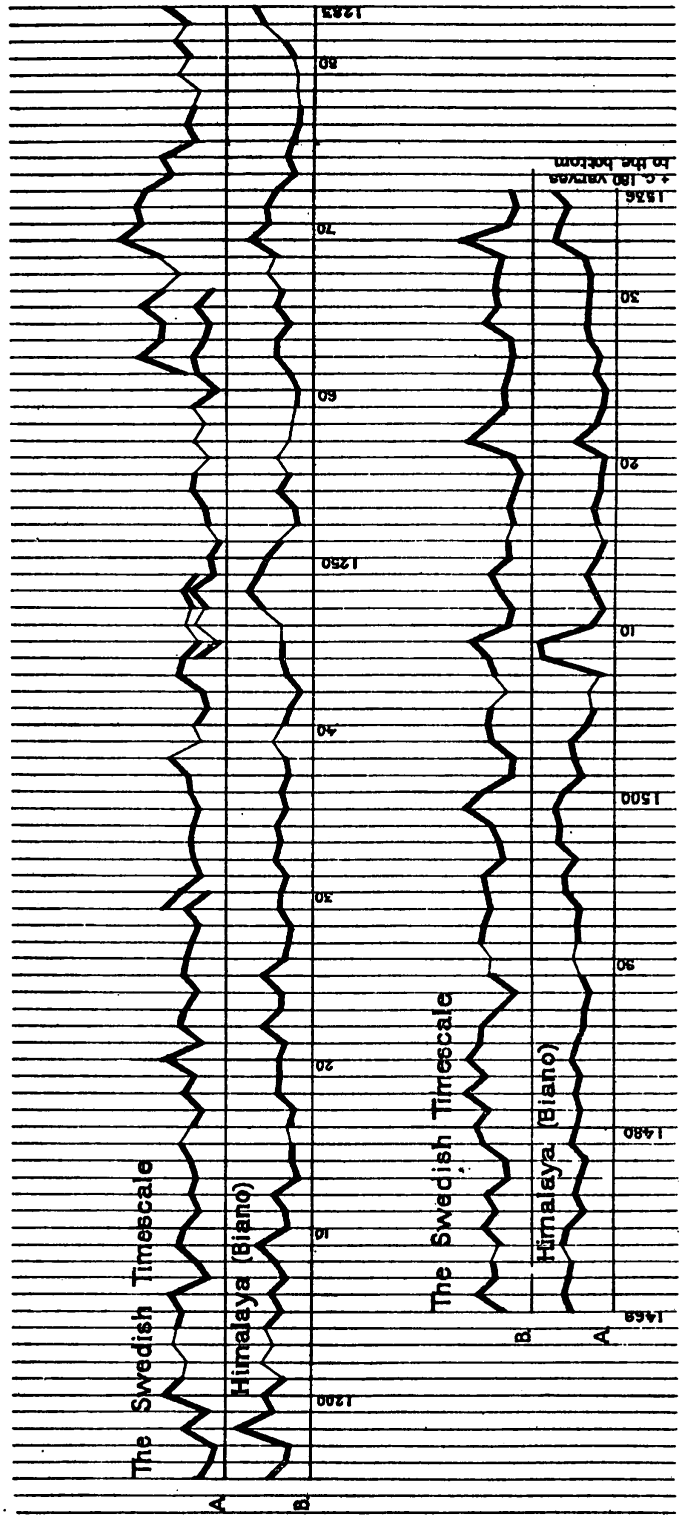


Fig. 56. The teleconnection of Himalaya varves found and published by E. Norin in 1925. *Data*, 2.

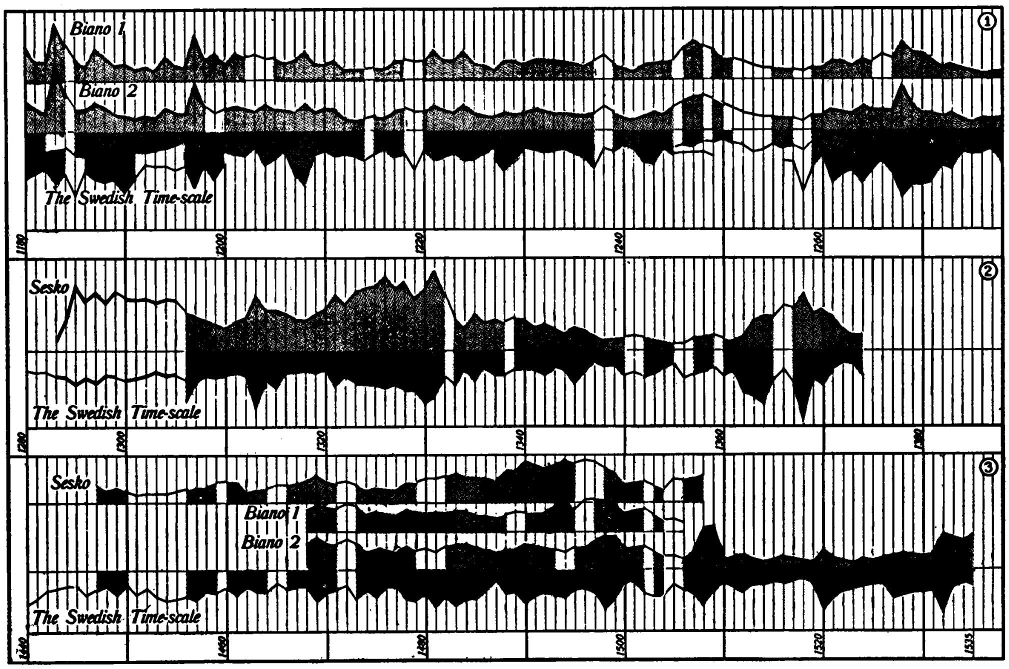


Fig. 57. Himalaya varves published by E. Norin in 1927. Thickness above or below (inverted graphs) zero-line 1/4. Connected curve parts (solar curve) shaded: the Swedish time scale dark. *Data,* 11.

This opened new possibilities and wide views for geochronology. Came hereto the necessity of sufficient room for preservation and studying the rapidly growing material of specimens, diagrams, photos, instruments, etc., it resulted in the idea of erecting a geochronologic institute which, thanks to the personal interest and generosity of several friends and patrons, made it possible for the present author to continue his investigations after retiring from his professorship at the Stockholm University.

This institute commenced working in 1924. It comprised all the geochronologic collections from the Geologic Institute of the Stockholm University.

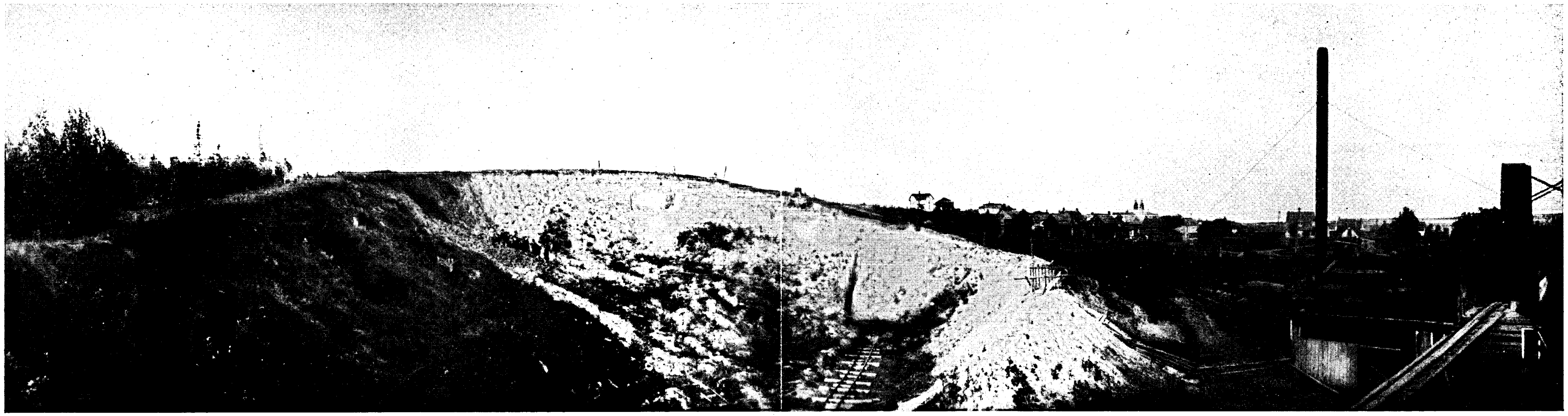
Among its new material may be mentioned the results of the America expedition of 1920 and of Dr E. NORIN's two expeditions to NW Himalaya in 1924 and 1925, the latter together with Dr A. SÖRLIN.

Already during the first visit NORIN found several varve series and one of them near a double frontal moraine which he called the Khapalu Moraine. In one of his varve graphs he found variations identic with those of the Swedish measurements, and especially so the characteristic varve constellation —1318 —1332, which I had called *Nebukadnessar.*

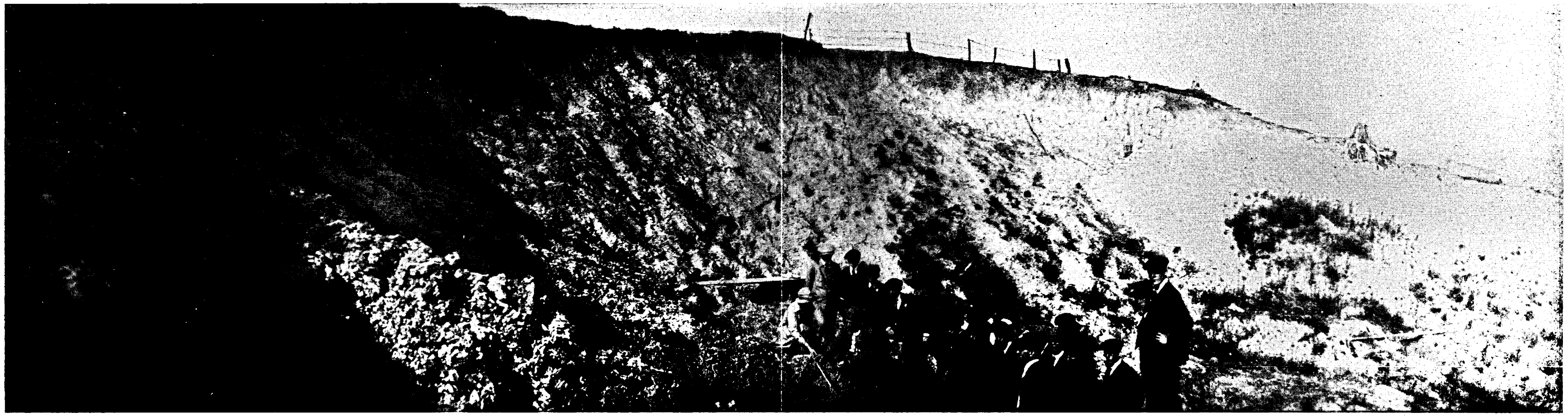
This suggested teleconnection certainly seemed to correlate the Khapalu moraines with the most pronounced Fennoscandian moraines but, considering the importance of getting definitive proofs, a second expedition was started.

Hereby NORIN's suggestion was fully certified and the dominion of the concordant melt-variations now had been extended quite a way nearer to the equator.

The Khapalu moraines in the Biano Valley, Himalaya, found by E. Norin to correspond to the Nordic Finiglacial moraines. Photo E. Norin, 1925.



a. Varve locality at Haileybury on the western shore of Lake Timiskaming (r.). Ont., Canada. Photo Haileybury Mining School, 1920.



b. Detail of the same. Members of the Haileybury School of Mining, studying the method of measuring varves. Photo Haileybury Mining School, 1920.

a. 

 b.

c. 

a, b. Profile of varve sediments at Rio Corintos, Argentina. c. Close view of the varves at Rio Corintos. Photo C. Caldenius, 1926.

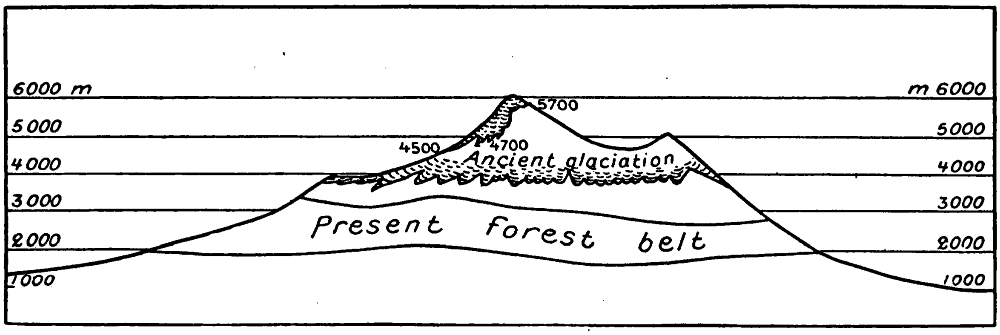


Fig. 58. Glaciations of Kilimandjaro, present and late glacial. The latter was more abundant and not restricted to winds of a few certain directions. (Scale of length about 1:600 000.) E. Nilsson, 1932.

NORIN also brought to the institute long series of varves from earlier stages of the Quaternary glaciation, which in lack of comparative material are not yet published. Confer E. NORIN, *Data* 2, 11.

South America.

The next step was to conquer the transequatorial hemisphere.

By correspondence with Dr JOSÉ M. SOBRAL, then director of the Geological Survey of Argentina, his lively interest was gained for founding a geochronologic basis to the Quaternary investigation of Argentina. Thus Dr CARL CALDENIUS, one of my most successful pupils, was appointed for that purpose during two years and got so good results that his appointment was extended another two years, in all 1925—29.

Some of his measurements were sent over to our institute for comparison, and I had the good fortune to obtain an excellent correlation of the stately varve series from Rio Corintos, comprising 560 varves. The similarity was so consistent that it was possible to point out in print a few special varves in Sweden which evidently were overlooked in Argentina, as stated soon afterwards in the field by another measurement of CALDENIUS at another locality, as is thouroughly described on p. 35. This seems to be a prime example of undeniable teleconnections and at the same time of the transequatorial and thus no doubt universal extension of those climatical factors which determined the variations of varves and ice-melting. Confer G. DE GEER, *Data*, 10, and C. CALDENIUS, *Data*, 17.

New Zealand.

Now the next step was to try a varve investigation in the last remaining region of the southern hemisphere, where it could be expected finding melt-sediments from a Quaternary, somewhat extended glaciation. It was in New Zealand.

Came hereto that the Australian geologists had found promising deposits from a great Carbonian glaciation. After correspondence with the now so deeply missed leading Australian geologist, Sir EDGEWORTH DAVID and with the former professor R. SPEIGHT, Christ Church University, New Zealand, it was arranged for another expedition, 1932—34, by Dr CALDENIUS, now as always assisted by

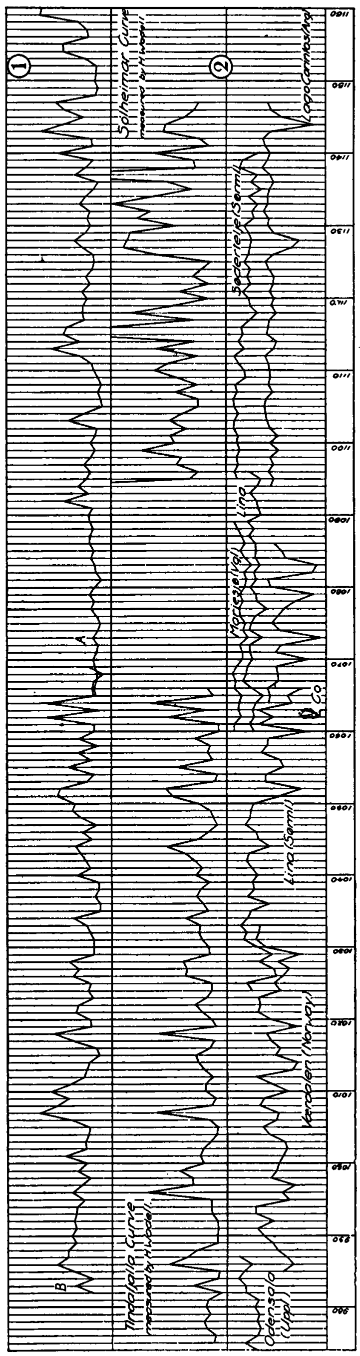


Fig. 59. Clay varves from Iceland and the Swedish Time-scale, as published by J. Askelsson in 1930, in Geol. F. Förh., Sthm. 1. Varves from: A, Hlið and B, Bjarnarhagagil near Solheimar in Arnessysla, measured and connected by J. Askelsson. 2. Varves from Tindafjöll and Solheimar, measured by H. Wadell, connected by Ebba Hult De Geer, Geogr. Ann. 1928.

Mrs SELMA CALDENIUS, his wife and experienced companion.

Even here several difficulties were happily overcome and the application of the Swedish time scale was successful. Also a continuous, long varve series was carefully worked out from the Carbonian glacial bedrocks and has been prepared and published as the first measurement of Carbonian varves, inviting to parallel measurements in other parts of the world.

Central East Africa.

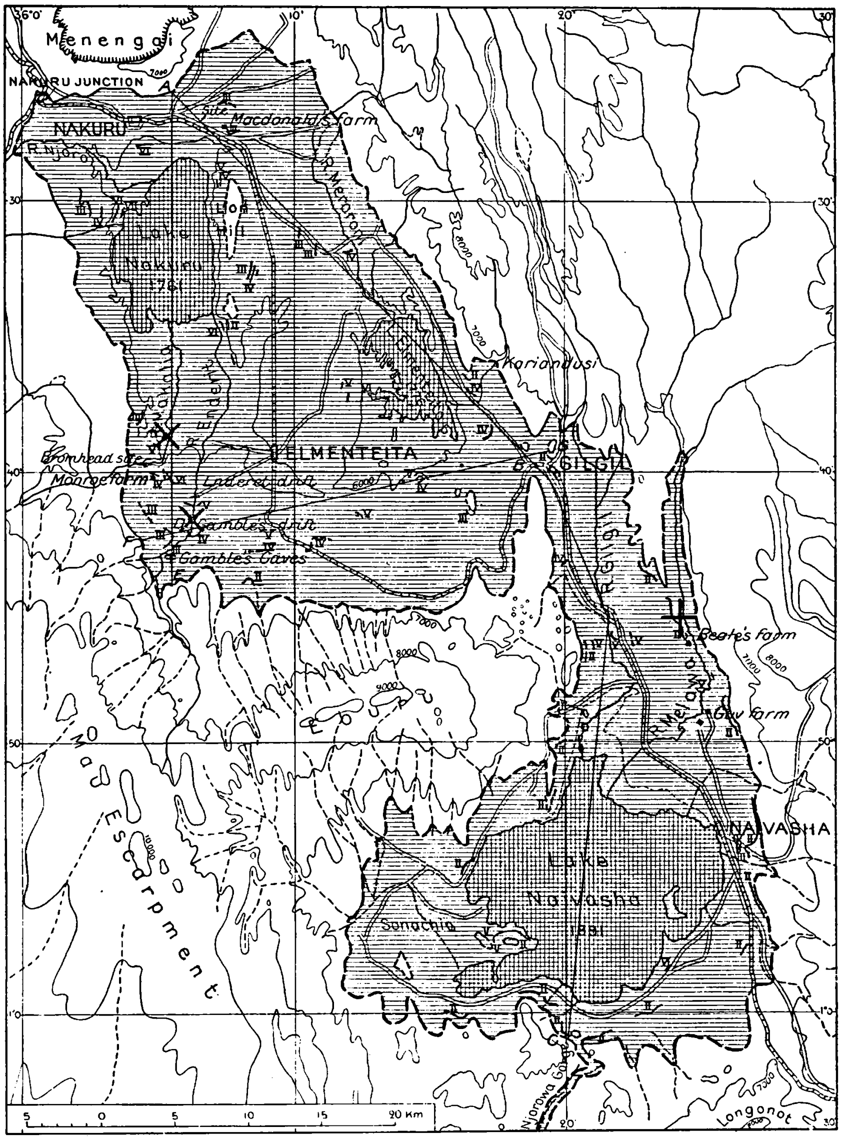
In British East Africa, right in the neighbourhood of the equator, another of my most experienced pupils, Dr ERIK NILSSON, in 1927—28, investigated and mapped out the glacial formations on the highest mountain tops of Africa in comparison with the Quaternary glaciations in other regions. Furthermore he succeeded in discovering and measuring in pluvial lake-sediments three varve series which at our institute could be identified with three corresponding series in Sweden. The earliest of them thereby could make possible the dating of the remarkable archaeologic finds by Dr S. A. LEAKEY, described as being of Aurignacian type, which thus here existed about 15 000 years ago, while hitherto nothing has been determined concerning its dating from other regions. Confer G. DE GEER, *Data*, 20.

This locality at the very equator tied together the synchronized variations of the two transequatorial hemispheres, accentuating their universal nature.

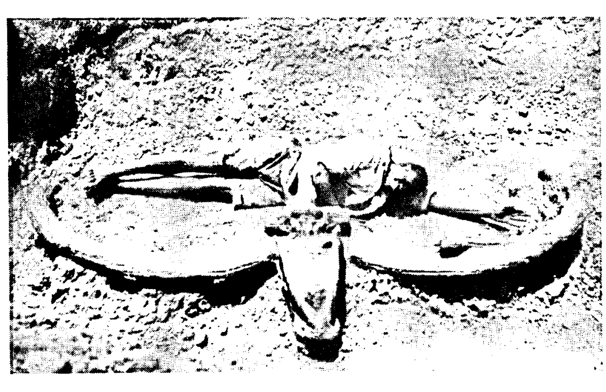
Iceland.

In Iceland two young Swedes, H. WADELL and E. YGBERG, in the southwestern part of the island, in 1919 measured varves at two localities, the graphs of which in 1928 were connected, by EBBA HULT DE GEER, with the Swedish time scale and were found to correspond closely, two and two, with varve series near the Goti-Finiglacial limit of the year –1073. (*Data*, 12, 1928).

Varved delta-sediment near the River Makalia. The thin brown layers are hard and resist erosion better than the grey ones. Rift Valley, Kenia. Photo E. Nilsson, 1928.



Rift Valley Lakes in Pluvial Time. × Dated varve sections of Makalia and Enderit Rivers. + Find of a fossil buffalo in a varved sediment horizon at Melawa River, together with first varve-dated palæolithic remains, c. -6000 b.Z. G. De Geer, 1934, *Data, 20.* Map: E. Nilsson 1932, Fig. 33.



Skull and horn cores of dated *Bubalus Nilssoni,* Lönnbg., mentioned here above. Spread of cores 2,5 m. E. Nilsson, 1932, Fig. 57.

In her report she pointed out and emphasised by graphs that the two couples of Icelandic varve series were definitively identified with two corresponding parts of the Swedish time scale, separated by a gap of 28 years. Soon afterwards the Icelandic geologist, J. ASKELSSON, was able to show at another locality by a continuous varve series, that the gap in question comprised exactly 28 years, thus another prediction in print afterwards, undeniably verified by field observations.

Among performed teleconnections here may be mentioned two with Scotland and one with New Foundland, thus filling out the distance between already acquired teleconnections across the Atlantic.

Everywhere these connections by the mutual location of the teleconnected localities indicated a very natural rate of ice-recession within different parts of the earth.

New Foundland.

In New Foundland, by the kind assistance of the *Svenska Diamantborrningsbolaget*, careful measurements of ice-lake varves were obtained through Mr H. LUNDBERG's investigations of 1933. Thus it became possible even from this island to get a good teleconnection with the Swedish time scale.

The European Alps.

The European Alps, being well accessible amidst populated valleys, are among the best known mountain regions, and so are also their glaciers and glacial deposits. The succession of these latter often has been assumed to be representative for the glacial variations in general. Yet in lack of contact with the sea it scarcely has been possible to determine whether all the different glacier readvances have been connected with universal climatic phenomena or perhaps sometimes only with local changes of level of the very Alps.

In order to bring about independent datings by means of varve measurements, the author and his wife, during the autumns of 1928 and 1929, made a series of varve measurements along the northern side of the Alps from Austria to France.

At about 25 localities varve series were correlated with Swedish ones, whereby definitive connection was attained between the North European and the Alpine glaciations.

Hitherto only a few of these teleconnections have been published, namely in »The Quaternary Geology of the Stockholm region».

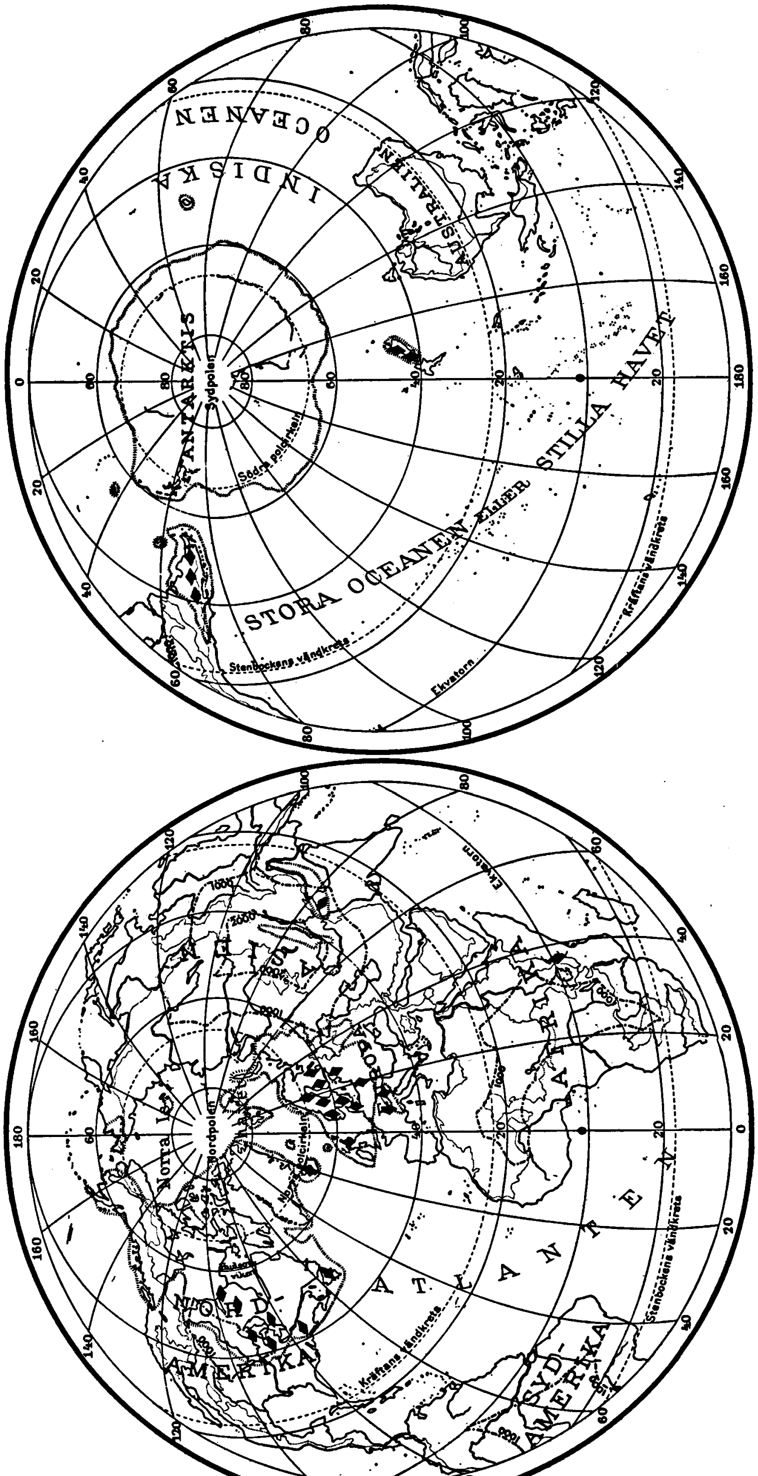


Fig. 60. Filials of the Swedish Time scale.

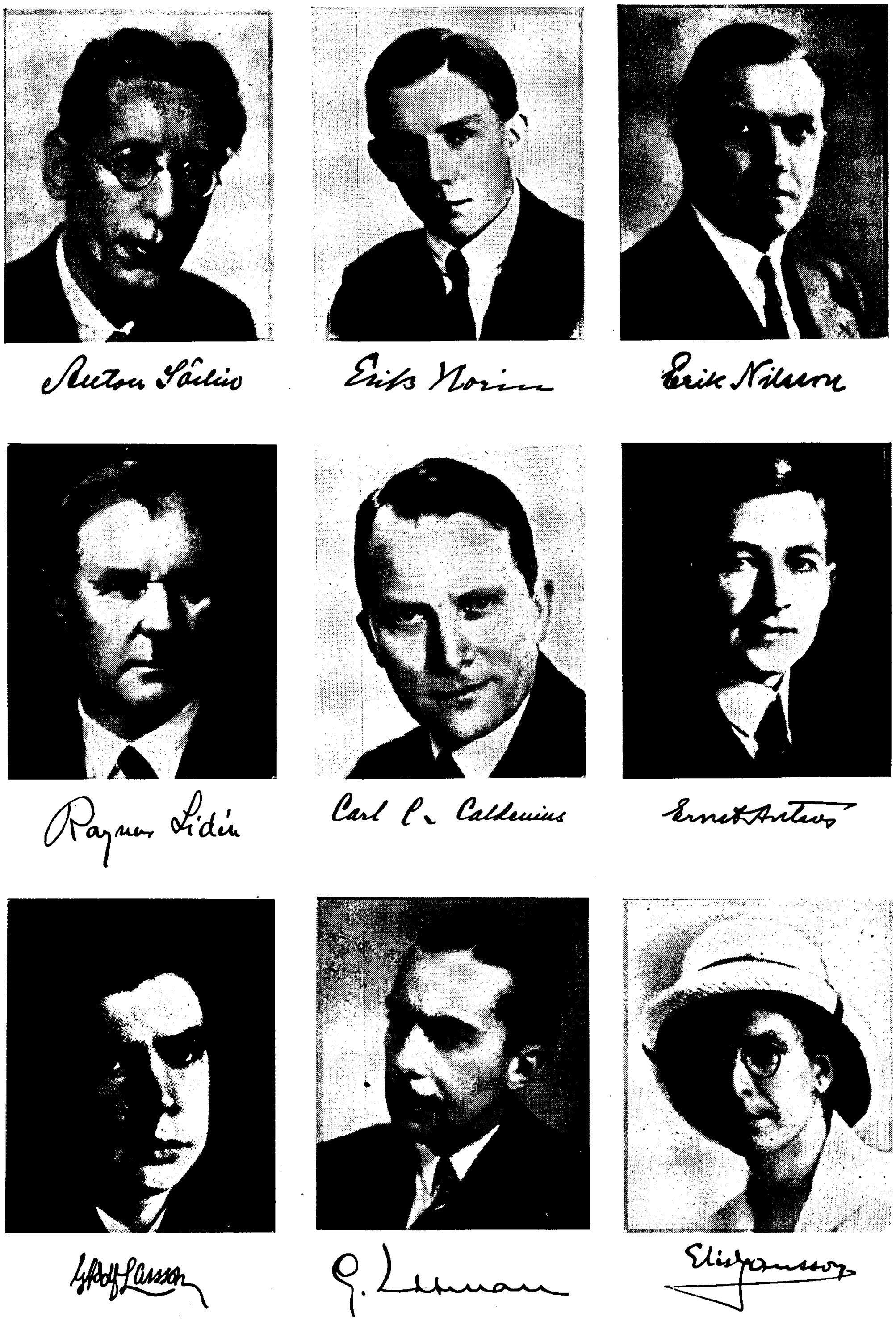



Fig. 61. Some Swedish Varve Specialists referring mainly to works mentioned in this volume.

Fig. 62. The Geochronologic Institute. From left to right: Mrs and Dr G. D. Osborne, Sydney; Professor and Mrs G. De Geer; Mrs and Dr C. Caldenius. Stockholm, 1931.

Summary of hitherto measured Late Quaternary varve series.

The length of hitherto measured and duly dated varve series are, for every different region, summarised in Pl. 90 and represented by thick, vertical lines, whereby the millennia are marked by thin horizontal lines with figures for every millennium, all from the Zero-year of the Swedish time scale with minus-years reckoned backwards in time and with plus-years up to our own epoch.

The historical chronology, corresponds to the last part of the Postglacial epoch, reckoned from the Zero-year, when the Scandinavian land-ice became bipartite and Lake Storsjön was drained down to its actual stage of a normal land-lake from the last of its earlier ice-blocked stages.

The preceding or Finiglacial stage is a rather short one, or only 1073 years long, which is reckoned from the year when the great south-Baltic ice-dammed lake was drained down to the sea-level, when its damming ice-border at Mt Billingen receded from that northernmost former cape of the south-Scandinavian land-barrier.

But this short stage represented the most characteristic and dramatic sub-epoch of the last ice-recession during the Late Quaternary epoch.

The cause hereto evidently was a marked amelioration of the climate, bringing about a rapid ice-recession over the greater middle part of Sweden and Finland.

The enormous masses of melt-water in connection with the rapid ice-melting created a great number of the best developed oses anywhere known and in connection with these a real record of varved clay, the widespread deposition being favoured thereby that a considerable part of the circum-baltic region during the stage in question was but moderately depressed below the sea-level, thus causing an uncommonly great extension of the varved clays within this region. As being also more accessible than older varves the finiglacial ones consequently have been reported from a great number of different localities and countries, wherefore no doubt they are best suited to represent the principles of geochronology. Certainly this marked amelioration of the climate deserves the name of the Finiglacial sub-epoch by putting an end to the Ice Age and, at the same time, by the extraordinary great masses of melt-water giving rise, everywhere, to a corresponding deposition of varved melt-sediments, rendering exactly this subepoch most representative for an introduction into geochronology and its application all over the earth.

In this publication also, besides the finiglacial varves, are discussed the postglacial ones, as connecting the Finiglacial subepoch with the historical one, and, with the end of the greater glaciation finishing the important registration by glacigene varves.

For about three millennia the continuity of the time scale by postglacial varves has been possible to perform only in the highlands of northern Sweden.

For about the same length of time it seems to be possible to work out part of the postglacial chronology by means of annual varves in Russian fresh-water lakes, though still some difficulties are to be overcome by continued investigations.

The paper mentioned was written in Russian, but by help of some other quoted publications by W. B. SCHOSTAKOWITSCH and B. W. PERFILIEW it was evident that the adjoined tables represented measurements of postglacial varves from mostly Russian fresh-water lakes. The measurements were given in tenths of mm, reaching down about 2000 years before present time. By putting together the figures into a graph it was found that for several different varve series the thickness of the lake varves as to their variation could be quite well identified with corresponding parts of the Swedish time scale, while other parts were rather different. This is probably due to a sometimes dominant influence of organic matter within the lake varves about as was the case with the postglacial varves at Ragunda in Jemtland, where often the autumn-layers were eaked out by leaves and other vegetable matter, no doubt hardly due to the same depositing factors as the very clay-sediment but to winds and plant variations.

By collecting lake varves in the ordinary zinc boxes and by magnifying their thickness by some 20, it may be possible to measure the mainly organic part of the autumn layers separately, apart from the inorganic clay-material, whereby the latter probably as a rule would show a better correspondence with the ordinary clay-varves. Still the inorganic part of the lake-varves may be derived mainly from redeposition by ordinary rivers and the leaves from the dominant direction of autumn winds. This may explain why SCHOSTAKOWITSCH reports correspondence between the variation of the sun-spots with the partly organic lake varves, while this has not been observed in the case of pure glacigene melt-varves.

In any case it is obvious that continued measurements of lake-varves, especially in regions with great climatic seasonal differences, will be of great value, the more so in regions where melt-varves are lacking.

For the very last millennia there are the masterly sequoia-investigations by Professor A. E. DOUGLASS. Though totally falling within the so-called historical epoch, they afford a very welcome, continuous time scale, which by several controlled connections with the Swedish varve measurements can be considered as a valuable member of the Swedish time scale. The connection between both of them has been, as far as I can see, reliably certified by a careful comparison, published by EBBA HULT DE GEER.

As to the Gotiglacial subepoch, important investigations are still going on in several countries, why they are not yet ready for summarising.

Of the Daniglacial subepoch hitherto only about half a millennium of varves has been measured from its oldest part at the very border of the last glaciation in Germany and in eastern Scotland, which I think to have connected with each other, though the certainly very considerable earlier part of this subepoch still is undetermined, although investigations are planned. It is one of the nearest great desiderata of geochronology, as including the dating of that very important, natural event, which must have put an end to the last extension of the Land-ice.

Desiderata as to scientific designations.

The geologic designations, essentially referring to pre-human affairs, ought to be, as far as possible, international, even with respect to the Quaternary period. It is, no doubt, often encumbrant with foreign designations, but it will be still more so if every new nation, now entering into the scientific collaboration, should strive for translating almost every scientific designation, which ought, instead, to form a common terminology, or a real *commune bonum.* It will be more and more necessary systematically to counteract such a Babylonian confusion, which is rising like a threatening flood.

It goes without saying that it is much easier to learn a restricted number of good international terms, e.g. the chemical designations, than multifarious translations to most different, even exotic, languages. And this applies quite as much also to big as to small nations, as new ideas can arise everywhere.

Yet it is important that new-coined scientific terms as far as possible are descriptive and self-explaining, characteristic and short. They must be chosen after a careful, critical private selection of the fittest in order to avoid later changes. From the example of the fundamental binary nomenclature of LINNAEUS it seems as a rule appropriate to use Latin or Greek terms, where it is not necessary to coin modern terms for specific new ideas.

The above remarks are, of course, aiming at scientific terms only and not at such designations as are long since incorporated in the vocabularies of the different languages.

Especially it seems desirable that designations connected with the new, universal chronology ought to be as universal as possible.

Thus it was proposed, at the International Geological Congress in Stockholm in 1910, to designate the whole of an annual cycle as a *varve*, while earlier it had been designated as a layer, consisting of a clay-varve and a somewhat sandy varve.[1]

The word varve is of ancient nordic origin and is used for a repetition of different layers, a turn of the handles of a watch, or in a dance round to the same point, and is affiliated with the German word *werfen*, with the Swedish *varpa*, an old Nordic play by throwing stones; with *Werft* as protected by an outbuilt stone-pier, and so on, spelt only a little differently in different countries: *varv* (Scand.), *varve* (Amer., Eng., Fr.), *Warw* (Germ.).

Among frontal moraines, those registering every year may be called annual

[1] Compte rendu, 1, p. 253, Foot-note 2. Report of President's address, 1910, Stockholm, 1912.

moraines, those from several years: plurennial moraines, and for a longer lapse of time: perennial moraines. Analogous terms may be used with respect to marginal deltas of melt-river deposits. See: E. H. De Geer, 1918, pp. 849, 918.

Marginal melt-rivers, having marked their way along the border of a regularly receding supramarine ice-border, as especially described by V. Tanner, sometimes may deserve the name of annual ice-rivers, though they are so irregularly and locally developed that they scarcely can be put together like the annual clay varves.

The annual deposits of the oses may be called annual ose-centres, but they are also too locally developed to afford any means of coherent and valuable time determinations. At stationary stages biennial or plurennial oses may be formed by the heaping of ose material at one place outside the ice-border up to near the water level; also called marginal terraces.

The term Geochronology, in accordance with the coining of the word, should be used only for the exact method of annual datings and not for approximate estimates, as in connection with the interesting but rather rough computations from the rate of radium decomposition, where the unit is not the year, but approximately a million of years, or what could be called a milli.

The main purpose of geochronology is to bring about, to control, and to fix a universal time scale, and — with respect to its Swedish origin and to the fact that only in Sweden it is possible to follow it up continuously from the last 15 000 years unto our historical era — this may be called The Swedish Time Scale.

As soon as additional varve measurements have been performed at a new place anywhere on the earth and by comparison connected with some part of the universal Swedish Time Scale, it ought to be designated by the years of this latter and thus be referred to one and the same starting-year, namely the well fixed Zero-point of the Ice Age. Only in that way the full use of geochronology will be attained, synchronising identic stages of time-evolution within all parts of the earth.

Hereby it is of course a necessary condition that the teleconnections are carefully carried through and duly controlled. With normal and sufficiently long varve series this, as a rule, will be well performable by the help of the considerable material of measurements now at hand for comparison.

Still I must use this opportunity especially to underline one instance which seems to be rather urgent, the more so as it is of special importance concerning geochronology.

The main purpose with this new branch of science is to provide natural, universal datings referred to one and the same Swedish time scale. Before this is done, the annual varves are only referable to other local measurements, but as soon as the local varves with certainty are teleconnected with the Swedish time scale, they also ought to be referred to the common annual reckoning of that time scale.

In that way long series of varve measurements in as well North as South America, in the Scandinavian and Baltic countries, in Poland and Switzerland, in the Himalayas, Kenia and New Zealand, all have been referred to the same time scale, but there are a few observers who, although certified teleconnections with the time scale are performed, still do not utilise the corresponding designations for the exact years.

It is to be hoped earnestly that such examples will not be followed, as that would mean clinging to the Babylonian confusion exactly when finally a possibility has turned up to get a clear understanding of the relation between phenomena which were earlier rather hopelessly isolated from each other.

Having now attained to establish the same modern time scale all over the earth, it does not seem practical, hereafter, for times begone to use different and incoherent time scales separated only by political limits.

Conclusions.

After this somewhat more elaborate presentation of geochronology it may be appropriate to add a few words summarising the principal points and aims regarding this new branch of natural science.

It is easily understood how the Quaternary Swedish time scale is intended to be used all over the earth and to furnish a back-bone or standard of time for tying together conditions on diverse parts of our planet.

In the first place the Quaternary geology of Scandinavia no doubt can be said to have got a new appearance by the introduction of the time factor, making it possible in many cases to get a general view of the successive evolution of continuous regions as well above as below the actual sea-level.

The time determinations, further on, have made it possible to perform a comparative study concerning the physics of cotemporary ice-formation in different parts of the world, at different latitudes and under different conditions as well in alpine regions as on the great glaciated lowlands. Thus it has been possible to fix and reciprocally to compare the mighty rivers of this unique melt-epoch at different stages and to determine their hydrologic capacity and power of distributing sediment of different coarseness.

A general view of the normal varve variations has been obtained by the specially constructed graph of the biennic or most dominating and regular varve variations. Thereby it has been definitively stated that, as to the variation of varves, evidently for the whole investigated epoch of 15 000 years back from our time, there seems not to have been any room for real periodic varve-variations of greater length than a few years.

Not even the sunspot cycle have I observed among the annual varves, though its rather mysterious middle length of 11.4 years seems to come forth within the annual tree-rings, thus probably being caused by some chemical radiation affecting the trees but not the ice-melting.

The obvious lack of reiterated cyclic variations with regard to the annual varves certainly is unfavourable as to long-range forecasts but of great interest as showing that the good connection between sufficiently long series of annual varves can be explained only by real time-identity.

As to the climatical factors which have put their stamp upon the evolution up to our days, indications are found to explain and date certain climatic changes mentioned in the historical traditions.

Other still greater prehistoric occurrences, which already are or soon may be reliably dated by means of the natural time scale, are shown to be of another origin, most probably depending of some accidental changes in the sun itself.

Among the most desirable datings are those of marked phenomena with a great extension, such as the immigration and spreading out of different mollusca and diatoms and, with respect to land-organisms, the interesting, more and more growing, considerable material of pollen investigations concerning the gradual immigrations of the dominating forest vegetation.

These immigrations, being successive and locally more or less diverging, of course cannot be dated in the same exact way as annual varves, but their study no doubt will be essentially favoured by connection with datable shore-levels or sometimes even by direct dating of local occurrences in annual varves of independently determined age.

Anyhow it seems probable that geochronology by the help of biochronology from stems in the peat-bogs and plant remains in varved lake deposits will be able to furnish at least general relative datings concerning the highly important problem of forest immigration into extended, formerly totally barren ice-deserts, thereby affording an ideal and quite unique opportunity of studying in detail the great general phenomenon of migration.

On the whole, the new possibility of putting exact time determinations in the place of uncertain postulations often may be able to replace so-called natural history by geophysical science.

Especially certain marked, prehistoric happenings, registered by rather conspicuous terminal moraines, no doubt are caused by some astrophysic events, as being everywhere by means of adjacent annual varves proved to be synchronously deposited; every occurrence during its own space of time, sometimes a few centuries, sometimes several ones, as witnessed by the surrounding varves.

Not being explainable by the annual radiation from the sun, the origin of these moraines must be sought in some other astrophysic phenomenon, probably affecting as well the sun as more or less of its planetary system.

By a continued use of the new working methods it seems further on to be within a near reach of the investigations to attain the very outer limit of the last glaciation and by the help of its dating and closer exploration finally to get a possibility of a real discussion concerning the nature and dating of the greatest of the Late Quaternary ice-oscillations.

What is true of these ice-oscillations may be true of the whole of the Ice Age. Especially at present, when we begin at least to extend a tentative string of real investigation towards the much ventilated, great problem of the Ice Age, it seems desirable to concentrate upon the conquest of that goal, which means a most remarkable geophysical event.

By a continued systematic use of geochronology it seems that the way has been opened, finally to get some real knowledge concerning the nature of the very Ice Age, the progenitor of the whole of our Late Quaternary climatic and biologic evolution.

Acknowledgements.

The investigations here summarised have been made possible only by several long series of diggings and measurements, collected during half a century, especially from all parts of Sweden and from the neighbouring countries but also from North America and from all five parts of the world. In this work have taken part eighty geologists, most of them young Swedes, and several expeditions have been sent out from here, working in foreign countries for several years, also supported by foreign authorities and even by appointment of a foreign State Survey. From different parts of the earth a great material has been brought together, everywhere proving the universal application of the Swedish time scale.

This could not have been possible without the intelligent interest so often exhibited in this country concerning scientific enterprise, and I may be allowed here most humbly and heartily to express my deeply felt thankfulness to all those who by their assistance, personally or economically, have helped starting this new branch of science, the *Geochronologia Suecica.*

All of my young collaborators I may here enclose in my hearty thanks — whether they belonged to the early clay-campaign, when the first groups were summoned to »put on their simplest clothes» and go out to hunt up the varves, »nowhere seen, but existing everywhere», or they joined the ranks later on for an individual extension or completing of the investigations. All of them have worked with an assiduous and honest devotion to the scientific zeal of inquiry, whatever the result may be, which is the real spirit of research. Nature has answered us, according to its laws, and beyond all expectations.

Not only Fennoscandia but also foreign continents, as especially North America, have been rather broadly examined as to there existing varve occurrences, and here I may specially express my thanks to Dr E. ANTEVS for his very assiduous field-work and for the interest in this branch he may have developed and spread within North America during these last two decades of years.

Among the collaborators remaining here I wish especially to thank Drs CARL CALDENIUS, RAGNAR LIDÉN, ERIK NORIN and ERIK NILSSON as well as Mr ERIK YGBERG and Miss BIRGIT BJÖRSELL who, during the last years, have executed a very valuable drawing and assistant work.

In this publication it has been endeavoured to put forth the principles of *Geochronologia Suecica.* Hereby it seemed natural to commence by the last epoch, as being at the same time best known and also most characteristic by the special conditions dominating the great melt-period which put an end to the Ice Age.

These conditions afford good opportunities of studying the working methods of this new kind of investigation by its extended use for more exact geophysical studies in recent evolution as well as for the farther extension of the time scale unto the unknown past. Within regions, the ice-free origin of which was dated by varve-measurements, it thereby also was possible to make out the rate of water-erosion, till-weathering, soil-evolution, as well as the relative capacity of cotemporary ice-rivers and different conditions which determine the recession of the ice-border, only to mention a few *items* as alluding into how much more precision and individual detail the knowledge of the past can be brought by the use of geochronology.

By secondary connection of local phenomena with already teleconnected, exotic head-stations chronologic colonies gradually will realise world-wide connections all over the globe, attached to regions with annual registration by varves.

The first steps in this direction already attained have craved quite a number of different excursions and even expeditions of several years' duration to various parts of the globe, not to speak of several decades of institution-work.

Soon it became obvious that for the building up of a real geochronology it was indispensable to organize a special institute, where from other duties undisturbed work could be concentrated upon the rather time-craving construction of a reliable and satisfactory, new chronology.

First measuring of the Swedish time scale by clay campaign of 1905.

Divisions and their participants.

A. Gerard & Sten De Geer	G. Gerard De Geer	M. J. P. Gustafsson a. o.
B. Walter Kaudern	H. » » »	N. » »
C. Gregori Aminoff &	I. † Adolf Larsson &	O. Otto Sjögren
D. Emil Lindegren	J. Hjalmar Ström	P. Ragnar Lidén
E. Rudolf Söderberg	K. Lennart von Post	Q. Artur Bygdén
F. John Söderlund	L. » » »	R. Simon Johansson.
	W. Nisser	

The Swedish time scale continued in 1906.

Participants.

Erik Bengtsson	† Axel Hamberg	Nils Odhner
Alexander Berglund	Sune Hansson	Gunnar Samuelsson
Gerard De Geer	† Harald Johansson	Gunnar Starck
† Sten De Geer	Simon Johansson	Albert Stark
Gösta Ekelöf	Erik Jonsson	† Ossian Vallin
Wilhelm Ekman	Walter Kaudern	Anders Wastensson
Eric Envall	Ragnar Lidén	Simon Werner
Matts Essén	Ragnar Looström	Nils von Zweigbergk
	William Nisser	

Of about 700 varve series measured at a corresponding number of localities within and around Stockholm about 530 were measured by myself, after 1908 in company with my wife, Ebba Hult De Geer, while 170 other localities were investigated by some twenty of my pupils, as enumerated below.

Varve measurements in the Stockholm region.

Participants.

W. Kaudern (1907)	2[1]	H. Ahlmann	8	† E. Granlund	3
† G. A. Larsson	4	P. Sederholm	2	T. Henschen	1
J. Söderlund	8	C. J. Anrick	4	R. Sandegren	2
R. Söderberg......	9	G. Aminoff	3	E. Norin (1924) ..	4
C. Caldenius	12	G. Starck	2	T. Hagerman (1933)	1
† E. Jansson........	25	E. Antevs	2	K. Fægri »	3
R. Lidén	4	S. Hagman	1	S. Thorarinsson »	3
O. Hammarsten ..	1	J. Grufman	11	P. Galenieks »	1
N. Odhner........	1	† S. Nehrman	2	E. Hyyppä »	1
† H. Johansson	16	S. Lindman	18	S. Iversen »	1
		A. Sörlin	30	V. Zans (1935)	1

[1] number of measurements.

Other contributions to the clay measurements

in Sweden by

H. Ahlmann	H. Eriksson	G. Lundqvist
J. Alin	S. Florin	G. Mead
N. Alsén	F. Folkesson	† S. Nehrman
G. Aminoff	G. Frödin	E. Nilsson
C. J. Anrick	† E. Granlund	N. Odhner
E. Antevs	J. Grufman	R. Sandegren
G. Blomberg	S. Hagman	S. Stengård
C. Caldenius	H. Hedström	† U. Sundelin
† S. De Geer	C. E. Hermelin	O. Tamm
E. Envall	N. Hörner	† G. Törnblom
G. Erdtman	W. Kaudern	N. Zenzén
	R. Lidén	

in foreign countries by

E. Antevs	J. De Geer	E. Nilsson
H. Backlund	G. Erdtman	E. Norin
C. Caldenius	R. Lidén	R. Sandegren
	H. Lundberg	H. Wadell
S. A. Andersen	G. Holmsen	Ch. E. Reeds
J. Askelsson	B. Hvistendahl	† J. B. Rekstad
D. Danielsen	S. Kilpi	M. Sauramo
E. W. Ellsworth	R. Lougee	† J. J. Sederholm
O. Grönlie	K. K. Markov	J. B. Simpson
B. Halicki	G. D. Osborne	† R. Tappan
S. Hansen	F. J. Pettijohn	S. Ting
O. Holtedahl	† W. Ramsay	V. Zans

At the same time the whole of the Geochronologic Institute, its archive and collections as well as all its performances, were brought about exclusively by private means, presented as a gift to the University of Stockholms Högskola.

As above mentioned, the Geochronologic Institute commenced working in 1924. In lack of a special building the suitable, new equipment was adapted to a locality, all since hired in a private office-building. The necessary costs as well for the institution as for all the expeditions, excursions, field-work, laboratory

and clerical work by help of two or more extra assistants, has been defrayed by private friends and patrons as well as by grants from different foundations or scientifical funds.

Thus I beg to express my very respectful and sincere thanks to all those who have made possible, during this long time, the elaborate work as well by the present author as by several advanced collaborators, of whose work the main results are extracted to build up the present *Geochronologia Suecica*, namely for:

Organization of the Geochronologic Institute.

To: the late Baron C. G. Langenskiöld and Family; Consul General Axel Ax:son Johnson and Family; Dr K. O. Bonnier and Family; the late Dr Emanuel Nobel; Dr Harry von Eckermann; Director Otto Hirsch; Director C. Carleson; Dr Axel Lagrelius.

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To: H. K. H. Prince Eugen
Georg Pauli, Artist
Nils Erdtman, »
Sigge Bergström, »
Ferdinand Boberg, »
Ragnar Östberg, Architect
Robert W. Bliss, Minister and Mrs
Eric von Rosen, Explorer
Josef Sachs, Consul General
Sam Wallin, Inventor
Former pupils.

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Printing of the present publication.

To: Consul General Axel Ax:son Johnson; the Foundation of Knut and Alice Wallenberg.

After the first ten years of the institute which were provided for by the donations mentioned above, the rent as well as all other expenses in connection with the institute and its investigations are due to special friends and patrons.

VARVE MEASUREMENTS
EXPRESSED BY FIGURE TABLES

GENERAL REMARKS

LOCALITIES AND MEASURERS

SUMMARY OF LOCALITIES AS TO CENTURIES OF THE TIME SCALE

TABLES

DIVISIONS STOCKHOLM—UPPSALA—GÄVLE 1905

MAIN TIME SCALE

Tables and graphs.

I. General remarks to the figure tables in the text and graphic plates in the atlas.

As already emphasised in the definition, the Swedish time scale comprises all measurements which are dated by means of the continuous standard line, thereby included all its filials in other countries, whenever reliably connected and thus representing a parallel from the same time. Also the Divisions and the Special graph lines are clearly connected with the main time scale.

The varves are generally directly marked according to the natural scale on paper-tapes and from these reproduced by graphs of 5 mm between the thickness lines for every year, as being the most convenient and conspicuous laboratory scale. In print they are directly reproduced by the graphs, on a diminished scale ($^1/_2$), if they are macro-varves, but magnified if they are micro-varves.

These graphs of the chronology are disposed so as to begin by the youngest years, nearly adhering to present time, and proceeding into the remote past, so as to admit further extension into the yet unknown, when more material is afforded.

The thicknesses of the single varves are also to be found in the tables, namely of the Main Time Scale and the Divisions.

The Graphs.

The Divisions (see pp. 146—154) represent the earliest systematical varve measurings unto a standard line of some 800 years, by sections of one Swedish mile. These sections are here reproduced side by side by the same annual line distance as the Main Time Scale, while the height of the varves in the Divisions is reduced to $^1/_4$. The years below the graphs show to what extent the measurements cover each other from one Division to another one.

The Main Time Scale is reproduced on six plates (Pls 73—78) for the years:

+2000 — +1200 a.Z.	± 0 — - 400 b.Z.
+1200 — + 400 »	-400 — - 800 »
+ 400 — ± 0 »	-800 — -1400 »

Figures of years = every 20 year before (–) or after (+) the Zero-year, denoting the End of the Ice Age, or, briefly:

\+ a.Z. = after Zero
\- b.Z. = before »

The graph plates are lined vertically by 2.5 mm distance for each year. All the graphs give the original, directly measured varve thickness, on the scale $^1/_2$ where not otherwise is indicated ($^1/_{10}$ $^5/_1$ $^8/_1$ $^{10}/_1$ $^{15}/_1$).

Means of several localities are given graphically for:

1. Each Division as a whole, in the Time Scale Plates marked each by its capital letter, T—E (Pls 76—77).

2. The Scandinavian localities -400 — -1000, placed lowermost on Plates 77—78.

3. Three groups of localities, given by special measurers, are represented in the Time Scale, Pl. 78, by a standardised means:

Vl.	9, 10	Filipstad	region,	measured by	E. Granlund,
»	8	Brattfors	»	» »	N. G. Hörner,
Vsl.	7	Malingsbo	»	» »	G. Lundqvist.

Signs. The lines combining the varve tops are drawn broad, where identity is found from normal variation, thin, where variation is local. Micro-varves (*mi*) are drawn by extra heavy lines. A special thin underlining denotes special variations to be observed.

Corrections. *Dotted lines* = varves referred to right years. *Broken lines* = missing or uncertain varves. *Arrows*, pointing up or down, indicate a varve thickness too great or too small; or sideways, varves to be moved back- or forwards.

Base-lines are drawn for the varve curves, where space allowed. The great amount of material necessarily caused some inevitable crowding of curves, but all measures are found in the figure tables.

Bottom varve is marked by a triangle, denoting moraine- or rock-bottom obtained, viz. in the tables and graphs of the Divisions. For the Time Scale the bottom varve is given in the list of localities, pp. 250—256.

Biennic variations (=peaks on every second year) are marked by crosses, thick for even years, thin for uneven years; and, in the Divisions, by dots. At the base of the plates they are likewise marked by a system of small staffs, directed downwards for peaks on even years and upwards for peaks on odd years. Only such series of biennic peaks as are found to be dominating, and thus normal, are taken into account.

Abbreviations refer to the list of localities, pp. 250—256 according to Swedish provinces and Scandinavian as well as non-Scandinavian countries (see below).

The single, long measurements from other continents here given are generally placed above the Scandinavian graphs.

Abbreviations.

Scandinavia.		Confer Fig. 63, p. 263.		*Non-Scandinavia.*	
La.	Lappland	Da.	Dalarna	E.Afr.	East Africa
Nb.	Norrbotten	Vl.	Värmland	Can.	Canada
Vb.	Västerbotten	Vsl.	Västmanland	U.S.A.	United States, America
Jl.	Jämtland	Up.	Uppland	Arg.	Argentina
Ång.	Ångermanland	Sl.	Södermanland	Him.	The Himalayas
Me.	Medelpad	Nä.	Närke		
Hl.	Hälsingland	Ög.	Östergötland	M	Sth medium
Gl.	Gästrikland	Vg.	Västergötland	Med.	Medium
Fin.	Finland	Sth.	Stockholm	*mi*	micro
Nor.	Norway			c.	circa
E—T	Signs of Divisions			G.D.G.	Gerard De Geer } Varve localities & photos
	Stockholm—Uppsala—Gävle.			E.H.D.G.	Ebba Hult De Geer } Varve localities & photos

M.G. = Highest marine limit; Y.G. = Yoldia limit; B.G. = Baltic Lake limit; A.G. = Ancylus limit; P.G. = Postglacial transgression limit; are terms often occurring in the Swedish Quaternary literature.

Numbers = Special localities: see tables of Localities, of Divisions and Time Scale.

The Special Lines represent regions of special close investigations, where the localities measured occur too tightly or in too great a number to be admitted into the reduced space of the sections of the Main Time Scale, with which they are quite analogous as to scale of varves, disposition, and signs.

To avoid confusion, however, also the names of the localities are put out, as well as some local designations or group numbers beside those of the general time scale, to be refound in the list of localities on pp. 257 and 258 and in the general list, pp. 250—256.

Biennic peaks, identic with those of the Time Scale, are marked by the same system of basal peaks, but occasionally some local ones too, when found to be a locally dominating feature.

Note to:

Frontispiece: Photo Wahlberg.
Blocks Grohmann & Eichelberg.

Pl. 52: Photo and Blocks Grohmann & Eichelberg.

Pl. 53: Photo Wahlberg.
Blocks Grohmann & Eichelberg.

Errata.

Fig. 41, Haileybury, I, II: figures to be moved one varve downwards.
P. 186, line 6 from above: for: beeches, read: beaches.

Localities and measurers.

Divisions: see text and figure tables.

Main time scale (Pls. 73—78).

Province	Designation	Bottom year	Locality: Region	Locality: Place	Measurer	Year of measuring
Lappland	La. 1	+521	Storuman	Gaskeluokt	G. Erdtman	1937
Norrbotten	Nb. 7	c. +620	Lule älv	Överedet	G. De Geer	1915
	6	c. +578	» »	Strömbacka	»	»
	5	+510	» » L 5	Åminne	»	»
	4	+463	» » L 4	Bredåker	»	»
	3	+434	» » L 3	Hednoret	»	»
	2	+414	» » L 2	Boden, Garnison	»	»
	1	+400	» » L 1	Boden, El.verk	»	»
Västerbotten	Vb. 6	—	Skellefte älv	Kusfors	»	»
	5	+273	Vindel älv	Strycksele	»	»
	[1](4)	+258	» »	Sirapsbacken	»	»
	3	—	» »	Juksån	»	»
	(2)	—	» »	Hällnäs	»	»
	1	-18	» »	Degerön	»	»
Ångermanland	Ång. 27	-422	Örnsköldsvik	Staden	E. Envall	1938
	26	—	»	Tvillingsta tegbr.[2]	G. De Geer	1915
	25	—	»	Våge tegbr.	»	»
	(24)	-75	Ångerman älv	Vallen	R. Lidén	1906–13
	(23)	-83	» »	Lillterrsjö	»	»
	(22)	-105	» »	Bölen	»	»
	(21)	-123	» »	Ovanmo	»	»
	(20)	-159	» »	Sjulsvedjenipan	»	»
	(19)	-172	» »	Vigdan	»	»
	18	-181	» »	Nämforsen	»	»
	(17)	-213	» »	Lillsjöbäcksmon	»	»
	(16)	-226	» »	Österrå	»	»
	15	-246	» »	Resele	»	»
	14	-246	» »	Omnäs	»	»
	(13)	-246	» »	Forse	»	»
	12	-248	» »	Sand	»	»
	(11)	-255	» »	Högmon	»	»
	(10)	-272	» »	Risöviken	»	»
	(9)	-304	» »	Strinne	»	»
	(8)	-306	» »	Tunsjön	»	»
	(7)	-362	» »	Utnäs	»	»
	6	-414	» »	Villola, Gammelgård	»	»
	5	-412	» »	» , Lillrännsfors	»	»
	4	-445	» »	Viksjö	»	»
	(3)	-490	» »	Hästholmen	»	»
	(2)	-509	» »	Fällön	»	»
	1	-227	» »	Gåsnäs	G. De Geer	1917
Medelpad	Me. 8	-245	Ljungan	Ljungaverken	»	1915
	7	—	Indal älv	Indal	»	1912
	6	-503	Sundsvall	Timrå	»	1912
	5	—	»	Högom	»	1911–14
	4	-547	»	Sidsjöbäcken	»	1911
	3	-620	Njurunda	Njurunda kyrka	E. Antevs	1918
	2	c. -620	»	Ovansjö	C. Caldenius	1938
	1	-608	»	Skedlo fäbod	J. Öster	1937

[1] ( ) here not reproduced. [2] = tegelbruk = brickyard.

Varve localities.

Province	Designation	Youngest year	Locality: Region	Locality: Place	Cald. No.	Measurer	Year of measuring
Jämtland	E Jl. 17	+3680	Ragunda— Indalsälven	Barksanden	R, a, b, c	G. De Geer C. Caldenius	1911
	16	+2210	»	Hammarstrandsterr.	9–11	»	1911–23
	15	+1969	»	Vikbäcksterr.	29	»	1911
	2	+1979	»	Vikbäcken	A	G. De Geer	1911
	3	+1692	»	»	C	E. De Geer	1911
	14	+1310	»	Pålgårdsravin	17	C. Caldenius	1911–12
	13	+1260	»	Remmarne	15	»	1911–12
	12	+1140	»	Gevågsbäcken	411	»	1923
	3 a	—	»	Sidoravin		»	
		Bottom year					
	11	-128	»	Krokvåg, Lokedan	(409)	»	1923
	10	-138	»	Krokvåg, Lokedan	402	»	1923
	9	—	»	Krokvåg, Kopparhällan	42	»	1915–23
	8 a	-107	»	Döviken, Storedan	35 a	»	1911
	8 b	-106	»	Döviken, Storedan	37	»	1911
	7	-200	»	Dynen		G. De Geer	1911
	6	-201	»	Bråtudden		»	1911
	5	-202	»	Alviksravin		»	1911
	4	—	»	Hammarstrand		G. Mead	1939
	3	-203	»	Gamla brons E fäste		G. De Geer	1911
	2 c	—	»	Vikbäcken	C	E. De Geer	1911
	2 a	-233	»	Vikbäcken	A	G. De Geer	1909–11
	1 a	-244?	»	Singsån tegbr.		R. Lidén	1906
	1 b		»	» E		C. Caldenius	1912
	W Jl. 18	c. +10	Ström	Klöva tegbr.		G. De Geer	1917
	17	—	»	Bonäset		»	1917
	16	c. -40	»	Fågelberget		»	1917
	15	-522	»	Ytterolden		»	1917
	14	-630	Offerdal	Kaxås		»	1919
Ice lake localities	13	-793	Kall	Gråsjöån		G. Frödin	1911
	12	-632	Storsjön	Brunflo, Vålbacken tegbr.		G. De Geer E. Antevs	1906, -17 1918
	11	—	»	Frösön		G. De Geer R. Lidén	1906 -06, -19, -20
	10	-698	Indalsälven	Järpen		G. De Geer	1916
	9	-708	»	Undersåker 1		»	1919
	8	-713	»	Undersåker 2		»	1919
	7	-723	»	Tegefors		»	1919
	6 c	-754	»	Duved 1, Monumentet		»	1919
	6 b	-755	»	Duved 2, Tegbr.		»	1919, -36
	6 a	-819	»	Duved 3, Staa bron		»	1919
	5	c. -820+	»	Bunnerviken		»	1919
	4	-858	»	Stalltjärnstugan		»	1916
	3	c. -892	»	Medstugan, Bonäset		»	1917
	2	c. -890	»	Medstugan, Sandbäcken		»	1917, -19
	1	c. -890?	»	Vålådalen		»	1936
Norway	NW 10	—	Trond	Værdalen		G. De Geer	1907
	9	—	»	Trondheim		»	1921
	8 a	c. -435	Glommen	Tönset, Sandbakken		»	1916
	8 b	c. -414	»	Alvdal		B. Hvistendahl	1939
	SE 7	c. -70	Randsfjord	Fluberg		O. Holtedahl	1919
	6	-590	Romerike	Jesseim		G. De Geer	1917
	5	c. -900	Oslo	Nygaards tegbr.		»	1916
	W 4	-1120	Sogn	Aardal, Moen gård		J. Rekstad C. Caldenius	1913 1933
	S 3			Kvarstein		D. Danielsen	1932

Province	Designation	Bottom year	Locality		Measurer	Year of measuring
			Region	Place		
Hälsingland (Dellen line)	Hl. 52: 17	—	Dellen	Ståläng	O. Vallin	1906
	16	—	»	Norrhavra	»	»
	15	—	»		»	»
	14	—	»	Sördala	»	»
	13	—	»	Bricka	»	»
	12	—	»	»	»	»
	11	-474	»	Svedjebo	»	»
	10	-475	»	»	»	»
	9	-474	»	»	»	»
	8	-475	»	Västansjö	»	»
	7	-479	»	»	»	»
	6	-475	»	»	»	»
	5	—	»	»	»	»
	4	-475	»	Delsbo	»	»
	3	-477	»	»	»	»
	2	-478	»	»	»	»
	1	-478	»	»	»	»
Hälsingland	Hl. 67	—	Voxna älv	Loos Norrgård (photo L. Wastensson)	E. H. De Geer	1939
	66	-317	»	Edsbyn	E. Antevs	1917
	65	-322	»	Fanta	»	»
	64	—	»	Ovanåker	»	»
	63	—	»	Myra	»	»
	62	-378	»	Alfta	»	»
	61	—	»	Sörbo	»	»
	56	—	Söderhamn	Sandarne	G. De Geer	1938
	55	—	Hudiksvall	Ilsbo	J. Öster	1937
	54	-586	»	Helsingtuna, Mo tegbr.	G. De Geer	1917
	53	-623	»	Lingarö	»	»
	52	-440—-478	»	Dellen 1—17 (see above)	O. Vallin	1906
	51	-614	Gnarp	Järnvägsstation	E. Antevs	1918
	50	-602	»	Berge	J. Öster	1936
	49	-602	»	Gingsta	»	1938
	48	-604	»	Sågbäcken	»	»
	47	-613	»	Dalbrands	»	»
	46	-614	»	Åkne	»	»
	45	-625	»	Milsbron 1	»	1936
	44	-627	»	Milsbron 2, E därom	»	1938
	43	-632	»	Gällsta, åbrink	»	»
	42	-627	»	Masugn	»	»
	41	-638	»	Bergsjö kyrkby	»	»
	40	-593	»	Gällstavallens fäbod	»	»
	39	-601	»	Åsnorrbodarna	»	»
	38	-287?	»	Färila, Föne	»	1937
	37	-253?	»	Veckebo	»	» ?
	36b	-311	Ljusdal	Tallåsen tegbr.	»	»
	35	—	»	Snäre	»	»
	34	-398?	»	Hybo	»	»
	33	-362	»	Sjövesta tegbr.	»	»
	36a	-311	»	Tallåsens tegbr.	G. Ekelöf	1907
	32	-380	»	Löräng	»	»
	31	-352	»	Karsjö stn	»	»
	30	c. -379	Undersvik	Löfvik	»	1906
	29	-380	»	Kyrkbyn	»	»
	28	-388	»	Djupa	»	»
	27	-389	»	Simeå	»	»
	26	-389	Arbrå	Vallsta	»	»
	25	-404	»	Haga	»	»
	24	-406	»	Arbrå skolhus	"	»
	23	-395	»	Liljendahl	»	»

Province	Designation	Bottom year	Locality: Region	Locality: Place	Measurer	Year of measuring
Hälsingland (Bollnäs line)	Hl. 22	-408	Arbrå	Järnvägsstation	G. Ekelöf	1906
	21	-413	»	Kyrkby	»	»
	20	-417	»	Koldemo 2	»	»
	19	-418	»	» 1	»	»
	18	-419	Bollnäs	Vexsjö	»	»
	17	-418	»	Åslingsgård	»	»
	16	-419	»	Röstebo	»	»
	15	-421	»	Framnäs	»	»
	14 a	-423	»	Hamre	W. Ekman	»
	14 b	—	»	» , micro-varves	E. H. De Geer	»
	13	-428	»	Järnvägstation	W. Ekman	»
	12	-430	»	Säverstad	»	»
	11	-431	»	Häggestad	»	»
	10	-440	»	Lennings	»	»
	9	-441	»	Voxsäter	»	»
	8	-442	»	Fällne gård	»	»
	7	-444	Hanebo	Böle	»	»
	6	-447	»	Granbo	»	»
	5	-448	»	Hårga	»	»
	4	-449	Kilafors	Berge	H. Ahlmann C. Caldenius	1911
	3	-451	»	Sibo	»	»
	2	-480	Holmsveden	Järnvägsstation	»	»
	1	-488	Lingbo	Strömsdalens tegbr.	»	»
Gästrikland (Ockelbo line)	Gl. 20	-494	Ockelbo	Norrbro 3, Svartbo	E. Envall	»
	19	-497	» O 13	» 2, Svarttjärn	»	»
	18	-500	»	» 1	»	»
	17	-503	»	Mo 4	»	»
	16	-504	»	» 3	»	»
	15	-507	»	» 2	»	»
	14	-509	» O 8	» 1	»	»
	13	-513	» O 7	Säbyggeby	»	»
	12	-517	»	Murgården	»	»
	11	-521	» O 5	Stenbäcken	»	»
	10	-526	»	Östby	»	»
	9	-528	» O 3	Fattiggården	»	»
	8	-545	» O 2	Konstdalen	»	»
	7	-559	» O 1	Kolforsen	»	»
	6	-575	»	Råhällan	G. Törnblom	»
	5	-616+	Gävle	Åbyfors	G. De Geer J. Grufman	» 1918
	4	-620	»	Hagaström	G. De Geer	1911, -30
	3	-624+	»	Åsbyggeby	C. Caldenius	1937
	2	-630	»	Rörberg	J. Grufman	1918
	1 a	-622	Torsåker	Kyrkbyn	R. Lidén	1917
	1 b	-625	»	Järnvägsstation	C. Caldenius	1924
	21	—	Hamrånge	Bergby	G. De Geer C. Caldenius	1930 1937
Dalarna	Da. 12	-364	Mora	Järnvägsstation	R. Lidén	1932
	11	-525	Hälgnäs	Tegelbruk	E. Antevs	1917
	10	-564	Korsnäs	Backa	»	»
	9	-551	Falun	Tegelbruk	G. Aminoff	»
	8	—	»	Järnvägsstation	U. Sundelin	1924
	7	-566	Korsnäs	Staberg	E. Antevs	1917
	6	-617	Gustafs	Älvskärning	C. Caldenius R. Lidén	1921 1929
	5	-651	Hedemora	Bältarbo tegbr.	S. Stengård	1915, -16
	4	-640	Smedjebacken	Kvarnsnäs	J. Grufman	1918
	3	c. -700+	Krylbo	Fors	»	»
	2	-737	Avesta b	Dalälven (river-section)	J. Anrick	1916
	1	-737	Avesta a	» »	G. De Geer	1906

Province	Designation	Bottom year	Locality: Region	Locality: Place	Measurer	Year of measuring
Värmland	Vl 18	—	Dalby—Klar-	Gunnebo (photo)	G. De Geer	1916
	17	—	» älven	Likenäs	E. Antevs	1917
	16	—	»	Brönäs	»	»
	15	—	»	Bråten	»	»
	14	—	»	Persheden	»	»
	13	-350	»	Knektarsheden	»	»
	12	—	»	Krusmon	»	»
	11	-584	Ekshärad	Fallet	»	»
	10	c. -680	Filipstad	Finnmossen	E. Granlund	1927
	9	-691	»	Fogdhyttan	»	»
	8	-802—-848	»	Brattfors	N. Hörner	1923
	7	c. -830	Lindfors	Tegelbruk	G. De Geer	1916
	6	c. -750	Arvika	»	E. Antevs	1917
	5	—	Kil	Sunnanå	»	»
	3 a	—	Munkfors	Höje Hpl.	S. De Geer	1909
	3 b	—	»		G. De Geer	1916
	3 c	—	»	Gersheden	E. Antevs	1917
	2	-905	Karlskoga	Tegelbruk	G. De Geer	1916
	1	-990+	Säffle	»	(prov) E. Antevs G. De Geer	1917 1935
Västmanland	Vsl. 11	c. -946	Västerås	N of cathedral	G. Erdtman	1939
	10	—	Sala	Tegelbruk	J. Grufman	1918
	9	-708?	Västanfors	Bank-house	J. Anrick J. Grufman	1916 1918
	8	-735	Norberg	Livsdalen	J. Grufman	»
	7	-787—-798	Malingsbo		G. Lundqvist	1930
	6	-842	Virsbo	Nordana	J. Grufman	1918
	5	-878	Ramnäs		»	»
	4	-902	Surahammar		»	»
	3	-948	Hallstahammar	Rallsta, Kolbäck	»	»
	2	—	Heby	Tegelbruk	G. De Geer J. Grufman	1916 1918
	1	—	Tillberga	»	J. Grufman	1918
Närke	Nk. 4	-879	Vedevåg	»	G. De Geer	1915
	3	-976	Örebro	Marks tegbr.	»	»
	2	-981	Fjugesta	»	J. Grufman	1919
	1	-984	Mosås	»	»	»
Uppland	Up. 40	-624	Älvkarleby	Kungsgården W of river	G. De Geer C. Caldenius & N. Zenzén	1905, -11 1911
	39	-607	»	Berget		»
	38	-614	Vestland	Nöttö by	»	»
	37	624 -625	» »	Sandby »	» »	» »
	36	-629	»	Vestlands gård	C. Caldenius	»
	35	629	Rörberg		J. Grufman	1918
	34 b	-682	Tierp	Hals	C. Caldenius	1938
	34 a	—	»	Bredäng	»	»
	33	-692	Östhammar b	Norrskedika	J. Grufman	1918
	32	-702	» a	Kannikebol	»	»
	31	-717	Gimo		»	»
	30	-732	Örbyhus	Järnvägsstation	»	»
	29	-767	Tärnsjö	Römyra	»	»
	28	-792	Broddbo	Vesterby tegbr.	»	»
	27	-806	Runhällen	Sillbo »	»	»
	26 a	—	Uppsala	S:t Erik »	G. De Geer	1917
	26 b	-878	»	Akad. Sjukhuset	H. Ahlmann	1923
	25	-894	»	Bergsbrunna tegbr.	G. De Geer	1917
	24	-907	Rimbo	Finnby	J. Grufman	1918

Province	Designation	Bottom year	Locality: Region	Locality: Place	Measurer	Year of measuring
Uppland	Up. 23	-942	Ekskogen	Broby	J. Grufman	1918
	22	-964	Enköping	Haga tegbr.	S. Nehrman	»
	21	-990	Bro	Brogårds tegbr.	O. Tamm	1911
	20 b	-996	Vaxholm	Resarön	A. Sörlin	1921
	20 a	-1007	»	Bogesund	G. De Geer	1929
	20 c	-1025	»	Hästnacken tegbr.	»	»
	19 d	-1075	Värmdön	Bo	»	1935
	19 e	-1073	»	Gustafsberg	»	»
	19	-1078	Bockholmssättra	Tegbr.	E. Antevs	1920
	18	-1020	Svartsjölandet	Hillevikens tegbr.	»	1915
	17	-1022	»	Viksund	E. Granlund	1924
	16	-1030	»	Nora	S. Nehrman	1918
	15	-1058	»	Alvik	J. Anrick J. Grufman	» »
	14	-1060	»	Tureholm	»	»
	13	-1064	»	Ekenslund	»	»
	12	-1072	»	Säby	»	»
	11	-1071	Ekerön	Skytteholm	»	»
	10	-1087	»	Runstenen	»	»
	9	-1087	»	Myran	»	»
	8	-1077	»	Tappström	»	»
	7	-1029	Munsö	Väsby, kyrkan	E. Granlund	1924
	6	-1043	Riddersvik	Kalvuddens tegbr.	G. De Geer	1914
	5	-1065	Kungshatt	S. tegbr.	»	1913
	4	-1057	Drottningholm d		»	1931
	3	-1062	» c		»	»
	2	-1064	» b		»	»
	1	-1067	» a		»	»
Sörmland	Sl. 50 g	-1009	Selaön	Berga	H. Eriksson	1915
	50 f	-1022	»	Äleby	»	»
	50 e	-1032	»	Näsby	»	»
	50 d	-1037	»	Mälsåker	»	»
	50 c	-1038	»	Husby	»	»
	50 b	-1013	Strengnäs	Sanda tegbr.	S. Nehrman	1918
	50 a	-1039	»	Stallarholmen	»	»
	49 e	-1065	Mariefred	Kalkudden	»	»
	49 d	—	Enhörna	Sättran	»	»
	49 c	—	»	Lövsta	»	»
	49 b	-1068	»	Lervik	»	»
	49 a	-1074	»	Sundsvik	»	»
	48 h		Södertelje	Viksberg	G. De Geer	1909
	48 g		»	Kiholm	»	»
	48 f		»	Ragnhildsberg	»	»
	48 e	-1114	»	Lina tegbr.	»	1909
	48 d	c. -1130	»	SW brofästet	»	1916, -17
	48 c	-1132	»	Scania Vabis	»	1907, -15
	48 b	-1140	»	Igelsta stn	»	1914
	48 a	-1145	»	Parkrestaurang	»	1916
	47 a	-1159	Rönninge	Elgerund	E. Janssen	1907
	41		Spårtorp		R. Lidén	1916
	40		Vagnhärad		»	»
Östergötland	1	-1202	Finspong	Castle park-river	G. De Geer	1919
Vestergötland	Vg. 2	-1426	Skövde	Mariesjö	»	1916, -17
	1	-1500	Korsberga		»	» »
Norway see p. 218.						
Finland	4	-465	Kristinestad		M. Sauramo	1931
	3	-510	Isojoki		»	»
	5	-547	Iisalmi	Terniemi	S. Kilpi	1937
	2	-966	Åbo	E of f. Observatory	H. Backlund	1920
	1	-1443	Leppäkoski		M. Sauramo	1918

Foreign localities.

	Designation	Series published years	Bottom varve	Locality	Measurer	Year of m.
Canada	Can. 5	+1319 — -588	—	Timiskaming	E. Antevs	1921
	4 a	+ 310 — -369	—	Haileybury brickyard	G. De Geer	1920
	4 b		-341	» Dickson Creek	»	»
	4 c		-394	» Devil's Rock	E. Antevs	»
	3	-204 — -908	-1708	Espanola	R. Lidén	»
	2	-911 — -1044	c. -1100	Sudbury	»	»
	1	-1201 — -1283	-1446	Toronto	G. De Geer	»
U. S. A.	USA 1	-1101 — -1168	-1208	Essex Junction	»	»
Argentina	Arg. 1	-1101 — -1200	-1337	Lago Corintos	C. Caldenius	1926
Himalaya	Him. 2	-1180 — -1278	—	Biano	E. Norin	1924
	1	-1293 — -1374	—	Sesko	»	»
Central East Africa	E Afr. 2	+123 — -44	—	Makalia River	E. Nilsson	1928
	1	- 406 — -546	—	Enderit River	»	»
Iceland	2	-975 — -1066	—	Tindafjöll	H. Wadell	1919
	2	-1094 — -1147	—	Solheimar	»	»
	1 B	-972 — -1069	—	Bjarnarhagagil	J. Askelsson	1930
	1 A	-1065 — -1160	—	Hlíð	»	»

Micro-varves.

Designation		Locality	Years measured by			Specimen taken by		Cfr pp.
Me	5 *mi*	Sundsvall, Högom	+146 — + 74	G.DG	1935	G. De Geer	1911	92–94
»	7 »	Indal	+100 — ±0	EHDG	1939	»	1912	163
»	2 »	Ovansjö	-200 — - 580	»	1938	C. Caldenius	1938	138
Hl	»	Tallåsen		»	1939	G. Ekelöf	1906	155
»	»	Arbrå, Liljendahl		»	»	»	»	»
»	»	» Koldemo		»	»	»	»	»
»	125 »	Bollnäs, Hamre	-200 — -390	G.DG	1936	»	»	138
»	54 »	Helsingtuna	-400 — -600	»	»	E. Antevs	1918	94
Gl	5 »	Gävle, Åbyfors	-c.430 — -c.490	»	1935	G. De Geer	1935	
»	4 »	» Hagaström	-c.300 — -580	EHDG	1939	»	1911	138
Up	1 »	Uppsala, S:t Erik	-c.400 — -620	»	»	J.P. Gustafsson	1906	»
»	2a, b »	» Ekeby		G.DG	1935	»	»	»
»	3 »	» Vaksala	-450 — -690	EHDG	1939	N. G. Hörner	1937	»
Sth	4 »	Bromma, Iris	-300 — -378	G.DG	1935	G. De Geer	1935	94
»	3 »	Sundbyberg	-400 — -442	»	»	»	»	»
»	2 a »	Linvävartorp	-380 — -450	»	»	»	»	»
»	2 b »	Haga Norra	-400 — -446	»	»	»	1936	91
»	1 a »	» »	-405 — -500	»	»	»	»	»
»	1 b »	» »	-614 — -700	»	»	»	»	»
»	1 c »	» »	-700 — -800	»	»	»	»	»
Sl	1 »	Fittja	-433 — -492	»	»	»	1935	

Special graphs (Pls 79—86).

Pl. 79 Åland.

Designation	Bottom year	Localities	Measurer	Year of meas.
Å 4	-847	Ödkarby, Saltvik s:n	E. Nilsson	1924
3	-864	Djäkneböle, Hammarland s:n	»	»
2	-869	Finby, Sund s:n	»	»
1	-912	Ängsbäck teg.br., Lemland	»	»
Sv. T. = Up. 25	For comparison:	Bergsbrunna	G. De Geer	1917
Nor 4		Sogn, Moen	J. Rekstad	1913

Pl. 80. Uppsala.

The Uppsala varve localities comprise series from bottom varves continuously over to distal and microdistal varves (*mi*). Broken lines = photos dated, cfr p. 136.

Localities: 1 = Up. 25, 7 = Up. 26.

Designation	Bottom year	Localities		Measurer	Year of meas.
1	-893	Bergsbrunna teg.br. (= brickyard)		G. De Geer & exk.	1917
2	890	Ultuna	NW limit	E. Antevs »	1917
3	892	»	Bäcklösa	V. Laurent »	1917
4	878	Uppsala	Academic hospital	H. Ahlmann	1923
5	876	»	Botanic garden	J. P. Gustafsson	1905
6	877	»	Vaksala (NE)	G. De Geer	1919
7	—	»	S:t Erik tegbr.	»	1917
8	—	»	Kakel fabrik	»	1919
9	—	»	Röbo tegbr.	»	1918
10 a	—	»	Polacksbacken	»	1882
10 b	884	»	»	J. P. Gustafsson	1905
11	881	»	Grindstugan NE	{Photo K. Winge Meas. G. De Geer	1897 1917
12	—	»	Läby vad	G.D.G., Hörner, Frödin	1918
	For comparison:				
Sv. T.		Vsl 10	Sala	J. Grufman	1918
		» 6	Virsbo	»	»
		» 4	Surahammar	»	»

Pl. 81. Ockelbo line.

Designation	Bottom year	Localities	Measurer	Year of meas.
O. 13 = Gl. 19	-497	Svarttjärn	E. Envall	1911
» 8 » 14	509	Mo 1	»	»
» 7 » 13	513	Säbyggeby	»	»
» 5 » 11	522	Stenbäcken	»	»
» 3 » 9	530	Fattiggården	»	»
» 2 » 8	546	Konstdalen	»	»
» 1 » 7	561	Kolforsen	»	»
» 6	575	Råhällan	G. Törnblom	1911
Hl. 2	480	Holmsveden jvgstn	Ahlmann & Caldenius	1911
1	488	Lingbo, Strömsdalen tegbr.	» »	»
Sv. T. Da 6	For comparison:	Gustafs	R. Lidén	»
Me 2 mi		Njurunda, Ovansjö	C. Caldenius, mätn. EHDG	1938–39

Pl. 82. Bollnäs line.

Designation	Bottom year	Localities	Measurer	Year of meas.
Hl. 32	-390	Löräng	G. Ekelöf	1907
26	389	Vallsta	»	1906
23	395	Liljendahl	»	»
22	408	Arbrå jvgstn	»	»
21	413	» kyrkby	»	»
20	417	Koldemo 2 mi (prov, $^{10}/_{1}$)	»	»
17	418	Åslingsgärd	»	»
15	421	Framnäs	»	»
14	423	Hamre	»	»

Designation	Bottom year	Localities	Measurer	Year of meas.
Hl 13	428	Bollnäs jvgstn (även prov, $^{10}/_1$)	G. Ekelöf	1906
8	442	Fällne gård	»	»
7	444	Böle	»	»
4	449	Kilafors, Berge	»	»
2	480	Holmsveden jvgstn	C. Caldenius	1911
Me 2		Njurunda, Ovansjö (prov, $^{15}/_1$)	»	1938
	Pl. 83. *Dellen* line = Hl. 52.		O. Vallin	1906
D 17	c. -440	Ståläng		
16	c. 450	Norrhavra		
13	c. 460	Bricka		
11	474	Svedjebo		
9	474	»		
10	475	»		
8	475	Västansjö		
6	475	»		
7	479	»		
4	475	Delsbo		
3	477	»		
2	478	»		
1	-478	»		
		Medium Dellen		
	Pl. 84. *Lule, Skellefte, Vindel, Indal Rivers.*			
Lule River.				
Nb. = L. 5	c.+510	Åminne River section	G. De Geer	1915
4	463	Bredåker »	»	»
3	434	Hednoret »	»	»
2	414	Boden, Garnison	»	»
1	+400	» El. verk	»	»
Skellefte River.				
Vb 6	—	Kusfors Railway stn	G. De Geer	1915
Vindel River.				
Vb 3	—	Juksån River section	G. De Geer	1915
Indal River.				
E Jl 8 b	Rag. 1 —	Storedan 35 a River section	C. Caldenius	1911
8 a	» 2 —	» 37	»	»

Pl. 85. *Ice Lakes, W Jemtland.*

	Localities dated				Dating parallel		
1	K=Klöva		WJl. 8	c.+10	G=Gåsnäs		Ång. 1
	F	Fågelberget	» 16	c.+40	S	Sand	» 12
					D	Degerön	Vb. 1
2	F	Frösön	» 11	c.-630	S	Sogn	Nor. 4
					I	Indal	Me 7
					Sth	Medium	
3	F	Frösön	» 11	» »	S	Sogn	Nor. 4
					I	Indal	Me 7
					D	Dellen	Hl. 52
4	V:b.	Vålbacken	» 12	-632	Sth	Medium	
	Y	Ytterolden	» 15	-522			
5	V:b	Vålbacken	» 12	-632	Hed.	Hedemora	Da 5
					Å	Åbyfors	Gl. 5
					Vsl.	Vestland	Up 38

	Localities dated			Dating parallel	
	Pl. 85. Jemtland (cont.).				
6	Duved	WJl. 6	c—754	Espanola	Can 3
	Järpen	» 10	—698	Uppsala	Up
	Slagsån	» 9	—708		
7	Staaby	» 6 a	—819	Up=Uppsala	
	Gråsjöån	» 13	—793	Sa	Sala
	Bunnerviken	» 5 c	—820+		
8	Medstugan 1	» 2 c	—890	S	Sogn
	» 2	» 3 c	—892		
	Pl. 86. *Gotiglacial, W Norway.*				
9	Værdalen	Nor 9		Kvarstein, Nor.	
				Hesselby	
				Vallby	
				Espanola	
				Manitoba	
10	Trondheim	» 8		Vå:ö	Vålarö
				Sl.	Slattefors
				Ho.	Hovertorp

Measurers, mainly G. De Geer, confer p. 251.

Dating of ice-recession in Finland.

	Finland year	Time scale year
From localities measured by M. Sauramo.		
Haapajärvi Church	+1112?	-136?
Ikaalinen, Riitila, 129	645	640
Jämijärvi, 128	614	671
Ikaalinen, Luhalahti, 121	592	693
Hämeenkyrö, Osara, 120	592	693
Kyrokoski, 118	+ 554	-728
Mouhijärvi, Hyynila, 114	514	768
Hämeenkyrö, Sirkkala, 109	464	829
Toijala	292	950
Vampula	411	848
Viiala Station	253	947
Somerniemi	214	1033
Sysmä, 22	120	1126
Lepaa, 24	106	1140
Hauho, 15	103	1143
Joensuu Electr.	85	1163
Vanaja, 72	38	1210
Temporary zero of Finland	± 0	1248
Heinäjoki, Kinnari, 68	-29	1277
Heinäjoki, 67	89	1337
Anianpelto, 61	189	1437
Leppäkoski, 65	200	1448
Launonen, 64	202	1450
Ruuhijärvi, 59	220	1468
Nastola, Immilä, 57	238	1486
Tiilola, 48	700	1970
Kuuru, Tiilola, 47	700	1979
Ridasjärvi, Sykäri, 46	751	2022
Jokela, 49	779	2050
Orimattila, Kuivanto, 21	787	2064
Jatila, 41	845	2124
Grevnäs, Mörskom, 11	1174	2450
Hivisaari, Vuoksela, 6	—	2849
Noisniemi, Vuoksela, 4	—	2897
Saijanjoki, 3 km S from Kiviniemi, 3	—	2960
Vammelsuu, railway bridge, 2	—	3112
Malaja Lavriki, River Ochta, 1	—	3162
Åland localities measured by E. Nilsson, 1924.		
Ödkarby, Saltvik	—	-847
Djäkneböle	—	864
Finby, Sund	—	869
Ängsbäck, Lemland	—	912
Åbo localities measured by H. Backlund, 1920.		
E. of former observatory	—	-966
E. of the town	—	980
Tammerfors localities measured by J. Sederholm, 1911.		
On the Loukko Market-place	—	-982
At the Firestation	—	983
Sjundeå localities measured by R. Tappan, 1907.		
Purnus, 1 km NE of Sjundeå	—	-1906
Sjundeå parsonage	—	1909

Summary of glacial melt-sediments or varves of annually rhythmic structure.

	Transport character	Material	Denomination	Order of magnitude	Recessional form	Stationary form
coarser	**Submarginal deposits.**					
	ultraproximal — proximal	cobbles gravel sand	annual ose centres	decametres	isolated ose-hills and radial ridges of successive hills or annual centra (concentrated deposition in narrow ice-vault)	
	Extramarginal deposits.					
	proximal	coarse sand sand	current-ridges	m		transverse plurennic oses or rand-deltas and transverse perennic marginal terraces
finer			varves proper			
	proximal	sand silt clay	bottom- or proximal varves	dm	extensive fans with shingle-like overlapping registering ice-recession	
	semidistal—distal	silt clay	ordinary semidistal and distal varves	cm		
	ultradistal	clay	microdistal and ultra-distal varves	mm		

Localities as to centuries of the Time Scale.

+2000 — ±0.

R a g u n d a

+2000 — +1800	17 Barksandsravin 16 Hammarstrand 15 Vikbäcksterrass	+1800 — +1700	17 Barksandsravin 16 Hammarstrand 15 Vikbäcksterrass 2 Vikbäcken A	+1700 — +1600	17 Barksandsravin 15 Vikbäcksterrass 3 Vikbäcken C 2 » A	+1600 — +1400	15 Vikbäcksterrass 3 Vikbäcken C 2 » A

	E. Afr.	*Can.*	*Nor.*	Ragunda *E. Jl.*	*Ång.*		*Vb.*
+1400 —+1300		5 Timiskaming		15 Vikb. terrass 2 » A	15 Resele 14 Omnäs		
+1300 —+1200		5 »		15 Vikb. terrass 14 Pålgårdsravin 2 Vikb. A	15 Resele 14 Omnäs		
+1200 —+1100		5 »		14 Pålgårdsravin 2 Vikb. A	15 Resele 14 Omnäs		
+1100 —+1000		5 »		14 Pålgårdsravin 13 Remmarna			
+1000 —+ 900		5 »	4 Sogn, Moen	14 Pålgårdsravin 13 Remmarna 12 Gevågsbäcken			
+ 900 —+ 800		5 »	4 »	14 Pålgårdsravin 13 Remmarna 12 Gevågsbäcken			13 Överedet 12 Strömbacka
+ 800 —+ 700		5 »	4 »	9 Kopparkällan			13 Överedet 12 Strömbacka
+ 700 —+ 600		5 »	4 »	10 Krokvåg			13 Överedet 12 Strömbacka
+ 600 —+ 500		5 »	4 »	8a Döviken 10 Krokvåg		*La.* 1 Gaskeluokt, Storuman	6 Kusfors 5 Strycksele 3 Juksån 1 Degerön
+ 500 —+ 400		5 »	4 »	8a Döviken = Cald. 35			6 Kusfors 5 Strycksele 3 Juksån 1 Degerön
+ 400 —+ 300		5 » 4 Haileybury	4 »	8a Döviken			5 Strycksele 3 Juksån 1 Degerön
+ 300 —+ 200		5 Timiskaming 4 Haileybury	4 »	8a Döviken			1 Degerön
+ 200 —+ 100	2 Makalia Riv.	5 Timiskaming 4 Haileybury	4 »	8a Döviken		*Me* 2 Sundsvall *micro*	1 Degerön
+ 100 —± 0	2 Makalia Riv.	5 Timiskaming 4 Haileybury	4 »	*W. Jl.* 16 Fogelberget 18 Ström, Klöva		2 Sundsvall *micro* 1 Indal *micro*	1 Degerön

Continuation, p. 264.

The Swedish provinces

(Fig. 63)

in Norrland

Lappland	Ångermanland	Medelpad
Norrbotten	Jämtland	Hälsingland
Västerbotten	Härjedalen	Gästrikland

in Svealand

Dalarna	Västmanland	Uppland
Värmland	Närke	Södermanland

in Götaland

Bohuslän	Dalsland	Östergötland
Halland	Västergötland	Gotland
Skåne	Småland	Öland
	Blekinge	

Abbreviations, see p. 249.
Confer pp. 250—265.

Scale 1:10 000 000 0 100 200 300 km

Fig. 63. Plan of Swedish Provinces.

	E. Afr.	*Can.*	*Nor.*	*W. Jl.*
± 0 — -100	2 Makalia Riv.	5 Timiskaming 4 Haileybury	4 Sogn, Moen (7 Randsfjord Fluberg)	16 Fågelberget
-100 — -200		5 Timiskaming 4 Haileybury	4 Sogn	12 Vålbacken
-200 — -300		5 Timiskaming 4 Haileybury 3 Espanola	4 Sogn	12 Vålbacken 11 Frösön
-300 — -400		5 Timiskaming 4 Haileybury 3 Espanola	4 Sogn	11 Frösön
-400 — -500	1 Enderit Riv.	5 Timiskaming 3 Espanola	4 Sogn	15 Ytterolden 11 Frösön
-500 — -600	1 Enderit Riv.	5 Timiskaming 3 Espanola	(8 a Tönset) (8 b Elvedalen) 6 Jesseim 4 Sogn	15 Ytterolden 12 Vålbacken 10 Järpen
-600 — -700		3 Espanola	4 Sogn	12 Vålbacken
	Arg.	*U. S. A.*	*Can.*	*Nor.*
-700 — -800			3 Espanola	4 Sogn 5 Oslo
-800 — -900	1 Lago Corintos		3 Espanola	4 Sogn
-900 — -1000	1 Lago Cor.		3 Espanola 2 Sudbury	4 Sogn
-1000 — -1100	1 Lago Cor.	1 Essex J-n	2 Sudbury	7 Værdalen 4 Sogn
-1100 — -1200	1 Lago Cor.	1 Essex J-n	*Him.* 2 Biano	4 Sogn 3 Kvarstein
-1200 — -1300		*Can.* 1 Toronto	2 Biano 1 Sesko	3 Kvarstein
-1300 — -1400			1 Sesko	3 Kvarstein
-1450 — -1510 -1870 — -1914		 6 Manitoba		6 Trondheim 7 Værdalen

— 1400

E. Jl.	*Ång.*	*Me.*	*Da.*	*Hl.*	*Gl.*
8a Döviken = Cald. 35	12 Sand 1 Gåsnäs	7 Indal			
2 Vikbäcken A	12 Sand 1 Gåsnäs	7 Indal	12 Mora		
2 Vikbäcken A	12 Sand 1 Gåsnäs	7 Indal	12 Mora	63 Edsbyn 125 Bollnäs *micro* 20 Koldemo »	Sth *mi.*
	4 Viksjö	7 Indal 5 Högom	12 Mora	63 Edsbyn 125 Bollnäs *micro*	4 Iris 2a Haga N
Fin. 4 Kristinestad 3 Isojoki 5 Iisalmi	4 Viksjö	7 Indal 5 Högom	11 Hälgnäs 10 Backe 9 Falun tegbr. 6 Gustafs	52 Dellen 4 Berga 2 Holmsveden 54 Helsingtuna *micro*	13 Ockelbo 11 Ockelbo Sth *mi.* 1a Haga N 2b Haga N 3 Sundbyberg
5 Iisalmi			10 Backa 9 Falun tegbr. 6 Gustafs 5 Hedemora 6 Smedjebacken 3 Krylbo 2 Avesta	40 Gnarp 54 Helsingtuna *micro*	9 Ockelbo 7 Ockelbo 5 Åbyfors 6 Råhällan
			5 Hedemora 4 Smedjebacken 3 Krylbo 2 Avesta		*Up.* R, S, T Sth *mi.* 1b Haga N
W. Jl.	*Vl.*	*Vsl.*	*Up.*	*Da.*	
13 Gråsjöån 6 Duved Tgb. 5 » Staa 4 Bunnerviken	7 Lindförs 6 Arvika	10 Sala 8 Livsdalen 7 Malingsbo 6 Virsbo	31 Gimo 30 Örbyhus 27 Runhällen 26 Uppsala 25 Bergsbrunna O, P, Q	2 Avesta	Sth *mi.* 1c Haga N
	8 Brattfors	10 Sala 6 Virsbo 5 Ramnäs 4 Surahammar	27 Runhällen 26 Uppsala 25 Bergsbrunna		*Fin.* 2 Åbo
	Vl. mi 1 Säffle	*Sth* Medium	7 Munsö 5 Kungshatt H, I, J, K, L	*Sl.* 50 Selaö	2 Åbo
		Medium	5 Kungshatt *Sl.* 41 Spårtorp 40 Vagnhärad	2 Lina	1 Leppäkoski
		Medium	*Ög.* 1 Finspong	3 Södertelje 2 Lina 1 Vagnhärad	1 Leppäkoski
			Vg. 2 Mariesjö 1 Korsberga	1 Vagnhärad	1 Leppäkoski
			2 Mariesjö 1 Korsberga		1 Leppäkoski
				Sl. 10 Vålarö *Ög.* 2 Slattefors 3 Hovertorp	

Divisions Stockholm—Uppsala—Gävle 1905.

T

	Lövlund	Berget	Nöttö	Nybo by	Åbyfors	Hagaström	Sandby	Sandby	Vestland	Älvkarleby	Åsbyggeby	Rörberg	Tierp Sld	Med.
	15	6	5 a	14	7	8	4	3	Up 36	2	10	9	Up 34	
—580					12	4				14	7		17	11
581					18	5				19	12		18	15
582					18	18				23	12		24	19
583					14	12				20	9		20	15
584					20	22				26	13		35	21
585					12	15				18	9		24	15
586					16	15				30	10		24	20
587					28	26			16	43	18		30	29
588					16	16			14	20	10		18	16
589			22		16	19			14	20	11		25	21
590			30		25	36			26	30	20		27	28
591		32	25		17	15			18	24	10		23	21
592		45	60		22	25			23	42	15		23	35
593		40	55		16	20			23	41	12		27	31
594		76	34		27	31			19	25	18		22	39
595	55	61	40		35	30			25	25	20		24	35
596	48	58	40		20	26			21	28	16		18	31
597	58	110	45		26	27			25	33	20		27	44
598	49	124	43		22	15			23	27	17		24	28
599	70	130	57		35	26			34	40	30		28	41
600	100	124	48		36	28			32	39	25		32	46
601	40	35	39		24	16			18	20	17		34	28
602	30	30	40		24	16			21	22	17		30	25
603	56	67	52		41	32			29	28	32		40	43
604	▽	52	42	19	34	30			23	27	25		29	31
605		520	42	25	32	28	24		24	32	26		38	33
606		640	52	29	31	25	35		25	25	23		36	24
607		40	54	28	70	38	31		26	30	28		42	40
608		▽	45	27	33	30	30		18	20	27	18	34	30
609			60	16	42	46	35		36	33	37	25	38	29
610			30	24	45	57	40		36	34	42	38	51	43
611			50	28	41	—	37		—	42	40	25	40	34
612			40	56	84	55	53		36	32		23	61	58
613			35	22	40	45	50	42	27	—		13	50	42
614			53	18	26	47	40	40	42	—		15	55	34
615			25	20	60	66	51	57	32	—		20	72	48
616			▽	▽	20	42	33	35	28	—		17	50	32
617					—	84	60	60	29	—		35	43	58
618					—	87	50	46	43	52		37	70	55
619					—	56	35	38	38	38		25	48	36
620					—	—	36	35	43	42		30	56	40
621					▽	▽	62	62	44	64		35	63	33
622							47	68	37	45		63	45	46
623							56	37	23	—		64	48	56
624							—	108	36	—		47	48	108
625							▽	65	25	—		80	66	65
626								▽	37	▽		37	50	
627									46			37	39	
628									45			57	50	
629									42			122	36	
630									▽			▽	43	

S

	Strömsberg	Hemmingsbo 2	Hemmingsbo 1	Norrby	Rocknö	Söderby	Med.
	8	7	6	5	4	3	
627	22						22
628	36	9					21
629	37	7		9			18
—630	43	13		32			29
631	26	13		24			21
632	32	7		44			38
633	39	12		185			79
634	32	13		44	6		24
635	37	9		31	8		21
636	40	10		33	11		24
637	35	18		17	6		19
638	52	18		8	10		27
639	21	12		8	8		12
640	73	55		21	10		40
641	49	26		17	6		24
642	9	35		48	8		30
643	▽	36	29	41	10		39
644		31	20	48	8		33
645		23	14	47	14		29
646		31	46	56	9		44
647		29	34	35	9	36	33
648		35	32	20	10	28	27
649		59	48	63	18	42	46
—650		—	52	126	12	38	34
651		▽	36	53	22	30	32
652			35	29	9	36	33
653			32	26	12	34	30
654			25	41	13	47	34
655			▽	57	11	44	39
656				53	11	19	37
657				64	13	44	41
658				42	13	50	28
659				48	14	23	31
660				36	13	49	25
661				6	16	6	
662				▽	10	8	
663					62	48	
664					▽	64	
665						10	
666						35	
667						10	
668						114	
669						45	
—670						6	
						▽	

	S					R											Q						Med.		
	Hemmingsbo 1	Norrby	Rocknö	Söderby	Tierp stn	Vallby	Ryan	St. Bultebo	L. Bultebo	Gåvastbo	Klingsbo	Ruvelsbo	Tobo stn	Hals	Tierp stn	Skämsta	Björnboda		Trollrike	Österväga	Örbyhus stn	Kråkbo			
	6	5	4	3	1 b	8	7	6	5	4	3	2	1	Sl c	Sl b	Sl a	7 b	7 a	6	5	3 c	1	S	R	Q
—650	52	126	12	38																			34		
	36	53	22	30																			32		
	35	29	9	36																			33		
	32	26	12	34																			30		
	25	41	13	47																			34		
	▽	57	11	44																			39		
		53	11	19																			37		
		64	13	44																			41		
		42	13	50																			28		
		48	14	23																			31		
660		36	13	49																			25		
		6	16	6	24										24								20		
		▽	10	8	15									58	15								15		
			62	48	18									81	18								18	50	
			▽	64	77									70	77								70	73	
				10	35									68	35								23	67	
				35	19			17						64	19								27	33	
				10	18			16						48	18								14	27	
				114	48			21						70	48								80	40	
				45	33			15						68	33								39	31	
670				6	30			17						72	30									40	
				▽	33			30						89	33									50	
					39			29						65	39									44	
					19			15						41	19									25	
					21			20						56	21									32	
					46			21						115	46									60	
					69			24	12					75	69									45	
					156			26	16					102	156									75	
					26			27	20					97										48	
					78			25	15	19				55										28	
680					88			30	17	21				121										23	
					177			32	19	15				78		57								40	
					▽	149		36	24	26		19	26	▽		138								(60)	
						150	53	23	23	25		17	23			115								(51)	
						56	24	27	14	20		30	27			80								40	
						77	37	34	18	20		23	25			79		27			27	26		34	27
						237	79	15	32	34		35	34			110		26			32	31		75	30
						70	58	28	19	20	12	22	20			62		22			20	18		37	20
						38	51	25	16	16	16	19	18			42		18			19	15		26	17
						89	39	38	29	36	31	36	29			▽		36			27	26		41	30
690						106	39	34	26	30	27	24	24					23			20	17		40	21
						167	56	38	25	27	29	28	24					28			27	23		50	26
						96	39	33	22	19	26	26	20					23			21	18		35	21
						286	63	47	35	16	16	18	14					33		16	38	28		62	32
						30	31	36	25	14	27	24	21				19	22		12	21	20		26	19
						▽	79	33	49	22	21	20	23				17	19		14	18	16		35	17
							70	34	43	39	34	34	36				31	29		27	25	20		41	26
							76	6	42	30	23	19	14				27	29		20	27	25		30	26
							▽	▽	4	38	35	27	22				24	27	28	24	24	26		25	25
—699									▽	32	27	28	27				20	23	24	14	22	20		29	20

	R				Q									P								Med.		
	Gåvastbo	Klingsbo	Ruvelsbo	Tobo stn	Björnboda		Trollrike	Östervåga	Mensta	Örbyhus stn	Berg	Skinnarbo	Kråkbo	Knypplan stn	Knypplan 1	Mangsbo	Lisbo	Jerlebo	Sillbo	Danboda	Fäboda			
	4	3	2	1	7 b	7 a	6	5	4	3 c	3 a	2	1	9	8	6	5	4	3	2	1	R	Q	P
—700	41	31	29	27	19	21	28	20		17			16									43	20	
	34	22	19	24	22	25	29	22		23			21									25	24	
	6	27	21	19	22	20	26	19		18			18									24	20	
	▽	22	28	25	54	30	34	28		26		20	20									27	30	
		26	25	24	42	20	34	31		20		18	20									25	26	
		37	35	35	21	30	22	20		27		30	25									35	22	
		77	42	40	27	26	28	22		23		23	22									41	24	
		▽	27	31	32	31	35	25		34		30	31									29	31	
			37	20	25	23	21	19		20		19	18										21	
			32	32	38	37	35	21		25		25	22										29	
710			44	15	29	29	31	25		21		23	22										26	
			54		46	46	45	28	24	22		18	20										41	
			▽		52	50	33	24	35	28		26	27										40	
					60	58	41	30	28	25		38	35										42	
					47	46	50	35	34	18		18	19										30	
							45	30	43	24		20	20										27	
							40	20	22	24	28	30	29										27	
							88	31	28	19	28	16	18										17	
							30	30	28	22	18	20	23										22	
							▽	29	39	19	22	21	23										25	
720								44	37	24	33	20	27	33	19	12							31	21
								41	20	19	23	19	22	18	16	14							24	16
								36	30	32	36	25	33	18	9	21							31	16
								32	43	40	45	22	32	32	24	13							36	28
								26	34	27	35	19	22	21	16	17							27	18
								†	42	31	50	16	20	12	10	8	8						18	9
									37	25	33	23	25	21	16	12	11						24	15
									45	23	33	18	24	23	13	10	8						21	13
									55	30	28	14	16	17	11	11	14						15	13
									62	40	24	20	22	19	19	16	17						36	18
730									26	47	46	26	29	16	22	25	25						37	24
									16	27	37	24	24	20	18	14	17						28	16
									▽	28	24	24	21	19	21	13	15						23	16
										▽	32	21	21	12	20	15	17						21	16
											41	24	24	14	21	14	14						30	14
											33	33	33	14	22	23	20						33	19
											▽	30	20	11	15	21	14							15
												▽	21	37	22	27	20		17	16				20
													▽	—	20	19	12		10	10				14
														▽	32	18	16		16	15				20
740															43	24	20		5	16				22
															99	19	19		15	14				17
															▽	14	14	13	13	12				13
																16	15	9	13	10				14
																15	15	14	17	11				13
																12	12	15	12	12				19
																20	20	20	19	19				20
																25	19	22	22	12	20			16
																16	15	20	18	13	14			20
—749																21	17	23	24	15	18			20

	P						O									N		Med.		
	Mangsbo	Lisbo	Jerlebo	Sillbo	Danboda	Fäboda	Skyttorp		Åsby	Karskulla	Björkhammar	Salsta	Vattholma stn	Vattholma bruk	Stenby	Kårbo	Björk			
	6	5	4	3	2	1	9b	9a	8	7	6	5	4	3	2	7	6	P	O	N
—750	25	18	20	21	16	18												20		
	23	22	16	18	11	14												16		
	22	15	19	24	15	16												19		
	35	24	22	24	15	16												23		
	44	16	22	28	17	18												20		
	▽	29	38	35	21	22												29		
		28	36	34	22	23												29		
		28	23	31	19	18												24		
		32	31	35	21	21												27		
		▽	26	29	33	21												25		
760			16	40	24	21												26		
			▽	42	22	22												32		
				57	18	33												45		
				44	21	27					24							35		
				33	15	21	14			24	29							23	24	
				43	22	22	16			34	27							29	30	
				35	16	21	19			21	14							24	17	
				143	32	29	30			34	22							68	29	
				62	34	29	28			23	20							31	24	
				▽	20	34	35	25		25	42							34	28	
770					▽	57	42	37		39	22							51	39	
						29	26	29		23	33							29	26	
						43	35	32		34	42								36	
						▽	27	29	26	26	28		20						26	
							26	23	26	21	38	24	18						23	
							33	33	30	28	27	36	27						30	
							31	33	28	25	22	20	23						27	
							47	41	43	41	37	31	37						40	
							31	27	27	21	32	18	14						24	
							42	36	34	32	44	34	27						35	
780							19	25	23	23	28	34	15						22	
							49	46	41	40	31	15	33	23					33	
							43	44	36	39	48	15	28	17	23				39	
								44	31	28	17	17	20	25	30				28	
								130	45	45	40	41	23	37	23				52	
								24	48	40	41	45	25	22	23				37	
								▽	49	44	42	43	39	34	20				42	
									36	30	37	35	25	34	23		28		33	28
									40	40	25	42	30	45	35		31		39	31
									30	20	21	29	21	41	34	24	22		28	23
790									27	21	23	25	16	31	23	23	21		24	22
									25	32	47	26	24	32	25	26	26		30	26
									156	56	32	40	41	38	21	20	20		66	20
									▽	60	43	28	30	25	21	16	18		36	17
										89	59	50	30	23	17	19	22		45	20
										118	51	30	20	25	20	19	20		29	16
										▽	97	296	52	29	28	24	24		36	24
											140	▽	59	29	35	32	31		47	31
											▽		38	38	32	29	30		35	30
—799													32	41	40	62	39		40	50
													▽							

	O		N													M	
	Vattholma bruk	Stenby	Kårbo	Björk	Årby	Storvreta	Storvreta	Fullerö	Fullerö	Hemringe							Med.
	3	2	7	6	5	4 b	4 a	3	2	1 e	1 c	1 b	1 a	M 7		7	
−800	60	61	51	48													50
	123	47	42	35													39
	▽	36	30	30													30
		49	41	35													38
		—	62	50													56
		▽	55	47													51
			39	33													36
			41	39													40
			79	61	46												62
			90	51	43												47
810			86	42	31												53
			43	29	23												32
			65	36	34												45
			60	48	42												50
			▽	46	32												39
				60	43												51
				64	51												57
				54	42												48
				65	52												58
				62	47			56									54
820				69	48			46									58
				100	66			55									74
				79	43	63		40									49
				▽	39	61		41		47							47
					39	51		30		50							40
					19	18		16		34							22
					71	75	69	54		46							61
					37	39	32	39		42							39
					61	59	53	49		51							55
					55	56	53	43		40							49
830					86	107	72	64		66							79
					92	137	115	60		51							115
					8	135	110	53		74							99
					▽	174	146	57		76	90						126
							110	44		71	73						77
							194	61		71	65						127
							172	69		42	86						42
							113	53		51	72						72
							86	51		44	56						68
							169	78		31	58						44
840							26	87		80	89						84
							▽	103		72	60						78
								90	103	57	91	56					83
								104	126	52	89	64					89
								120	160	115	143	76					123
								224	156		95	50		52		52	115
								76	192		157	78		53		53	107
								96	107		72	44	52	27		27	66
									144		69	42	38	24		24	63
−849									266		127	102	87	59		51	128

	N				M							L								K			Med.			
	Fullerö	Hemringe			Bredåker	Råby	Vaksala	Årstad	Norrby	Säby	Villinge	Berga		Bergsbrunna gård	Söderby		Orrslätt		Vrå	Knivsta tgbr.	Trunsta	Gredelby				
	2	1 b	1 a	M 7	7	6	5	4	3	2	1	9 b	9 a	8	7 b	7 a	6 b	6 a	1	9	8	7	N	M	L	K
−850	207	109	97	74	74																		130	77		
	207	106	109	79	79																		92	79		
	▽	94	85	33	33																		70	33		
		113	107	52	52																		90	52		
			110	52	52						13												110	32		
			113	69	69	63					44												91	59		
			68	47	47	45	40				9												51	37		
			87	90	90	72	51				59												88	65		
				65	65	20	37			23	29	29	27											35	28	
				70	70	35	33			22	19	19	29											36	24	
860				99	99	55	33			35	36	35	44											52	40	
					59	45	27			19	19	19	37											34	28	
					▽	42	22			10	13	12	18											22	15	
						42	36			9	8	8	10											24	9	
						55	56			23	16	16	13											38	15	
						30	43			11	10	10	10											23	10	
						40	23			23	25	24	22											29	23	
						96	44	41	39	24	23	23	22											32	23	
						▽	69	24	24	23	24	66	26											24	26	
							35	45	39	36	34	34	31											39	32	
870							61	27	50	36	25	25	36											40	30	
							45	21	25	17	14	14	17											24	15	
							58	89	59	44	48	48	52											60	50	
							68	57	29	20	19	20	23											31	21	
							▽	56	33	35	28	28	66	12			14							38	20	
								66	52	34	39	39	46	17	18		16							45	25	
								▽	73	49	37	37	34	25	27		20							53	31	
									44	20	15	15	14	21	18		29							26	17	
									43	22	17	17	24	20	23		7							27	21	
									▽	20	25	25	40	19	15		17							25	28	
880										23	22	22	23	16	12		15							22	18	
										36	23	23	28	16	14		14							29	20	
										65	55	55	98	89	67	53	6							60	64	
										10	54	54	107	68	80	58	51							32	73	
										▽	81		67	39	35	30	40								43	
											67		61	43	28	31	17								41	
											8		79	56	43	39	13								60	
											▽		119	66	58	57	30				5				66	
													84	46	33	30	20			26	18				43	22
													47	61	47	42	22			19	14				43	16
890													▽	105	73	70	38	46		60	39				71	50
														115	84	86	66	40		70	34				88	32
														82	45	42	31	31		15	12				46	13
														118		73	65	66		45	45				80	45
														24		147	78	58		36	34				68	35
														▽		53	96	93		28	25				94	26
																88	64	52	46	30	24				54	27
																79	68	60	47	96	78				58	87
																32		114	60	127	89	72			87	96
−899																▽		146	61	106	79	72			61	85
																		▽								

	L	K									J											I			Med.		
	Vrå	Knivsta tgbr	Trunsta	Gredelby	Knivsta stn	Knivsta kyrka	Kråklund	Forsby	Svartsjön	Pasta	Skönsta	Tollsta	Rohlsta	Arnberga	Märsta		Brista	Gustafsberg	Norrsunda	Rosersberg stn		Valstanäs 3	Valstanäs 1	St. Wäsby 3			
	1	9	8	7	6	5	4	3	2	1	9	8	7	6	5¹	5	4	3	2	1	I6	10	8	6	K	J	I
—900	26	57	56	45																					53		
	23	39	39	27		28	28																		32		
	49	36	25	24		16	17																		24		
	67	81	19	51	46	52	52																		56		
	69	86	61	56	41	39	83																		61		
	36	48	27	39	30	14	15																		29		
	28	27	26	23	20	23	14																		22		
	46	117	67	76	68	41	27																		66		
	67	50	41	50	30	18	13																		34		
	▽	114	65	74	53	33	25																		61		
910		109	79	80	55	47	34																		67		
		90	85	88	32	30	23	30	15																41		
		154	23	50	73	20	18	22	33																22		
		161	▽	86	103	44	29	37	45																86		
		▽		17	70	55	47	45	44																52		
				▽	83	61	68	57	56		26	10													65	26	
					▽	33	19	34	36		30	13													31	21	
						53	54	25	22	33	62	15	68												26	48	
						68	55	28	42	37	53	11	20												36	28	
						29	81	38	49	53	46	18	28												55	23	
920						63	75	56	43	66	60	33	42												59	45	
						81	72	89	47	65	56	27	35												71	39	
						69	60	34	39	64	73	40	43												53	52	
						15	35	34	39	65	66	26	36												46	43	
						▽	▽	84	69	95	82	38	41												83	54	
								83	42	110	89	39	48	26											96	51	
								19	▽	115	115	12	49	32			24								67	40	
								▽		▽	—	36	32	26			18									29	
											▽	14	37	47			15									42	
												49	66	59			29									51	
930												201	85	58			27									57	
												—	65	56			21									47	
												▽	78	138		73	26									79	
													175	112	21	159	30									117	
													195	179	19	110	58									103	
													▽		83	184	45									133	
															53	142	50									97	
															38	126	55			52	16					82	
															112	340	120	75		50	14					162	
															85		59	38		25	13					44	
940															134		95	53		36	18		15	18		67	16
															99		119	65		37	21		19	21		60	20
															▽		99	50		22	13		17	13		46	15
																	220	55	49	20	4		22	4		32	13
																	▽	123	43	31	14		30	14		53	22
																		77	56	39	18		27	18		38	22
																		162	35	27	7		19	7		23	13
																		326	72	51	10	17	31	10		44	20
																		▽	98	62	8	17	11	8		80	12
—949																			89	65	14	40	6	14		65	27
																			— ▽								

	J		I										H																	Med.		
	Rosersberg stn		Valstanäs 3	Valstanäs 2	Valstanäs 1	St. Wäsby 3	St. Wäsby 2	St. Wäsby 1	Väsby stn 2	Väsby stn 1	Edsby	Elvsunda			Sollentuna	Överby	Rävgärdet	Skälby 2		Norrviken stn	Pommern	Skålby 1		Malmbacken	Skansen	Tureberg	Håreby	Kummelby 2	Kummelby 1			
	1	I 6	10	8a	8	6	5b	5a	5	4	3	1	2b	15	12	11	10	9	8b	8^4	7^4	7	5^2	5	4^3	4^2	3	2b	2a	J	I	H
—950	126	10	25		10	10														9			5							68	15	7
	79	11	40		11	11														12			5							45	21	8
	140	7	20	11	7	7														16			6							73	1'5	11
	247	36	62	25	24	36														44			29							36	37	37
	91	21	68	15	17	21														17	8		7							21	30	11
	75	13	85	10	15	13														29	17		17							44	31	21
	▽	▽	100	15	14	14														26	10		10								36	18
			134	28	32	15														22	17		18	8							52	15
			224	66	72	39													50	50	12		37	22							100	33
			92	28	34	16													19	29	28		18	15							42	19
960			124	75	74	33													36	44	13		38	33							76	36
			160	100	103	31													21	37	7		29	25							101	25
			—	52	63	43													28	40	7		21	21							58	23
			▽	106	108	44													38	51	22		11	13							86	24
				53	75	31		40			43								35	50	9		24	19							48	30
				119	77	48		48			36								18	33	25		14	16							65	18
				113	58	40		51			20								36	45	16		14	17							56	27
				81	45	80	69	80			21								23	41	13		25	30							63	27
				144	89	125	81	120			41								22	41	22		21								100	28
				144	76	79	60	76			18								20	44	9		15	21							75	18
970				85	44	126	42	52			22									47	17		8	5							62	7
				▽	▽	119	76	109			21									62	29		25	13							81	18
						73	128	123		59	79	19								29	23		34	39							97	34
							62	65		36	29	35								54	26		25	27							48	25
							74	73		87	35	25								51	20		23	20							67	23
							178	▽		82	42	22								25	19		26	27							81	27
							260		64	172	47	36								61	22		25	24							(116)	23
							130		57	122	30	26								77	16		24	25							73	37
							168		89	250	26	25				27				88	23		24	26							169	49
							▽		58	59	61	55				21				106	17	52	24	24							58	59
980									116	131	83	140	32			58		26		79	23	32	20	18							117	34
									112	267	67	72	39			52		27		139	23	30	45	26							150	57
									92	122	64	72	39			35		23		81	29	32	27	20							76	36
									210	▽	120	127	60	34	36	34	27	35		112	19	22	56	53							152	56
									160		140	109	35	19	44	36	15	24			92	34	50	46							134	34
											159	124	44	40	40	36	43	54			89	27	52	54	58			38			91	77
											177	90	43	32	22	19	30	51			—	42	31	27	62			44			133	63
											130	43	69	30	57	64	47	58			—	27	104	102	47			35			86	71
											▽	85	65	18	46	22	31	45			—	75	81	55	102			55			85	49
												100	124	80	101	71	44	91			—	57		178	67	75		37			108	110
990												40	109	61	70	70	39	74			—	111		101	91	121		51			40	69
												142	102	78	92	73	39	177			▽	165		159	34	183		74			142	111
												10	107	101	135	128	78	75				106		192	103	147	63	68			10	126
													129	66	103	77	41	86				162			91	103	52	40				86
													312	56	97	212	121	105				166			52	79	67	49				120
														83	115	108	91	109				127			91	138	96	92	104			65
														45	▽	147	309	111							151	98	191	133	117			104
														52		196	116	61							▽	130	327	222	157			147
																▽	217	106								156	144	143	120			156
—999																	91	▽								▽	—					91
																	—										—					
																	▽										—					

	H			G																Med.	
	Häreby	Kummelby 2	Kummelby 1	Åkeshov	Äppelviken	Haga, Linvävartorp	Hagalund tunnel	Frescati	Valhallavgn 70	Idrottsparken	Ljudar Lake	K. Biblioteket	Sundbyberg lok.	Hammarby Lake	Danviken	Drottningg. 92	Hägerstens tgbr., brickyard	Neglinge stn	Lina		
	3	2 b	2 a	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	H	G
—1000	398	144	134		12	15	27			24			20				13			225	20
	17	105	102		9	14	22			10			18				14			178	15
		226	212		8	18	15			29			19				12			219	22
		228	171		13	15	16	22		28			7				10			200	16
		▽	116		27	27	38	46		18			19				14			116	14
			▽		21	17	33	35		28			23				18				23
					25	41	28	39		23			21				22				28
					15	20	12	20		11			8				18				15
					33	23	23	39		26			18				29				27
					20	27	27	43	21	28		16	28			16	16				25
1010					11	25	11	28	17	16		13	21			8	15				17
					65	55	45	52	24	29		24	36			15	14				38
					29	—	52	60	35	40		30	52			25	17				39
					38	—	30	30	13	13		10	20			15	17				18
					35	—	33	36	23	25		13	22			25	25				23
					66	▽	24	27	17	16		17	21			52	38				21
					32		32	34	22	24		14	28			13	17				28
					57		41	61	42	38		34	35			17	16				38
					42		29	29	31	36		27	27			14	12				27
					33		29	39	29	28		25	17			18	16				26
1020					51		51	43	32	36		24	16			33	39				41
							57	83	56	56		49	41			22	23				57
							58	59	31	30		19	30			23	26				38
							15	16	10	7		7	11			13	15				12
							31	30	14	20		15	19		43	39	20				26
							—	82	49	50		45	100		56	81	35				62
							—	104	41	40		31	68		30	25	17				36
				48			—	82	43	44		40	76		33	33	32				43
				49			—	220	65	51		49	62		41	40	35		15		58
				61			—	—	65	55		60	83	30	56	63	37		26		54
1030				63			—	—	26	32		25	64	22	28	33	26		14		33
				109			—	—	47	38		62	81	34	45	65	38		4		58
				64			—	▽	80	65		75	88	43	90	81	39		7		63
				59			▽		64	61		60	67	36	37	59	26		4		47
				76					37	45		49	65	36	46	68	24		8		43
				54					52	50		45	77	27	39	40	19		12		39
				159					79	92		92	—	79	110	—	90		25		91
				98					—	—		84	—	47	52	—	33		7		53
				56					—	—		91	▽	70	76	—	24		13		62
				74					—	—		78		38	50	—	51		12		45
1040				106					—	—	46	91		34	51	—	33		15		55
				149					▽	—	100	—		70	86	—	63		11		94
				40						▽	83	—		30	32	—	14		8		54
				155							85	▽		70	114	—	84		9		80
				102							86			43	55	—	45		25		25
				162							inverted 97			90	110	—	57		16		16
				—							157			63	54	▽	25		14		85
				△							115			103	105		75		7		61
											135			54	75		41	6	11		73
—1049											112			192	190		107	9	10		61

	G						F																	E					Med.		
	Ljudar Lake	Hammarby Lake	Danviken	Hägersten tgbr., brickyard	Neglinge stn	Lina	Nyboda tunnel	Elvsjö SW^{I}	Elvsjö SW^{II}	Kiholm	Vårby	Huddinge^{II}	Huddinge^{I}	Tyresö skans	Örby gård	Elvsjö stn	Örby Vst.	Bäcken torp	Gökdalen	Magelungen	Fagersjö	Lina	Vagnhärad	Marieberg	Södertörns Vst.	Örby Vst.	Bäcken torp	Gökdalen			
	9	6	5	3	2	1	9	12	11	20	19	18	17	16	7	6	5	4	3	2	1	22	21	10	9	F 5	F 4	F 3	G	F	E
—1050	123	188	85	37	4	12	118																						114		
	89	356	165	134	8	32	156																						176		
	117	276	200	144	20	48	192																						120		
	77	188	160	56	8	20	38																						71		
	—	187	215	107	11	20	33																						68		
	▽	156	175	115	6	34	95																						55		
		153	▽	77	12	31	86		24		110											30							50	50	
		173		70	6	16	50		18		68							34				17							11	48	
		—		▽	6	20	46	22	12		42							25				17							13	22	
		—			8	21	83	26	26		122							26				25							15	44	
1060		▽			16	50	183	50	138		178							44				53							33	90	
							82	32	116		80							28				13								60	
							▽	45	112		128							25				26								67	
								40	80		85				79			8				10								51	
								84	104		109				138			12				33								60	
								55	72		70				48			9				32								48	
								58	46		186				61	71		10				40								68	
								86	104		218				87	99		9				74								85	
								54	36		94		25		38	30		16				41								42	
								56	42		106	34	33		45	40		19				39								38	
1070								82	70		134	90	57		84	79	34	20				82								73	
								45	64		144	76	32		89	78	31	18				62								64	
								30	30	16	60	22	20		37	59	23	16				24								31	
								44	30	30	29	30	23		—	59	26	32				36	18							32	
								24	26	23	25	21	20		▽	32	22	18				24	9							22	
								46	30	24	22	22	20			35	30	20				27	25							30	
								57	36	30	30	58	29			36	39	26				34	19							36	
								37	26	36	24	22	16			27	23	20				20	14							21	
								47	42	27	28	38	30			32	28	30				33	15							30	
								34	40	25	47	41	28			—	38	37				33	17							22	
1080								—	30	28	21	16	16			▽	34	22			19	21	10							20	
								▽	42	47	43	32	27				—	36			52	34	18							40	
									32	44	28	27	16				▽	38			25	24	22							28	
									▽	63	79	48	32	28				31	46		43	33	18							46	
										53	22	28	26	22				45	38	45	32	28	21							32	
																								E 10	9	F 3	F 2	F 1			
										39	—	26	23	18				50	37	33	28	24	6				33	28		22	30
										42	126	28	23	27				—	43	37	31	25	14				37	31		40	34
										32	152	48	32	27				▽	—	40	35	24	18			43	40	35		45	39
										36	68	35	27	31					35	34	30	31	22			35	34	30		25	33
										33	34	22	13	20					25	23	17	19	9	28	15	25	23	17		23	22
1090										61	78	29	20	29					43	33	30	28	21	48	28	43	33	30		47	36
										—	90	39	25	30					38	26	25	28	16	30	26	38	26	25		35	29
										▽	72	39	21	25					48	39	32	30	14	30	29	48	39	32		35	36
											32	28	17	21					22	30	17	14	13	16	17	22	30	17		21	20
											58	38	26	30					46	31	26	27	14	29	23	46	31	26		33	25
											108	76	27	27					47	33	35	33	15	34	37	47	33	35		44	35
											64	50	16	19					—	25	21	20	14	21	21	F 16	25	21		30	22
												—	15	39					▽	57	36	35	18	35	40	33	57	36		33	42
												▽	37	40						39	38	39	17	40	39	39	39	38		34	39
—1099													18	15						35	19	16	15	16	14	15	35	19		14	21

	F					E										Med.	
	Huddinge[1]	Tyresö	Fagersjö	Lina	Vagnhärad	Marieberg	Södertörns Vst.	Forssen	Magelungen	Beateberg	Ängsnäs	Länna	Tyresö skans	Magelungen	Fagersjö		
	17	16	1	22	21	10	9	8	7	6	5	4	F 16	F 2	F 1	F	E
—1100	41	33	38	37	17	38	39	37					33	35	38	37	36
	40	34	39	38	8	39	29	31			30		34	26	39	38	32
	43	35	32	31	20	34	27	29			28		35	—	32	35	30
	16	12	12	13	19	12	43	11			11		12	▽	12	14	12
	13	8	8	10	18	9	36	8			8		8		8	11	8
	8	41	46	36	23	40	34	33			46		41		46	31	39
	—	33	35	39	13	42	40	35			35		33		35	30	37
	—	—	—	—	—	38	16	34			28		32		27		33
	▽	—	—	—	—	21	20	17			10		10		—		16
		+	▽	—		26	21	20			17		22		▽		21
1110				—		29	23	22			9		18				21
				—		40	52	36			52		18				45
				—		43	15	45			14		13				29
				—		47	55	37			74		12				53
				—		29	23	16			15		10				21
				▽		7	28	46		28	26		28				32
						▽	37	21	59	17	10						16
							▽	30	51	52	31						38
								19	28	11	31						22
								77	77	50	36						60
1120								48	53	74	26						50
								81	25	27	36						32
								▽	53	78	40	63					58
									55	99	33	38					56
									84	91	45	88					77
									39	18	7	8					18
									41	31	22	48					35
									31	29	25	27					28
									105	52	71	103					83
									▽	98	24	28					26
1130										▽	63	54					58
											72	65					68
											82	89					85
											58	71					36
											▽	85					
												—					
												▽					
1140																	
—1149																	

Main Time Scale.

	Hammarstrand (Ragunda) E. Jl. 16	Barksandsravin (Ragunda) 17	Med. Scand.
+2000	3	5	(4)
+1999	5	1	(3)
	3	1	2
	2	2	2
	2	4	3
	5	7	6
	4	4	4
	3	3	3
	3	2	3
	1	2	2
1990	3	4	4
	5	6	6
	3	1	2
	6	4	5
	5	2	4
	4	2	3
	4	3	4
	6	5	6
	6	3	5
	4	3	4
1980	3	3	3
	1	3	2
	5	5	5
	4	2	3
	3	2	3
	5	4	5
	5	2	2
	3	5	4
	1	4	3
	2	5	4
1970	3	6	5
	5	9	7
	3	8	6
	1	3	2
	1	5	3
	5	10	8
	1	9	5
	1	5	3
	1	5	3
	5	8	7
1960	2	7	5
	1	4	1
	3	2	3
	1	3	2
	7	10	9
	4	4	4
		7	
	2	8	5
	4	11	8
	6	16	11
+1950	2	4	3

	Ragunda Vikb. 29 E. Jl 15	Hammarstrand 16	Barksandsravin 17	Med. Scand.
+1949		3	4	4
		4	10	7
		3	6	9
			10	(5)
		2	5	(4)
		3	5	(4)
		2	11	(7)
		3	14	(9)
		4	5	5
1940		2	5	4
		3	8	3
		2	10	2
		2	7	2
		5	4	5
		4	8	6
		2	5	4
	9	3	9	6
	7	5	17	5
	10	7	9	8
1930	12	6	7	7
	10	3	7	5
	7	4	16	10
	22	2	10	6
	13	4	12	7
	17	1	4	5
	20	4	6	5
	32	3	4	13
	30	16	9	18
	6	2	2	3
1920	9	1	5	5
	15	4	8	9
	31	9	22	21
	17	7	7	10
	9	5	25	7
	21	5	21	16
	30	4	16	23
	8	5	3	5
	20	7	15	18
	37	4	16	19
1910	6	3	10	6
	7	3	5	5
	12	10	19	14
	6	4	8	6
	10	3	5	4
	25	3	6	5
	10	6	10	8
	9	2	3	6
	13	4	3	4
	12	5	5	5
+1900	21	4	4	4

	Vikb. 29 E. Jl. 15	Hammarstrand 16	Barksandsravin 17	Med. Scand.
+1889	6	4	4	5
	10	5	6	7
	17	9	7	11
	9	3		3
	8	7	7	7
	11	4	5	5
	11	3	10	7
	11	10	15	8
		4	7	6
1890	26	5	5	13
	26	6	8	20
	22	5	10	12
	10	3	5	8
	6	6	5	6
	15	4	7	9
	9	3	7	6
	11	11	21	14
	5	4	11	7
	6	9	13	11
1880	5	12	22	17
	10	2	7	5
	11	2	5	4
	4	4	6	5
	3	5	9	7
	4	15	4	10
	2	2	6	3
	4	16	19	13
	5	4	5	5
	3	4	8	5
1870	7	11	24	14
	5	6	14	10
	4	7	7	6
	4	3	8	6
	4	4	6	5
	4	3		4
	4	3	5	4
	5	3	8	5
	7	6	10	4
	4	5	9	5
1860	3	4	10	4
	5	3	6	4
	6	5	5	6
	6	3	5	4
	8	3	4	4
	5	4	6	5
	5	5	7	6
	6	3	8	6
	6	4	15	8
	10	5	17	14
+1850	4	7	7	6

	Vikb. 29 E. Jl. 15	Hammarstrand 16	Barksandsravin 17	Med. Scand.
+1849	5	5	7	6
	4	3	4	2
	5	2	7	5
	11	4	10	7
	10	6	17	11
	7	4	3	5
	6	5	5	6
	5	5	6	6
	7	6	11	9
1840	9	5	8	7
	6	3	5	5
	11	7	13	10
	7	4	9	7
	21	9	17	16
	9	5	9	8
	6	6	10	7
	11	7	16	11
	6	3	6	5
	7	5	5	6
1830	10	7	13	10
	6	4	5	5
	5	3	6	5
	7	5	6	9
	6	7	10	9
	10	5	8	7
	9	4	7	6
	12	5	7	6
	10	7	11	9
	25	14	20	20
1820	10	4	9	11
	10	5	7	7
	5	5	6	5
	8	6	8	7
	6	7	8	8
	8	5	6	6
	5	4	5	5
	11	5	9	8
	16	12	21	13
	22	15	21	19
1810	10	9	12	10
	11	8	13	11
	13	6	3	7
	16	6	5	9
	10	4	4	6
	13	8	6	9
	6	6	8	7
	9	5	7	7
	10	9	9	9
	25	13	9	16
+1800	14	8	5	9

	Ragunda Vikb. 29 E. Jl. 15	Barksandsravin 17	Hammarstrand 16	Med. Scand.		Vikb. A E. Jl. 2	Vikb. 29 15	Vikb. B 17	Med. Scand.		Vikb. A E. Jl. 2	Vikb. C 3	Vikb. 29 15	Vikb. B 17	Med. Scand.		Vikb. A E. Jl. 2	Vikb. C 3	Vikb. 29 15	Vikb. B 17	Med. Scand.
+1799	15	14	19	16	+1749		9	6	8	+1699	9	19	22	25	19	+1649	5	24	31	12	18
	26	21	25	24			11	9	10		4	15	16	15	13		5	15	5	7	8
	12	10	15	11			16	13	15		5	14	12	14	11			7	7		7
	22	12	9	14			9	6	8		10	44	30	31	29			9	14		(12)
	16	14	9	13			11	10	11		2	9	5	12	7		4	12	13		(10)
	20	10	16	23			4	5	5		4	10	19	17	13		3		15		(9)
	16	14	12	15			6	7	7		4	16	20	14	17		5	9	11	8	8
	10	12	14	11			9	5	(7)		9	12	19	10	15		6	15	41	20	21
	25	15	16	20		2	6	7	5		5	6	20	12	(11)		4	9	21	12	12
1790	6	13	20	(13)	1740	2	10	10	7	1690	5	10	13	12	6	1640	3	8	10	11	8
	9	8	17	(11)		4	14	11	10		5	18	11	31	8		5	19	20	18	14
	11	23	9	(14)		6	16	9	16		9	8	17	20	13		3	8	11	10	8
	16	5	8	(10)		4	12	11	9		4	6	13	17	10		2	5	10	6	6
	11	5	6	(7)			10	7	9		6	6	15	20	14		2	6	10	7	7
	8	5	10	(8)		5	8	6	6			9	12	11	11		2	6	6	8	5
	12	7	12	10		3	5	5	4		13	43	33	19	27		3	11	16	13	11
	10	6	10	9		4	8	9	7		5	17	18	12	13		2	6	16	12	9
	6	6	9	7		6	6	9	7		7	16	19	12	14		3	6	16	11	11
	13	7	12	13		9	18	12	13		9	21	21	11	13		3	10	25	16	17
1780	9	10	10	6	1730	4	12	11	4	1680	5	11	12	21	12	1630	4	6	15	9	8
	7	5	7	6			8	9	(9)		7	14	16	25	16		3	7	13	10	8
	13	7	14	14		4	8		6		3	8	6	20	4		4	11	19	13	12
	7	10	11	9		6	19	15	13		3	9	11	16	8		3	9	11	8	8
		30		30		5	15	9	10		5	11	16	15	(12)		5	15	28	15	16
	15	10	10	12		4	8	10	6		4	13	9	20	12		3	9	11	10	8
	16	4	6	3		5	11	9	8		9	20	16	23	17		2	6	10	5	6
	13	5	10	12		5	10	8	8		6	16	29	22	15		2	6	16	8	8
	6	6	8	7		4	10	12	9		8	21	15	18	16		1	5	12	6	6
	11	7	12	10		5	8	11	8		3	13	18	10	9		6	18	20	14	10
1770	16	9	12	12	1720	9	24	17	17	1670	11	35	10	11	23	1620	3	10	15	11	6
	9	8	11	14			16	10	13		10	22	25	17	(19)		3	6	17	9	9
	20	10	20	17		5	18	20	12		5	24	22	8	(15)		4	9	14	7	8
	25	16	30	17		9	26	21	12		4	15	27	15	15		1	7	9	6	6
	7	10		9		5	17	11	11			6		9	8		2	15	13	7	9
	6	5		6		5	20	17	14		4	10	13	12	20		2	10	22	17	12
	3	5		4		7	31	29	22		5	19	28	13	16		2	5	10	6	6
	9	7		8		14	44	45	34				5	11	8		4		20	10	11
	5	10		8		10	15	20	15		3	12	14	11	10		2	4	10	6	6
	9	10		10		5	11	15	10		11	39	33	30	21		2	4	9	7	6
1760	10	10		10	1710	7	17	14	13	1660	3	10	11	15	10	1610	2	7	11	9	7
	6	7		7		10	28	17	18		3	11	12	10	9		5	10	16	11	11
	15	8		12		5	17	10	11		4	11	13	11	12		3	6	9	10	7
	20	3		17		9	27	17	17		5	5	9	10	7		2	6	10	10	7
	7	17		7		6	16	11	9		5	7	15	10	9		4	12	15	19	12
	10	10		10		4	20	9	7		11	32	49	26	29		6	26	29	21	21
	20	5		18		10	14	18	14		2	13	18	8	10		5	8	16	13	10
	8	3		6		7	15	15	7		2	9	12	9	8		2	5	11	12	7
	8	6		7			11	23	17			12	9	10	10		1	5	9	10	5
	5	5		5		10	33	45	29			10	17		(14)		4	7	5	11	7
+1750	5	8		7	+1700	14	45	48	36	+1650	4	12	15	11	11	+1600	2	5	15	11	6

	Vikb. A E. Jl. 2	Vikb. C 3	Vikb. 29 15	Med. Scand.
+1599	5	8	7	7
	4	17	6	11
	2	6	11	4
	2	8	9	5
	3	7	20	5
	2	6	12	4
	5	10	15	8
	2	8	18	5
	2	8	22	5
1590	5	15	14	10
	4	8	17	6
	3	6	12	5
	5	11	8	8
	4	9	14	9
	5	16	16	12
	3	11	6	7
	4	12	11	9
	4	7	10	9
	3	16	25	16
1580	40		25	(33)
	10	30		10
	5	13	42	9
	5	13	20	13
	6	15	20	14
	10	35	56	34
	4	7	11	7
	4	9	11	8
	5	24	20	16
	4	10	15	10
1570	4	6	12	7
	6	18	16	13
	11	30	27	23
	4	7	14	8
	4	10	19	11
	4	8	19	8
	5		16	(11)
	6	14	5	(10)
	5	19	15	(17)
	5	12	18	(15)
1560	5	12	14	(13)
	6	10	14	12
	6	13	13	13
	5	17	19	14
	7	21	19	16
	6	23	28	19
	3	16	18	12
	4	12	23	13
	12	59	45	39
	6	10	27	14
+1550	4	7	19	10

	Vikb. A E. Jl. 2	Vikb. C 3	Vikb. 29 15	Med. Scand.
+1549	5	13	21	13
	13	50	39	34
	6	17	20	14
	6		21	14
	2	15	18	9
	4	16	14	17
	9	32	33	25
	7	22	35	21
	9	27	45	27
1540	11	45	50	35
	3	13	11	9
	2	7	5	6
		8	7	8
	2	7	6	5
	3	11	9	7
	2	7	9	9
	2	8	7	6
		5	5	5
	3	7	9	6
1530	3	7	7	6
	2	6	5	4
	4	10	7	7
		6	7	7
		7	9	8
	3	7	6	5
	1	6	12	4
	3	10	4	7
	1	8	5	5
	2	7	7	5
1520	5	15	11	10
	6	15	17	13
	2	10	7	6
	3	12	10	8
	4	6	6	6
	4	5	5	5
	2	7	8	8
	1	6	8	4
	4	9	5	7
	2	8	8	6
1510	2	8	8	6
	4	7	8	6
	5	14	11	10
		10	6	8
	4	19	14	12
	2	6	9	6
	2	7	8	6
	4	12	10	9
	5	20	21	15
	2	8	13	8
+1500	3	10	13	9

	Vikb. A E. Jl. 2	Vikb. C 3	Vikb. 29 15	Med. Scand.
+1499	3	7	11	7
	5	11	12	9
	2	5	7	5
	5	6	7	6
	2	8	4	5
	9	43	25	26
	3	5	6	5
	4	10	7	7
	2	9	6	6
1490	5	16	11	11
	4	9	6	6
	7	7	14	9
	3	8	6	6
	4	9	6	6
	3	5	5	4
	2	5	3	3
	4	8	3	5
	4	9	13	4
	5	11	9	8
1480	5	8	6	6
	7	21	11	13
	3	12	9	8
	4	8	6	7
	4	10	8	9
	4	8	5	7
	3	12	7	7
	12	37	23	24
	3	8	7	6
	2	8	4	5
1470	4	10	8	7
	3	6	3	4
	2	6	3	4
	3		6	5
	2	9	5	4
	2	8	3	3
	3	7	8	5
	4	7	4	5
	2	6	4	4
	5	15	14	11
1460	5	14	10	10
	3	6	2	4
	2	5	3	3
	3	6	2	5
	3	7	4	5
	4	9	4	6
	2	6	3	4
	2	5	5	2
		6	4	
		6	6	
+1450	2	7	9	5

	Vikb. A E. Jl. 2	Vikb. C 3	Vikb. 29 15	Med. Scand.
+1449	4	11	6	8
	4	7	4	6
	2	5	6	4
	4	6	5	5
	4	6	5	5
	4	9	7	6
	7	26	14	12
	4	7	8	6
		5	6	6
1440	3	5	5	4
	3	5	5	4
	7	15	11	11
	2	5	5	4
	5	7	5	6
	2	7	5	5
	2	7	4	6
	4	7	3	5
	4	7	4	5
	9	24	13	15
1430	2	12	7	12
	3		6	5
	3	9	7	10
	9	35	8	17
	3	11	2	6
	5	11	2	6
	6	10	4	5
	3	13	3	3
	2	13	2	6
	3	16	4	8
1420	5	17	5	9
	6	29	7	14
	8	12	6	
	6		9	9
	5	13	8	7
	5	22	10	12
	9	24	11	15
	2	7	8	6
	3	8	10	7
	2	7	8	6
1410	6	31	11	16
		8	6	
	5	16	5	9
	10	24	21	18
	3	10	6	6
	5	8	6	6
	6	13	13	11
	3	11	11	8
	2	7	6	5
	3	12	9	8
+1400	5	20	9	13

	Ragunda Vikb. A E. Jl. 2	Vikb.-terrassen 15	Resele Ång. 14 a	Omnäs 14 b	Med. Scand.
+1399	2	5	10	4	4
	2	3	28	23	3
	2	4	10	8	4
	8	15	11	8	11
	1	5	6	5	4
	3	6	8	6	5
	2	10	5	7	7
	4	7	5	3	5
	4	5	16	9	5
1390	4	6	5	5	5
	3	6	41	22	18
	2	4	13	6	6
	3	4	15	8	6
	5	8	12	6	7
	2	5	7	5	6
	6	9	85	21	30
	3	4	7	3	4
	3	6	11	7	7
	3	10	26	13	16
1380	4	7	22	12	14
	3	5	4	2	4
	3	9	18	10	12
	3	8	12	5	7
	2	6	8	2	3
	4	9	4	3	7
	5	7	2	4	6
	4	10	3	5	8
	4	6	5	4	5
	4	9	7	5	7
1370	5	6	5	6	6
	4	6	46	18	32
	3	7	23	10	17
	5	5	7	9	6
	4	6	10	6	5
	5	8	5	6	6
	4	9	35	12	13
	3	8	6	5	5
	5	4	11	8	7
	5	6	4	6	5
1360	10	15	7	8	10
	5	7	7	3	5
	9	4	4	6	6
	3	9	3	3	5
	4	10	3	4	6
	3	9	4	3	5
	4	6	10	3	5
	5	9	6	3	7
	6	7	10	6	7
	9	12	28	20	17
+1350	5	11	18	12	12

	Timiskaming Can. 5	Vikb. A E. Jl. 2	Vikb.-terrassen 15	Resele Ång. 14 a	Omnäs 14 b	Med. Scand.
+1349		9	14	2	3	12
		5	12	3	5	9
		4	10	6	5	6
		7	15	16	8	12
		6	11	5	3	6
		4	10	10	7	10
		2	6	6	4	5
		9	11	7	5	8
		6	9	5	4	5
1340		6	6	4	6	5
		9	4	17	40	22
		8	4	10	8	6
		7	8	8	6	7
		6	11	11	11	11
		6	10	8	7	8
		6	15	29	12	19
		11	13	7	2	(8)
		8	10	8	6	7
		7	10	4	5	6
1330		12	9	7	7	7
		9	7	13	5	8
		6	9	25	9	11
		8	7	17	4	7
		4	10	6	4	10
		5	11	15	8	(13)
		5	19	13	6	(16)
		3	21	8	6	(12)
		4	11	16	9	(15)
		5	9	5	5	(6)
1320		4	12	24	12	13
	8	9	7	4	6	6
	4	14	11	16	7	14
	5	4	7	3	12	5
	8	7	10	38	12	17
	6	5	5	3	5	5
	4	4	7	28	14	6
	7	9	9	2	2	9
	10	13	11	3	3	12
	7	6	7	21	3	14
1310	7	3	11	8	12	8
	8	5	6	4	5	5
	11	7	7	6	4	6
	4	7	15	7	3	8
	5	23	23	4	10	19
	6	6	15	5	6	11
	7	5	6	12	8	7
	9	2	15	2	10	6
	9	5	12	7	1	6
	10	6	15	2	2	6
+1300	10	9	20	5	4	9

	Timiskaming Can. 5	Ragunda Vikb. A E. Jl. 2	Pålgårdsravin Vikb. 29 14	Resele Ång. 14 a	Omnäs 14 b	Med. Scand.
+1299	8	5	15	2	4	4
	11	12	12	5	5	7
	13	13	25	7	8	13
	9	7	15	2	3	7
	12	23	35	6	3	17
	8	6	13	4	5	7
	8	7	12	3	3	6
	15	12	17	22	10	15
	11	3	8	3	5	5
1290	11	5	15	3	5	10
	10	4	8	10	8	6
	9	3	10	9	7	7
	8	6	13	2	4	10
	7	5	10	3	3	8
	8	6	15	4	3	11
	8	7	12	11	7	10
	10	7	12	8	7	10
	12	9	22	6	5	11
	8	7	9	5	6	7
1280	12	24	36	10	7	19
	13	7	13	2	2	6
	13	15	28	3	2	12
	17	20	30	5	5	15
	11	12	17	3	2	8
	14	16	27	7	7	16
	16	11	5	4	4	6
	12	44	9	5	5	18
	15	9	8	16	13	20
	14	2	20	15	8	14
1270	12	2	12	6	4	6
	15	22	14	7	5	12
	14	6	11	4	3	6
	17	5	12	5	4	6
	14	12	13	14	7	12
	19	10	18	9	7	11
	25	8	23	10	9	14
	23	10	18	7	6	10
	24	2	21	25	14	15
	23	3	19	5	3	9
1260	24	2	24	7	4	5
	22	2	28	5	2	2
	33	19	13	5	5	19
	22	4	19	30	12	19
	23	2	23	6	5	15
	19	3	15	4	6	10
	23	2	19	8	5	11
	25	3	22	42	15	26
	22	28	16	7	2	17
	13	7	11	5	4	8
+1250	17	7	8	4	6	6

	Timiskaming Can. 5	Vikb. A E. Jl. 2	Pålgårdsravin 14	Resele Ång. 14 a	Omnäs 14 b	Med. Scand.
+1249	14	11	21	5	6	12
	11	7	7	3	6	6
	10	8	9	6	6	7
	11	8	9	5	4	6
	11	9	30	6	6	13
	9	5	16	2	4	7
	9	11	16	12	8	12
	15	4	13	5	5	3
	13	5	37	5	5	3
1240	12	6	9	7	6	9
	11	9	10	13	11	11
	8	4	9	9	6	6
	6	16	7	12	9	12
	13	10	9	6	3	10
	10	6	48	5	5	5
	16	8		6	6	5
	14	9		5	6	9
	9	4	5	11	7	7
	10	4	7	12	10	9
1230	9	4	11	2	4	3
	10	2	20	2	2	9
	8	6	30	6	5	12
	11	3	17	2	5	7
	14	6	23	7	8	12
	8	3	13	4	4	6
	7	7	21	7	7	12
	9	6	19	9	6	11
	8	8	13	3	4	7
	10	7	15	4	5	10
1220	9	12	12	6	5	12
	10	2	12	6	7	7
	10	2	20	5	7	9
	7	1	18	4	3	6
	6	3	33	20	8	20
	6	8	24	6	6	12
	7	8	26	7	6	13
	8	5	18	5	5	9
	10	9	13	7	7	9
	7	14	6	5	5	6
1210	8	10	15	3	5	10
	9	6	13	3	2	6
	11	7	17	60	8	25
	9	4	21	6	5	5
	8		12	8	9	9
	9		15	6	6	6
	9	5	16	7	5	6
	9	12		7	6	8
	15	2		2	5	
	9	3		5	4	
+1200	11	3		3	4	

	Timiskaming Can. 5	Ragunda Vikb. E. Jl. 2	St. Pålgårdsravin 14	Resele Ång. 14 a	Omnäs 14 b	Med. Scand.
+1199	7	5	$\frac{1}{1}$ 16	3	4	7
	8	8	17	4	6	9
	5	6	9	4	4	4
	6	5	18	4	5	
	8	5	11	3	6	
	9	29	12	6	5	8
	9	8	16	13	9	13
	8	2	12	4	5	6
	4	4	20	13	9	12
1190	5	5	17	5	5	11
	5	8	19	4	4	9
	4	11	22	15	10	15
	4	6	24	3	3	9
	9	9	21	15	7	13
	8	4	22	4	3	10
	9	6	17	2	3	11
	13	5	21	6	6	11
	12	9	15	5	6	9
	10	12	12	2	2	5
1180	13	12	25	7	5	12
	10	14	12	3	3	3
	12	5	11	7	6	8
	10	7	12	2	2	6
	14	16	20	3	3	10
	13	12	26	2	4	12
	11	9	24	5	4	6
	13	8	14	10	10	9
	12	5	28	6	5	5
	20	73	12	13	12	33
1170	12	9	28	1	2	4
	10	10	12	2	3	6
	13	4	36	12	7	18
	10	5	36	2	2	
	9	7	11	6	2	
	8	10	11	7	7	10
	14	15	14	6	6	15
	11	13	30	7	7	19
	13	41	20 ↑	24	14	33
	10	13	21 $\frac{1}{1}$	3		13
1160	13	8	54	2		5
	15	57		6		31
	10	32		4		18
	13	267		6		137
	10	11	29 $\frac{1}{2}$	3		14
	11	13	30 ↓	5		16
	13	15	75	6		32
	13	7	22	8		12
	11	5	16	6		11
	18	4	16	7		10
+1150	16	14	38	5		26

	Timiskaming Can. 5	Ragunda Vikb. A E. Jl. 2	St. Pålgårdsravin 14	Resele Ång. 14 a	Med. Scand.
+1149	17	7	$\frac{1}{2}$ 22	6	15
	16	16	45	6	30
	17		15	7	
	15	7	6	7	7
	17	13	33	5	23
	16	9	31	8	24
	16	8	21	4	11
	15	5	13	2	7
	19	7	19	8	11
1140	15	6	15	3	8
	16	22	55	4	27
	19	10	32	2	21
	16	9	23	2	26
	16		7	2	5
	17	7	11	3	7
	17	7	18	5	8
	12	5	8	6	7
	13	7	14	4	11
	15	8	17		13
1130	20	7	15		11
	17	10	26		18
	22	13	31		22
	21	9	12		11
	20	13	7		10
	22	24	80		24
	25		7		7
	27	9	7		7
		6	17		17
	19	5	11		8
1120	19	6	16		11
	15	8	19		14
	17	5	12		9
	19	5	12		9
	22	5	14		5
	25	8	14		8
	19	6	15		6
	23	9	16		9
	26	↓ 26	10		18
	29	15 80	35		58
1110	20	Remmarna 18	5		11
	20	30	19		25
	19	27	13		20
	16	37	10		28
	18	39	11		25
	20	34	7		21
	22	54	9		31
	23	54	9		31
	17	21	10		16
	22	25	5		15
+1100	21	26	9		18

	Timiskaming Can. 5	Ragunda Remmarna E. Jl. 13	Pålgårdsravin 14	Med. Scand.
+1099	20	16	5	11
	24	34	6	20
	15	35	20	28
	23	25	9	17
	21	30	5	18
	27	61	12	42
	21		4	4
	25	19	6	19
	21	21	10	21
1090	15	13	29	13
	22	25	28	25
	20	24	50	24
	18	27	10	19
	19	24	15	20
	20	21	17	19
	19	14	10	14
	24	18	7	7
	18	28	5	5
	19		38	38
1080	16	9	4	7
	23	10	6	8
	20	17	6	17
	19	16	40	28
	23	15	6	11
	20	20	20	20
	25	16	16	16
	26	11	16	14
	20	16	16	16
	19	20	2	11
1070	22	25	5	15
	22	21	4	21
	20	9	10	9
	25	21	7	14
	25	23	15	19
	22	18	10½	14
	27	34		34
	23	19		19
	18	55		
	26	39		39
1060	22	25		25
	23			
	19	22		22
	23	42		42
	23	28		28
	16	39		
	31	30		
	25	26		
	19	98		
	24	43		
+1050	23	22		

	Timiskaming Can. 5	Ragunda Remmarna E. Jl. 13
+1049	14	21
	24	51
	24	88
	19	38
	22	46
	29	26
	22	65
	23	107
	20	41
1040	22	46
	22	37
	23	39
	23	38
	28	52
	23	25
	19	18
	22	35
	19	34
	21	10
1030	18	24
	14	25
	28	38
	21	20
	23	14
	30	55
	18	9
	22	29
	28	31
	22	10
1020	18	29
	27	25
	22	50
	16	31
	18	40
	20	41
	21	24
	31	15
	19	24
	21	5
1010	19	10
	18	10
	22	24
	20	10
	23	55
	23	7
	19	7
	17	10
	27	16
	20	18
+1000	26	11

	Timiskaming Can. 5	Gevågsbäcken E. Jl. 12	Remmarna 13	Med. Scand.
+999	30		35	35
	26		8	8
	20		5	
	16		97	
	19		70	
	25		26	
	30		7	7
	27		19	19
	16		5	5
990	23		7	7
	20		5	5
	28		51	51
	16		49	
	20		5	
	17		32	
	23		4	
	20		6	6
	19		6	6
	30		8	8
980	19	70	7	7
	22	26	9	
	23	7	19	
	23	90	17	54
	20	101	26	64
	23	36	10	23
	33	17	5	16
	28	30	8	
	22	32	4	
	26	12	11	
970	22	6	16	
	24	11	6	9
	20	28	19	24
	19	20	10	10
	17	175		
	27	103		
		65		
		11		
		18	15	17
	33	90	77	84
960	29	16	5	11
	39	90	68	79
	30	19	13	16
	15	80	57	69
	39	15	9	12
	26	188	141	165
	28	37	11	24
	40	43	20	32
	25	30	20	25
	26	50	22	36
+950	31	29	17	(23)

	Timiskaming Can. 5	Sogn Moen Nor. 4	Gevågsbäcken E. Jl. 12	Remmarna 13	Med. Scand.
+949	15		19	10	
	19		26	11	19
	35		26	11	19
	27		18	10	12
	34		49	19	34
	25		40	19	
	22		47	14	
	25		16	9	
	23	¼ 23	18	12	
940	23	↓ 11	23	14	
	20	16	25	9	21
	10	13	14	8	14
	7	33	29	8	19
	9	21	68	9	68
	6	37	27	20	24
	8	28	75	34	55
	10	66	7	20	
	7	25	9	12	
	8	17	75	23	
930	7	13	102	56	
	11	1/1 26	18	6	26
	11	↓ 18	15	6	18
	7	12	75	25 E. Jl. 14	12
	7	12	17	2	12
	9	41	18	3	41
	9	23	24	7	23
	8	13	37	10	13
	9	34	12	4	
	8	37	17	5	
920	9	17	25	12	
	10	19	8	6	11
	10	28	12	6	17
	11	41	8	8	25
	8	26	10	5	14
	8	18	8	3	10
	12	15	61	20	32
	10	23	11	6	13
	8	16	8	7	12
	9	17	12	6	12
910	7	32	15	9	13
	9	27	18	11	19
	9	18	10	8	9
	9	28	7	7	7
	10		10	5	8
	12	19	55	20	25
	9	16	8	2	9
	9	18	3	2	3
	8	17	2	5	2
	9	18	3	5	3
+900	13	10	10	3	10

	Timiskaming Can. 5	Sogn Moen Nor. 4	Pålgårdsravin E. Jl. 14	Remmarna 13 a	Med. Scand.
+899	11	1/1 10	5	10	8
	9	9	4	5	6
	8	18	4	7	6
	9	17	6	13	10
	12	17	5	9	10
	11	7	4	7	6
	13	20	4	8	11
	15	29	4	9	14
	10	24	3	7	11
890	11	1/4 15	6	12	11
	9	13	4	8	6
	10	12	20	38	29
	12	18	5	12	12
	8	38	33	62	44
	10	20	3	5	9
	9	24	5	6	6
	9	70	4	3	4
	11	27	4	4	4
	9	14	62		
880	9	28	5		
	10	25	6	5	25
	12	34	4	2	34
	10	13	6	9	13
	12	18	7	5	18
	10	12	3	3	12
	6	11	6	6	11
	9	16	3	3	
	13	9	3	10	
	11	5	6	13	8
870	12	5	2	6	4
	9	24	2	2	9
	11	76	6	9	30
	10	45	3	5	4
	14	15	6	13	11
	13	7	3	7	6
	11	6	6	14	9
	14	4	2	10	5
	6	4	1	3	3
	11	6	2	4	4
860	10	4	3	5	5
	14	7	2	6	7
	9	5	3	5	4
	9	6	2	4	3
	12	4	3	6	4
	15	9	3	4	9
	11	5	4	6	5
	14	5	4	4	4
	19	9	5	6	7
	16	10	5	5	5
+850	14	5	8	17	10

	Timiskaming Can. 5	Sogn Moen Nor. 4	Pålgårdsravin E. Jl. 14	Pålgårdsravin 13 a	Strömbacka Vb. 12	Med. Scand.
+849	11	4	5	6		8
	10	7	5	7		6
	15	6	3	5		4
	13	15	3			3
	12	30	3	3		3
	12	6	4	5		5
	14	6	5	6		6
	12	8	4	4		5
	13	4	3	8		5
840	14	8	8	20		14
	13	22	4	9		7
	15	3	4	11		8
	11	5	2	4		4
	14	6	2	4		4
	15	5	3	5		5
	8	14	4	4		4
	9	4	6	7		7
	13	5	5	7		6
	11	4	7	10		9
830	18	5	5	5		5
	15	4	4	6		5
	11	7	4	3		4
	15	18	3	2		3
	16	6	2	6		5
	14	5	6	14		6
	13	6	4	15		5
	16	9	3	9		6
	19	12	5	5		5
	14	19	2	5		2
820	14	17	3	4		
	16	12	4			4
	16	26	5			5
	16	51	7			7.
	20	5	21			
	21	6	11			11
	11	19	4			4
	13	14	4			9
	15	28	5			17
	10	12	9			11
810	11	17	3			17
	9	54	2			
	15	44	3			24
	10	7	3			5
	14	1/1 18	4		19	14
	14	↓ 15	6		10	10
	14	18	3		12	15
	10	7	5		11	9
	10	11	3		14	13
	10	12	3		14	10
+800	15	23	4		9	14

	Timiskaming Can. 5	Sogn Moen Nor. 4	Kopparhällen E. Jl. 9	Strömbacka Vb. 12	Med. Scand.
+799	12	11		1/1 8	10
	10	16		↓ 9	12
	11	27		10	19
	9	14		6	10
	11	20		10	15
	10	16	5	4	8
	9	21	7	5	11
	10	19	4	4	9
	12	14	5	5	12
790	9	20	5	17	19
	11	17	5	5	9
	13	12	9	6	8
	7	15	9	6	8
	10	17	6	5	6
	9	12	8	14	11
	12	12	5	9	7
	13	16	3	12	8
	19	7	4	27	12
	15	8	3	97	8
780	17	12	3	60	12
	14	9	8	13	9
	13	8	5	33	15
	13	25	10	34	23
	19	19	3	31	18
	14	20	3	54	26
	15	12	2	11	8
	11	24	7	16	16
	11	11	3	21	7
	16	13	4	9	9
770	14	17	9	16	13
	16	18	3	1/4 5	18
	16	16	4	↓ 15	16
	10	15	5	6	11
	12	24	13	10	17
	13	42	4	20	31
	11	19	6	34	19
	13	21	3	17	21
	11	8	4	25	12
	14	15	6	21	14
760	13	13	2	8	8
	10	20	5	22	16
	8	20	7	26	18
	11	32	9	49	30
	15	27	6	13	20
	21	27	4	18	23
	20	15	4	12	14
	11	9	3	12	11
	20	9	2	52	31
	19	12	3	43	19
+750	15	17	4	49	23

	Timiskaming Can. 5	Sogn Moen Nor. 4	Kopparhällen E. Jl. 9	Strömbacka Vb. 12	Med. Scand.		Timiskaming Can. 5	Sogn Moen Nor. 4	Krokvåg E. Jl. 10	Strömbacka Vb. 12	Med. Scand.		Timiskaming Can. 5	Sogn Moen Nor. 4	Krokvåg E. Jl. 10	Med. Scand.
+749	10	12	5	5	9	+699	21	25	11	11	18	+649	27	7	5	6
	15	21	4	7			19	9	77	3	6		15	7	5	6
	19	10	3	10	10		19	10	35	4	16		10	15	13	14
	12	7	9	16	7		15	10	6	5	8		16	15	8	
	10	8	6	2	8		19	97	5	9	36		20	12	6	12
	15	14	3	8	14		20	17	9	3	3		16	7	8	8
	14	14	4	20	17		20	15	8	5	5		20	6	12	12
	16	25	3	28	27		16	30	7	2	19		20	6	11	11
	11	21	2	12	17		19	69	24	3	47		17	7	18	18
740	14	10	4	5	6	690	12	19	7	16	13	640	14	12	8	10
	18	10	4	10	8		13	11	3	2	7		20	16	46	31
	15	12	10	17	13		15	13	2	3	8		19	11	20	16
	21	14	13	29	19		19	18	4	2	11		14	9	3	6
	19	9	6	10	8		17	13	5	3	14		15	9	6	8
	12	16	7	10	13		20	15	9	3	12		19	7	3	
	14	23	6	23	23		11	15	9	5	17		19	17	4	
	9	12	8	10	12		10	15	6	3	11		18	6	16	
	18	26	9	6	26		14	19	15	2	12		23	10	6	
	13	19	10	11	19		17	16	9	2	9		23	7	2	
730	11	22	7	7	22	680	14	23	7	5	14	630	18	7	3	7
	19	37	5	7	37		18	9	10	3	7		19	12	2	7
	16	15	5	11	15		16	10	6	2	6		20	13	13	13
	12	12	5	12	9		21	17	13	14	15		20	7	2	9
	11	14	4	6	8		21	10	11	4	11		19	12	2	7
	12	12	5	6	8		17	12	49	2	21		18	13	6	10
	21	23	7	16	20		13	10	16	5	10		16	8	5	7
	16	24	5	20	22		21	13	10	2	8		18	7	10	10
	13	11	4	11	11		22	14	7	6	10		19	7	9	9
	15	15	5	16	16		15	8	9	4	6		16	9	3	6
720	11	12	5	4	8	670	17	11	5	3	6	620	21	12	5	9
	17	24	4	16	24		15	8	2	3	12		19	10	4	7
	16	30	4	14	30		22	12	2	3	8		21	24	10	17
	15	21	4	15	18		16	8	10	2	5		19	16	3	10
	13	16	5	4	8		17	11	2	4	6		16	9	2	6
	15	15	6	6	9		17	14	3	2	6		19	15	17	16
	13	35	11	14	20		16	17	4	5	11		24	18	15	17
	11	8	5	3	5		19	12	41	3	8		23	24	5	3
	15	16	6	3	11		22	11	5	2	7		20	20	2	11
	17	24	5	3	15		16	16		3	10		21	23	12	18
710	15	16	5	5	11	660	20	13		2	13	610	19	8	2	5
	11	35	7	5	20		19	11	2	5	6		20	13	2	8
	11	21	8	3	12		25	6	9	4	6		18	11	1	6
	19	26	7	13	20		16	5	5	3	4		21	22	4	14
	11	44	5	43	44		15	11		2	6		15	11	3	3
	12	21	5	6	14		20	25	23	5	18		17	9	12	11
	13	18	5	5	12		19	13	4	7	10		20	9	1	5
	15	66	4	19	19		18	13	4		13		23	14	2	8
	19		5	18	18		12	4	23		4		16	7	2	5
	15	30	7	5	14		17	5	12		5		21	13	9	11
+700	17	52	4	10	22	+650	22	13	9		11	+600	17	11	9	10

	Timiskaming	Sogn, Moen	Döviken	Krokvåg	Sirapsbacken	Med. Scand.
	Can. 5	Nor. 4	E. Jl. 8	10	Vb. 5	
+599		8		3		
		20				
		35				
	11	7		2		
	10	3		12		8
	10	4		7		6
	15	4		6		5
	12	3		5		4
	10	3		3		3
590	13	3		7		5
	18	7		20		14
	18	8		19		10
	14	9	9	10		
	14	11	16	7		17
	17	16	13	7		12
	11	8	8	5		10
	13	6	10	9		10
	15	5	20	9		15
	17	6	10	4		7
580	16	4	16	3		8
	20	10	45	13		29
	22	13	21	5		13
	18	11	15	4		15
	27	11	4	4	15	13
	23	14	5	3	27	21
	18	9	9	3	14	13
	18	10	4	5	33	16
	17	7	8	3	28	13
	20	9	14	7	30	15
570	21	8	29	24	31	16
	19	7	33	12	35	10
	25	9	21	15	31	19
	23	7	11	6	26	17
	23	6	11	3	30	18
	18	5	22	6	25	15
	25	8	16	5	35	22
	25	8	42	5	28	18
	21	9	16		26	18
	20	5	10		16	11
560	18	10			27	19
	19	6	60		25	16
	15	7	11		21	13
	16	8	11		26	12
	21	9	14		36	23
	19	7	21		18	23
	17	12	46		26	36
	21	12	9		18	
	21	9	7		25	
	19	5	10		34	5
+550	24	10	8		26	10

	Timiskaming	Sogn Moen	Döviken	Sirapsbacken	Med. Scand.
	Can. 5	Nor. 4	E. Jl. 8	Vb. 5	
+549	27	11	6	54	11
	21	9	6	46	9
	27	10	7	25	27
	25	10	9	19	25
	19	7	40		19
	21	10	10	25	21
	18	6	15	11	18
	22	11	14	9	
	17	32	54	13	
540	16	7	30	18	16
	19	13	10	14	19
	18	13	19	14	15
	21	12	33	16	20
	22	10	24	13	
	24	14	6	16	15
	21	21	5	17	19
	23	19	8	11	15
	21	31	14	14	20
	18	10	4	17	14
530	15	7	6	11	9
	17	14	4	14	14
	20	19	4	17	19
	19	5	7	19	
	18	6	41	13	6
	17	32	25	14	29
	16	9	16	18	13
	20	17	19	12	18
	18	6	10	15	8
	21	18	8	15	13
520	18	12	7	17	10
	15	11	23	12	17
	21	7	22	14	
	20	8	8	16	
	17	12	15	10	12
	15	8	16	12	8
	18	6	14	22	6
	20	21	7	16	21
	20	21	8	25	15
	19	18	15	15	17
510	16	8	7	12	9
	18	14	6	22	14
	16	10	5	29	15
	19	13	19	50	27
	15	18	25	20	22
	19	10	16	16	
	21	12	7	12	
	16	13	25	17	
	18	21	5	25	
	18	8	4	20	
+500	17	11	7	20	

	Timiskaming	Sogn Moen	Döviken	Degerön	Strycksele	Sirapsbacken	Kusfors	Med. Scand.
	Can. 5	Nor. 4	E. Jl. 8	Vb. 1	4	5	6	
+499	19	19	19	10	20	50		30
	25	22	6	30	18	19		11
	20	20	5	13	27	36		32
	21	9	10	21	22	25		24
	20	9	13	32	28	28		23
	21	14	10	40	47	17		26
	23	13	15	28	23	29		17
	20	20	7	30	↑ 22	39		20
	17	23	14	35	$\frac{1}{5}$ 28	26		25
490	20	17	9	23	11	18		15
	22	13	16	16	$\frac{1}{1}$ 48	25		26
	20	10	52	14	↓ 76	44		12
	15	13	5	21	43	37		—
	17	120	7	19	41	30		7
	22	11	4	12	35	40		4
	17	17	10	11	28	40		19
	18	14	9	12	40	55		21
	17	20	10	13	43	31		24
	22	24	3	10	59	27		25
480	20	11	4	22	58	30		37
	25	20	4	17	58	25		28
	20	23	5	17	45	27		31
	14	26	7	19	23	33		25
	20	20	15	21	27	14		21
	20	14	2	21	26	12	27 $\frac{1}{2}$	15
	17	22	3	33	36	15	35	31
	21	45	3	19	28	12	38	29
	15	18	11	15	26	11	40	23
	23	45	3	11	25	15	49	28
470	18	15	2	14	28	14	16	12
	17	11	2	9	32	12	20	9
	17	12	3	23	31	17	25	14
	22	18	5	20	30	23	18	16
	19	30	4	16	27	23	24	18
	20	14	6	13	32	23	22	19
	17	11	3	21	43	20	16	10
	19	14	6	18	49	15	25	23
	20	14	5	12	44	13	36	21
	14	10	5	15	35	16	34	16
460	14	18	22	18	28	20	25	20
	17	25	7	20	18	20	39	26
	20	15	9	15	28	14	20	16
	15	12	7	16	25	17	26	18
	17	15	10	24	22	28	32	25
	16	19	3	27	21	59	29	34
	24	7		21	22	25	15	27
	25	14		32	35	43	15	28
	26	11		22	19	24	12	17
	24	10		35	28	49	16	32
+450	12	12		24	25	35	13	22

	Timiskaming Can. 5	Sogn Moen Nor. 4	Döviken E. Jl. 8	Sirapsbacken Vb. 5
+549	27	11	6	54
	21	9	6	46
	27	10	7	25
	25	10	9	19
	19	7	40	
	21	10	10	25
	18	6	15	11
	22	11	14	9
	17	32	54	13
540	16	7	30	18
	19	13	10	14
	18	13	19	14
	21	12	33	16
	22	10	24	13
	24	14	6	16
	21	21	5	17
	23	19	8	11
	21	31	14	14
	18	10	4	17
530	15	7	6	11
	17	14	4	14
	20	19	4	17
	19	5	7	19
	18	6	41	13
	17	32	25	14
	16	9	16	18
	20	17	19	12
	18	6	10	15
	21	18	8	15
520	18	12	7	17
	15	11	23	12
	21	7	22	14
	20	8	8	16
	17	12	15	10
	15	8	16	12
	18	6	14	22
	20	21	7	16
	20	21	8	25
	19	18	15	13
510	16	8	7	12
	18	14	6	22
	16	10	5	29
	19	13	19	50
	15	18	25	20
	19	10	16	16
	21	12	7	12
	16	13	25	17
	18	21	5	25
	18	8	4	20
+500	17	11	7	20

	Timiskaming Can. 5	Sogn Moen Nor. 4	Döviken E. Jl. 8	Degerön Vb. 1	Strycksele 4	Sirapsbacken 5	Kusfors 6	Med. Scand.
+449		12		25	20	49	16	26
		8		27	19	41	16	19
	17	8		28	18	25	23	18
	16	10		20	14	18	25	19
	15	12		29	22	49	36	30
	15	11		19	19	31	33	23
	15	30	15	37	17	39	41	30
	15	16	5	23	12	8	27	15
	12	10	5	25	12		26	16
440	15	26	12	36	19	24	42	27
	13	11	5	35	19	22	31	28
	18	8	5	46	21	20	34	30
	17	9	6	42	24	17	29	9
	15	9	4	36	17	27	32	9
	14	8	10	40	20	29	30	8
	20	8	36	31	23	23	30	23
	20	10	4	53	18	33	43	35
	13	8	7	39	17	23	21	23
	13	10	6	38	17	35	28	34
430	16	51	5	35	20	14	24	25
	15	52	6	30	18	14	19	24
	17	139	5	33	24		21	24
	13	14	7	50	21	31	17	21
	14	12	5	40	14	31	15	20
	15	24	9	53	14	59	23	34
	15	15	6	42	19	37	19	38
	17	14	23	45	26	27	28	31
	15	19	3	41	17	39	24	21
	15	20	4	42	15	29	21	17
420	21	24	4	36	15	33	23	24
	17	22	3	30	16	29	23	27
	16	6	2	28	14	23	12	16
	20	33	2	42	17	32	21	27
	16	32	3	65	16	41	17	17
	11	33	4	35	13	31	13	22
	16	13	2	26	11	30	10	16
	17	7	3	26	13	29	12	13
	16	7	7	21	10	21	13	13
	17	23	8	27	8	29	15	22
410	16	13	7	44	9	30	20	22
	15	15	12	33	8	33	14	27
	20	25	3	54	8	40	19	35
	13	16	8	27	10	31	19	22
	15	19	20	37	10	22	13	23
	12	20	5	44	8	29	17	23
	11	12	5	37	12	31	17	18
	17	15	7	40	10	29	25	23
	18	17	10	41	12	37	20	26
	11	7	4	35	12	27	28	18
+400	15	8	3	32	13	34	23	19

	Timiskaming Can. 5	Sogn Moen Nor. 4	Döviken E. Jl. 8	Degerön Vb. 1	Strycksele 4	Sirapsbacken 5	Kusfors 6	Med. Scand.
+399	21	17	7	37	12	23		16
	17	9	5	26	10	7	30	18
	15	25	5	20	11	8	16	13
	19	18	3	22	10	6	21	13
	22	11	5	27	17	7	22	18
	20	19	6	16	11	7	20	12
	19	15	13	27	11	10	40	15
	16	16	6	21	7	6	55	13
	13	22	26	30	9	7	23	23
390	12	15	16	21	9	7	25	17
	16	29	74	25	10	10	45	32
	14	12	3	18	7	8	22	11
	29	7	6	47	8	10	36	21
	26	10	5	33	6	5	20	9
	30	6	8	31	11	6	22	11
	17	6	3	49	9	3	15	5
		9	8	26	10	5	13	12
		14	13	35	12	7	11	16
		9	7	29	10	4	16	16
380	17	8	69	26	9	6	13	12
	19	10	3	40	8	8	12	16
	19	10	4	38	6	4	10	8
	16	12		70	7	8	10	10
	19	15		41	8	6	18	18
	19	8	7	33	6	6	11	13
	21	12	5	43	10	6	10	18
	13	10	5	48	8	6	21	21
	13	45	6	32	6	5	12	14
	15	18	3	41	10	6	11	17
370	17	28	5	44	7	7	9	19
	16	7	4	23	7	7	10	11
	20	8	6	37	8	5	23	18
	20	6	10	41	6	7	26	21
	15	9	2	32	9	4	12	12
	17	10	2	31	6	5	19	13
	14	10	3	22	7	4	19	11
	15	18	8	23	8	6	29	16
	12	16	3	20	6	5	23	15
	20	10	2	32	5	6	17	11
360	23	30	1.5	27	6	4	25	16
	22	42	3	39	5	6	20	20
	20	25	2		8	6	22	12
	27	8	5		8	3	29	17
	21	9	3	44	9	9	25	
	19	14	3	30	8	6	20	
	14	22	2	30	9	8	30	14
	13	21	2	58	8	7	44	43
	18	15	4	24	9	7		15
	24	40	2	30	10	15		24
+350	17	22	2	22	8	6		15

	Haileybury Can. 4	Timiskaming Can. 5	Sogn Moen Nor. 4	Döviken E. Jl. 8	Lillrännforsen Ång. 5	Degerön Vb. 1	Strycksele 4	Sirapsbacken 5	Med. Scand.	Med. Not Scand.
+349		17	29	6		28	7	7	18	
		15	37	5		35	8	6	26	
		21	33	4	15	31	10	5	9	
		18	13	3	13	46	7	3	7	
		20	10	11	22	26	8	7	12	
		22	22	2	9	33	5	5	13	
		27	23	3	18	32	7	8	15	
		16	8	2	12	23	6	8	7	
		16	9	3	9	37	7	8	7	
340		20	58	4	17	40	4	4	20	
		20	35	6	37	59	5	3	27	
		18	20	3	14	41	9	3	10	
		20	28	4		39	11	4	19	
		18	8	3	18	37	7	4	15	
		20	13	3	14	36	5	5	17	
		18	9	4	11	30	4	5	20	
		17	20	2	11	42	5	5	31	
		16	7	4	18	37	5	6		
		14	8	2	10	23	2	4	8	
330		13	27	4	12	29	4	5	14	
		14	9	2	13	30	5	4	11	
		15	9	3	10	29	4	7	11	
		15	58	6	22	65	6	6	31	
		17	40	3	9	24	7	4	19	
		17	25	2	12	22	5	5	11	
		19	5	2	14	29	7	5	12	
		16	5	3	18	27	4	4	10	
		19	8	2	11	27	6	7	10	
		19	20	2	6	30	6	6	14	
320		21	18	1	7	30	7	7	12	
		14	9	3	20	29	8	22	15	
		20	20	2	10	23	6	12	14	
		15	31	4	16	29	9	6	16	
		18	31	2	14	29	9	5	15	
		25	25	2	13	32	9	11	15	
		16	10	3	7	25	13	8	11	
		15	14	5	7	25	7	8	12	
		24	25	8	12	26	6	10	18	
		24	18	4	9	19	12	16		
310	15	23	50	4	20	17	12	15	16	
	11	19	192	4	8	37	10	10	18	
	13	17	9	5	17	20	10	14	14	15
	16	19	32	5	17	21	12	7	18	18
	12	15	6	7	9	17	11	10	10	14
	12	18	5	16	9	15	16	10	16	18
	9	14	7	7	12	19	13	12	15	12
	18	21	7	4	9	22	19	12	15	20
	19	23	7	2	8	20	8	6	11	21
	14	17	15	5	15	25	11	10	16	16
+300	12	17	13	7	8	15	15	7	12	15

	Haileybury Can. 4	Timiskaming Can. 5	Sogn Moen Nor. 4	Döviken E. Jl. 8	Lillrännforsen Ång. 5	Degerön Vb. 1	Strycksele 4	Sirapsbacken 5	Med. Scand.	Med. Not Scand.
+299	14	20	15	9	15	21	8	12	11	17
	12	17	7	3	8	19	17	10	9	15
	14	22	7	2	12	21	15	20	12	18
	10	23	35	4	14	21	18	18	30	17
	16	22	53	5	9	19	14	6	19	19
	16	18	38	2	11	16	11	5	14	17
	15	24	48	3	7	22	35	14	22	20
	11	19	6	2	7	17	26	13	12	15
	18	24	7	4	9	21	37	16	16	21
290	19	25	8	2	10	16	30	9	16	22
	14	14	6	3	8	17	18	15	12	14
	15	14	15	2	8	12	24	15	17	15
	12	15	17	3	8	11	13	15	11	15
	13	16	71	3	12	10	12	3	7	16
	11	18	75	5	9	9	31	13	11	18
	10	22	56	2	8	13	17	17	11	22
	12	20	16	3	8	15	20	21	18	20
	12	15	19	3	7	14	20	15	15	15
	11	20	30	6	8	16	21	20	18	20
280	17	17	23	6	8	19	23	31	12	17
	17	20	5	2	12	15	18	33	4	19
	13	19	5	2	18	11	35	39	4	16
	18	26	18	2	10	11	25	29	10	22
	21	30	32	3	21	14		17	19	26
	15	22	12	2	9	35		12	7	15
	21	19	13	3	8	11		10	12	20
	15	19	10	5	10	10		9	8	17
	14	19	9	2	9	13		11	7	17
	15	19	10	3	11	8		12	10	17
270	18	21	7	3	9	10		16	12	18
	21	17	7	3	13	11		16	13	21
	14	16	10	4	14	11		6	8	15
	15	17	12	3	12	21		16	13	17
	17	14	10	2	12	10		7	7	16
	15	15	14	4	9	9		12	7	15
	19	19	8	14	9	12		10	15	19
	16	15	11	5	8	12		8	9	15
	22	16	8	5	16	10		7	8	16
	16	17	9	5	8	11		5	8	17
260	19	20	12	3	8	12		4	9	20
	16	19	11	2	9	15		7	8	18
	12	14	8	3	8	12		4	7	18
	12	17	9	2	10	11		16	7	20
	15	29	20	3	9	13			11	15
	15	27	48	4	12	18			21	14
	16	23	7	2	10	18			5	12
	12	25	11	2	9	13			9	19
	11	22	10	3	9	14			9	17
	12	19	8	2	10	12			10	16
+250	15	19	15	2	8	12			14	17

	Haileybury	Timiskaming	Sogn Moen	Döviken	Lillrännforsen	Sand	Degerön	Med.	
	Can.		Nor.	E. Jl.	Ång.		Vb.	Scand.	Not Scand.
	4	5	4	8	5	16	1		
+249	15	15	7	5	10		9	11	15
	16	23	7	16	20		10	18	15
	13	20	7	2	9		12	10	17
	10	17	5	4	10		10	8	10
	15	15	25	3	8		14	16	15
	15	21	19	3	8		11	6	18
	14	24	12	5	11		9	8	19
	13	16	17	5	7		9	8	15
	13	18	20	3	8		11	10	16
240	13	20	11	3	9		14	11	20
	16	20	7	5	8		9	7	16
	12	20	30	3	9		11	11	12
	12	18	70	5	10		15	23	18
	17	20	41	3	9		10	18	20
	12	19	12	3	12		8	8	12
	15	13	9	3	8		12	7	14
	14	17	14	3	12		10	10	16
	15	21	5	2	11		10	2	15
	17	20	4	5	11		7	7	19
230	12	22	15	2	24		10	15	22
	13	25	9	3	11		7	6	25
	18	19	6	15	13		11	11	19
	15	20	10	3	11		10	7	18
	12	19	14	3	12		9	3	16
	23	25	9	10	11	3	7	10	24
	20	16	6	3	18	3	9	5	16
	20	17	8	4	11	2	8	8	17
	19	22	20	3	10	3	8	12	22
	19	16	8	3	15	9	10	6	16
220	13	21	11	4	13	1	9	6	17
	20	25	53	3	8	2	7	28	23
	16	17	39	4	13	2	7	23	17
	14	16	27	5	16	31	5	16	15
	14	21	13	6	9	2	4	9	18
	17	24	23	3	11	3	6	10	21
	15	21	9	2	19	4	2	4	18
	12	23	15	2	12	2	4	7	18
	14	27	18	3	14	3	5	7	21
	16	27	21	4	12	2	2	13	22
210	11	20	17	3	10	3	3	10	16
	13	22	18	2	8	2	3	6	22
	14	25	17	3	9	3	4	7	25
	18	21	9	2	7	2	2	4	20
	8		8	5	12	2	4	6	8
	16	19	7	2	12	1	3	10	19
	20	16	6	4	12	2	2	7	16
	12	20	8	2	14	2	5	10	20
	16	17	11	2	12	12	5	12	17
	15	22	14	3	13	4	5	10	22
+200	13	26	25	4	13	14	4	19	26

	Haileybury	Timiskaming	Sogn Moen	Vikbäcken	Gåsnäs	Lillrännforsen	Nämforsen	Degerön	Med.	
	Can.		Nor.	E. Jl.	Ång.			Vb.	Scand.	Not Scand.
	4	5	4	2	1	5	16	1		
+199	17	23	10	2		12	2	5	8	
	13	30	7	3		15	3	4	5	22
	21	29	9	10		11	2	5	10	25
	16	22	8	3		16	2	7	4	19
	15	27	8	4			15	5	9	21
	14	29	5	3		7	3	4	6	14
	21	23	6	3		20	2	3	10	21
	17	29	5	3		8	3	3	5	17
	19	24	10	2		15	2	4	10	19
190	16	25	12	5		11	3	3	12	21
	16	23	8	8		19	3	2	5	20
	22	24	14	2		12	1	7	7	23
	13	23	23	3		15	2	3	3	18
	14	25	14	5		10	2	2	9	20
	15	26	16	2		10	2	4	10	21
	21	20	15	3		9	3	4	3	21
	15	21	11	3		15	1	7	1	18
	14	26	16	3		12	3	5	5	20
	16	26	40	4		16	2	4	4	21
180	22	30	19	2		10	1	4	12	22
	24	25	60	3		16	25	5	27	25
	22	22	30	5		10	3	3	14	22
	21	22	11	5		8	2	2	7	22
	18	23	10	3		9	6	4	8	21
	17	24	10	4		15	3	5	8	
	21	26	8	5		10	2	4	6	
	19	21	15	4		7	3	4	7	
	19	21	18	3		25	3	5	15	
	18	23	17	3		8	2	5	8	
170	13	22	22	3		11	4	6	11	
	16	32	12	4		13	4	5	5	
	12	29	37	5		14	3	4	4	
	20	22	10	3		14	2	3	3	22
	17	25	7	4		12	3	6	6	25
	17	24	12	2		8	2	4	7	24
	12	29	24	4		9	2	2	14	29
	18	21	17	2		11	3	3	10	18
	18	23	12	3		12	2	4	12	18
	16	19	12	4		15	25	4	20	19
160	12	25	11	3		11	3	4	5	19
	11	22	13	2		11	2	3	5	17
	14	27	9	2		12	4	4	4	21
	13	24	23	3	5	13	3	5	3	19
	16	27	24	3	3	11	4	5	5	22
	10	23	37	13	5	12	3	3	6	17
	12	31	9	2	3	16	4	4	10	31
	17	25	22	3	3	13	3	5	13	21
	12	19	16	4	3	11	4	3	8	16
	14	24	21	2	4	9	6	2	14	19
+150	15	30	17	3	2	14	3	3	11	23

	Makalia River E. Afr. 2	Haileybury Can. 4	Timiskaming 5	Sogn Moen Nor. 4	Döviken E. Jl. 8	Sundsvall *mi.* Me. 5	Gåsnäs Ång. 1	Lillrännforsen 5	Sand 12	Nämforsen 16	Degerön Vb. 1	Med. Scand.	Med. Not Scand.
+149		11	29	7	4		3	17		3	4	4	29
		8	36	7	2		4	17		5	3	5	36
		12	33	9	5		3	16		4	4	5	12
		15	22	12	3		3	10		5	3	4	15
		12	25	13	2	8	3	9		6	2	5	12
		12	21	37	3	10	4	10		4	3	11	17
		8	17	11	4	9	3	14		7	2	6	18
		13	23	19	5	9	6	10		16	3	11	23
		18	24	9	3	6	3	11		8	4	7	18
		12	21	11	4	9	4	25	5	5	3	6	12
140													
		14	23	15	2	11	4	10	5	7	4	7	19
		12	22	19	2	8	2	7	5	6	4	8	17
		10	20	15	6	5	3	8	3	7	3	5	15
		16	21	15	21	7	5	9	8	6	3	9	19
		16	19	24	5	7	5	9	6	10	3	7	
		14	20	11	7	8	6	18	4	14	3	9	
		14	20	20	6	6	3	8	7	10	4	8	
		24	22	15	8	9	4	8	4	8	2	7	
		20	18	25	10	9	6	13	5	11	3	11	20
		15	18	24	7	6	4	12	3	9	4	6	
130													
		13	21	14	2	7	5	11	5	10	4	7	13
		22	20	26	3	10	8	9	6	12	4	10	22
		23	27	19	4	9	5	10	7	10	4	9	25
		18	25	27	8	8	5	11	12	13	4	11	23
		16	21	21	3	6	4	10	11	14	3	8	22
		17	27	20	3	10	5	10	12	16	4	11	19
	25	15	23	19	3	7	6	13	8	13	4	7	44
	19	29	20	12	2	9	9	8	10	21	5	9	29
	27	27	24	18	4	6	6	12	4	24	7	7	27
120	23	30	21	18	2	10	8	13	24	8	4	14	30
	45	17	20	21	2	8	5	9	5		5	9	45
	23	17	21	21	3	9	150	11	5		3	5	20
	27	21	23	15	4	7	12	13	8		10	7	24
	19	12	25	20	2	9	18	10	12		6	2	16
	30	16	21	15	2	11	8	9	21		5	8	23
	30	19	17	18	2	6	8	12	13		7	11	25
	16	17	21	16	3	8	9	16	10		5	8	13
	17	15	22	17	5	7	16	10	13		6	11	19
	21	12	20	11	2	10	19	11	11		4	5	11
110	27	14	22	9	4	10	14	9	12		6	9	12
	15	15	22	14	3	8	11	10	13		5	9	12
	33	18	29	21	12	6	12	9	12		4	19	16
	20	18	21	7	3	6	10	9	13		4	8	13
	33	20	26	6	2	10	9	8	13		4	8	15
	26	14	26	5	2	8	17	13	24		6	15	
	20	14	31	11	4	8	15	11	17		2	8	18
	13	15	35	8	9	9	17	15	21		3	12	25
	11	14	25	8	4	10	22	12	26		5	14	20
	33	10	20	49	29	4	29	11	24		3		
+100	34	18	21	7	5	4	16	7	16		4		

	Makalia River E. Afr. 2	Haileybury Can. 4	Timiskaming 5	Sogn Moen Nor. 4	Fågelberget W. Jl. 16	Sundsvall *mi.* Me. 5	Gåsnäs Ång. 1	Villola 5	Sand 12	Nämforsen 16	Degerön Vb. 1	Indal Me. 7	Med. Scand.	Med. Not Scand.
+99	20	25	29	9		11	32	10	22	17	4	20	15	25
	18	21	25	12		7	24	10	17	16	3	12	13	18
	30	17	23	23		6	33	15	18	21	8	18	16	30
	15	27	26	17		5	23	18	19	12	7	10	15	23
	17	18	23	11		4	23	9	21	12	7	14	15	20
	22	15	25	18		7	37	10	26	19	6	20	18	24
	22	15	24	13		5	31	12	18	17	10	17	16	20
	27	13	21	22		6	26	10	18	15	7	12	13	17
	23	15	24	7		7	24	7	18	14	5	12	6	40
90	19	21	26	6		9	21	9	13	12	7	15	7	22
	9	15	19	6		6	20	10	15	13	5	10	8	14
	10	14	19	6		7	18	11	13	14	5	15	11	14
	17	13	20	8		8	14	16	12	10	5	13	10	17
	35	20	25	13		7	24	11	18	17	6	16	15	27
	17	16	26	29		4	20	9	17	12	6	12	18	60
	19	20	30	29		6	26	9	20	13	5	13	18	19
	27	19	29	35		10	32	8	22	14	5	15	23	27
	14	27	31	26		6	22	8	17	9	11	12	17	21
	11	15	25	25		9	21	9	18	10	9	9	14	17
80	22	16	25	36		15	26	14	18	15	10	15	16	16
	17	18	21	28		18	30	12	24	15	11	20	21	17
	11	19	31	18		9	21	10	17	11	11	17	9	11
	16	15	24	11		8	23	10	19	13	5	12	14	15
	14	21	21	14		7	33	12	22	17	7	13	18	21
	18	16	20	30		7	25	10	19	10	7	15	16	18
	11	22	22	35			20	11	15	10	6	16	17	19
	29	17	20	28			21	9	17	12	4	15	15	17
	15	15	26	35	23		19	9	14	12	4	13	17	15
	18	15	22	44	24		30	13	20	16	8	20	24	11
70	13	14	20	40	22		21	16	17	11	6	13	14	16
	17	13	26	20	24		15	10	13	8	8	20	13	19
	19	11	27	22	13		12	7	10	7	6	15	10	19
	11	17	29	15	23		21	10	15	12	6	22	16	23
	13	11	21	34	13		21	11	15	11	7	20	15	15
	13	13	20	27	49		12	14	10	9	8	16	11	15
	20	16	23	20	31		15	15	13	10	6	15	13	20
	31	17	26	15	25		15	9	10	12	8	18	12	25
	20	14	23	12	26		15	9	7	11	10	20	9	19
	20	18	26	20	18		14	12	15	10	10	13	14	22
60	12	20	30	27	21		16	12	15	11	12	15	17	21
	15	21	30	22	20		16	15	10	8	11	20	13	25
	18	20	22	88	40		10	10	8	9	7	15	16	20
	20	21	21	37	45		16	13	11	14	10	21	21	21
	12	15	20	16	19		13	8	7	10	4	15	11	16
	14	17	29	30	54		13	7	11	10	6	22	15	16
	20	24	24	28	37		21	15	14	12	7	20	19	22
	15	15	29	17	32		15	9	11	9	7	17	18	15
	13	15	22	20	22		13	11	12	9	10	15	15	14
	20	23	25	36	23		17	11	12	10	6	17	17	20
+50	25	22	21	37	22		22	12	15	14	3	12	18	25

	Makalia River E. Afr. 2	Haileybury Can. 4	Timiskaming 5	Sogn, Moen Nor. 4	Fågelberget W. Jl. 16	Gåsnäs Ång. 1	Villola 5	Sand 12	Nämforsen 18	Degerön Vb. 1	Indal Me. 7	Med. Scand.	Med. Not Scand.
+49	23	24	18	27	15	15	9	11	12	4	16	13	23
	20	19	25	22	17	11	12	7	10	5	14	12	20
	30	18	25	26	29	15	41	9	13	7	19	20	30
	18	22	30	25	24	10	25	7	10	4	17	14	18
	31	16	24	15	11	15	13	10		5	18	12	31
	17	21	20	26	7	21	16	12		6	22	15	17
	12	21	26	23	7	16	12	14		5	13	13	12
	21	20	25	30	13	14	8	10		5	16	15	21
	26	22	30	41	12	17	20	11		7	20	20	26
40	20	19	26	26	8	14	11	10		8	18	13	26
	14	18	29	55	10	18	13	12		10	10	13	14
	15	17	16	27	8	21	13	15		9	15	13	15
	14	18	17	40	6	15	10	12		6	15	10	16
	26	21	22	55	8	22	12	14		9	19	13	23
	23	21	21	80	5	16	12	12		12	15	9	21
	10	22	24	37	17	16	10	13		11	20	22	23
	19	19	22	20	12	20	25	14		16	14	16	20
	20	25	29	34	14	21	20	27		11	20	21	27
	19	19	21	14	9	7	9	13		12	13	10	20
30	20	23	21	29	6	30	12	16		12	17	19	14
	22	25	22	31	23	31	9	20		15	20	22	24
	14	16	26	49	8	28	21	19		8	18	22	26
	30	16	18	20	9	20	10	15		7	15	14	18
	23	15	18	18	17	22	11	16		10	19	16	23
	17	17	20	10	11	21	10	17		10	12	14	17
	19	15	19	24	18	24	21	20		9	21	21	19
	33	21	24	23	6	20	14	17		10	20	13	21
	30	19	23	10	10	28	20	25		11	22	19	24
	13	15	20	23	6	15	11	15		9	13	14	14
20	15	22	24	29	12	18	16	13		10	14	18	15
	26	17	15	29	8	21	14	15		10	22	18	26
	20	19	18	19	7	17	17	13		9	24	14	20
	25	20		27	10	26	20	23		10	22	21	25
	18	24		29	16	24	15	24		6	18	16	21
	25	30		44	15	21	14	17		8	24	20	28
	18	25	28	45	5	29	12	27		9	14	26	26
	14	23	18	14	6	23	18	20		12	10	16	21
	18	16	17	6	14	22	18	17		10	17	10	17
	21	22	20	12	28	18	13	16		9	20	19	21
10	15	21	22	10	15	20	17	16		11	20	15	19
	34	23	28	11	12	24	11	17		8	24	16	25
	21	18	22	10	8	18	22	15		5	20	14	22
	14	17	18	20	9	15	16	15		14	26	17	16
	19	15	22	50	3	19	27	15		4	21	25	21
	14	15	17	17	6	18	12	15		4	20	11	16
	12	13	21	22	7	13	13	13		6	20	11	12
	19	19	14		2	14	23	13		18	25	18	19
	13	14	11	22	3	15	18	13		9	19	16	13
	18	13	9		5	21	18	19		8	20	19	18
±0	16	16	14	23	6	20	14	15		10		16	16

	Makalia River E. Afr. 2	Haileybury Can. 4	Timiskaming 5	Sogn Moen Nor. 4	Fogelberget W. Jl. 16	Döviken E. Jl. 8 a	Gåsnäs Ång. 1	Sand 12	Med. Scand.	Med. Not Scand.
—1	9	16		28	8	32	18	16	32	
	18	17		32	24	42	22	17	33	17
	22	13		19	17	34	26	19	23	13
	8	15		12	6	27	24	18	15	15
	6	28		29	5	34	21	19	23	28
	12	26		15	20	26	23	21	21	14
	6	22		31	18	20	18	16	18	14
	10	24		42	25	15	20	16	28	17
	6	18		10	6	29	22	13	13	12
10	9	22		6	5	25	19	14		16
	8	21		6	4	20	15	14		
	21	15		6	19	29	25	18		
	18	26		9	8	30	19	18	19	22
	12	22		7	20	21	19	15	14	17
	20	18		7	5	26	20	16	17	19
	10	16		6	6	20	14	13	16	13
	11	24		17	6	19	15	13	11	18
	10	25		5	10	27	16	12	11	18
	8	19		11	23	35	24	14	19	8
20	6	21		6	12	16	20	16	14	6
	10	23	14	8	16	18	18	13	13	17
	10	21	11	10	7	18	16	13	13	16
	12	17	12	20	4	26	14	14	14	10
	14	22	14	15	9	25	16	13	13	17
	17	18	14	21	14	20	19	16	16	16
	20	13	16	12	5	21	18	18	19	18
	13	16	11	10	6	16	17	16	16	12
	12	20	12	10	5	26	16	16	16	12
	18	19	12	30	13	21	20	19	21	18
30	6	20	12	13	5	22	17	16	13	6
	11	23	11	15	8	14	19	13	14	17
	17	18	14	9	7	18	15	13	10	18
	23	22	16	5	10	21	24	23	19	21
	8	22	12	6	10	18	21	16	16	14
	8	22	11	6	11	22	20	11	16	21
	25	17	10	22	12	23	20	16	20	25
	21	16	14	18		18	19	13	16	21
	27	22	10	7		18	11	12		
	23	17	10	10		16	14	11	13	23
40	12	23		6		13	13	11	11	12
	18	26	10	24		10	14	13	17	22
	15	18	11	13		15	12	10	12	17
	33	19	13	15		18	11	8	11	19
	21	22	10	23		15	15	14	17	22
		21	13	11		16	13	12	12	21
		22	11	25		13	11	11	12	22
		25	15	5		16	14	12	14	20
		29	14	10		21	14	12	16	22
		26	12	41		12	13	9	11	19
—50		23	11	21		15	13	10	13	17

	Haileybury Can. 4	Timiskaming 5	Sogn Moen Nor. 4	Vålbacken W. Jl. 12	Döviken E. Jl. 8 a	Indal Me. 7	Gåsnäs Ång. 1	Sand 12	Med. Scand.	Med. Not Scand.
—51	24	9	24		12		11	9	11	9
	21	14	13		15		15	13	14	18
	20	12	25		11		10	8	10	16
	21	13	38		12		15	13	20	17
	18	14	21		10		13	13	16	16
	21	15	19		11		15	16	20	18
	16	11	9		16		9	10	9	14
	26	12	8		13		8	8	9	12
	20	15	21		17		10	8	14	15
60	28	14	21		16		8	9	14	21
	27	15	19		15		9	8	14	27
	31	17	24		16	2	8	6	10	24
	21	11	26		13	3	8	8	20	16
	30	12	16		15	4	12	8		
	29	14	23		15	2	11	10	15	22
	27	10	25		15	3	7	6	13	19
	28	14	9		19	392	8	8	34	21
	20	13	6		17	4	7	5	8	17
	23	14	13		17	5	9	9	11	19
70	22		25		16	4	8	6	9	22
	23		25		20	4	7	7	17	24
	24		15		21	5	9	8	18	24
	30		15		17	4	9	6	12	15
	23		6		25	5	9	9	7	23
	25		11	6	39	6	11	8	15	25
	20		7	5	27	6	9	11	11	20
	27		10	7	31	5	12	10	15	27
	25		7	5	25	6	8	6	10	25
	30		10	8	28	10	11	11	13	30
80	25	12	10	5	33	5	11	10	8	25
	26	12	8	2	38	6	9	8	7	
	21	12	13	2	33	23	9	7	15	
	22	16	15	6	24	7	6	6	13	
	25	13	30	12	30	7	8	5	16	25
	26	16	33	3	20	14	8	9	14	21
	19	18	28	7	17	6	6	5	12	19
	22	17	32	4		7	10	11	18	22
	21	16	8	10		4	6	6	6	19
	20	19	11	3		6	6	7	8	20
90	26	20	18	6		3	8	8	9	23
	25	18	26	12		7	9	9	9	22
	21	16	17	12		3	6	6	10	19
	19	13	12	3		4	7	7	8	16
	24	17	10	9		5	9	8	8	21
	23	17	22	9		5	10	9	8	20
	18	19	15	6		6	12	10	9	19
	21	17	16	10		6	13	11	12	21
	19	18	20	5		6	8	9	7	19
	20	20	26	5		7	9	8	11	20
—100	17	17	17	3		4	5	9	7	17

	Haileybury	Timiskaming	Sogn Moen	Vålbacken	Vikbäcken	Indal	Gåsnäs	Sand	Med.	
									Scand.	Not Scand.
	Can. 4	5	Nor. 4	W. Jl. 12	E. Jl. 2	Me. 7	Ång. 1	12		
−101	21	20	12	4	35	10	7	8	10	21
	16	19	8	6	40	7	9	10	8	18
	22	19	12	3	95	53	9	6	52	21
	17	18	15	2	30	4	6	5	16	18
	32		16	3	41	5	6	4	21	32
	23		17	7	33	4	7	5	18	23
	18		42	4	32	6	8	6		(18)
	26		10	6	32	4	10	9	17	26
	28		7	14	25	7	7	7	11	28
110	40		6	9	38	7	9	8	14	40
	25		8	5	20	5	6	6	8	25
	25		11	7	182	700	10	8	21+	25
	21		5	3	12	5	9	9	7	21
	25		4	7	12	5	8	8	8	25
	20		3	7	12	5	6	6	6	20
	26		4	5	17	5	6	6	7	(26)
	24	22	9	7	18	5	10	10	10	23
	22	19	14	3	15	4	10	6	6	21
	23	20	15	6	17	4	10	10	8	22
120	24	20	27	6	11	3	8	9	9	22
	18	16	20	7	18	6	12	6	12	(17)
	20	20	12	2	12	4	9	5	6	(20)
	18	14	33	3	11	7	9	6	(11)	(16)
	22	19	45	2	12	6	9	5	27	21
	18	16	24	9	14	6	7	5	11	17
	21	21	22	4	15	7	9	6	9	21
	17	17	55	2	12	6	7	4	7	17
	17	20	15	4	14	5	8	7	8	19
	17	17	44	5	19	4	10	10	7	17
130	24	18	50	4	19	27	7	6	32	21
	23	18	33	7	16	3	7	5	12	21
	25	18	37	4	13	4	6	4	7	(18)
	21	16	[1]18	4	16	4	9	6	9	(16)
	27	16	17	3	14	4	6	4	7	(16)
	21	14	14	9	18	4	8	6	10	(18)
	20	18	18	7	17	5	5	4	8	(18)
	24	20	20	9	18	4	8	8	11	(24)
	20		38	6	16	5	6	5	8	(20)
	19	16	36	10	14	6	5	6	9	18
140	27	21	24	15	32	4	8	5	18	24
	15	13	17	7	12	7	7	6	11	14
	18	17	27	10	16	4	9	7	14	18
	20	17	31	5	16	4	7	6	13	19
	20	16	28	8	16	7	7	5	9	18
	23	18	18	9	20	5	12	9	12	21
	25	21	36	9	21	4	12	9	18	23
	15	14	11	5	15	3	15	12	11	15
	16	14	12	5	15	3	10	7	9	15
	17	15	38	4	19	3	9	5	20	16
−150	19	16	28	5	17	5	11	15		

	Haileybury	Timiskaming	Sogn Moen	Vålbacken	Vikbäcken	Sand	Gåsnäs	Indal	Mora	Med. Scand.
	Can. 4	5	Nor. 4	W. Jl. 12	E. Jl. 2	Ång. 12	1	Me. 7	Da. 12	
−151	20		23	5	18	6	11	5	5	5
	21		15	5	18	6	10	5	9	8
	22		46	9	20	8	12	4	23	16
	34		13	9	22	8	12	5	20	11
	27		13	8	19	9	11	4	21	11
	18		24	7	22	3	7	5	12	7
	15		33	5	18	7	11	6	8	
	22		13	3	20	8	11	4	12	
	25		24	3	11	5	7	4	7	
160	22		39	3	20	6	12	5	13	17
	19		21	4	28	6	9	4	9	10
	22		9	3	21	5	10	3	13	12
	18		15	3	34	5	9	4	11	10
	23		20	2	40	6	13	6	14	16
	22		19	2	29	3	8	6	7	12
	16		21	2	18	2	5	6	12	11
	21		34	9	20	4	10	5	11	15
	26		20	4	15	4	7	5	10	10
	27		15	4	13	2	3	5	7	7
170	36		20	6	23	5	12	4	8	12
	20		23	7	24	5	10	3	7	11
	15		23	10	23	6	15	4	9	14
	18		11	5	18	8	14	5	10	12
	22		9	2	16	5	13	6	10	11
	20		14	3	24	6	17	5	12	13
	23		10	1	21	4	17	4	13	11
	26		14	1	22	11	26	3	10	
	30		6	1	22	12	27	3	12	18
	19		28	2	22	10	16	3	8	14
180	17		19	3	36	12	26	3	9	22
	18		24	2	23	10	20	4	8	15
	25		8	6	19	5	8	4	7	8
	18		19	5	24	5	10	5	9	11
	28		24	15	60	25	29	7	10	24
	20		14	7	31	13	21	5	9	15
	23		41	14	36	13	23	4	6	26
	24		21	4	26	11	18	4	5	14
	16		40	6	24	10	18	3	4	11
	23		14	7	33	16	30	4	7	15
190	26	8	12	5	28	8	15	3	5	11
	20	9	14	5	25	8	16	3	6	11
	17	7	18	6	30	12	22	4	7	15
	25	7	12	6	29	15	29	3	6	
	28	17	9	9	39	13	31	10	5	20
	25	8	12	5	28	8	18	5	5	13
	20	8	47	6	31	5	10	6	5	
	25	9	26	4	29	7	18	5	4	13
	14	7	28	5	25	5	12	6	6	14
	17	10	33	8	30	10	30	3	7	17
−200	22	10	61	5	28	9	21	5	6	14

	Espanola Can. 3	Haileybury 4	Timiskaming 5	Sogn Moen Nor. 4	Koldemo Hl. 20	Vålbacken W. Jl. 12	Gåsnäs Ång. 1	Sand 12	Vikbäcken E. Jl. 2	Indal Me. 7	Mora Da. 12	Edsbyn Hl. 66	Bollnäs *mi.* Hl. 125	Med. Scand.	Med. Not. Scand.
—201		20	11	36		7	31	13	32	5	9		19	22	11
		23	8	58		2	21	10	29	5	6		15	14	8
		21	10	21		3	20	7	27	6	7		11	12	10
	½ 20	26	7	13		6	31	13	30	6	6		17	20	26
	24	20	11	25		4	20	11	28	8	7		11	15	20
	24	23	7	30		6	15	7	28	7	8		12	14	24
	22	21	11	27		7	9	4	21	6	6		14	9	22
	29	24	10	52		8	22	12	33	5	7		24	18	27
	17	16	16	31		7	22	11	22	6	5		13	15	17
210	17	18	12	8		7	35	12	21	7	7		15	15	16
	37	19	9	10		5		13	30	5	4		14	7	19
	30	20	13	24		7		9	24	8	6		19	11	25
	23	26	12	22		4		24	26	7	9		16	9	25
	22	18	11	12				18	29	5	7		15	11	20
	26	22	8	11				14		5	7		13	10	24
	51	24	9	30				11	17	7	4		30	19	28
	51	16	10	97				14	51	7	5		16	19	13
	36	19	12	13				23	61	8	6		18	23	12
	21	30	11	15				10	46	6	5		20	17	11
220	24	29	10	28				17	53	6	7		17	21	10
	31	19	10	72				23	68	7	5		16	29	31
	21	16	9	14				24	73	7	5		12	24	19
	22	22	8	30				31	90	7	8	3	14	34	22
	21	21	8	22				26	82	7	6	3	16	38	21
		33	8	10				25	75	8	8	8	13	36	
		21	8	19				26	73	7	7	5	15	38	
	10	17	15	13				21	64	8	6	6	14	25	
	12	25	13	79				13	46	10	5	8	19	17	25
	15	18	10	19				36	68	7	4	6	14	26	17
230	10	22	10	21				16	50	6	7	5	14	18	22
	14	28	10	11	11			22	65	8	4	6	18	24	28
	10	23	11	25	12				77	6	3	8	22	36	17
	19	15	9	73	10					8	6	7	19	13	12
	12	21	12	47	12					7	6	8	13	7	17
	20	23	10	26	10					6	5	4	10	5	17
	11	30	9	23	15					6	6	5	11	6	30
	17	25	16	17	13					6	7	5	28	6	25
	19	26	10	10	14					10	4	7	11	9	23
	20	24	9	27	9					8	5	4	12	6	22
240	21	17	14	22	13					6	5	7	15	9	18
	15	22	9	25	7					4	4	7	13	7	12
	17	25	13	24	23					7	5	6	20	11	15
	12	24	11	34	14					3	7	5	29	4	16
	14	23	10	21	21					4	6	3	9		
	13	21	14	10	16					5	5	4	12	9	
	16	22	10	11	25					6	7	2	16	7	19
	14	21	8	15	11					6	8	4	13	8	18
	11	24	13	11	15					5	7	3	18	5	
	21	20	15	9	18					8	7	3	14	5	
—250	20	18	13	7	9					7	8	3	18	6	

	Espanola Can. 3	Haileybury 4	Timiskaming 5	Sogn Moen Nor. 4	Vålbacken W. Jl. 11	Bollnäs Hl. *mi.* 125	Edsbyn Hl. 66	Indal Me. 7	Mora Da. 12	Koldemo Hl. 20	Med.	
											Scand.	Not Scand.
—251	½ 11	18	9	22		36	5	8	7	10	18	
	24	21	16	13		21	3	11	6	15	11	
	22	21	10	15		20	6	12	6	14	18	
	14	19	11	35		30	8	5	6	22	17	15
	10	28	14	41		24	21	5	8	16	20	21
	20	22	9	16		19	4	4	5	14	10	16
	4	25	9	14		18	6	4	6	8	10	9
	14	24	14	14		22	4	11	7	12	13	14
	14	22	13	16		21	5	10	6	10	12	14
260	10	22	12	13		16	3	4	4	10	8	15
	19	24	11	15		18	5	5	5	17	10	22
	10	27	12	12		16	6	3	3	9	8	13
	16	28	15	18		25	4	3	6	12	11	20
	19	21	11	5		17	3	3	4	9	7	17
	20	30	15	20		20	5	7	5	11	11	22
	11	22	9	14		19	4	5	7	7	10	14
	18	23	12	20		20	4	9	4	10	16	18
	17	24	15	14		21	5	9	5	20	11	19
	16	23	9	17		22	3	6	3	15	4	16
270	15	23	15	19		17	5	9	4	15	9	19
	20	22	11	11		14	6	4	5	10	8	17
	12	24	18	46		18	5	3	4	12	32	
	18	19	15	61		28	8	3	5	17	25	
	18	16	13	21		25	6	14	4	7	14	20
	16	17	11	4		19	4	11	3	11	8	14
	23	19	14	4		23	5	12	3	7	9	14
	19	16	14	5		30	7	12	5	11	12	14
	23	20	17	5			5	4	4	9	5	17
	17	19	22	6			4	12	5	14	7	22
280	35	22	16	4			3	5	4	10	4	16
	52	21	20	4			3	3	4	13	4	
	16	23	15	5			6	5	5	10	5	23
	16	23	16	11			5	4	5	12	6	20
	29	20	16	8			5	4	4	10	5	18
	33	23	17				5	7	8	14	7	20
	15	29	16				4	6	5	15	5	8
	21	23	15				5	4	5	16	5	15
	14	21	16	5			5	8	4	14	5	17
	15	21	17	5			6	11	5	13	6	18
290	18	27	15	8	22		7	7	7	16	12	20
	15	24	13	17	19		5	10	5	10	10	17
	15	27	14	8	19		8	11	6	15	11	19
	18	27	19	7	15		5	8	5	12	13	23
	30	29	15	6	11		10	9	6	17	8	30
	20	21	12	7	17		5	6	4	16	5	18
	9	23	15	9	19		8	10	5	22	10	16
	15	27	12	43	45		9	12	5	17	23	21
	14	21	13	22	33		6	6	5	21	15	18
	11	26	12	17	34		6	3	5	23	15	19
—300	14	35	12	15	20		8	4	4	13	6	25

	Espanola Can. 3	Haileybury 4	Timiskaming 5	Sogn Moen Nor. 4	Fluberg 6	Frösön W.Jl. 11	Indal Me. 7	Högom 5	Edsbyn Hl. 66	Mora Da. 12	Haga N *Sth.* 2	Iris *mi.* 4	Med. Scand.	Med. Not Scand.
−301	11	25	12	11		16	5	4	14	6		10	9	18
	10	23	11	14		32	12	4	13	6		17	19	17
	15	29	15	14		35	10	3	13	6		5	16	20
	10	21	15	6		20	6	4	8	5		9	9	15
	16	29	13	11		27	11	6	8	3		11	13	23
	24	26	13	6		20	7	6	9	5		14	10	26
	14	29	15	5	5	10	8	4	7	4		14	7	14
	22	27	15	5	9	10	9	4	9	6		17	9	18
	13	24	10	6	5	13	10	6	10	6		13	9	16
310	37	29	12	6	9	24	10	5	13	11		15	11	26
	30	27	10	6	8	33	7	2	14	6		16	5	22
	16	29	14	7	7		4	4	9	7		14	6	22
	16	26	13	10	6		11	3	18	9		12	7	20
	45	29	14	14	8		10	5	19	6		16	9	29
	22	23	13	17	7		10	3	45	6		11	7	19
	10	30	16	13	6		9	3		7		15	8	23
	9	16	11	20	15		13	3		4		10	6	12
	11	17	12	31	13	23	18	3		5		11	14	13
	21	16	15	18	12	31	12	4		7		11	11	8
320	14	36	14	13	9	14	12	5		4		22	12	14
	15	25	13	10	10	9	17	5		4		13	10	(18)
	20	36	16	11	15	25	16	2		6		21	15	18
	19	37	13	38	8	30	9	3		4		15	9	16
	25	21	18	14	10	32	6	2		5		21	12	22
	20	25	12	7	8	17	8	3		4		16	9	16
	14	30	21	8	9	18	9	4		10		22	11	21
	10	44	11	12	10	16	13	5		7		15	10	11
	15	46	16	4	10	30	15	4		5		17	14	16
	7	31	15	5	9	11	14	4		5		22	14	11
330	8	20	16	12	10	11	9	5		6	12	12	10	(15)
	10	13	17	8		27	15	3		9	14	13	(11)	(13)
	12	12	18	14	10	25	12	8		6	20	9	15	(14)
	14	14	21	34	14	46	15	4		5	30	23	20	21
	16	15	18	22	16	21	14	4		8	20	17	18	18
	7	25	20	12	14	8	5	3		10	12	24	7	(14)
	9	11	15	10	15	28	4	5		8	20	15	15	(12)
	9	13	14	33	17	35	6	3		5	13	35	23	(12)
	10	18	17	7	13	36	5	7		7	14	20	11	(15)
	16	12	19	12	17	32	10	8		8	18	19	11	18
340	16		18	20	16	28	8	6		7	24	21	14	17
	14		14	9	15	27	3	3		12	17	12	10	14
	17		14	8	22	40	9	4		7	20	11	12	21
	19	19	25	12	22	17	10	4		7	25	13	12	22
	15	17	17	5	16	25	9	4		7	23	12	7	16
	19	16	15	14	22	15	10	7		11	25	13	15	19
	15	22	16	9	18	22	8	4		9	22	7	11	13
	18	18	15	18	25	26	6	5		12	24	16	17	18
	20	16	23	9	15	21	7	5		12	25	12	11	20
	20	19	18	17	21	30	9	5		17	33	22	21	39
−350	14	19		5	20	13	11	6		27	30	16	18	14

	Espanola Can. 3	Haileybury 4	Timiskaming 5	Fluberg Nor. 3	Sogn Moen 4	Frösön W.Jl. 11	Viksjö Ång. 4	Indal Me. 7	Högom 5	Mora Da. 12	Bollnäs Hl.mi 125	Iris Sth. 4	Haga N. mi. 2	Med. Scand.	Med. Not Scand.
—351	9	22	12	24	7	21		7	5	23	10/1	10/1 29	10/1 36	23	22
	7	15	12	30	5	14		7	5	20		14	35	18	11
	10	21	11	19	8	22		6	5	30		19	27	14	10
	21	19	13	22	21	39		16	5	23		20	17	24	21
	12	17	15	24	11	22		16	5	22		7	20	14	12
	15	15	11	23	7	15		11	5	42		19	16	25	15
	9	18	10		8	18		25	5	60		17	22	34	18
	12	24	10		17	20		5	6	44		20	28	23	24
	11	23	12		13	24		9	5	49		25	20	27	23
360	21	18	13		52	17		8	4	29	18	20	23	18	18
	22	22	11			20		24	3	47	15	30	40	29	22
	14	17	10			11		17	6		16	20	12	15	10
	17	18	12		15	20		14	4		19	22	10	19	16
	16	20	8		10	17		22	5		23	19	10	17	15
	15	21	11		9	17		11	5		24	23	11	15	16
	29	27	12		19	25		17	6		29	13	20	17	23
	20	21	15		15	14		10	3		19	14	10	14	21
	17	23	14		8	17		10	4		19	18	13	15	19
	30	18	10		15	16		12	4		20	23	10	15	14
370	18		13		19	21		20	7		23	19	11	16	(16)
	21		17		11	35		12	4		25	31	10	25	19
	11		15		7	12		10	9		21	15	6	13	23
	10		13		17	22		9	7		26	16	5	18	12
	15		15		9	32		18	5		35	29	16	26	15
	12		14		11	21		11	6		30	24	14	20	13
	31		10		8	25		21	6		28	25	17	24	31
	20		12		9	35		13	6		30	29	10	31	20
	11		14		35	4		15	7		28	9	10	14	11
	15		15			7		26	11		30	10	9	21	15
380	16		16		10	6		12	7		28	11	11	15	16
	14		14		6	22	27	15	6		38		20	24	(14)
	10		10		7	13	33	29	10		32		10	18	(10)
	16		16		8	17	21	12	4		31		9	17	16
	28		9		9	26	18	11	4		30		11	18	28
	43		17		10	21	22	26	7		34		10	16	30
	18		19		9	17	23	18	5		37		11	17	19
	24		16		14	17	26	33	10		40		14	23	24
	13		13		9	19	25	31	8		34		10	15	13
	21		15		7	14	29	32	5		43		11	24	18
390	14		13		8	15	19	28	4		31		5	17	14
	13		17		15	43	22	25	8				4	22	17
	13		15		18		18	28	6				10	13	14
	23		15		12	42	28	56	9				19	31	19
	15		16		9	16	11	40	9				20	18	16
	12		20			25	12	8	5				10	25	20
	20		16		13	22	15	1/10 13	3				16	18	16
	11		16		12	18	20	10	5				15	15	16
	12		17		19	37	25	9	2				16	28	17
	25		14		55	46	12	22	5				10	25	20
—400	21		14			29	28	11	8				5	16	18

	Enderit Riv.	Espanola	Timiskaming	Sogn Moen	Frösön	Backa	Hälgnäs	Ockelbo	Indal	Högom	Viksjö	Holmsveden	Berge	Dellen	Hälsingtuna	Fittja, Sl.	Stockholm	Stockholm		Med. Scand.
	E. Afr. 1	Can. 3	5	Nor. 4	W.Jl. 11	Da. 10	11	Gl. 19	Me 7	5	Ång. 4	Hl. 2	4	52	54	*mi* 1	*mi* 3	*mi* 1	*mi* 2	
−401		$\frac{1}{2}$ 25	22	16	$\frac{1}{2}$ 31				$\frac{1}{10}$ 13	10	15		4		22	$\frac{10}{1}$	$\frac{10}{1}$ 31	$\frac{10}{1}$	$\frac{10}{1}$ 14	21
		14	12	10	18				14	5	13		5		20		17		9	12
		11	15	12	10				15	7	30		6		30		7		10	9
		15	18	18	21				13	7	14		9		20		10		15	15
		11	16	12	21				10	8	27		5		20		13	15	6	12
	10	16	19	10	20				9	7	21		6		12		25	31	15	18
	8	20	15	13	17				10	6	15		4		10		18	18	11	12
	5	12	16	15	15				15	8	20		6		14		20	20	10	14
	25	23	12	54	21				13	5	19		4	2	15		21	21	9	13
410	13	18	16	65	13				14	4	33		9	2	16		31	23	10	23
	15	10	16	23	17				5	2	14		5	3	14		12	16	20	11
	17	14	17	14	15				11	3	16		5	2	19		13	12	—	11
	15	11	16	19	22				19	4	27		7	3	32		19	20	—	17
	12	13	20	19	23				21	3	11		5	2	25		16	11	—	14
	15	15	16	17	20				30	2			4	2	19		15	19	16	12
	14	17	20	33	51				74	2			6	3	22		31	15	15	20
	16	15	20	18	26				35	5			3	5	15		16	10	18	18
	14	16	28	21	33				47	3			5	5	24		18	20	20	24
	16	21	20	19	34				64	4			8	6	19		20	15	35	18
420	14	17	32	12	20	2				2			6	6	20		16	9	23	11
	15	$\frac{1}{1}$ 21	21	13	11	3				2			5	6	23		23	14	22	12
	24	21	28	12	9	3				2			10	6	40		29	10	15	21
	16	22	23	21	15	3		3		6			6	9	19		24	14	16	10
	25	28	26	21	22	4		2		3			9	11	20		13	15	20	12
	5	22	19	23	21	4		3		4			5	10	22		16	8	18	23
	8	28	25	25	26	4		7		9			7	13	29		20	14	20	15
	12	17	19	35	15	2		4		2			5	5	13		10	12	21	9
	6	32	23	12	17	4		5		4			7	12	16		22	22	28	13
	13	34	34	27	10	2	9	3		5			5	7	14		21	15	20	10
430	15	22	20	18	13	3	8	3		Fin. 4			10	7	15		26	20	16	12
	19	23	19	51	18	2	6	2		3			8	4	15		16	4	20	8
	24	50	29	21	26	3	7	3		5			10	7	17		29	19	24	13
	9	21	19	15	19	2	13	1		5			9	11	12		19	6	29	10
	15	17	16	13	9	2	7	1		7				6	18	16		9	7	9
	32	31	24	19	22	3	11	2		8				7	25	27		14	15	14
	11	9	25	18	19	3	9	1		4		10		4	22	18		12	16	12
	14	6	23	10	14	5	11	3		5		8		4	19	21		19	14	11
	7		20	9	9	3	7	2		8		7		7	15	12		15	10	9
	29		21	12	13	5	14	3		5		11		6	20	9		11	19	12
440	32		17	33	24	3	7	4		9		8		10	23	16		15	19	19
	13		23	53	19	5	10	3		7		12		9	21	15		16	10	12
	25		19	15	26	4	7	3		5		10		11	20	39		34	19	20
	18		26	16	17	2	8	2		4		10		4	22	15		12	10	10
	20		23	20		6	9	1		9		10		2	14	9		16	20	10
	8		17	31		3	16	2		9		11		7	15	12		20	22	14
	28		21	15		5	6			6		9		5	16	15		15	20	11
	24		27	20		5	7			13		8		5	24	24		20		16
	16		20	25		6	14			9		12		5	15	19		17		14
	14		16	19		5	12			8		8		6	20	10		19		11
−450	11		27	21		6	15			14		9		9	18	14		29		15

	Enderit Riv.	Espanola	Timiskaming	Sogn Moen	Ytterolden	Höje	Gustafs	Faluns tegbr.	Backa	Helgnäs		Holmsved	Hälsingtuna	Dellen	Kristines.	Fittja, Sl.	Stockholm	Med. Scand.	Med. Not Scand.
	E. Afr.	Can.	Can.	Nor.	W. Jl.	Vl.	Da.				Gl.	Hl.			Fin.	*mi*	*mi*		
	1	3	5	4	15	3	6	9	10	11	13	2	54	52	4	1	1 a		
—451	8		33	17	7		7	5	6	14		9	11	10	9	$\frac{10}{1}$ 13	$\frac{10}{1}$ 12	13	
	12		32	22	7		9	2	4	17		5	20	9	15	20	10	17	
	10		30	25	8		6	4	7	20		10	24	10	21	30	14	19	
	11		29	20	5		10	6	6	13		10		12	12	24	11	12	29
	12		22	19	7		6	3	5	13		11		15	11	7	15	12	22
	7		41	37	7		5	3	3	21		3	23	17	19	7	14	16	41
	10		22	27	8		10	7	5	17		5	14	25	16	15	21	15	22
	12		46	21	7		5	6	6	16		10	17	9	11	9	10	11	29
	6		31	20	7		10	7	6	28		10	24	13	20	15	11	14	31
460	7		22	23	9		5	5	4	19		8	20	12	13	12	11	11	22
	16		29	32	10		5	5	5	26		9	23	31	17	7	9	19	23
	11		29	30	6		11	9	7	43		10	20	15	13	8	7	13	20
	15		26	31	6		5	4	5	20		9	24	33	15	9	20	25	15
	5		27		8		9	6	5	22		11	23	28	15	15	17	17	5
	10		36		7		6	6	6	15	11	10	17	34	13	20	9	11	
	8		44	38	6		6	6	6	22	18	9	15			14	10	15	
	6		30	16	5	10	6	7	5	25	9	7	15			13	10	9	18
	6		27	16	6	9	10	9	7	20	11	14	22			9	19	12	6
	2		28	12	6	11	6	5	7	39	13	15	17			6	10	9	2
470	4		38	29	7	9	9	7	6	29	9	11	17			9	17	13	21
	4	28	29	83	6	12	11	10	9	26	15	12	20			12	16	22	
	17	14	26	49	7	12	8	6	6	16	13	10	21			17	18	13	
	4	14	36	31	9	11	7	8	8	20	20	16	19			25	25	18	
	7	11	34	42	9	12	6	6	5	17	11	14	22			20	20	18	
	8	9	24	47	7	11	10	7	6	14	16	19	19			17	21	20	
	10	8	40	14	6	11	6	7	7	17	13	16	15			18	13	17	
	14	10	39	23	6	12	10	8	6	25	16	21	18			21	31	16	21
	7	4	31	13	5	9	6	8	5	17	10	20	14			10	21	12	14
	8	3	30	15	6	10	5	8	4	28	12	21	20			17	20	15	8
480	6	5	36	10	6	12	6	6	6	37	8	9	20			11	27	12	
	9	4	38	27	5	11	7	6	4	11	12		12			12	16	14	17
	8	2	26	7	12	10	10	6	9	20	11		15			20	15	14	12
	15	4	44	11	6	17	8	9	6	8	11		19			14	7	13	21
	11	5	38	11	7	10	5	5	6	9	18		16			12	10	13	18
	10	2	29	10	18	12	9	8	6	28	13		15			15	27	17	14
	5	3	30	42	7	15	10	8	8	10	11		12			12	13	11	13
	17	5	42	16	5	26	10	7	9	19	10		26			7	12	15	21
	11	3	24	10	6	15	5	5	7	17	10		15			16	15	12	13
	13	4	34	11	7	19	14	10	9	15	14		16			18	13	14	17
490	11	4	43	18	7	15	8	6	7	20	16		19			24	15	13	19
	7	6	43	10	5	16	8	7	6	10	13		15			17	16	11	18
	10	10	50	6	6	30	8	6	6	11	20		19			14	13	14	23
	8	5	24	10	7	10	6	5	5	9	15		19				15	11	15
	4	4	24	7	7	10	10	7	6	16	17		22				14	13	24
	9	5	20	23	6	11	9	8	7	17	21		12				17	13	20
	11	4	30	20	12	20	12	10	6	23	21		15				16	14	21
	6	4	28	19	13	17	7	6	4	16	23		20				10	12	18
	13	5	27	11	14	18	13	9	7	19	30		20				19	17	15
	8	3	19	12	11	10	11	8	8	14	23		19				14	12	10
—500	10	6	12	13	11	11	10	7	9	14	19		15				12	12	9

	Enderit Riv.	Espanola	Timiskaming	Sogn Moen	Jesseim	Ytterolden	Iisalmi	Falun	Backa	Smedjeb.	Hedemora	Gustafs	Älvkarleby	Råhällan	Ockelbo	Åbyfors	Gnarp	Hälsingtuna mi.	Med. Scand.	Med. Not Scand.
	E. Afr. 1	Can. 3	5	Nor. 4	6	W. Jl. 15	Fin. 5	Da. 9	10	4	5	6	Up. 40	Gl. 6	9	5	Hl. 40	54		
—501	5	4	15	12		15		6	7	12	3	6		5	8		6	10/1 13	13	15
	18	3	17	20		14		6	4	25	2	6		4	11		8	14	22	18
	15	5	15	38		10		7	6	15	5	8		4	20		4	15	11	15
	16	4	18	46		13		9	5	20	5			7	16		7	14	16	17
	4	5	17	17		22		6	6	7	3	8		11	9		5	11	7	11
	12	3	17	31		18		9	9	28	4	9		14	12		4	20	17	15
	5	3	13	31		35		6	9	23	5	10		5	15		4	20	16	9
	4	5	13	26		42		7	6	15	3	6		7	10		4	22	24	5
	8	2	14	12		38		7	6	14	4	10		4	5		5	20	14	2
510	4	3	13	14		44		9	8	10	6	12		7	7		5	21	16	3
	10	3	11	10		34		6	7	5	5	9		3	5		9	17	12	7
	10	3	20	15		82		9	8	11	5	9		7	11		7	19	20	15
	3	5	16	10				10	10	8	5	11		4	7		3	13	7	10
	9	3	20	12				6	7	9	4	9		5	10		3	15	12	15
	7	5	25	12				8	9	10	5	12		13	12		6	19	13	7
	11	4	17	20				8	7	6	6	12		8	8		4	18	11	11
	15	2	27	26			7	9	7	9	5	13		4	8		4	18	9	21
	11	4	26	16			10	11	10	12	6	15		8	10		6	24	12	15
	8	5	17	13			7	9	10	4	7	14		7	6		4	17	10	13
520	10	2	31	17			10	10	7	6	7	15		10	14		6	21	13	20
	10	3	37	13			9	11	10	14	5	13		6	7		3	19	10	17
	5	5	27	11			10	13	10	11	9	20	5	8	9		7	20	12	16
	12	3	19	10			6	10	9	15	5	15	3	5	11		5	13	13	11
	4	5	30	14			6	9	7	5	6	13	9	5	15		5	16	10	13
	4	5	26	12			6	10	10	9	7	14	2	7	11		5	21	7	12
	6	4	24	11			5	8	10	7	8	14	4	5	16		5	27	11	11
	7	5	23	10			9	15	14	6	9	24	2	5			6	19	13	12
	5	4	29	12			8	15	12	4	7	19	3	5			4	20	10	13
	10	3	20	13			16	10	10	3	7	17	2	8			7	17	12	10
530	9	4	20	11			10	8	8	4	7	12	4	5			4	19	10	9
	14	3	40	½ 21			14	12	12	19	8	17	3	5			4	21	14	27
	10	6	57	15			12	12	9	4	5	12	1	5			4	14	9	8
	18	3	66	13			18	10	10	7	6	13	2	4			4	20	10	42
	8	4	25	29			16	10	9	8	6	12	4	6			4	20	8	12
	6	2	31	28	15		23	11	11	9		16	2	6			8	20	15	12
	3	3	17	15	14		11	12	11	15	6	19	2	5			5	21	12	8
	9	4	22	4	16		21	31	13	7	9	22	3	7			8	15	15	12
	5	4	24	5	20		13	11	6	9	8	16	3	4			2	16	10	11
	7	5	24	25	26		14	8	7	7	7	13	9	5			2	18	15	12
540	8	4	20	5	12		15		6	9	5		8	4			3	17	9	11
	9	4	19	8	10		15	14	7	10	7	19	5				4	15	10	11
	11	5	20	12	21		23	15	17	15	9	21	3				6	29	17	12
	3	7	19	9	15		22	19	14	12	7	17	2				3	24	13	11
	8	4	33	16	10		25	13	12	12	6	13	3			6	4	25	12	20
	2	4	21	5	12		40	7	10	7	6	10	4			4	2	20	8	9
	5	5	21	9	10		45	40	21	14	3	10	6			8	1	21	17	10
		5	20	8	16		42	49	31	9	4	12	3			6	7	20	18	13
		4	21	5	9		△	20	18	14	5	10	5			18	4	16	11	4
		5	17	17	17				37	11	7	17	5			6		19	18	11
—550		20	23	10	19				22	7	6	9	6			9		22	12	

	Espanola	Timiskaming	Sogn Moen	Jesseim	Vålb.	Backa	Smedjebacken	Hedemora	Gustafs	Avesta	Krylbo	Tierp	Vestland	Älvkarleby	Åbyfors	Hälsingtuna *mi.*	Med. Scand.	Med. Not Scand.
	Can.		Nor.		W. Jl.	Da.						Up.			Gl.	Hl.		
	3	5	4	6	12	10	4	5	6	1	3	35	38	40	5	54		
—551	31	30	½ 33	46		34	11	5	12	5				5	7	10/1 21	23	31
	30		9	26		7	8	7	17	4				6	5	19	12	30
	25		14	40		11	5	6	22	5				4	7	21	14	
	47		15	56		52	9	5	13	4				3	5	16	10	
	69		41			35	10	8	20	6				10	8	25	16	69
	41	28	20			31	5	5	12	4				4	5	21	12	35
	30	30	20			12	13	5	16	3				5	9	20	13	30
	21	22	14	24		31	7	9	25	6				11	7	21	14	22
	24	25	19	29		16	11	5	17	3				15	9	22	14	25
560	18	25	17	26		11	6	4	13	3				11	4	20	12	22
	38	½ ↓ 14	24	37		50	19	6	15	5			5	12	7	18	18	26
	19	15	26	24		20	15	5	11	3			4	13	5	15	13	17
	46	18	50	30		53	16	8	23	5			6	10	7	22	22	32
	17	20	31	25			5	6	16	4			6	15	9	20	13	19
	19	23	20	35			12	6	13	4			4	22	8	15	19	26
	17	18	12	27			6	5	13	6			8	19	7	19	12	18
	19	12	39	32			4	8	17	6			7	18	6	30	15	16
	28	15		30			9	9	23	8			9	16	35	24	18	22
	20	13	20	25			5	8	23	7			6	15	8	19	12	17
570	18	16	16	33			10	7	19	6			5	20	14	15	14	17
	15	24	14	41			5	10	29	7			8	19	12	20	18	24
	17	16	25	24			7	7	16	4			12	22	12	24	15	17
	19	16	17	21			4	7	15	4			12	24	7	36	12	18
	25	19		38			8	10	31	7			9	19	10	25	18	22
	19	14	21	24			8	7	23	4			6	14	12	16	14	17
	20	14	26	30			11	11	34	7			9	21	17	29	19	17
	24	20	26	46			15	8	27	7			12	20	9	19	15	22
	28	16		22			12	6	20	4			15	28	8	20	13	22
	17	12		41			9	6	14	4		17	7	20	20	20	12	15
580	18	9		15			10	9	23	7		18	7	20	11	24	15	14
	20	19					11	11	31	5		23	11	25	41	21	20	20
	18	14					6	7	22	5		20	11	27	10	31	14	16
	20	23	23				13	10	25	8		21	9	25	9	32	17	22
	17	11	21		30		5	6	11	4		16	15	30	15	28	10	14
	26	24	20		39		4	10	35	7		26	11	26	8	27	20	25
	22	20	25		36		7	10	25	6	6	26	15	35	9	30	19	21
	26	25	11		47		7	9	23	4	4	32	16	39	35	30	24	26
	20	26	10		35		6	8	20	5	3	20	14	26	7	24	14	23
	17		25		20		10	13	64	8	3	26	14	26	10	19	22	17
590	28		21		45		9	10	32	6	7	29	26	35	31	30	21	28
	19		18		26		16	8	31	6	3	25	18	29	28	19	19	19
	28		40		40		10	11	38	8	4	25	23	45	27	32	26	28
	22		20		7		20	10	43	7	3	28	23	44	17	26	21	22
	10		9		13		8	9	34	5	4	23	19	32	36	25	18	10
	19		9		15		6	8	44	6	5	26	25	30	41	23	21	19
	16		6		9		3	8	52	4	6	20	21	35	21	23	12	16
	27		7		20		9	17		10	7	27	25	40	29	32	21	27
	12		9		20		6	16		12	7	26	23	54	28	27	20	12
	16		5		27		8	17		11	8	30	34	48	35	29	25	16
—600	15		10		35		9	15		8	6	24	32	46	39	30	21	15

	Espanola Can. 3	Sogn Moen Nor. 4	Filipstad Vl. 10	Avesta Da. 1	Krylbo 3	Smedjebacken 4	Hedemora 5	Västanfors Vsl. 9	Sthlm, *mi* 1 b	Up. 35	38	40	S	T	Åbyfors Gl. 2	Åsbyggeby 3	Med. Scand.
—601	12	$\frac{1}{2}$9	20	5	3		10		$\frac{10}{1}$13	35	18	6		19	27	18	13
	13	17	29	10	7	4	18		8	30	21	9		17	31	17	15
	19	14	40	11	9	10	21		17	40	29	15		23	50	33	25
	10	10	27	8	5	4	14		13	31	23	15		19	56	25	20
	9	13	22	14	9	8	25		16	40	24	19		25		26	20
	13	16	17	4	4	5	11		13	37	25	14		21		23	15
	12	19	22	7	4	10	11		12	44	26	.18		26		27	20
	7	16	22	6	3	3	8		16	36	18	9		22		28	16
	12	14	18	9	6	7	16		17	40	36	20		30		38	22
610	15	19	26	9	8	7	16		9	54	36	21		34		44	25
	8	35	21	7	4	4	13		20	42		14		27		43	20
	10	10	11	10	5	9	20		12	63	36	21		33		62	40
	6	11	10	9	7	7	17		20	53	27	17		21		44	21
	9	23	15	7	8	9	23		9	56	42	29		23			22
	9	43	20	18	7	7	25		18	75	32	24		32			31
	12	21	17	5	3	5	11		16	50	28	28		28			21
	·11	26	21	7	5	8	12		19	45	29	21		30			19
	18	36	26	13	8	9	28		24	72	43	41		38			30
	12	16	18	9	4	3	7		15	50	38	30		21			18
620	11	10	23	7	5	8	16		16	58	43	56		21			19
	13	7	23	9	6	6	13		12	65	44			25			24
	10	12	20	6	4	7	11		16	47	37			22			20
	11	22	30	6	5	5	10		22	50	23			27			19
	13	26	42	10	7	4	12		32	51	36			29			24
	9	11	17	11	7	5	18		15	68	25			28			13
	18	13	20	15	8	5	21		22	52	37			15			20
	8	12	19	9	4	5	13		22	40	46			17			16
	10	22	22	24	13	9	29		23	51	45			32			25
	12	21	19	9	6	6	10		13	38	42			27			16
630	10	35	30	12	7	8	13		12	46	▽			31			20
	10	16	26	19	12	8	21		16	52				24			21
	8	39	15	7	3	7	8		12	48				19			15
	7		24	12	7	9	13		13	50				24			18
	15		·23	23	10	8	24		22	59				19			28
	7	32	20	14	5	11	12		17	56			22	17			20
	10	10	25	7	5	9	11		11	44			24	20			16
	7	17	23	18	8	7	23		15	60			20	16			23
	10	21	30	15	7	8	15		17	64			27	23			24
	10	14	17	7	5	9	11		8	47			18	15			16
640	12	12	14	12	5	19	21		7	60			38	34			11
	13	17	28	8	4	11	17		11	56			26	20			19
	13	17	9	13	6	7	20		17	51			31				14
	10	16	8	19	9		22	16	16	53			33				13
	8	17	10	12	6		19	17	16	63			30				14
	16	20	30	13	9		16	15	17	55			26				24
	9	30	28	19	8		24	21	31	64			32				22
	10	26	30	13	6		19	15	16				25				18
	14	19	27	27	7		24	19	20				26				19
	10	16	17	14	4		14	16	17				31				15
—650	11	17	10	8	3		19	19	16				32				13

	Espanola Can. 3	Sogn Moen Nor. 4	Arvika Vl. 6	Filipstad Vl. 10	Avesta Da. 1	Krylbo 3	Västanfors Vsl. 9	Stockholm *mi* 16	Uppsala S:t Erik Up. 26	Örbyhus 30	Gimo 31	Q	R	Uppland S	Stockholm Med.	Med. Scand
—651	13	½ 18		16	15	8	20	10/1 17						36	16	14
	15	19		13	14	8	17	17						32	17	14
	11	13		13	12	6	16	21						23	21	12
	10	19		16	10	6	16	10						28	10	12
	13	46		22	14	7	16	8						38	8	23
	9	32		15	13	8	17	16						36	16	18
	16	40		17	16	7	17	10						41	10	23
	9			30	11	6	16	11						28	11	16
	12	15		19	15	7	15	13						34	13	18
660	9	8		17	7	5	17	9						29	8	12
	7	12	2	16	8	4	15	18						21	18	10
	15	17	15	23	24	11	21	16						31	16	20
	12	21	2	42	12	8	15	14					27	23	14	13
	15	25	5	40	29	11	20	17					23	21	17	17
	10	8	2	16	10	7	17	15					25	22	15	12
	17	11	4	19	6	6	16	32					34	34	31	17
	20	9	2	32	8	6	16	12					32	26	12	10
	13	14	4	12	6	7	18	14					24	29	13	11
	8	9	2	8	8	6	18	15					28	23	15	9
670	12	6	4		10	6	17	17		10			29	34	18	12
	17	15	3	16	36	15	18	15		16			29	29	15	23
	19	15	2	14	18	10	17	20		20			29	24	21	14
	16	17	2	16	10	11	16	12		15		16	32	31	11	14
	14	17	4	13	10	8	17	12		14	9	14	29	27	12	12
	19	35	2	30	10	8	14	26		20	10	18	34	34	25	26
	21	22	3´	31	15	10	16	31		16	11	16	33	29	32	21
	12	35	3	11	½ 12	13	16	13		19	17	20	36	33	10	21
	16	15	4	11	↓ 15	13	18	15	8	17	10	15	28	30	16	15
	13	12	3	15	30	22	19	13	10	21	12	18	44		14	24
680	16	17	3	10	10	11	16	10	6	25	14	23	31		11	17
	18	30	4	8	32	21	16	9	9	26	18	22	44		9	22
	11	20	3	7	6	9	15	12	4	28	18	24	32		12	14
	11	25	4	15	4	8	16	10	4	16	10	12	28		11	11
	14	15	6	25	20	18	18	14	7	20	15	15	42		15	18
	12	16	4	20	13	9	18	10	10	29	21	24	35		10	16
	18	11	7	18	13	13	19	9	3	32	19	26	41		9	18
	18	18	4	24	9	11	18	10	10	21	13	20	33		10	16
	17	51	5	41	15	12	15	8	9	20	15	17	32		9	15
	23	45	9	23	30	15	18	11	12	28	18	21	35		13	20
690	17	19	10	22	17	10	18	14	6	21	15	19	31		15	18
	11	14	7	30	13	11	20	16	6	27	20	25	40		17	22
	15	17	6		21	12	18	11	9	22	15	21	35		10	17
	14	11	9		19	13	17	12	3	34	25	30	39		13	22
	12	11	6		25	12	19	10	4	21	14	22	35		11	16
	9	9	9		24	14	20	15	9	19	13	19	38		16	19
	13	15	8		35	12	17	10	8	28	25	25	34		15	16
	16	21	10		36	14	17	16	7	30	26	27			17	17
	10	29	9		14	16	22	18	7	25	29	27			18	18
	17	26	8		11	11	15	13	3	21	21	23			14	13
—700	19	27	11		10	18	19	20	3	18	18	21			22	16

	Espanola	Sogn Moen	Oslo	Arvika	Malings.	Livsdal	Avesta	Stockholm	Bergsbrunna	Uppsala	Örbyhus	Gimo	Stockholm	Medium		Med. Scand.
	Can. 3	Nor. 4	Nor. 5	Vl. 6	Vsl. 7	8	Da 1	Med.	Up. 25	26	30	31	*mi* 1	P	Q	
—701	11	½ 42		10	5	7	8	16		8	25	23	10/1 16		25	18
	11	35		8	8	6	5	12		11	20	20	12		20	15
	12	30		7	7	5	7	18		7	28	28	18		26	23
	6	13		5	7	5	10	15		13	24	18	14		22	14
	10	25		9	11	7	10	20		9	31	33	20		25	20
	12	11		6	9	4	5	9		12	27	29	19		23	15
	10	13		10	13	8	8	13		4	30	38	13		29	18
	10	10		6	12	5	4	12		6	22	22	11		23	13
	10	11		9	16	6	8	26		10	27	28	26		28	17
710	8	7		6	13	4	6	22		9	24	26	21		25	15
	10	10		9	16	10	1/10 11	11		11	25	32	13		32	17
	9	6		6	12	6	10	7		9	32	½ 31	9		30	13
	11	11		10	16	8	21	16		8	36	38	17		35	17
	12	9		7	12	7	9	18		6	23	23	17		24	13
	13	10		6	12	8	9	26		6	24	30	26	11	25	13
	8	17		10	9	12	9	14		15	27	39	14	13	32	21
	11	11		6	14	9	14	13		5	19	30	13	10	19	12
	12	16		6	13	6	12	12		14	24	40	12	15	23	20
	12	16		9	10	8	10	13		7	24	33	11	8	22	17
720	15	17		6	14	7	10	12		15	24	55	13	14	25	22
	19	14		9	12	7	5	17		11	20	31	19	13	22	16
	12	13		8	13	10	5	19		7	34	36	19	15	26	20
	8	15		7	16	8	9	20		9	39	53	20	18	27	22
	14	20		5	15	6	6	22		12	30	42	22	12	20	15
	11	26		7	24	8	8	24		12	33	40	25	8	21	19
	9	23		5	12	9	10	28		10	26	—	29	13	24	14
	12	30			13	14	5	16		11	25	—	17	10	22	16
	8	20			18	7	7	7		10	33	▽	9	13	23	10
	10	24			16	15	11	12		10	44		13	18	30	21
730	15	47			19	12	21	19		13	50		21	22	33	26
	11	21			15	8	16	14		12	30		15	16	26	18
	15	28			13	10	18	15		13	30		17	16	28	17
	13	33			19	11	12	15		10	▽		16	18	22	16
	13	50			21	10	11	27		5			28	15	25	23
	15	33			18	18	18	21		8			22	20	30	23
	12	52			25		20	33	9	12			34	18	23	23
	15	21			27		13	18	11	14			19	23		17
	10	8			27			19	13	16			19	16		18
	12	16	13		12			11	11	15			12	17		12
740	14	22	18		13			9	16	18			10	21		16
	15	38	15		11			12	11	20			14	14		13
	19	31	24		12			21	13	18			21	12		16
	13	15	23		16			20	12	16			19	14		15
	10	7	25		13			27	16	20			28	16		20
	7	17	17		10			9	11	15			10	12		12
	15	18	16		14			15	20	24			16	21		20
	19		35		11			21	18	25			22	21		16
	12		16		13			20	9	15			19	17		15
	18		12		12			14	8	17			12	21		15
—750	14		21		15			10	12	15			9	18		14

	Espanola Can. 3	Sogn Moen Nor. 4	Oslo 5	Gråsjö Jl. 13	Lindfors Vl. 7	Virsbo Vsl. 6	Malingsbo 7	Sala 10	Bergsbrunna Up 25	Uppsala 26	Sillbo 27	O	Stockholm *mi* 1	P	Stockholm Med.	Med. Scand.
—751	15		16				12	2	12	18			18	21	16	16
	13		17				10	5	16	22			25	24	26	22
	19	23	25				12	6	19	25			18	24	18	20
	12	10	15				18	4	17	22			17	21	17	15
	12	11	12				14	3	12	14			11	27	10	11
	18	12	14				17	5	17	20			15	28	14	16
	13	12	25				15	4	21	24			21	26	22	23
	12	11	10				16	4	17	24			23	30	24	18
	14	10	9				13	5	13	21			16	27	17	16
760	18	15	13				16	7	24	30			23	32	23	21
	20	12	11				16	6	19	25			10	33	10	18
	20	7	15				14	5	14	21			13	43	13	14
	22	8	18				19	6	21	31			14	33	15	18
	15	12	15	11	6		16	3	14	24		25	8	28	8	15
	7	17	21	13	6		20	5	19	24		29	12	31	12	16
	15	20	14	6	8		19	5	20	20		22	14	31	14	18
	21	18	12	10	10		27	4	22	24		32	14	40	14	19
	19	21	13	30	14		28	8	27	30		27	13	30	13	24
	12	13	9	9	7		23	4	13	18		31	9	37	8	15
770	17	25	18	15	7		22	5	20	28		38	17	44	17	35
	15	30	7	9	15		18	6	18	23		28	13	31	14	21
	13	24	10	6	10		20	7	23	30		32	11	37	11	26
	16	26	—	5	8		18	6	19	26		25	23		25	22
	19	33	63	5	14		22	3	22	28		23	16		16	24
	10	31	35	9	8		23	6	22	32		30	12		12	20
	16	34	26	7	9		20	5	29	34		28	11		11	26
	12	24	24	10	11		23	7	34	40		37	23		24	29
	9	25	25	9	9		28	3	18	25		23	14		13	18
	10	23	21	8	10		28	3	21	34	7	30	18		18	23
780	12	30	21	9	8		33	4	17	26	11	24	12		12	17
	14	20	25	8	22		28	5	19	30	9	40				28
	9	50	20	10	18		35	5	21	33	11	35				27
	10	23	18	8	15		31	7	24	31	5	30				26
	10	14	30	10	12		29	8	19	26	10	39				20
	9	16	36	13	18		28	6	33	37	17	34				25
	14	17	38	16	12		20	14	32	37	18	38				24
	14	17		11	12		16	14	34	36	10	29				28
	6	22		15	9		18	17	30	39	15	37				30
	7	23		14	9		25	18	24	36	16	28				24
790	17	15		11	27		23	17	29	34	24	25				22
	19	18		15	7		31	17	30	31	24	30				24
	20	20		14	8		28	7	19	26	19	41				18
	22	28			12	7	27	8	15	33	28	25				23
	19	21			9	11	28	18	22	33	23	28				20
	11	20			9	6	25	13	19	27	24	24				22
	6	24			12	8	20	13	20	28	25	40				24
	12	18			10	7	19	21	27	35	11	43				29
	14	21			15	7	23	29	23	41	31	35				27
	8	12			10	10	18	20	23	33	10	39				18
—800	16	13			14	11	21	30	41	49	16	52				30

	Lago Corintos Arg. 1	Espanola Can. 3	Sogn Moen Nor. 4	Brattfors Vl. 8	Virsbo Vsl. 6	Sala 10	Bergsbrunna Up. 25	Uppsala 26	Sillbo 27	M	O	Med. Scand.
—801	25	13	$\frac{1}{2}$16	47	8	14	36		25		31	32
	20	18	12	44	7	15	32		27		26	28
	26	11	14	47	5	7	27		15		26	31
	25	14	13	46	8	19	31		31		44	30
	25	9	15	42	9	18	33		33		40	15
	26	11	15	40	6	8	18		28			15
	23	8	12	50	9	11	26					12
	31	16	12	54	10	18	36					45
	21	18	14	40	6	22	32					36
810	28	14	18	46	6	18	26					32
	25	14	15	50	8	23	24					20
	28	7	12	39	8	15	34					25
	31	8	15	48	7	17	22					32
	38	6	17	53	10	15	27					35
	29	10	16	49	9	21	31					25
	31	12	22	53	12	28	54					35
	26	10	13	55	12	16	20					14
	24	13	17	48	10	20	35					22
	30	24	33	58	11	17	24					34
820	20		19	50	9	27	25					26
	20	15	20	52	12	32	41					28
	35		18	55	7	28	29					55
	23	8	20	43	13	35	27					43
	20	10	17	43	9	28	29					25
	21	15	18	57	15	12	38					32
	17	12	14	55	11	25	20					25
	14	7	14	49	17	28	11					25
	14	11	23	50	15	15	17					30
	19	8	25	52	19	9	29					31
830	14	8	21	50	15	16	23					27
	16	5	23	55	17		25					30
	17	6	19	43	14		17					23
	13	9	19	42	5		19					19
	15	4	14	45	14		24					14
	22	10	16	54	24		44					35
	11	3	12	52	19		21					26
	12	4	18	55	24		32	25				31
	9	6	13	40	17		26	18				23
	15	4	19	43	26		48	22				32
840	13	3	19	47	29		47	23		27		33
	19	3	15	41	19		12	22		37		22
	16	4	21	45			27	26		29		30
		4	15	45			10	18		31		22
	29	2	20	51			30	19		42		32
	14	4	33	45			23	16		35		30
	33	2	23	48			31	27		43		37
	32	3	11	44			18	17		26		23
	22	3	10	37			17	14		23		20
	29	5	12	43			25	16		42		28
—850	20	3	7				12	12		40		18

	Lago Corintos Arg. 1	Espanola Can. 3	Sogn Moen Nor. 4	Surahammar Vsl. 4	Ramnäs 5	Up. A 15 J 6	K	L	Up. 25	26	M	N	Med. Scand.
—851	28	5	½ 9						31	29	43	49	30
	32	3	9						27	25	32	34	25
	33	4	20						38	26	39	39	32
	22	7	11						20	14	37	40	24
	27	3	14		20				42	22	44	46	34
	15	2	9	7	15				35	28	35	31	33
	20	2	10	3	12				23	15	43	37	18
	23	3	15	6	21				41	11	29	30	20
	30	3	10	19	23				65	31	25		35
860	17	4	21	18	23				64		38		32
	20	5	13	9	19				27		28		19
	19	3		15	27				47		26		26
	26	2	17	6	19				13		30		14
	22	3	16	9	28				43		35		26
	20	5	14	6	19				10		25		15
	27	5	19	16	28				48		28		28
	15	3	16	8	20				27		40		18
	19	5	19	13	25				22		35		20
	25	2	23	4	26				28		38		26
870	17	3	26	7	26				28		35		27
	19	2	21	4	21				27		26		
	25	2	18	8	24				28		43		24
	20	5	11	7	29				11		28		14
	23	4	13	10	38				25		35		24
	28	3	14	18	27			24	20		38		25
		3	16	15	43			31	41		48		43
	13	1	17	22	47			23	51		26		24
	13	4	14	17	39			27	39		27		27
	22	4	15	9				20	17		19		16
880	14	6	16	12				23	51		23		19
	19	4	15	5				19	16		23		16
	19	3	27	11				33	22		45		26
	17	3	21	12		19		36	35		32		21
	13	3	20	16		26		21	25		39		25
	14	2	19	13		20		19	9		34		19
	13	4	20	15		23		24	24				21
	10	2	18	20		19		35	35				24
	11	4	17	10		19	8	22	20				18
	10	4	20	15		23	8	25	27				21
890	14	3	10	17		20	19	36	—				15
	16	3	15	13		18	16	40	—				15
	12	5	12	13		17	9	30	—				15
	24	2	15	11		25	19	42	—				17
	18	2	13	7		23	18	45	—				14
	20	4	12	15		17	15	36	▽				11
	32	4	22	16		24	17	35					19
	15	2	19	27		21	35	40					19
	16	3	17	24		21	42	50					21
	17	4	22	34		26	44	52					28
—900	9	3	12	29		21	30	32					21

	Lago Corintos Arg. 1	Sudbury Can. 2	Espanola 3	Sogn Moen Nor. 4	Säffle Vl. 1	Selaö Sl. 50	Munsö Up. 7	I	A 15 J 6	J	K	L	Åbo Fin. 2	Med. Scand.
—901	10		6	$\frac{1}{2}$ 13					26		31	32	9	
	18		2	23					22		26	44	6	
	11		5	19					25		44	49	8	
	15		4	16					23		50	51	6	6
	17		7	12					27		28	31	9	9
	16		5	14					23		24	29	5	5
	22		3	15					29		48	37	9	12
	33		5	56					22		35	30	9	56
	18			15					26		54		8	15
910	17			14					25		56		6	10
	20	14		14					29		57		7	11
	16	18		11					24	16	48		5	8
	13	11		8					23	12	64		7	8
	23	18		9					26	16	58		5	9
	20	12		12					24	13	65		5	12
	25	14		15					26	18	34		10	14
	16	10		13	16				23	15	39		10	9
	17	12		13	15				29	28	50		8	14
	16	13		16	25				22	22	48		5	21
920	15	12		14	18				26	24	56		6	16
	20	6		12	7				21	22			6	11
	29	14		16	9				27	36			14	13
	24	11		12	8				21	38			10	17
	17	10		12	11				22	25			6	16
	26	9		21	14				15	20			6	15
	38	11		41	22				20	24			10	24
	29	15		26	15			9	16	19			7	17
	20	11		27	11			15	22	34			8	18
	29	13		18	12			14		39			10	21
930	25	8		33	17			26		41			7	7
	16	11		15	6			4		33			10	10
	14	10		10	15			32		39			16	10
	18	12		14	11			25		60			11	14
	15	11		9	10			29		45			8	9
	15	13		11	11			19		57			10	22
	23	11		18	16			24		48			7	27
	16	9		18	12	9		16		43			7	18
	25	10		21	18	10		15		55			10	22
	16	8		17	15	4		12		28			8	14
940	20	10		21	13	6		16		37			7	17
	19	13		28	20	15		19		41			9	22
	20	12		16	9	12		15		30			7	15
	18	11		11	11	10		13		25			8	13
	18	12		15	13	27		20		40			11	21
	20	10		32	10	18		22		33			11	21
	25	15		53	15	8	19	18		26			13	25
	16	41		55	17	14	21	21		38			8	18
	24	9		17	12	14	19	16		42			9	18
	21	11		20	8	16	22	24		29			10	17
—950	20	13		46	8	22	17	20		39			12	23

	L. Co. Arg. 1	Sudbury Can. 2	Værdalen Nor. 9	Sogn Nor. 4	H	I	J	Munsö Up. 7	Selaön Sl. 50	Kungshatt Up. 5	Sth. Med.	Säffle Vl. 1	Åbo Fin. 2	Med. Scand.	Med. Not Scand.
—951	10	13		½52	12	24	36	16	29			9	8	23	12
	11	10		67	15	20	43	23	26			11	8	38	11
	10	10		28	30	39	58	26	24			11	6	29	10
	12	14		15	14	26	44	25	23			9	10	22	—
	14	10		18	21	25	45	21	15			10	14	24	14
	13	15		18	15	31	53	20	22			12	10	23	14
	15	24		21	19	36	65	16	11			17	11	28	20
	21	34		30	26	59		21	25			13	17	36	28
	14	17		8	19	34		26	16			11	15	21	20
960	17	27		12	28	55		26	18			15	21	22	22
	15	16		11	24	49		23	12			13	18	21	16
	20	13		13	30	61		21	16			15	17	25	17
	24	12		16	20	64		30	18			15	24	28	18
	46	23		30	24	50		16	10			20	35	25	30
	25	14		12	19	58		23	19			6	25	15	20
	27	12		13	28	52		20	7			7	24	15	20
	39	17		39	26	55		19	9			17	▽	28	28
	32	15		54	23	64		28	13			10		17	15
	30	23		15	32	45		24	15			13		22	23
970	34	31		35	29	50		31	9		25	15		33	33
	31	23	22	29	37	46		20	20		19	10		25	27
	35	25	16	34	47	58		28	21		21	16		34	30
	32	9	33	22	43	46		16	20		12	11		26	20
	39	17	48	31	48	54		22	29		22	20		22	28
	30	20	29	25	36	40		14	29		20	11		21	25
	27	20	39	19	33	62		22	19		18	13		16	20
	32	14	21	10	37	43		17	·20		15	19		18	14
	25	17		9	32			18	17	15	17	15		17	17
	30	21	31	18	43			25	19	20	21	17		24	25
980	29	7	50	23	35			22	16	17	16	20		25	18
	30	14	36	16	56			26	24	24	22	10		25	22
	30	12	32	13	44			19	29	10	18	13		20	21
	30	12	32	13	54			23	23	8	20	14		25	21
	26	9	43	23	45			18	20	3	16	27		26	18
	31	13	32	18	56			26	26	6	19	20		27	22
	33	16	41	24	44			17	15	4	17	28		22	25
	27	25	35	23	46			24	20	7	24	22		25	25
	27	11	29	19	37			19	21	7	19	33		23	11
	27	11	25	17	47			28	31	5	27			11	19
990	28	16	18	19	41			14	24	4	23			12	22
	28	22	13	13	45			37	25	5	23			28	22
	29	25	28	22	50			34	52	18	26			33	25
		9	13	19	40			23	25	6	20			21	9
	40	9	13	12	38			26	26	9	21			22	25
	31	7	38	13	30			24	24	8	20			21	19
	43	12	30	16	37			40	27	12	24			26	28
	23	15	43	19	31			43	27	9	18			19	19
	29	23	23	16	51			33	38	17	22			32	26
	26	9	30	12	44				16	10	19			18	23
—1000	30	20		19	58				33	14	22			29	25

	L. Co. Arg. 1	Sudbury Can. 2	Sogn Moen Nor. 4	Værdalen 9	Kungshatt Up. 5	Sth. Med.	Med.	
							Scand.	Not Scand.
	31	19	20		17	22	20	25
—1001	26	18	10		13	20	14	18
	23	23	13	35	12	23	16	23
	20	22	15	35	20	23	17	22
	24	24	15	22	10	23	33	24
	26	8	20	16	12	19	18	8
	20	31	32	28	14	29	23	25
	18	27	27	29	8	27	18	18
	22	18	9	15	10	28	18	22
	25	5	9	19	14	27	21	15
1010	19	8	14	39	14	22	18	14
	28	27	10	27	20	25	24	33
	22	14	12	12	15	15	14	18
	21	19	12	41	13	15	23	21
	24	8	27	45	8	23	32	24
	18	27	18	27	15	16	20	18
	21	23	14	32	25	17	16	21
	25	15	13	25	13	22	18	20
	18	13	10	19	12	18	17	16
	19	15	21	46	27	23	29	(17)
1020	22	20	15	25	22	20	19	20
	16	20	19	15	33	23	25	20
	20	14	16	16	23	20	20	17
	16	14	12	15	Sml. 2	17	15	15
	22	15	18	30	20	23	23	19
	20	14	14	26	16	19	16	17
	29	17	21	32	36	26	28	23
	24	12	17	38	34	23	26	18
	21	19	20	28	25	25	24	20
	35	35	28	48	23	35	34	35
1030	16	8	13	22	21	17	18	17
	18	15	15	13	14	21	16	17
	28	16	10	16	16	25	19	22
	28	6	11	16	12	20	15	6
	22	10	14		16	25	18	10
	30	11	13		17	22	17	21
	35	31	19		29	39	29	33
	16	23	15		16	30	23	20
	17	40	14		20	35	28	29
	17	11	18		19	21	19	17
1040	18	5	19		21	20	19	5
	16	19	21		18	35	25	19
	17	11	14		13	20	16	11
	20	15	23		15	30	23	17
	15	13	24		30	30	25	15
	14		21		21	18	20	14
	33		23		22	22	22	33
			23		14	18	18	
			28		17	23	23	
			24		15	20	23	
—1050			29		16	22	22	

	L. Co. Arg. 1	Essex J-n U.S.A. 1	Sogn Moen Nor. 4	Lina Sl. 2	Leppäkoski Fin. 1	Sth. Med.	Med.	
							Scand.	Not Scand.
								25
—1051	19		50	19		35	35	18
	12		48	23		36	36	23
	16		17	13		19	16	22
	19		21	14		20	11	24
	15		11	17		30	19	16
	17		13	18		25	18	25
	22		11	12		14	12	18
	17		8	12		13	11	22
	17		17	15		19	17	15
1060	19		19	28		26	28	14
	24		16	8		15	13	27
	16		19	13		25	19	18
	17		17	11		15	14	20
	12		21	20		30	25	24
	15		27	22		8	15	18
	12		17	25		14	17	21
	19		10	28		12	20	40
	19		14	20		6	13	16
	17		14	26		9	18	17
1070	40	15	18	51		33	42	20
	17	16	31	32		29	30	20
	22	14	20	15		28	21	17
	49	13	15	20		30	22	15
	21	12	7	14		26	16	19
	28	12	7	14		26	16	17
	19	16	8	17		28	23	23
	22	16	7	22		34	28	18
	31	8	9	17		30	24	20
	43	14	8	16		33	25	35
1080	15	11	11	13		25	16	12
	12	8	14	15		26	18	17
	43	13	12	13		27	17	16
	46	15	19	23		33	25	17
	24	13	13	21		29	25	16
	22	9	8	20		24	22	20
	15	11		22		24	(23)	33
	21	13		15		30	15	20
	13	8		21		26	24	29
	15	7	7	16		22	15	19
1090	14	5	13	25		25	21	18
	13	9	13	23		23	23	19
	13	7	8	23		24	23	
	20	7	9	14	15	21	15	
	14	8	17	20	19	23	20	
	17	5	13	23	15	18	15	
	12	6	17	15	19	19	17	
	17	8	33	28	23	24	27	
	13	7	31	31	15	20	31	
	20	11	18	13	18	25	16	
—1100	13	8	20	23	15	25	22	

	L. Co. Arg. 1	Essex J-n USA 1	Sogn Moen Nor. 4	Finspong Ög. 1	Lina Sl. 2	Södertälje 3	Stockholm Med.	Leppäkoski Fin. 1	Med. Scand.	Med. Not Scand.
—1101	20	10	15		18		23	20	19	15
	15	8	8		11		19	20	16	8
	12	11	8		7		24	19	22	12
	11	6	12		33		20	15	20	11
	10	7	9		26		16	12	16	10
	10	6	13		32		16	15	16	10
	16	10	12		31		19	14	19	16
	13	11	11		22		15	14	16	11
	14	5	10		20		14	14	15	5
1110	14	8	10		31		14	16	20	14
	13	8	10		55		22	15	31	13
	10	9	11		42	16	18	15	20	10
	16	10	12		—	16	21	13	16	13
	19	11	9		—	8	16	11	11	11
	11	15	10		▽	11	19	13	13	15
	13	11	9			7	17	14	11	13
	14	10	14			14	22	11	15	12
	19	10	23			20	27	15	21	15
	14	9				14	22	13	16	12
1120	16	9				12	21	14	17	18
	13	6				9	20	17	15	10
	16	10				15	22	20	19	13
	16	10				12	20	17	16	13
	13	13				16	22	19	19	13
	10	8				10	15	12	12	9
	16	10				13	19	19	17	10
	30	8				15	20	17	17	30
	35	8				16	26	20	21	15
	17	11				15	22	20	19	11
1130	12	8		6		12	19	21	17	10
	13	10		6		—	22	23	23	12
	9	8		4		—	18	21	20	9
	13	12		7		▽	23	23	23	12
	10	10		5			19	13	16	10
	13	12		8			21	21	21	12
	15	10		6			17	19	18	13
	14	13		8			25	39	32	14
	8	10		6			16	20	18	9
	12	10		6			16	20	18	11
1140	14	13		10			25	38	32	14
	10	11		8			16	17	16	11
	9	10		6			17	21	17	10
	14	16		7			25	20	25	16
	41	13		6			25	27	26	13
	23	15		7			32	33	33	19
	14	13		5			24	20	22	13
	11	15		7			27	23	25	15
	14	12		5			21	20	21	12
	7	15		10			32	38	35	15
—1150	10	11		7			22	20	20	11

	L. Co. Arg. 1	Essex J-n USA 1	Biano Him. 2	Kvarstein Nor. 3	Finspong Ög. 1	Spårtorp Ög. 2	Vagnhärad Sl. 40	Stockholm Med.	Leppäkoski Fin. 1	Med. Scand.
—1151	14	10			5			21	22	16
	17	13			8			21	42	24
	16	12		10	7			23	25	16
	13	13		13	8			33	40	23
	13	10		9	5			24	14	14
	20	14		8	7			27	16	17
	27	10		14	5			27	15	12
	34	12		9	6			32	17	16
	16	8		5	8			27	15	16
1160	18	11		6	10			30	20	17
	15	11		5	5			27	19	9
	21	9		7	7			25	15	16
	11	13		4	10			30	18	19
	30	12		9	8			27	14	12
	17	15		9	7			28	18	18
	12	17		6	8			33	18	20
	14	15		15	8			26	16	17
	29	15		9	11	18		29	21	18
	19			7	8	21	19	26	16	17
1170	14			10	8	28	23	26	13	17
	11			6		12	20		16	14
	25			7		12	14		13	12
	23			13		32	19		21	24
	25			7		29	15		18	13
	21			8		25	15		16	13
	14			14		9	17		21	17
	31			6		15	14		16	12
	20			13		10	23		27	18
	19			13		15	17		19	12
1180	39		18	12		12	22		25	17
	25		11	8		10	18		35	13
	21		11	6		8	17		24	7
	27		30	7		15	13		16	16
	19		28	10		11	16		17	14
	12		11	12		22	20		24	19
	17		9	7		10	21		20	17
	16		17	9		13	27		40	20
	17		12	8		15	32		24	23
	19		8	10		14	20		25	17
1190	25		9	12		20	28		36	24
	14		6	7		13	19		15	16
	11		8	8		8	18		20	16
	14		7	7		9	18		25	17
	25		12	7		10	17		26	17
	11		8	7		12	15		20	14
	23		7	11		9	14		55	22
	25		23	18		19	22		54	28
	11		12	9		9	16		22	14
	8		14	21		17	24		49	28
—1200	7		8	12		9	19		30	10

	Toronto Can. 1	Biano Him. 2	Kvarstein Nor. 3	Vagnhärad Sl. 1	Med. Scand.	Med. Not Scand.
—1201	12	13	7	11	9	12
	15	11	17	13	15	15
	10	12	6	9	8	10
	17	10	7	17	7	14
	23	11	12	15	14	17
	10	9	12	10	11	10
	11	11	12	21	11	11
	14	14	13	27	27	14
	10	8	14	10	10	9
1210	13	8	5	10	10	8
	13	7	6	12	12	10
	13	5	8	12	12	9
	16	5	6	13	13	16
	28	5	7	16	16	28
	21	6	12	12	12	14
	16	6	7	10	10	11
	23	9	9	14	14	16
	21	10	12	12	12	16
	19	9	8	20	20	14
1220	26	10	16	11	11	18
	47	15	10	15	13	32
	32	11	10	14	12	22
	25	11	7	11	9	11
	20	14		14	14	14
	25	8	4	14	4	17
	33	8	45	11	28	21
	21	6	36	9	23	14
	19	10	18	14	21	15
	41	10	8	8	8	26
1230	32	9	15	12	14	21
	34	12	11	8	10	17
	41	11	17	10	19	21
	37	11	10	11	10	24
	8	10	17	8	8	9
	10	9	17	10	10	10
	13	8	12	12	12	11
	21	11	6	17	17	
	11	13	8	9	9	
	12	8	17	10	14	10
1240	9	7	11	8	8	8
	8	6	14	7	7	7
	8	9	11	10	11	9
	12	11	16	11	14	12
	10	9	10	5	8	10
	16	11	17	10	14	14
	8	16	18	8	13	12
	11	21		12	12	16
	8	18	17	5	5	13
	—	15	10	7	9	
—1250	—	12	5	4	5	

	Toronto Can. 1	Biano Him. 2	Kvarstein Nor. 3	Mariesjö Vg. 2	Vagnhärad Sl. 1	Med. Scand.	Med. Not Scand.
—1251	8	11	6		7	7	8
	8	10	10		8	9	8
	14	8	20		12	16	14
	11	7	15		11	11	11
	7	7	15		7	7	7
	10	6	11	15	10	12	10
	7	6	9	15	8	11	7
	10	5	18	29	10	20	10
	6	8	25	19	5	16	7
1260	10	8	25	11	10	11	9
	14	11	12	27	11	17	13
	14	11	15	21	9	15	13
	11	8	9	20	8	12	10
		12	11	26	11	16	12
	16	10	12	19	7	12	13
	36	14	17	14	7	17	25
	24	12	12	21	8	14	18
	40	20	48	35	10	28	25
	28	15	12	27	8	16	22
1270	26	15	22	27	6	18	20
	22	11	16	25	4	15	17
	16	8	16	17	2	10	12
	19	10	13	20	4	24	15
	6	7	13	9	11	11	7
	6	5	10	11	8	11	6
	5	5	9	10	2	10	5
	8	6	8	8	4	8	7
	10	5	13	16	3	15	8
	4		9	12	7	9	4
1280	5		16	15	8	13	5
	4		10	12	5	9	4
	5		21	19	10	17	5
	4		11	10	6	9	4
			16	11	7	(11)	
			24	14	2	(13)	
			11		2	(7)	
			19		3	(11)	
			8		5	(7)	
		Sesko	10		6	(8)	
1290		Him.	18		4	(11)	
		1	18		6	(12)	
			19		3	(11)	
		7	8		5	7	
		16	15		5	10	
		35	26		13	20	
		27	10		4	7	
		31	10		5	8	
		26	13		5	9	
		31	12		3	8	
—1300		27	13		4	9	

	Sesko Him. 1	Kvarstein Nor. 3	Mariesjö Vg. 2	Korsberga Vg. 1	Leppäkoski Fin. 1	Med. Scand.
—1301	26	14		4	10	7
	27	10		8	12	15
	25	14		8	26	19
	27	11		4	7	6
	26	9		6	26	16
	20	15		4	17	11
	18	10	14	5	16	8
	16	11	11	5	11	9
	15	14	13	6	13	11
1310	13	12	11	5	10	9
	15	12	10	6	18	5
	18	16	12	9	17	13
	29	9	29	10	24	27
	21	8	12	10	20	13
	21	6	18	4	13	8
	20	10	8	5	20	10
	17	8		10	14	9
	16	7		8	17	11
	20	10		11	18	15
1320	22	14		9	4	7
	30	14		18	8	13
	25	13		13	9	13
	30	18		15	10	17
	33	7		16	20	12
	34	6		16	10	7
	38	22		18	21	20
	33	10		16	10	13
	36	9		19	13	16
	27	11		18	14	15
1330	33	26		26	12	26
	42	11		22	18	25
	30	18		12	7	10
	17	10		17	25	21
	13	13		8	14	11
	20	11		14	14	14
	15	8		7	4	6
	16	9		11	18	13
	15	8		12	19	16
	17	20		8	5	5
1340	16	15		8	16	8
	13	12		8	20	13
	14	25		12	21	19
	11	13		8	15	12
	9	14		8	9	10
	12	15		15	13	15
	11	14		10	30	20
	8	40		5	14	10
	6	21		6	17	15
	6	14		7	16	12
—1350	7	18		12	26	19

	Sesko Him. 1	Kvarstein Nor. 3	Korsberga Vg. 1	Leppäkoski Fin. 1	Med. Scand.
—1351	8	13	9	12	11
	6	10	12	24	18
	5	25	10	5	13
	4	26	8	12	15
	4	11	5	20	12
	3	12	12	14	13
	6	35	11	18	21
	7	15	9	12	12
	8	6	7	12	9
1360	6	8	11	17	13
	6	12	10	30	17
	8	16	20	9	18
	16	24	23	9	24
	18	20	25	17	23
	17	12	13	24	12
	23	16	9	9	16
	23	10	15	11	13
	30	15	38	18	27
	20	16	13	30	13
1370	22	13	17	13	15
	17	32	8	13	11
	11	34	5	9	16
	8	15	6	6	9
	9	21	12	16	16
		16	8	9	11
		15	7	19	14
		16	8	31	16
		10	12	15	12
		22	13	18	18
1380		22	8	11	14
		22	10	22	18
		10	10	17	12
		12	14	27	14
		13	6	25	15
		21	14	27	17
		15	14	19	16
		8	15	23	15
		7	9	7	8
		10	9	22	14
1390		30	14	25	23
		17	12	25	18
		17	12	27	9
		17	13	41	27
		16	18	11	15
		14	16	16	16
		17	14	12	18
		19	20	24	21
		13	13	14	13
		14	16	10	13
—1400			28	14	21

Affix to pp. 292 293 294

	Vikbäcken 175 mm E. Jl. 2	Hammarstrand E. Jl. 4		E. Jl. 2	Hammarstrand E. Jl. 4		Hammarstrand E. Jl. 4		Singsån E. Jl. 1 a		E. Jl. 1 a
−1	½ 5		−51	9	22	−101	8	−151		−201	12
	6			15	19		10				13
	6			14	17		15				14
	5			25	21		15				26
	5			10	15		27				11
	25			35	15		28				13
	18			14	20		21				11
	35			12	22		17				15
	9			12	19		26				12
−10	7		−60	13	20	−110	21	−160		−210	10
	8			13	22		21				16
	12			12	22		24				12
	11			12	21		28		17		15
	8			8	21		25		17		14
	11			11	23		19		15		12
	8			14	17		22		8		8
	27			15	18		18		10		14
	8			10	21		18		8		10
	14			10	22		23		8		14 ↑
−20	6		−70	8	17	−120	22	−170	12	−220	10½
	6			12	20		26		10		¼ 11
	5			12	23		22		11		10
	4			12	19		21		10		↓ 11
	3	18		½12	26		26		11		9
	8	15		20¼	25		22		12		10
	9	17		10	26		25		11		11
	4	15		10	27		18		11		12
	4	19		11	20		27		11		11
	5	17		8	22		21		10		3
−30	3	16	−80	10	30	−130	20	−180	16	−230	8
	6	13		8	32		26		13		7
	5	18		6	27		17		12		13
	15	19		9	20		26		11		10
	9	17		12	23		19		23		30
	8	18		10	17		28		19		11
	10	19		11	14		20		15		14
	5	17		23	23		23		12		8
	6	19		20	24		22		13		20
	5	17		16	22				14		14
−40	4	15	−90	12	20	−140		−190	12	−240	18
	5	12		11	18				12		15
	3	17		12	27				17		21
	6	18		15	23				17		19
	6	19		19	23				20		30
	6	23		21	20				13		49
	5	18		9	31				14		58
	3	20		18	23				16		40
	4	26		14	15				10		58
	4	18		20	8				15		36
−50	3	22	−100	16	9	−150		−200	14	−250	52

EXPLICATIONS
TO MAPS AND PLATES
OF THE ATLAS

Remarks to the maps.

Pl. 54. Ose hills at Ulriksdal, Stockholm N.

From the very north end of Stockholm the so-called Stockholm ose or rather the stroke of ose hills deposited by the late Glacial melt-river at Stockholm is here given with isohypses for every 5 m unto somewhat north of the Royal castle, for the regions where such are available.

The map includes from S to N the series of prominent ose-hills from Långkullen and Storkullen at Haga Norra past the main Ulriksdal or Kvarnkullen ose hill with the big section shown by Pl. 8 b, and further up to the island Kaninholmen, where most of the gravel is carried away.

All this ose material is evidently deposited by one and the same ose river, following the depressions of Lake Brunnsviken and the Baltic bay of Edsviken, while outside of the map the melt-river was captured by the northernmost part of the bay named and thereafter by the present Lake Norrviken.

On the map are also marked some so-called storm terraces, at various stages of the land upheaval, cut out at the wind side by especially heavy gales, which at the corresponding lee-side level have left no traces of erosion.

Near the north end of Lake Brunnsviken an example of some such storm terraces is given by a map on a larger scale and by a photo of the north slope of Ling's ose hill, Figs 12, 13.

Pl. 55. Storkullen ose hill.

One of the most representative of the ose-hills north of Stockholm is that one called Storkullen, about to the west of the Royal castle of Haga. Its actual summit, which now is a little lower, reached very nearly 51 m a. s., being the highest point in the environs and possibly cut down to this level at the maximum stage of the Postglacial Sea, thus forming the so-called PG. Its rather free situation has allowed the cutting out of storm terraces at the following levels and from about the following directions:

c. 50	m	from	about	E	31.6	m	from	about	SW
42.0	»	»	»	W	29.2	»	»	»	E
40.1	»	»	»	SW	24.6	»	»	»	N
36.8	»	»	»	NW	22.9	»	»	»	NNW
33.0	»	»	»	NNE	20.5	»	»	»	NNW
					13.4	»	»	»	NNW

On the upper, more flat summit of the ose the waves have not been capable of cutting terraces but have washed and reassorted the gravel into half a dozen of pebbly beaches in concentric bows around the summit, showing a small slope from east to west, or probably in the direction of the stronger winds from the open sea. Small figures: level of beaches in m above 40 m a. s. Bigger figures: heights in m a. s.

On the east side, some local block rafts occur through icebergs stranded on this side.

In the great gravel and sand section, on the south side of the hill, postglacial shells of the ordinary Baltic species were found in the lower part of the considerable masses of marine down-wash which, with a thickness up to about 10 m, surrounds especially the western side of the ose-hills, proving that its original height has been considerably lowered and smoothened by wave action, a circumstance necessary to take into account when discussing the original, but now as a rule very degraded form of the oses.

By the help of the map and of what has been said concerning Storkullen hill, this region is very instructive to ose studies in the field, as seen also from Pls 56, 57 and Pl. 10.

Pl. 56. Glacial traces north of Stockholm. Ice recession.

As already mentioned, the region north of Stockholm is of special geologic interest, exhibiting along the west side of Lake Brunnsviken a most instructive part of the Stockholm ose, and especially along the lee sides of the lake shores of Brunnsviken and the bay of Lilla Värtan, interesting sets of terminal moraines, indicating a special supply of boulders from fissure systems along those old depressions.

Except along the shore of Värtan the region is mostly but moderately hilly and thus favourable to the study of varve deposition and ice-recession.

The receding ice-border exhibited somewhat protruding lobes along the lake depressions, thus lingering at the Haga region along the Brunnsviken depression about a couple of years longer than at both sides. Westwards from the ose the ice-recession was more uniform.

Pl. 57. Glacial traces north of Stockholm. Varve thickness.

This map gives an example of the clay distribution within one single annual varve from the year −1028, when the ice-border passed just north of Storkullen hill, sending out smaller and less marked lobes of clay along the west side of the ose.

Towards the east side of the ose the varve deposition was much more considerable. The thickness of the synchronous bottom varve could here be determined at quite a number of points, thus allowing the drawing of isopachytes or lines of equal thickness for every 0.1 m, thereby indicating how the varved clay became distributed over the ground below the whole of the so-called »Scientific town» along the east side of Lake Brunnsviken.

In the neighbourhood of the very mouth of the ose river depositing the varve of year −1028 it has not succeeded to get any measurement of the corresponding varve thickness; but a little farther out toward SE the greatest thickness of the bottom varve along its axis was somewhat more than 5 dm until about toward SE, where the axis of the clay varve in question was bent in a bow toward E and ENE, rapidly thinning out to about 3 dm. Being directed toward the site of the Riksmuseum, its foundation is enclosed by two arms, being still somewhat over 2 dm. From this point, all the way following the land-ice border of the year in question (−1028), the clay-lobe is now directed towards E, gradually being diminished to less than 1 dm.

When reaching the depression of the actual Lake Brunnsviken, the clay-lobe is sending out a side branch, 2 dm thick, toward SSE, thinning out to 2 dm, about off the Veterinär Institute, being soon bipartite with the southeastern branch the longest and still reaching the thickness curve of 1 dm, somewhat E of Albano towards Östra Stn.

From other observations along the Swedish time scale it has been found that the finest sediment of one and the same varve can reach more than 170 km out from its origin at the ice-border with a thickness of some single mm.

But already from the proximal parts of the varve, here mapped out as an example, it means that the clay sediment and the bottom current may have had an easterly deviation.

On the opposite, the great masses of ice-drifted, leading Baltic erratics have certified that the cotemporary surface current quite dominantly must have had a westerly direction. This may be explained by the downsinking winds from the land-ice with their westerly deviation.

If the east-going bottom current will be certified, it might be explained as a reaction current, at least partly caused by those at the surface which worked in the same direction as the considerable quantities of water from rivers and melting land-ice, streaming westwards out of the Baltic.

Obvious is that continued studies of chronologic methods can elucidate also this kind of geophysic events.

Pl. 58. Quaternary geology of the Stockholm region.

1: 150 000.

This map is a photographic reduction to a smaller scale of the map of 1932 with the same name. It comprises a region which from Stockholm as a rule can be reached by one or a few days' excursion. It represents a happy variation of Mid-Swedish Quaternary geology and most of the important phenomena are described in a chapter called English Explanations with detailed maps and other illustrations.

By the help of more than 700 varve measurements ice-border lines are given for every tenth of the 170 years –1150 to –980 b. Z. just at the transition between the Goti- and Finiglacial subepochs and the corresponding changes in the water level and climate.

Within the so-called Södertörn horst, and especially in the southeast part of the map counted from the renowned marine inlet to Stockholm, an obvious bipartition is accentuated by a somewhat darker colour from the preponderance of lakes and narrow fissure valleys while the depressions outside the horst are much more widened by weathering, covered by Quaternary sediment, and thus on the map represented by a lighter shade.

This milder topography also no doubt favoured the first location of Stockholm.

Pl. 59. Bromma region; seismic moraines W of Stockholm.

In 1889 the first small terminal moraines were mapped out in this region, and all since that time by and by the remainder of this remarkable morainic association has been plotted in on the adjoined map. During this half century the observations have been too accumulated to be all appropriately reproduced in this publication, whereas the map may speak for itself. It gives the essential part of the morainic group, showing its rather well limited extension toward the W, S and E. As already stated at their discovery, the distance between the different moraine lines was in the main about the same as that found by varve measurements for the annual ice-recession in the Stockholm region, which made their annual origin probable and somewhat later also directly proved by detailed varve measurements.

Big boulders occur mainly on the south side of the morainic ridges, and especially at the southern part of the occurrence the blocks often had large dimensions and angular borders. The southernmost moraines sometimes passed over into an accumulation of boulders or crossed bed-rocks almost in situ.

The ice-edge of every third year is marked with a blue line for the years –1051 to –1030.

A. *South Part.*

In 1935, when preparing a geologic map of the environs of the new aerodrome at Bromma, I became convinced that the quite local, overwhelming occurrence of great, angular boulders scarcely could be explained without the assumption of a considerable earthquake at the time of the ice-recession whereby, as already mentioned, the boulders were shoved together along the winter moraines, thereby exhibiting, by the help of the map, excellent opportunities of getting easily accessible, very striking insights concerning the magistral results of the cooperation between two such prominent forces.

Close to the point from where the earthquake seems to have originated and where as a confirmation Professor R. Speight suggested the occurrence of a synchronous rock-fissure, this was also afterwards investigated in detail, being reproduced by the photo, Pl. 34, showing the open fissure along the foot of a vertical rock-side and also, by the special map, Fig. 63, just east of the considerable Ragnarök moraine.

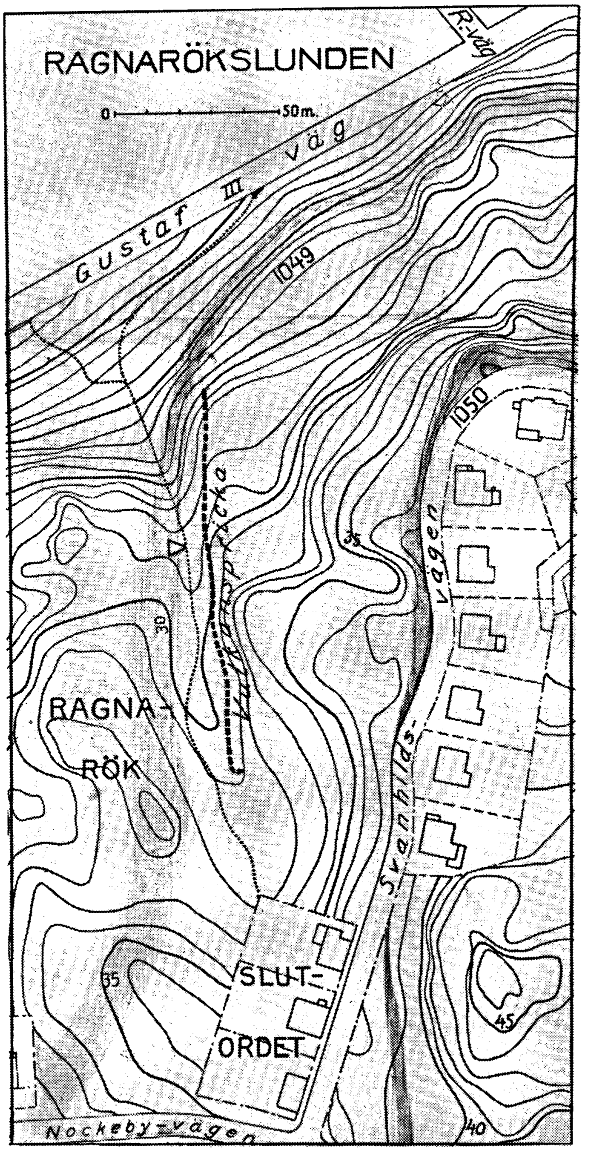

Fig. 64. Stockholm, Bromma. Ragnarök block chaos or seismic centre with dated volcanic fissure: thick, broken line. Shaded zones: annual block moraines of the years –1050 and –1049 b. Z.

A special interest is having here, so easy of access, an excellent example, the very first one of that special kind of earthquakes, which perhaps will show to be a quite normal effect of such movements in the earth crust as could be expected to have followed the rapid and considerable land upheaval which seems to have been a general consequence of the disappearance of the heavy ice-load.

The possibility of getting definite figures for the solution of these interesting geophysical problems seems to make it well worth to continue, as far as possible, with measurements and detailed mapping at this uncommonly favourable instance of a quite special kind of crustal phenomena, which must have been very common, though hitherto rather unknown.

Seismic Centre of Ragnarök. The oldest, continuous boulder moraines on this map are those of the year –1050, visible just north of the word 'Ragnarök' as closely engirdling the Nockeby Plateau, and formed when the ice-body pressed tightly against its slopes, while protruding in the valleys at both sides. The open fissure or volcanic vent is seen just north of letter 'R' in Ragnarök. In the next year, –1049, there were at hand still greater block-masses, forming the real block-chaos of Ragnarök, and pushed together into the concentric winter moraine bows of the year –1049, round the marked land-ice tongue, which reached exactly to the present end-station of the electric line at Nockeby, on the height near Drottningholm bridge. Just east, where Gustaf III Väg branches out from Drottningholmsvägen Road, this lobe left the negative trace of its ice-body in form of the deepest hollow of the region — sediment surface 16 m a. s. — while the positive traces are to be seen in the several series of boulder garlands pressed against each other in the chaos of Ragnarök and showing repeated assets of the ice-push against this slope. During the winter of the following year, –1048, the ice-push formed an inner concentric bow of a similar block chaos, at this very place. Towards the sides the moraine garlands mainly continue eastwards. Thus the ice-edge of –1049 has aligned the earthquake-broken rock boulders especially in the marked seismic moras of Odinslund (SW of Gustaf III Väg and Djupdalsvägen) and Olovslund (SE of the big, new school), also presented by the photos of Pls 26—28. At the latter place two horse-shoe bows of the moraines –1048 closely approach from the north, to the east clearly showing their transition into broken bed-rocks. North of Gustaf III Road the moraine –1048 forms the block chaos of Torslunden, while Mimer's lund — at the SE corner of Djupdalsvägen and Drottningholmsvägen Roads — belongs to the years –1047 and –1046. In Smedslätten, at the east side of the Nockeby plateau as a whole, there are also some groups of rock-boulders, e.g. in the little park of Fågelsång and near Smedslätten mansion. The biggest boulder of the region is the so-called 'Domarstenen' at the lake shore in Ålstensparken, probably loosened from the fissures of the waterways, but it is an isolated erratic of which the origin scarcely can be closely traced.

B. *North Part.*

In this part of the map the generally rather straight moraines, from the outdying effect of the earthquake, denote a far more regular ice-recession, which is also confirmed by the varve measurements. However, sometimes intermediate moraines are found within one year's recession, probably denoting small autumn stops or micro-advances of the ice-border. As mentioned in 1936, a very local oscillation occurs just north of the Bromma aerodome, as seen in the midst of this map. Beginning in –1039 by a smaller lobe, it was always more accentuated unto the year –1034, of which a triangular ice-tongue overlapped the winter-margin of the preceding year, –1035. In NW, close southwest of Bromsten, there are, on the heights of Sundby Villastad, very abundant boulder-moraines of the years 1033—1031, of which, within the year –1032 was formed a garland round a small but accentuated ice-tongue. Also even smaller analogous, annual tongues can be found, but no one ever seen consequence to the great, recessional phenomenon as a whole.

Pl. 60. Kaknäs region, seismic moraines E of Stockholm.

This morainic region probably forms quite a parallel to the moraine association at Bromma, though it is hitherto less studied in detail. Here the earth movements seem to have got hold of the principal block material from extended, earlier fissure zones along several lakes as well as along Värtan Strait, Brunnsviken and Edsviken Bays and Norrviken Lake farther north.

By the measurements of bottom-varve series it has been possible even among this medley of intermediate moraines to follow the trend of single ice-margins, of which those of –1039, 1042 and 1045 b. Z. are marked out with colour. Here also is the situation of the first measurements A, B, C, also marked on Fig. 23.

Pl. 61. Maps of the Uppsala region.

A. The map of the Uppsala ose. From the University building west of the cathedral and toward SSE to the Polack hill the ose was mapped and levelled, by and by, during my studies in Uppsala about in 1880, on the scale of 1 : 2000, here reduced to 1 : 6000.

Soon it turned out that the ose was built up of a series of individual centres with coarse, pebbly material in their northern or proximal part, which was explained as due to successive deposition, every year, in the glacier vault of the receding ice-border. The occurrence of the coarsest, most pebbly material was explained as marking the place in the vault where the current of one year began to slacken and thereby to deposit the coarsest material, while farther out successively was deposited, first a layer of sandy clay, soon going over into a greater percentage of clay.

In the magnificent section cut right through by the high road crossing the ose details of the great section, Pl. 62, were also by and by closely measured and put together, affording a typical example of the ose structure where it had not been too disturbed by changes in the current.

The main direction of the ose current was here determined by the eastern slope of the flat plateau, rising immediately along the west side of Uppsala. Between this plateau and the ose ridge south of the transverse road named for a length of nearly 1 km, or slightly beyond the small but marked transverse valley, called Geijersdal, traces were found of a little ose-dammed lake, determined by erosion terraces at the outlet to about 20 m a. s.

On the east side of the Sture hill some storm terraces have been levelled, as also a faint shore-line E of Grindstugan at 30 m a. s., turned northwards, and another one on the east side of Tunåsen, at 31 m a. s.

For further investigations are recommended the interjacent regions and especially whether earthquakes may have influenced the structure of the synchronous ose-hills.

B. The adjoined *map of Old Uppsala,* measured by C. J. ANRICK, is diminished from the work of SUNE LINDQVIST on Uppsala högar with an attempt to sift out the natural iso hypses of the ose and its environs. Scale 1: 6000.

C. The little *map of Tunåsen hill,* situated between Old and New Uppsala, as a whole is measured by C. J. ANRICK, while the shore-line of 31 m a. s. is just mentioned. 1: 6000.

D. Map of Uppsala and environs. On the scale of c. 1 : 150 000 are given the general features of the Uppsala region. The trend of the Uppsala ose is winding from Lake Mälaren in the south, along Fyris River to Uppsala town, from there northwards to Tunåsen and Old Uppsala hills. At some distance to the east the markings of annual ice-recession along Divisions L and M are showing how the clay campaign of 1905 was carried across the Uppsala plain.

Topographically the map is cut by a diagonal NW—SE, forming the slightly dissected border of the uplifted region to the southwest. It is along this border that the ose river found its way, probably along the most depressed part of the adjoining plain, which may be slowly rising to the northeast, a parallel to the conditions south and north of the Stockholm inlet and other analogous fault-lines in Middle Sweden.

The local varve measurements from Pl. 80 and pp. 135—136 are also marked with their respective bottom years, but the drawing of continuous ice-margins over the region is left until a still greater number of measurements may be obtained.

Pl. 62. Profile of the Uppsala ose.

Just at Uppsala, where the ose, having crossed the plain about from N to S and turned somewhat more toward SE along the side of the plateau on the south side of the town, the ose-river evidently had its outlet, year after year, about southwards and thus across the ultimate, main direction of the combined ose-ridge.

Thus when some sixty years ago the new road was cut across the ose a little south of Uppsala, it happened to expose a rather ideal section along the axis of a typical ose-centre.

The successive sections thereafter exposed I levelled and combined into the profile, Pl. 62, being thus as to the details rather correct, but as to the connection somewhat schematic.

In the main the very ose-centre was cut through the northern part of the section, where in the coarsest portion of the cobbly and gravelly material I counted some 300 well rounded cobbles, more than 0.3 m in diameter. About at the midst of the section this passed gradually over into finer gravel with a southerly dip, in its order passing over a considerable layer of clean, middle-grained sand, which must have been the direct distal continuation of the just mentioned, coarser, proximal complement. An indication of that distal sand as being deposited in the widening part of the then opening of the melt river is given by a couple of only 1 cm thick, but very persistent, grey winter-layers, which was followed all the way, probably indicating the winter minimum of the sedimentation.

These two, tiny clay beds made it possible to follow accurately the whole present attitude of the sand beds, and to fix in detail the existence of one marked fault with a throw northwards of no less than 4.5 m and at some 8 m westwards another parallel fault with a similar fall of more than 5 m in the same direction, making some 10 m in all.

Such big faults, being also at several other places observed near the sides of the oses, no doubt may be due to basal parts of the glacier vaults, being somewhat melt-eroded, covered by ose sediment, and afterwards by their final melting causing the faults in question.

That also a smaller ice-flake happened to be covered by the sand seems to be indicated by a series of one-sided, small faults converging towards a certain point of the section.

Some details from the marine covering of the ose indicated that the fault-engendering melting of the ice-remnants in question continued at least some time after the deposition of the ordinary varved clay, but that it was finished before the deposition of regularly bedded sand-layers below the postglacial baltic clay.

The great faults named certify that the ose, when still covered as well by its own fault-witnessed parts as by later marine sediments must have been some 10—20 m higher than now.

As witnesses of later shore-erosion have been observed numerous lumps of varved clay, preserved in occasional depressions with postglacial sand on the actual summit of the ose.

The ose section affords a magnificent example of how necessary, by discussing the present topography of the oses, to take into account the sometimes very intense secondary wave erosion, which often so essentially has smoothened and joined together the separate ose-hills.

Pl. 63. Land-emergence during ice-recession in Middle and North Sweden.

The basement map was constructed in 1897 by the present author and founded on hypsometrical maps, reduced, by the help of MG determinations, to the heights at the time when the land was most deeply depressed. This reduction is of course only approximate, but gives, no doubt, the whole then situation much better than a recent hypsometric map. The highest summits of those days, SW of Kvarken Strait, must have been some 300 m lower than now with the highest sea-shores accordingly reaching almost as much higher than the present sea-level. Still the blue colour marks depths between −100 — −200 — −300 m and deeper, while the brown colour marks heights between −100 — ± 0 — + 200 — + 400 and higher.

The black lines of ice recession for Sweden, S Norway and Finland are drawn mainly according to bottom varve datings of the time scale. They show equal ice-recession for every 100 years, with the curves for every 500 years are somewhat thicker. The thick broken curves delimit the subepochs, namely the Goti- and Finiglacial ones by the ice-border line of −1073 b. Z., and the Finiglacial and Postglacial ones by the ice-border line of the Zero year, which marks the *Finis Aetatis Glacialis* or the end of the Ice Age at about 8640 years before 1900 A. D.

The Ra-stage of terraces compiled from Norwegian authors (VOGT, GRÖNLIE, KALDHOL, UNDÅS, a. o.) is averagely simultaneous with the Goti-Finiglacial limit. The northernmost trend of the ice-margins is mainly after TANNER (1914), to the SE combined with SAURAMO's of 1929.

Pl. 64. Bilateral ice-recession.

Scale 1 : 2 mill.

The map gives a general view of what is known concerning the bilateral ice-recession within the Jemtland depression across the Scandinavian peninsula.

The ice-border lines for every 100th years are full-drawn, yet for every 300th years marked by broken lines.

Some of the main points of varve measurements are marked by crosses.

Somewhat earlier ice-sheds are indicated by round dots, joined in pairs like small dumbles.

Remarkable is how the catastrophic ice-recession over the Botnic depression during the century −600 to −500 has essentially influenced the ice-recession during the following centuries up towards the Postglacial ice-borders, which still in lack of direct determinations are rather schematical.

The Zero line, or the ice-border marking the limit between the Fini- and Postglacial subepochs, indicates that Sweden to the north of the Kvarken Sound at the beginning of the Postglacial subepoch was still covered by a rather vast land-ice.

The secondary ice-border lines in the region of Frösön remind, by small, broken lines, of the last Finiglacial ice-readvance from NE into the space left free by the drainage of the Central Jemtland ice-lake.

Pls 65—67. Circum-Botnic crustal movements dated.

Scale 1 : 1.5 mill.

Maps representing leading lines of Fennoscandia and of the Baltic slope.

Legend. Dots = flexure and fissure lines of post-Algonkian age.
Broken lines = isobases of late Quaternary land-uplift, for every ten meters.
Light grey with isohypses = present sea.
Dark grey = late Quaternary extension of Baltic sea or lake.
Black lines = late Quaternary ice-margins.
Black figures = years before and after the Zero-year.
Black bows (Pl. 67) = moraines of post-Glacial age.

General remarks.

In this synopsis two different kinds of land-deformation are discussed. The earlier one is summarised by the small-scale map, Fig. 47, of the post-Algonkian deformation of Fennoscandia. From this earlier deformation the main features of the maps, Pls 65—67, have got their stamp, still representing the traces of pre-Quaternary events by their subdivision into marked, extended plains on one hand, and rather dissected regions on the other.

Also they represent this pre-Quaternary stage of land-evolution as farther developed by the late Glacial land-upheaval.

Further on they indicate the simultaneous ice-recession, gradually leaving access to the wave registration of the highest shore-level reached by the sea on the successively rising land. This »marine limit» is thus not all the way quite synchronous, whereas the isobases and ice-margins indicate at every place the earliest possible time of its formation.

The different kinds of combinations made for the geochronology seem to shed a new light upon the main structure and origin of Fennoscandia and its environs.

Everywhere around the Botnic depression there is a continuous rim of remarkably flat coast regions, at several places coarsely datable by scattered remnants of Silurian (Si), Cambrian (Ca), and Eocambrian (Eo) witnesses of erosion, testifying that their subbasement is somewhat older, or a post-Algonkian baselevel plain.

The continuous, flat topography of this extended baselevel plain is generally rather possible to trace, though as a rule not quite sharp. Along the SE side of Mts Kilsbergen it seems to follow an old dislocation, exhibiting at its down-sunk side Cambro-Silurian beds. In the Gävle region remnants of eo-Cambrian sandstone still occur just as far as the baselevel plain is preserved, and it seems likely that also the Dellen andesite represents a downsunk angle of the baselevel in question.

Pl. 65. Baltic region.

Post-Algonkian features.

On the southern part of the map is shown by curves for every hundredth meter the submarine slope of the regular Archean surface or Baltic flexure which, according to several deep-borings from the Fennoscandian shore-level has a regular southeasterly dip below the Paleozoic bed-rocks of the Baltic States.

Near the Swedish coast and the hinge-line of this Baltic flexure there is an interesting sink-hole, somewhat over 450 m deep, at present representing the maximal depth in the whole of the Baltic and by its steep wall toward the land-side indicating the direction of the dislocation. This very marked sink-hole seems to have been formed about at the intersection between the border of the great Baltic flexure, which is limited by the Archean coast-belt along southeast Sweden and the south Finland coast, representing the southern limit of the azoic Finland region.

From the environs of the sink-hole named, or about from the acute southern prolongation of the Södertörn peninsula south of Stockholm, and following its eastern coast, there occurs a very obvious garland of almost continuous islands, along their land-sides enclosing a continued series of water straits of essential importance to the Stockholm navigation (confer p. 202).

The main lines of the garland are here marked by dotted lines, as no doubt representing fissure zones along dislocations, which have opened the deep strait of the Åland Sea, cutting through the Åland barrier between the Baltic and the Botnic depressions and determining the main configuration of the great peninsula, embracing the whole of the Stockholm region with its thousands of skerries, and northwards continued by the Litho-Botnic flexure, seen on Fig. 47.

Along the opposite land-side border of the best preserved lowland-baselevel its average limit against the much more dissected and hilly, inner parts of the country also is marked by a dotted line, indicating approximately the Alto-Botnic flexure line, visible from its southern end at Mts Kilsbergen by a rather marked, real fault, W of Lake Hjälmaren.

In the more elevated western parts of the country the Paleozoic beds and its nearest Archean subbasement generally are rather dissected.

Just north of the considerable Lake Siljan it seems that the curious, circular central dome of Archean rocks may represent a locally uplifted and less eroded part of the baselevel, surrounded by a ring-formed depression of Paleozoic remnants.

The isobases of late Glacial uplift. The amount of the land-upheaval after the last ice-recession can be directly certified only where the topography was sufficiently elevated to register the highest stages of wave erosion, and this was mainly in the hilly region on the land-side of the still preserved great baselevel plains and the Alto-Botnic flexure.

By a number of levelings of the highest marine limit in that region the present attitude of this unequally upheaved highest shore-level has been determined and marked on the map with isobases for every ten meters. By help of the determinations the corresponding highest coast-line has been constructed as far as the height indications of the maps allow.

The level of the coast-line in question at present is here somewhat over 200 m a. s. As to the probable height of the corresponding sea-level over the great plains to the east, with due regard to the attitude of lower strand-levels, it has been provisionally extrapolated with isobases for a corresponding attitude, giving e. g. for the Stockholm region an amount of about 100 m.

Pl. 66. The Botnic Sea and environs.

In this region the coastal plains are generally more narrow, thus allowing direct determinations of the highest marine limit, at many points of which, especially northwards, completing measurements seem desirable. However, the isobases on the flat coast-land north of Kvarken Strait are partly but extrapolated, as a help for continued direct measurements.

The ancient, large fjord-system around the great rivers Vindel-, Ångerman- and Indals-älven as well as several others are founded on a greater number of direct determinations.

The Botnic Sea with its rather regular elliptic circumference also has a very regular and flat bottom at a depth of generally less than 100 m. East of its axis the flat bottom somewhat exceeds the depth named, but it is not until close in the neighbourhood of the Swedish coast that this depression reaches a depth of 200—300 m.

Like the Baltic also the Botnic Sea has its greatest depth in its northwest part, near the Swedish coast and in form of a narrow sinkhole. This depth of more than 300 m occurs right opposite the well-known region of Nordingrå with marked shore-lines up to 284 m a. s., or the very highest shoremarkings in the whole of Fennoscandia and forming a remarkable, bald part of the Swedish coast with rocky shores, suddenly rising some 200—300 m a. s.

As already emphasised in the text, this very interesting region no doubt deserves a special most detailed investigation. At present the map only in a general way indicates the position of this remarkable land-upheaval. Probably its amount northwards decreases rather rapidly and may reach a centre at the sound of Kvarken, where, especially on the Finland side, the sea-bottom rises by several islands. On the Swedish side the elongated island Holmön may represent the southernmost part of a long, narrow coastal post-Algonkian horst, forming the west coast of Kvarken Strait and continuing northwards to the flat Botnic Bay, or the northernmost, rounded widening of the whole Botnic depression.

Pl. 67. North Botnic region.

Here the submarine plains of late Quaternary age are of a wider extension, as the lower parts of the region were subjected to a shallow transgression. Extended, narrow and also wide bays along the river valleys characterise this northernmost part of the Baltic depression according to principally a number of good barometric measurements, by the help of a motor car systematically executed by C. G. Santesson.

In lack of varve measurements, with exception of those at Lule and Skellefte Rivers, the ice-recession in this flat region is unsufficiently known as to its details. However the varve series date the entire region of this map section to have been laid bare from the ice cover not until during the Postglacial Subepoch, and it was even about half a millennium after its beginning that the above named transgression took place.

North of the marine region, however, there may be a possibility of determining the ice-recession, as varved clay is reported from Pajala in connection with the marked moraine bow, mapped out by K. A. Fredholm in 1886.

In lack of detailed topographic surveying the map has not been carried farther than to the Swedish frontier along the Torne and Muonio Rivers.

Pls 68—71. Ice-recession and some recessional oses in Middle and North Sweden.

Scale 1 : 1 mill.

General remarks.

To the International Geological Congress of 1910 the present author succeeded in getting published a map of late Quaternary phenomena in southern Sweden, including striæ, oses, and the highest marine limit of the region.

The oses were photographically diminished from the map sheets of the Geological Survey, viz. from the scale of 1 : 50 000 to that of 1 : 500 000, thus by 10 : 1, forming a small-scale, very minute reproduction, the first existing of that kind over so great a region. No less than 320 geological map sheets thus were calqued as to this special phenomenon.

That map however reaching northwards only to about the 60th parallel, just north of Uppsala, an extension northwards was desirable but difficult to perform, as the geological mapping had not as yet proceeded but slightly farther north, viz. to southern Dalarna and at the coast to the Gävle region. By half the scale or that of 1 : 1 000 000, however, we have found possibilities of here giving a first general survey of the late Glacial conditions of Middle and North Sweden, including ice-recession, oses, the highest marine limit or ancient water levels of the coast, as also the foremost late Glacial ice-lakes of the region.

In lack of a detailed geologic survey for most part of this region, the present map, reproduced in four sections, Pls 68—71, is founded on a different material, or the topographic maps of the *Generalstaben*, mainly on the scale of 1 : 100 000.

By a long experience, namely, it is found that well developed, typical recessional ose ridges of the type annual oses (cf. E. H. D. G., 1918, p. 846) really do protrude in the landscape as a morphologic form, thus also automatically coming out by careful topographic mapping almost as clearly as by geological surveying. These peculiar, narrow ridges, easily traced on the topographic map sheets, thus give an example of horizontal, regular recession of the ice-edge, as witnessed by the successive deposition of annual ose-centres and further checked by varve measurements.

For more than half of the surface, however, the correctness of this topographic ose-mapping has been controlled by comparison with special ose-mapping of certain regions, investigated and described by various authors.

With respect as well to more schematical investigations as to more detailed ones, we have councelled the following maps of oses and ice-margins, compiled by E. HULT DE GEER.

for the entire region:

1. AXEL ERDMANN, 1868. Öfversigt af rullstensåsarnes utsträckning inom Mälarens och en del af Dalelfvens vattenområden. 1 : 1 000 000. Sveriges Qvartära bildningar, Pl. 8, S.G.U. Oses schematical. Mainly historic interest.

2. A. G. HÖGBOM, 1885. Geologisk karta öfver mellersta delen af Jemtlands län. 1 : 1 000 000. S.G.U., Ser. C, No. 70, 4°. Oses schematical.

3. A. G. HÖGBOM, 1906: Glacialgeologisk karta. 1 : 3 500 000. Norrland, Naturbeskrivning. Norrländskt handbibliotek, Uppsala. Here also a thourough description of many prominent oses.

4. AXEL GAVELIN and A. G. HÖGBOM, 1910: Glacialgeologisk översiktskarta över norra Sverige. 1 : 3 500 000. From 2, with addition of ice-lakes and single oses. S.G.U., Ser Ca, No. 77, frontispiece. Oses schematical.

for parts of the region:

5. GUSTAF FRÖDIN, 1913. Karta över de nordliga Centraljämtska issjöarna. 1 : 200 000. S.G.U., Ser C, No. 246. Oses rather detailed.

6. GUSTAF FRÖDIN, 1914. Isrörelserna under isavsmältningen inom nordvästra Jämtländ. G.F.F., Bd 36. Striæ and ice margins.

7. GUSTAF FRÖDIN, 1925. Glazialgeologische Übersichtskarte. 1 : 800 000. Bull. Geol. Inst. Ups., Vol 19, Pl. 6. Oses half-schematical. Extension: western half of the country across Härjedalen, Jämtland, W. Ångermanland, SW Västerbotten.

8. A. G. NATHORST, 1909. De lösa jordlagren kring Medstugan, Jemtland. 1 : 50 000. G.F.F., Bd 31, Pl. 1. Oses schematical.

9. ALVAR HÖGBOM, 1924. Glacialgeologisk karta över Ångermanälvens källområde. 1 : 200 000. S.G.U., Ser C., No. 328, Årsbok 23.

10. ERIK GRANLUND, 1937 (Not yet published). Jordartskarta över Västerbottens län nedanför odlingsgränsen. 1 : 300 000. S.G.U., Ser. Ca, No. 26. Detailed ose-mapping.

11. VÄINÖ TANNER, 1914. Geografisk översikt över kvartärgeologiska iakttagelser i nordligaste delen av Fennoskandia. 1 : 1 000 000. Bull. Geol. Comm. Finl., No. 38. Semi-detailed ose-mapping.

Fig. 65. Former ose mapping.
--- G. Frödin; —··— J. Frödin; —— E. Granlund; ... A. Hamberg; .... A. Högbom; —·— A. G. Högbom; —– V. Tanner; ⌐⌐ S.G.U. —— Pls 68—71.

12. AXEL HAMBERG, 1906. Geologisk öfversiktskarta öfver de närmaste omgifningarne till Lule älf. 1 : 500 000.

13. JOHN FRÖDIN, 1914. Karta öfver issjöarna i Stora Lule älfs dalgång. 1 : 200 000. Detailed ose-mapping.

Datings.

Varve measurements with bottom varve, geochronologically dated, are given by dots with a figure of years before or after the Zero-year. The lines of ice-recession, when determined by varve measurings, are generally full-drawn. Some ice-border lines among the ice-lake systems as followed by field investigations are taken from other authors, mainly G. FRÖDIN and A. G. HÖGBOM. Legend, see Pl. 69.

The shore-lines for the highest level of the Baltic resp. Botnic sea- and lake-levels are drawn coherently, although they denote successive stages, as dated by the lines of ice-recession for each region. Accordingly the so-called MG, BG and LG are here successively represented from south to north, quite as on Pls 65—67.

Pl. 68. Middle Sweden and environs, or Åland—Oslo region.

It is to be observed, that the *Yoldia* was confined only to the region of brackish water in the east-Mälaren basin and does not occur north of the ice-border line for the year –900 b. Z. From then on the abundance of glacial melt-water must have been more and more dominating, even before the Mid-Swedish sounds were closed and finally the threshold of River Svea älv was uplifted, all until finally the *Ancylus* arrived at Latorp, Närke (confer pp. 209—211). Tentatively these events may be estimated to have occurred respectively about the years –300 and + 300.

The southernmost section of the present map, Pl. 68, represents the ice-recession through Middle Sweden. It begins in SE by the oldest years here concerned, just after the stage of the Finiglacial moraines, and includes all across the Uppland plain the line-measurings of 1905 (E—S), continued by Division T (confer Fig. 37). This region as a whole is the first where the varve triangulation outside Stockholm was extended over a still greater area, according to our plans mainly by J. GRUFMAN (for Sörmland-Uppland-Västmanland), further also for Sörmland the present author; R. LIDÉN, S. FLORIN, A. SÖRLIN, E. NILSSON and others, for Västmanland J. ANRICK, G. LUNDQVIST, for Dalarna some long standard measurements by C. CALDENIUS, R. LIDÉN, S. STENGÅRD, E. ANTEVS, and the present author, while G. AMINOFF measured some localities in the region of Falun to be used for coming detailed works; for Värmland-Norway scattered measurements by the present author, E. ANTEVS, S. DE GEER, E. GRANLUND, and N. G. HÖRNER. The full record of measurers and localities is found on pp. 253—257, and the main pertaining measurements are given graphically on Pls 72 and 77—80.

Two of Dr E. NILSSON's Åland localities are visible on this map as tying on the ice margins from Sweden.

Pl. 69. South Norrland and environs, or Dellen—Femund region.

This map represents the south-north direction of the ice-edge in the Helsingland region of tiny varves, in the south part of the Indal River and in the lower Ångerman fjord, all covered by connections of as well macro- as micro-varves. Confer Localities and Measurers, pp. 252—3 and 257—8, and for the graphic datings Pls 76—77, 81—83.

In the central parts of the region the ice-edge of the Zero year may be better traceable by further investigations, if varves can be found. On the western side some undated ice-margins from field-survey of G. FRÖDIN and G. HOLMSEN are taken in, the latter with its ice-dammed Lake Femunden, where however two short varve series from the Glommen valley are not far distant and give hints as to their age.

Pl. 70. Central Norrland and environs, or Kvarken—Værdalen region.

This map-section represents the interesting part of the country where the bipartition of the Zero year took place and the entangled systems of ice-borders and ice-lake shores of Central Jemtland has been dissolved, in a preliminary way, mainly by G. FRÖDIN and A. G. HÖGBOM. Their main results are here tentatively also combined by our varve datings.

The trans-Scandinavian Jemtland depression during the late Glacial Subepoch still was about twohundred meters lower than now above the sea-level, which means a considerable difference, as the present level of Lake Storsjön is 292 meters above the sea-level. Conclusively through this depression the surrounding parts of the land-ice found a natural outlet towards the western sea, thereby overflowing lower obstacles, such as the pass-points of the mountain valleys, also then much depressed. During the recession of this west-bound Jemtland ice-current quite a series of local ice-dammed lakes were formed which, by their varved deposits, afforded a unique possibility of dating certain stages of this trans-Scandinavian ice-recession. No doubt this quite unique possibility ought to be studied in the greatest possible detail.

The formation of the latest large and deep ice-dammed lake over the Central Jemtland depression of Lake Storsjön seems, by ice-berg fracture, to have caused a rapid, non-climatic ice-recession which, in its order perhaps even after the drainage of the ice-lake through the Indal valley, seems to have given rise to a secondary land-ice advance from the still ice-covered regions to the north, as is also earlier discussed in detail by G. FRÖDIN (1914). In any case the youngest varve measured at Frösön is dated −290, which gives the earliest date possible for the moraine cover at the place. Probably still a number of varves may have been eroded away by the advancing ice.

It is also in accordance with FRÖDIN's investigations concerning the westward migration of the ice-shed that the westerly ice-margins of the Zero-year and the earlier plus-years are drawn highly bending over to the west, however with an indentation for Ströms Vattudal, where the measurement from Fågelberget seems to give no younger a date than −40 for the disappearance of the land-ice over the valley depression, which on a small scale may have formed an indentation analogous to that of Central Jemtland, also here with a pertaining extended ice-dammed lake (GAVELIN, 1910).

On the Norwegian side this map goes down to the coast, showing the situation of the locality of Værdalen, where, although the bottom varve is not attained, the oldest measured varve bears witness of a very high age of the varve deposition in question from the time of the Finiglacial moraines, thus proving the very slow rate of ice-recession on this oceanic side of the ice-shed.

On the eastern, Botnic side is shown the important passage of Kvarken, where, through our datings of SAURAMO's varve localitites, the ice-edge of −300 and a little farther north also that of the Zero year passed over to the present Finland shore, however then submerged by the same extended Baltic ice-lake.

The northeastern part of this map section is covered by the region surveyed by E. GRANLUND, of which the limit is marked on the little plan of ose-maps hitherto compiled, Fig. 63. The oses generally follow the main slope of the land, and the ice-margins tend to adjust themselves somehow at right angles to that slope, as is the case also in south Norrland.

Mainly southwest of GRANLUND's map is the region of River Ångermanälven with LIDÉN's important varve measurements, now well dated by the Time Scale. However, especially for the region of Central Jemtland and Ströms Vattudal further varve measurements are much needed in order to attain a more detailed solution of the entangled problem of the ice-recession in this dissected area, also in close connection with the many successive stages of the ice-lakes.

For the graphic datings, see Pls. 75—76 and 85—86. Localities and Measurers, pp. 250—251.

Pl. 71. North Botnic region.

As to this northernmost map section, the region's uncovering of the land-ice belongs entirely to the Postglacial Epoch. The datings here are wholly based on the few measurements gained during our raid of 1915 for the first tests of long-distance connections, represented graphically on Pls 74 and 84. Also here extended measurements are desirable, not least northwards, in order to settle the local moraine bows of which the southernmost are very near the northwestern corner of the map and a much bigger one farther north, seen on Pl. 67, near the Tärendö bifurcation. It is mentioned already in 1886 by K. A. FREDHOLM, S.G.U., Ser. C, No. 83, and from his map it seems likely that varves could be obtainable within the region, and probably at Pajala. Seemingly this readvance may not have been of very long duration.

As to the oses, the southern part of the map section includes a corner of GRANLUND's map, while the shores of Lule River are surveyed by A. HAMBERG from the sea upwards a little past the inflow of Little Lule River in NW. In the very NW corner is an ose, forming the southernmost of those surveyed by JOHN FRÖDIN for the upper part of the river, outside this map. So are also the main part of V. TANNER's oses (1914), although some of them enter here, duely compared to those of our topographic maps. As an example may be mentioned that one of the oses down in the flat coast-land near Haparanda, bending strongly NW—SE, seemingly crosswise to the general direction, by an occasional visitor was reported to be a real ose, cut through by a road section so that the rounded pebbles were visible, and thus, for its part, bearing witness of a correct topographic ose mapping.

The many extended sand plains, bearing names of heaths, in the neighbourhood of Luleå and Piteå on the main coast as well as on several big islands, at least partly may be interpreted as marginal terraces, although on the other hand this vast distribution of sand in the lower coast-land may be due to wave-outwash from morainic material and oses. Coming field investigations thus may interpret the real nature of the sandplains of Seskarön, Kallaxheden, Sandön at Luleå and Sandön at Piteå, Pitholmsheden, Bondön and Mitterstön islands.

Localities and Measurers, p. 250. Graphic datings, Pls 74, 84.

Remarks to the graphs.

Pl. 72. Divisions of the Swedish time scale.

Although mentioned in the text, pp. 142—154, the Divisions also here may be described according to the very graphs.

Each division is here reproduced separately, so as to show the results as they were gained through the work of the individual measurers at that time of beginning as connected by the author and only exceptionally corroborated by later control measurements. On the Main time scale, Pls 77—78, their mutual connection is given by a single medium curve for each division, correctly dated and thus also partly covering its neighbouring divisions unto a firmly coherent chain.

The southernmost divisions A—C are omitted as belonging to the stage of the Gotiglacial moraines, not treated here, while E and F belong to a region of transition where the very limit between the two subepochs, or the drainage year of the Baltic ice-lake, appears on *Division F.*

The ice-recession across this division is well covered by ten parallel varve graphs of regular and closely identified variations, and it is with a striking conformity that all the present localities exhibit a decided thickness augmentation of the annual sediment after the drainage year of −1073. Confer photos Fig. 26 and Frontispiece.

Division G passes right through Stockholm, from where a number of representative curves are chosen, all as a rule quite regular.

In *Division H, 1, 2,* the measuring line along the railroad passes in a close neighbourhood of the ose, wherefore also the bottom varves attain a rather encumbrant thickness. However even those sandy, proximal varves in general follow the regular climatic variations, as is found by the many parallel measurements.

Divisions I and J likewise follow rather close to the ose, thus also showing a marked parabolic augmentation of the varve thickness towards the bottom.

Divisions K and L in the lower parts, on the contrary, show a tendency to a succession of strong variations in marked bows, spanning over some five to four years, through several decades above the bottom varve. Similar bows are refound in the sediment from Åland, Pl. 79, as well as in Aardal, Sogn, although not being normal in a wider sense, as already in Finland, No. 2, Åbo, there are regular biennic peaks among distal varves of those years, as also at other localities.

Division M shows the regular deposition of sediment along the eastern border of the Uppsala plain at some distance from the ose. For the locations confer the map, Pl. 61, D, and for special Uppsala varve measurements, the graphs of Pl. 80.

In *Division N* the measuring line again approaches the ose, as seen from the lively variations of the curves.

Divisions O, P, and Q, again show a more quiet sedimentation, as especially the two latter ones are carried through at a good distance from the ose. The measurement Q 3c, was a favourable additional one obtained in 1918 by J. GRUFMAN.

In *Division R* the line is gradually approaching the big Tierp ose, and consequently the varve curves change from low and regular all unto the bottom varves in R 1—6, to a decided accretion of thickness in R 7 and especially R 8. Here are also inserted the measurements S 1a, b, c, to show the way in which these two divisions are finally combined after the helpful control measurements of 1937, S 1c and d, or Up. 34a, b, by Dr C. CALDENIUS could be introduced as a connecting link. For the regular sedimentation in that locality, see Pl. 52.

Division S was always regarded as a troublesome passage, but now CALDENIUS' long measurements of Up. 34 also control the number of varves along this division. Some NW—SE ridges, vaguely visible on the Geol. and Top. maps, may be annual moraines.

Division T was fulfilled mainly during the years 1905 and 1911, in order to bridge the distance past Gävle over to the localities of Dalarna and S Norrland. Through the close connection of these several measurements in NE Uppland was confirmed the great bow of the ice-margins of the years −650 to −600, due to an accelerated melting across the inner Uppland plain and a simultaneous retardation, or even a small extension of the land-ice over the southern Botnic depression (p. 157). The mighty deposition of sand in the Tierp—Älvkarleby ose and the westerly parallel oses likewise confirm the existence of very great melt-rivers in this region, while east of the Uppland measuring line the oses are almost none. Also in this division CALDENIUS' long measurement of Up 34 is represented, namely by its more distal varves, distinctly identic with varves from the region of Gävle, thus giving a direct connection of the region of Tierp with that of Gävle and further with the far-reaching, long and regular measurements from southern Dalarna.

The main time scale.

When commencing, in 1904, to work out a natural time scale in the Stockholm region, I did not know if it should ever reach up to historic or present time. At first I reckoned, from the ice-border at the old Stockholm Observatory, minus years for recessional ice-borders to the south and plus years to the north. By this dating thus having followed the ice recession northward to the important year when the great glaciation became bipartite, and still being uncertain if it should ever be possible definitively to connect the natural and the historical chronologies, I found it best to adopt the remarkable year of bipartition as the Zero Year, well representing the end of the Ice Age, dividing, backwards, finiglacial minus years and, forwards, postglacial plus years. The main thing was to have a well defined, natural starting point for the extended tabular work and, as far as possible, to avoid changes.

Later on, when the Swedish time scale was found to be of general application, it seemed earnestly desirable that all later varve measurements in other countries, as soon as they are reliably connected with the original time scale, should adopt the same Zero Year, the principal purpose of the whole undertaking being at last to get out of our Babylonian confusion and to get a clearer view of our mutual relationships.

The local ice recession is equally well shown by any zero year, but local tabulations soon would lead to a scarcely desirable isolation from the common evolution.

Though the varve measurements commenced at Stockholm and were continued in both directions, it seems practical here to begin the general review of the time scale by the youngest series hitherto reached, above the Zero Year, and to continue southwards without interruption in one succession.

Pl. 73. Years +2000 to +1200 a. Z.

The youngest measurements to be presented in this part of our geochronology are those carried out by C. CALDENIUS in the region of Ragunda by the localities E. Jl. 15—17, or the Vikbäcksterrassen, Hammarstrandsterrassen, and Barksanden, like all the following ones to be refound in the list of Localities and Measurers. From the year +1740 they are joined by the author's measurement at Vikbäcken and from the year +1400 downwards they are all together accompanied by some of R. LIDÉN's measurements in the Ångerman valley, of which the mutual identity may be indisputable already from the striking accordance of the very first decades +1390 to +1330 and +1300 to +1200. The far distant parallel, Can. 5, from the Timiskaming region, measured by E. ANTEVS, undeniably gives a thourough similarity, although sometimes interrupted by some flat or indifferent series. Yet, the connections of these different regions of course all are carried out by the present author.

Pl. 74. +1200 to +400 a. Z.

The series of E Jl., or the Ragunda region, continue downwards, now with more lively variations and steadily accompanied by identic peaks and bows on the always more quiet or complacent Timiskaming curve. REKSTAD's long measurement from Moen in Aardal, Sogn, sets in at the year +940, especially from +800 showing an excellent identity with the locality Nb. 7, Överedet; also E Jl. 10, Krokvåg, is well tied on to E Jl. 8; and Vb. 3, although somewhat irregular, is from +500 well identified with the many other parallel series. One single measurement from an ice-dammed lake in Lappland, La. 1, Gaskeluokt at Lake Storuman, is obtained by G. ERDTMAN and is found to fit in on the years +580 to +522.

The last century of this plate gives especially several parallels from River Vindel älv, called Vb. 1, 3, 5, and 6, together with Nor. 4 and Can. 5, continued from above.

Pl. 75. +400 to ±0 = the Zero Year.

This plate begins to the left, below, with the three thin-varved curves of Vb. 3 and 5 and E Jl. 8. This latter, above, is combined, first, to Vb. 6 or Locality Kusfors at River Skellefte älv and further unto +200 to Ång. 5 = Lillrännforsen at Villola, in its turn further accompanied by the thin Vb. 1, Degerfors, at River Vindel älv. This measurement in its upper part gives thicker varves with lively variations, here accompanied by similar ones at Sogn as well as by lower ones at Can. 5 and 4. The number Can. 4 designates our measurements of 1920 at the town of Haileybury in the county of Timiskaming. All these series form an interesting complex of biennic variations among conspicuous longer ones, though scarcely with any decided periodicity.

A century above Zero also E Afr. 2, Makalia River, measured by E. NILSSON, joins into the concert by well marked, good accords. Here also are dated the youngest micro-varves, a series from Me. 2, Ovansjö, out of a very thin-varved specimen, taken by Caldenius in 1937 and containing several hundreds of micro-varves (Pl. 47), while Me. 1 *mi* is measured directly above the Zero varve on a specimen taken at Indal by G. DE GEER in 1912 (Pl. 51, 7).

Pl. 76. ±0 to -400 b. Z.

The measurements directly attached to the Zero Year are E Jl. 2 and 8, namely from Vikbäcken and Döviken in Ragunda together with that of E Jl. 4, Hammarstrand at Ragunda bridge. At about -90 to -100 these, and especially E Jl. 4 and 8, show a peculiar, local »Ragunda»-facies, differing from most of the other localities, although for all the other decades there is an often perfect conformity between Ragunda and e. g. the Ångerman series, Nor. 4, Sogn, and even the ice lake curves, W Jl. 16 and 12, from respectively Ströms Vattudal in NW Jl. and from Vålbacken at the south end of Lake Storsjön.

From -160 the lower Ångerman and Jemtland series are very closely attached to the uppermost varves of the long and regular series from Dalarna, namely Da. 12, Mora, measured by R. LIDÉN. Here we find also the series of Singsån River, E Jl. 1a, by the same measurer, while Hl. 125 *mi* is a micro series from Bollnäs (specimen taken in 1906 by G. EKELÖF, measured by G. DE GEER).

To the last century of the plate, -300 to -400, even several of the upper micro series from Stockholm are dated. At about -200 the topmost varves of Sudbury, Can. 3, join the lower series of Haileybury.

Pl. 77. -400 to -800 b. Z.

The plate is the one most crowded with parallel measurements, among which several micro series from Stockholm and Helsingland. From -500 several parallels from Dalarna join in, passing even the Gävle region by the strictest conformity. From −570 follows, below, a series of curves, marked T—O, being means of the Divisions, given in detail on Pl. 72. Lowermost, following all this plate (77), goes a curve which is a means of the present Scandinavian localities, while the broken curve −700 to −800 is a means of the non-Scandinavian series. This century also is characterised by the upper macro series of Uppland and Vestmanland varves. Together with the many parallel, continuous and uninterrupted oses all these varve series give a most coherent example of the regular ice-recession through northern Svealand over to southern Norrland, in spite of a different facies of the varves of the inland, along the S Norrland coast, and, finally, along the big Norrland rivers.

Pl. 78. −800 to −1400 b. Z.

From −800 to −1000 the material has allowed the continuing of the mean curves as well for Scandinavian as for non-Scandinavian localities and also for each of the Divisions O—H. Thereby a local facies is exhibited by the Divisions L and K in general, while locality A 15 or J 6 from Knifsta gives a more normal curve. A similar local facies is seen in Division N and the measurements Vsl. 10, Sala, and Up. 27, Runhällen, both in NW Uppland. The marked series of Up. 25, Bergsbrunna goes down to −889.

The Vsl. Vestmanland, measurements go down to the region of Lake Mälaren by Vsl. 5, 4, and 1, as also by Vsl. 11, a very desirable bottom series, finally obtained from Västerås by G. Erdtman. Further here are localities within the Lake Mälaren islands, such as Up. 7, Munsö, and Sl. 50, Selaö.

Above, there are the long, continuous series Can. 3, Sudbury, Can. 2, Toronto, Nor. 4, Sogn, and Arg. 1, Lago Corintos, Argentina, of which the constellations may speak for themselves.

The right half of this plate gives, above, the series −1000 to −1200 and, below, the series −1200 to −1400. From −1000 to −1070 there is a continuous medium curve, marked M, for the Divisions G and F, passing the Stockholm region, and already published in 1932. Up. 5 is from an island in Mälaren, Sl. 2 (= Sl. 48e) from Lina brickyard S of Mälaren and Sl. 3 also from that region.

Now approaching the region of the Fini-Gotiglacial moraines, the Swedish localities are from the southerly provinces of Östergötland, Ög., and Västergötland, Vg., while Finland is represented by the measurement at Leppäkoski, situated between the two Salpausselkä ridges, and U. S. A. by Essex Junction. In Argentina the Lago Corintos series is continued unto −1200, while in Himalaya the uppermost varves obtained reach −1180, continuing to −1300 at Biano and to −1374 at Sesko. From −1200 to −1400 there is also a part of D. Danielsen's long measurement from Kvarstein in Norway. The Gotiglacial series will be more fully represented in a volume devoted to that subepoch, as the present one mainly has given our Finiglacial material.

Pl. 79. Åland. −810 to −912.

The varve series from Åland were all measured by Dr Erik Nilsson in 1924 and are of a special importance by fixing the direction of the ice border, evidently a short time before the catastrophic ice-recession across the Botnic depression.

The Åland varve series give a most striking parallel to locality Up. 25, Bergsbrunna, S of Uppsala, as well in the configuration of the curve as in the thickness of the varves. As a corollarium also the Scandinavian medium is a repetition of the same dominating variations unto the lowest two decades, where the medium is influenced by the Finland curve, while the series Åland 1 seems to follow the special rhytm of the Uppland-Vestmanland varves with marked bows over three to five years. The long series of biennic peaks on odd years −829 to 839, so well marked in Aardal, Nor. 4, also in Åland is even better developed than in Uppsala. On the whole it is remarkable to see the great conformity of this distribution of sediment, as being spread in equal portions year by year over wide areas.

Confer pp. 157—158, 257, and Pl. 68.

Pl. 80. Uppsala. –600 to –900.

This plate gives the measurements from about a dozen different localities, enumerated on p. 257 and exhibiting the remarkable regularity, characterising the clay distribution over the great Uppsala plain. By the help of the already executed varve measurements it would be a relatively easy task, through well chosen completing measurements to make out of the Uppsala plain a magistral example of regular clay distribution.

At some places in the Uppsala region, as at the brickyards of Bergsbrunna, S:t Erik and Vaksala, the distal varves are passing over into microdistal ones in a continuous and undisturbed succession. The frontispiece gives in rather natural colours by direct photographic reproduction the somewhat brown specimen No. 4 from S:t Erik, in its uppermost part passing over into microdistal varves, according to the graph, Pl. 80 b, amounting unto the year –610.

Confer pp. 135—141 and Pl. 68.

Pl. 81. Ockelbo. –445 to –580.

On this plate is represented the continuation past the depressions of S Helsingland and Dalarna. According to the character of the bedrocks the varves were more or less thin, but still completing each other and allowing a reliable passage of the time scale, partly by the help of biennic variations.

At the base of the plate, below the double line, three series of microdistal varves from Up. 26, S:t Erik, Uppsala, Gl. 4, Hagaström, Gävle, and Me. 2, Ovansjö, are given magnified by ten, and their contents of micro-boulders is marked at the base lines of the two upper series, respectively.

For measurers etc., see pp. 155, 257 and Pl. 69.

Pl. 82. Bollnäs. –200 to –480.

These series from Helsingland are all generally micro-varves, almost from the bottom. Their mutual identification is often facilitated by relatively gigantic single varves, which may probably represent subglacial momentaneous drainings from the great Central Jemtland ice-lake through the valley of River Ljusnan. The main drainage varves of this region are those of –350, –379, and –434.

As already mentioned, the drainage varves generally in their lower part show current-bedded, fine sand, upwards passing over into fine silt without bedding.

Confer also pp. 155, 257, Fig. 39 and Pl. 69.

Pl. 83. Dellen region. –380 to –480.

This plate gives a number of varve series, measured by O. Vallin, in the region NW of Lake Dellen and along the western lake shore. The thick varves about –456 to –466 at some of the localities are only locally developed proximal varves, probably due to bottom currents, and not drainage varves. The medium and biennic series, although partly somewhat local, however in the main follow those of the time scale.

Confer pp. 155, 258, Fig. 39 and Pl. 69.

Pl. 84. Indal, Vindel, Skellefte, Lule Rivers. +540 to +400.

This plate gives in all about 140 varves along the coherent measurement Ragunda 1 = E Jl. 8, Storedan in Döviken, on which the scattered shorter series are dated, viz. from Lule and Skellefte Rivers, while several series from Vindel River are dated on the Main time scale, Pls 74, 75.

These sections along some of the northernmost Swedish rivers represent a northeasterly side-branch of the Swedish time scale, the main trunk of which follows the Jemtland and

Ångermanland depressions with their detailed investigations. Still the marked variations along the northernmost river valleys may be helpful, if it succeeds to find and measure varve series also at the north side of the flat Botnic Bay.

Confer pp. 177—180, 258, and Pl. 71.

Pl. 85. Ice Lakes, W Jl. +50 to c. -900.

The ice lake varves here given all have been dammed up by the land-ice border, receding past the Jemtland depression. By this registration thus it was possible in this region to date the bilateral Scandinavian ice-recession and its bipartition, which has been chosen as marking the Zero Year or the Finis Year of the Ice Age, as well as of the Finiglacial subepoch and the beginning of the Postglacial Epoch. This Zero Year thus at the same time marked the last drainage of the great Central Jemtland ice-dammed lake down to the new-born ordinary land lake of Storsjön.

Among other interesting teleconnections may be mentioned several good identifications with microdistal varves deposited in the Baltic depression, as in the Stockholm region, from where microdistal varves have been magnified and teleconnected.

Here for the first time it has succeeded by datings of the identic ice lake varves to synchronize the two-sided ice-recession and thus to get an idea concerning the last stages of the Scandinavian ice body and its recession as a whole.

As an example may suffice that when the western or Atlantic ice-border already had reached the region of Duved near Mt Åreskutan, the land-ice on the Baltic side still was extended all the way down to the Uppsala region.

Confer pp. 164—172, 183—184, 258, and Pl. 70.

Pl. 86. Gotiglacial, W Norway. -1430 to -1520, -1820 to -1920.

This double plate, 9 and 10, gives some diagrams from our measurements in Norway, teleconnected with the Swedish time scale and its filials.

Pl. 86, 9, gives a series of sixty varves from an excursion in 1907 with my students to the renowned, great land-slide in Værdalen of 1903, from where the existence of clay varves had been reported by A. Hamberg. This was the very first varve measurement in Norway.

The varves were well visible on the remaining, dried and stonehard clay surface. But the fine clay inside was so loose and plastic that it could not be cut to any plain surface, and therefore the measurement could not be completed in the field down to the bottom on the dried clay, as exposed along fissures. Still the different series seem to be reliably connected with also geographically quite reasonable parts of the time scale.

The graph from Kvarstein belongs to a special varve measurement, kindly carried out by D. Danielsen, and of which several parts are reproduced on the Main time scale, Pl. 78, Nor. 3. A special purpose was the dating of the Mid-Scandinavian or Fini-Gotiglacial moraines, in Norway known as the Raers.

The graph Can. 6, Manitoba, is measured by E. Antevs and was assumed not to be connectable with the Swedish time scale, which still has been performed in the whole of its length, though hitherto space has not allowed publication of more than a few parts of the whole series.

Of Can. 3, Espanola, the magnificent section of some 1200 varves, measured by R. Lidén in 1920, only a small middle part or some 70 varves, rather thin and but vaguely varying, are from the time in question.

Pl. 86, 10. In 1921, during a visit for lecturing at the Institute of Technology in Trondheim, I measured a good varve section at an occasional digging close by the north side of the very institute building.

The varve dating indicates that they were deposited about at the time of the stationary stage of the great Mid-Scandinavian moraines, which also may explain that real varves could be deposited near the mouth of a stationary ice-river, though in the front of the salt sea.

Two of the Swedish localities are from Östergötland, Slattefors and Hovertorp, while the upper one is from Vålarö in the skerries of Sörmland.

The two Norwegian series here given are of special importance, as hitherto being the single representatives of the ice recession from the Atlantic coast up to the Swedish frontier.

Confer pp. 181—183, 258, and Pls 64, 70.

Pls 87—88. Biennic variations of the time scale.

As a whole these two plates give a contracted facsimile of all the localities, reproduced in full on the Main time scale, each locality here being represented by a thick horizontal line, with the usual small, vertical keys, directed downwards for peaks on even years and upwards for peaks on odd years. Designations as on the time scale.

Pl. 87 includes the younger part of the time scale, or the years +2000 to ± 0 of the Postglacial Epoch, while Pl. 88 gives the same kind of variations of the time scale during the Fini- and Gotiglacial subepochs of the Ice Age from ± 0 to −1400 b. Z.

From the biennic keys it is easily seen that, in an overwhelming number of cases at the most different localities, this registration everywhere is alike on identic years, being but locally deficient, evidently by quite local deviations.

Conclusively also the intervals between the biennic series coincide extremely well.

On the whole the grouping of the biennic series affords a clear and easy control of the connection between different varve localities all over the earth.

Pl. 87 b. Mean centennial percent of biennic variations.

In the left upper part of Pl. 87 is given a condensed oversight of the biennic variations from the whole of the time as yet covered by geochronology, viz. from present age down into Daniglacial age, in all some 15 millennia. By means of centennial percent with a smoothed medium curve the main variations are exhibited, and thereby also the influence that the biennic variations possibly may have had or not had upon the climate and the partial shadowing of the sun radiation to the earth. This is further discussed on pp. 37—41. Since the time of the Fini-Gotiglacial limit, −1073, there was a steady decrease of biennic *ombreros* unto some 3000 to 2000 b. C., or the well-known Mild Stage, while since then the biennic maxima seem to be in a slow, but steady increase, until 1900 A. D. A further study of these variations seems to be highly recommendable.

Pl. 89. General teleconnection between transatlantic and transequatorial varves.

The description of this world-wide teleconnection is given on pp. 34—36. Here may be added that the second, graph above the base gives the first measurement by Dr Caldenius at Rio Corintos in Argentina, S Lat. 43°10′, submitted to De Geer in Stockholm, teleconnected and published by him (1927) together with diagrams from the northern hemisphere, here placed above the thick horizontal line indicating the equator. Examples from the N hemisphere are chosen from N America, Finland, Sweden and Norway.

The transequatorial connection between the parts of the graphs here given is amply certified by about half a hundred often very striking similarities occurring in the same order in this planetary registration.

Transequatorial conformity is underlined by a thick, double line below the fine curveline, being interrupted only where the curve is only locally developed.

Biennic maxima are marked by black balls, or half balls, where but partly developed. Triennic variations are marked by special hooks above the curve.

In some instances there will be connection if a piece of the curve is moved one step to the side, whether it may be due to some retardation or a go-and-back error (confer p. 28). Such occurrences are marked by thick, stipled lines.

In the curve S Am. 1, from Lago Corintos, with long, vertical spears are marked those varves which at the first teleconnection were judged to have been overseen in the field. These were the years –841, 876, 893 and 1047—1049. These six missing links at their respective years were indicated in Geogr. Annaler, 1927.

Soon afterwards Dr CALDENIUS, on another expedition in Argentina, farther south, S Lat. c. 46°40′, at Lago Buenos Aires, thus at a distance of some 300 km, found and measured another varve series given at the base of Pl. 90, S Am. 2. While in the field he did not know what years he had measured, but on his return to the office in Buenos Aires City, when comparing the graph with that of Lago Corintos, he found, 1, that there was connection between those two measurements — this certainly implying a teleconnection of several hundred kilometers — and, 2, that six varves occurring at Lago Buenos Aires were missing at Lago Corintos. Finally, 3, DE GEER found that these also were representing all six of the missing links beforehand in print indicated, five of them on the exact years predicted, and one on a neighbouring year.

It seems difficult to imagine a better verification of far-reaching teleconnections, at the same time bearing witness of the fact that the glaciations on both of the transequatorial hemispheres were simultaneous and not alternative.

Pl. 90. General view of Postglacial and Late Glacial datings.

This general view of all datings gives the time divided by millennia as unity, marked each by its first figure, plus years and minus years towards both sides of the Zero Year.

The various regions of varve measurements are given each by one single thick line as far as its measurings are mutually close-connected. Thin lines denote the still empty space to be filled in by future measurings, if varves can be found.

The Swedish time scale — *den svenska tidskalan* — forms the main back-bone or standard line, as reaching well over fifteen millennia, through Postglacial, Finiglacial and Gotiglacial age. For further elucidations, see pp. 227—229.

As a result of the foregoing plates and tables in this volume all the different chronologies from various parts of the globe now are united into one common, terrestric chronology, wherever it may be applicable giving the exact time of the natural evolution, as yet through about fifteen millennia.

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Special Abbreviations.

G.F.F. Geol. Fören. Förhandl.
N.G.U. Norges Geologiske Undersökelse.
S.G.U. Sveriges Geologiska Undersökning.
Z.f.Gl. Zeitschrift für Gletscherkunde.

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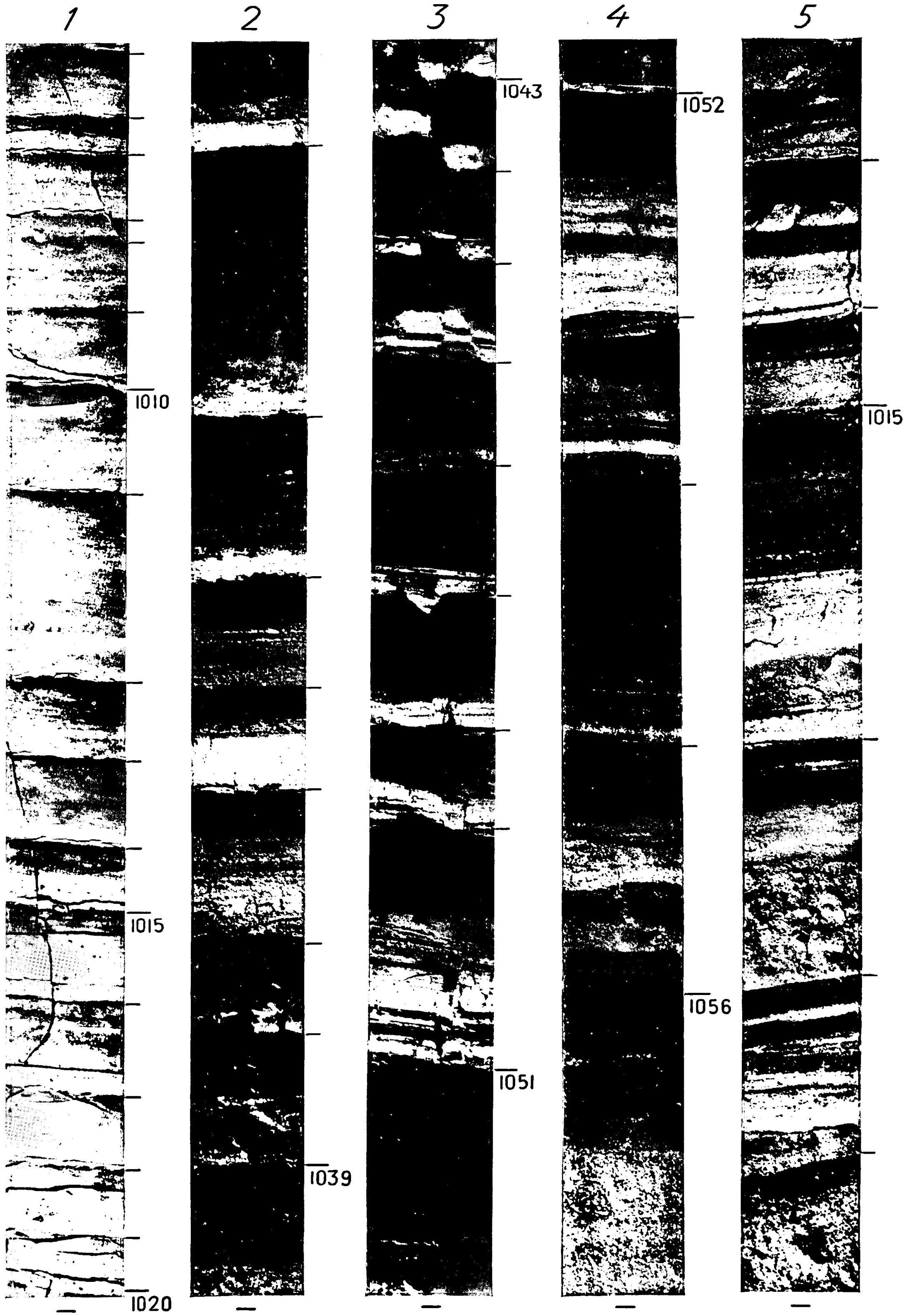
PLATES 45—53

WITH EXPLANATIONS

Pl. 45.

Varves from Stockholm.

1. Distal or semidistal varves of a homogene structure, mainly consisting of clay, which is gradually fatter and darker upwards, reddish in colour, varve-limits black. Specimen from Sundbyberg.
2. Fleminggatan, Stockholm W. Semiproximal varves, summer-zone consisting of sand.
3. Hornsgatan 70, Stockholm S. Semiproximal varves, sublayers of sand alternating with thin lamellæ of clay. Typical small faults disturbing the varves.
4. Hornsgatan 70, Stockholm S. Proximal varves, sand-fraction increased as to grain and total amount.
5. Linvävartorp, Haga, Stockholm N. Proximal varves, containing still coarser sand and even gravel. Confer varves of this proximal facies with varves of the distal facies in No. 1, deposited in the same years, but at greater distance from the glacial river-mouth. 3—5 exhibit varves of a composite structure of various sub-layers within the distinctly rhythmic total sequence of the year. Specimens 1—5 taken by G. De Geer.



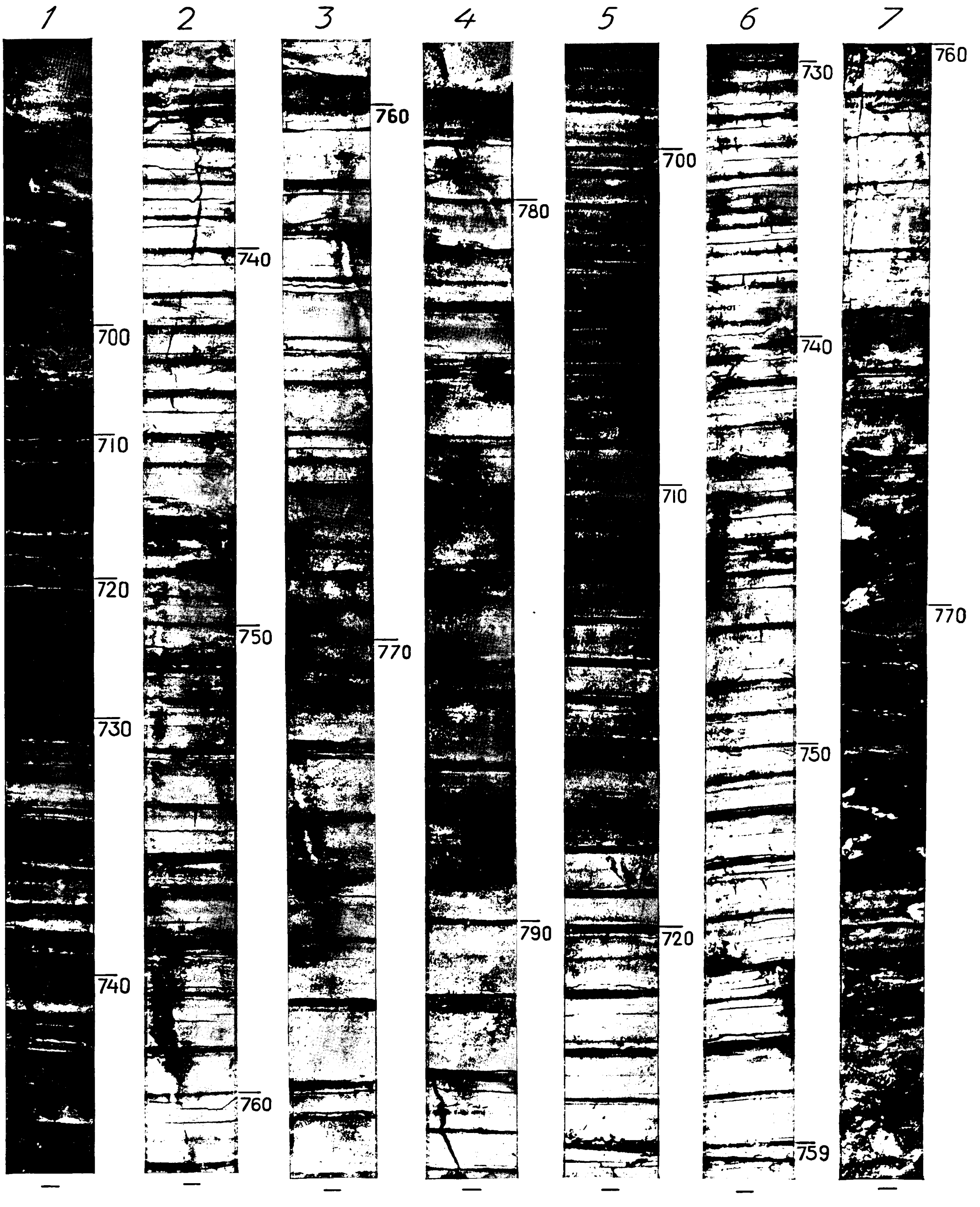
Stockholm: 1 semidistal varves; 2, 3 semiproximal varves; 4, 5 proximal varves. 2:5.

Pl. 46.

Varves from the Uppsala region and from Duved, Jl.

1—4 Bergsbrunna brickyard, 6—7 S:t Erik brickyard. Varves of distal facies, homogene, fat clay, grayish rose in colour. 1, near transition to microdistal varves. 7, calcareous nodulæ.

5. Duved, west of the ice-shed, varves simultaneous with the upper Uppsala varves in No. 1. Specimens 1—7 taken by G. De Geer.



1—4, 6—7 Varves from Uppsala, SE of the ice-shed; 5 Varves from Duved, W of the ice-shed. Dating, see Pls 77 and 85. 2 : 5.

Pl. 47.

Varves from Dalarna and Helsingland.

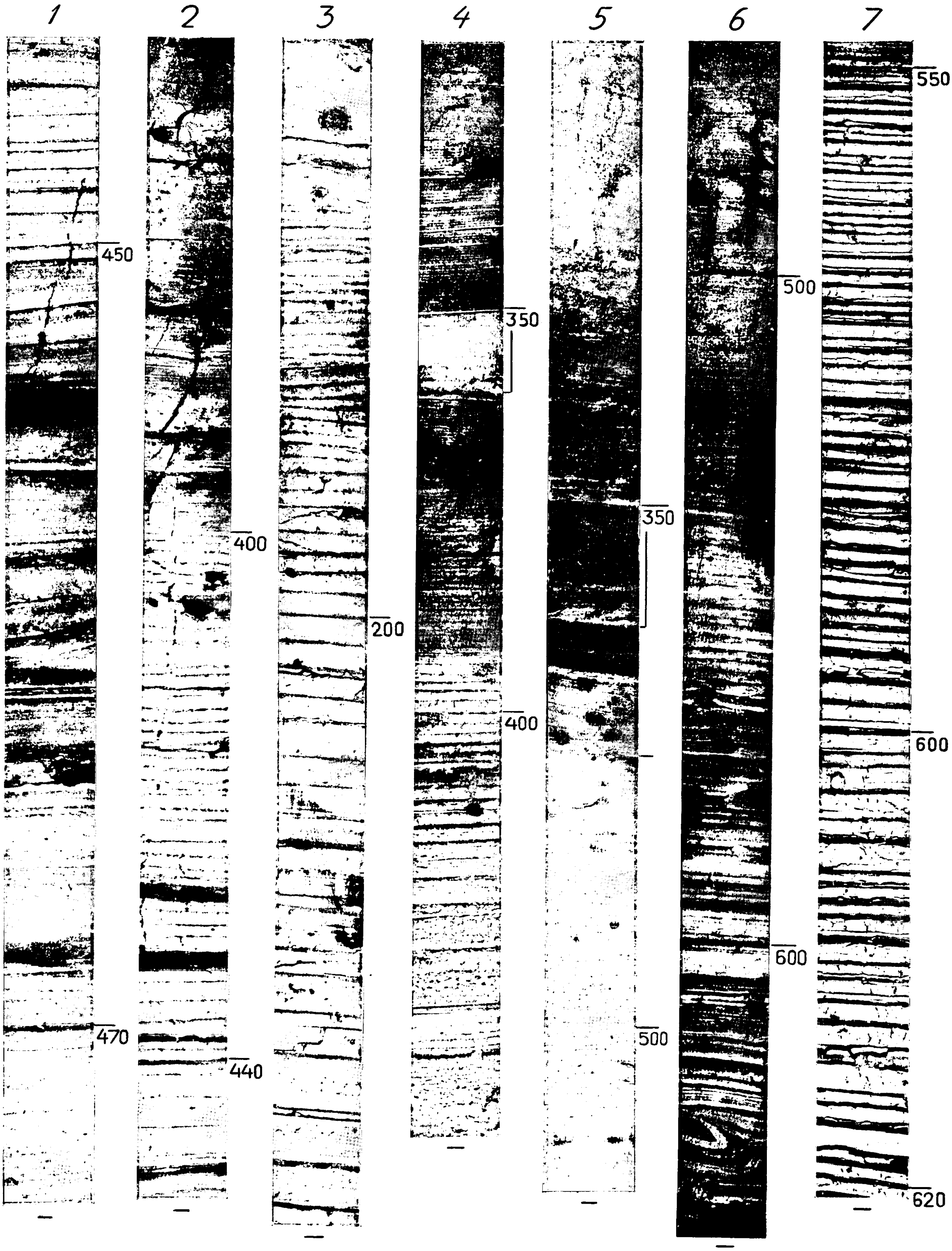
1—2. Dellen region. Micro-boulders in the lower series. — O. Vallin.

3. Ljungaverken at river Ljungan. — G. De Geer.

4. Hamre in Bollnäs at river Ljusnan. Mainly micro-varves with drainage varve -350. Micro-boulders in lower series. — G. Ekelöf.

5—6. Ovansjö in Njurunda, south Medelpad. Mainly micro-varves with drainage varve -350. Confer graphs, Pl. 81. — C. Caldenius.

7. Avesta in south Dalarna. Macro-varves of very regular and distinct distal facies. — G. De Geer.



1—6 Varves from Helsingland, W of Botnic sea. 7 Varves from Avesta, Dalarna. 2 : 5.

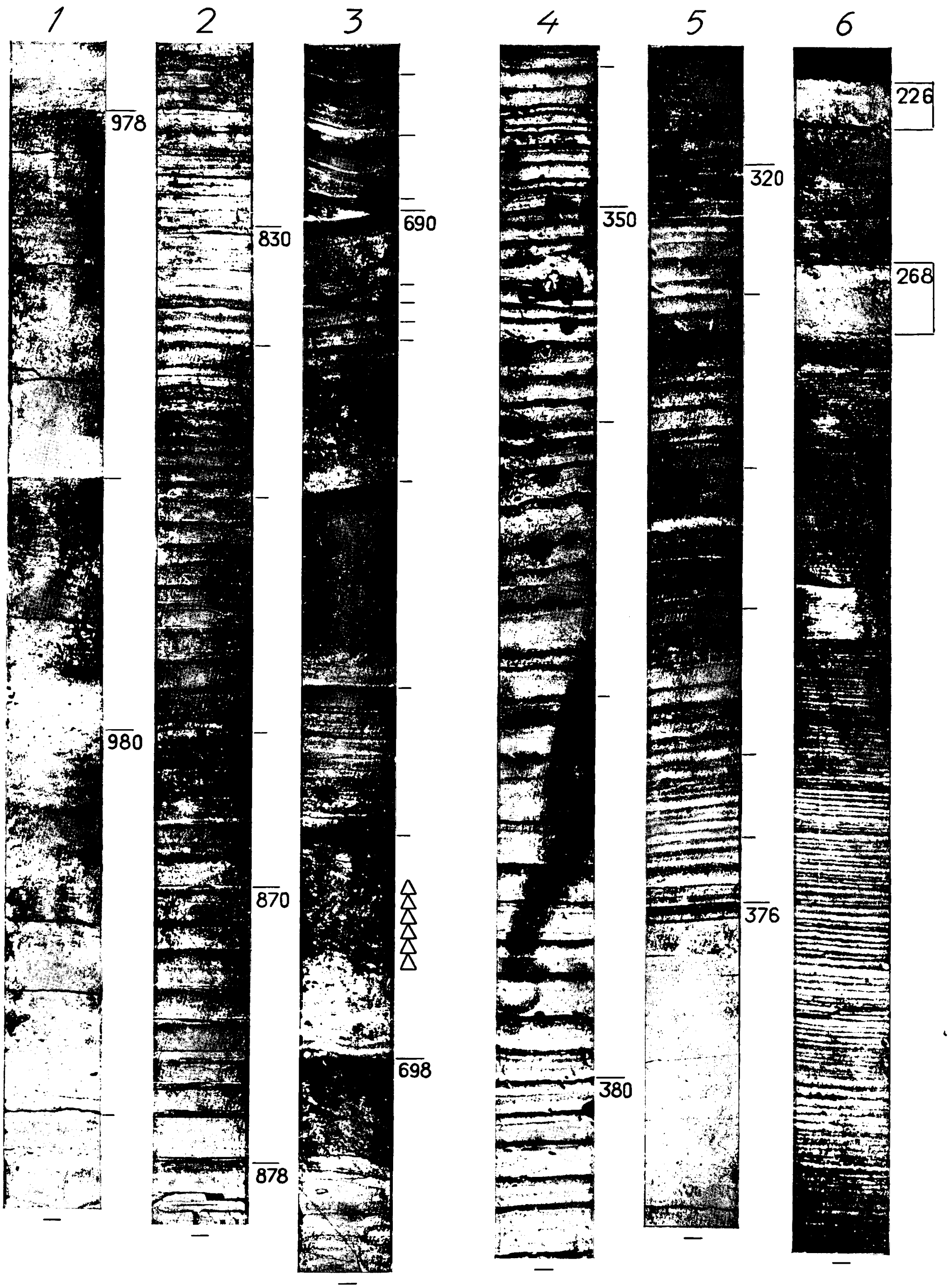
Pl. 48.

Varves from W. Norway, Jemtland, Ångermanland, Medelpad.

1—3 Varves from west side of the ice-shed.

1. Værdalen at inner Trondheim fjord. Light grey, thick, homogene varves of very fat clay.
2. Medstugan, Jemtland. Regular ice-lake varves of distal facies.
3. Järpen, Jemtland. Ice-lake varves of proximal facies. In varve -697 a thin bed of till from a slight readvance of the land-ice. Varves 691-693 thinned out by sliding.
4. Tvillingsta brick-yard, near Örnsköldsvik, Ång. Regular, distal varve series.
5. Högom brick-yard, Medelpad. Drainage varve of the year -376, overlaid by semi-microvarves. Homogene, fat clay.
6. Timrå, Medelpad. Micro-varves with two drainage varves.

Specimens 1—6 taken by G. De Geer.



1—3 Varves from W of the ice-shed. Dating, see Pls 85, 86.
4—6 Varves from near the Botnic coast. 2 : 5.

Pl. 49.

Varves from Ragunda, Jl., from Degerön, Vb., and from Österbotten, Finland.

1—5 Ragunda region.

1—2. Vikbäcken: uppermost level of thick, current-deposited varves, in 1 showing fractions of two varves, in 2 about five, by a dense and dark winter-zone with plant-remnants. The main mass of these varves consist of a repeated interbedding of sublayers of sand and of sandy clay, often with typical current bedding (see lower varve, below the line in 1). Peculiar are the zones of small, grainy claynodulae, viz. fractions of eroded clay-layers rolled and rounded by the current (basal part of lower varve in 1).

3. Gerilån, Caldenius 400, 1915. Sandy lake varves of medium size.

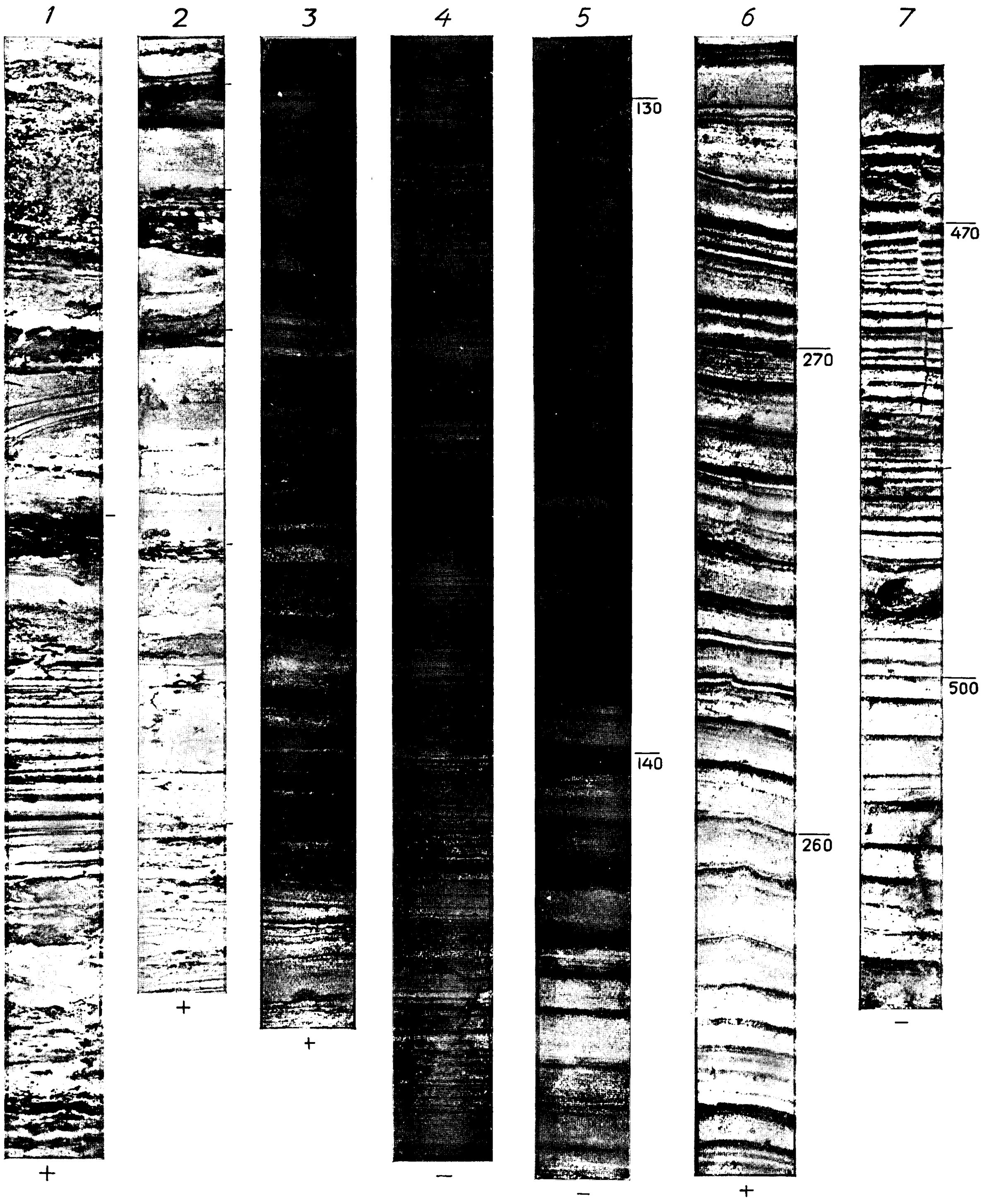
4. Lokedan in Krokvåg, Caldenius 402 = E Jl. 10. Micro-varved lake sediment of the years c. + 600 to + 800. The sediment is mainly sandy, with blueish-gray winter-lines of slightly more clayey material.

5. Storedan in Döviken, Caldenius 35 a = E Jl. 8 a. This clay belongs to the typical glacial deep-water sediment of the region, very distinctly varved with black winter-sublayers clearly contrasting against the blueish light-grey summer-zones. No sand in these varves except in the lower, proximal levels towards the very bottom-varves near the year –200. Here: varves –130— –146.

Specimens: 1, 2, taken by G. De Geer, 3—5 by C. Caldenius. Size $^2/_5$.

6. Degerön at River Vindel älv, Vb. Glacigene varves of plus-years, postglacial age. G. De Geer, 1915. Here: varves + 254— + 276.

7. Isojoki, Österbotten, Finland. Finiglacial glacigene varves. M. Sauramo. Here: varves –465— –509.



1—5 Varves from Ragunda at River Indalsälven. 6 Varves from Degerön at River Vindel älv. 7 Varves from Isojoki, Finland. Confer Pl. 52. Size: 1—6, 2 : 5; 8, 1 : 3.

Pl. 50.

Dated micro-varves with micro-boulders from

a. Uppsala, NW, S:t Erik brickyard, J. P. Gustafsson, 1906, and
b. Gävle, W, Hagaström, G. De Geer, 1911.

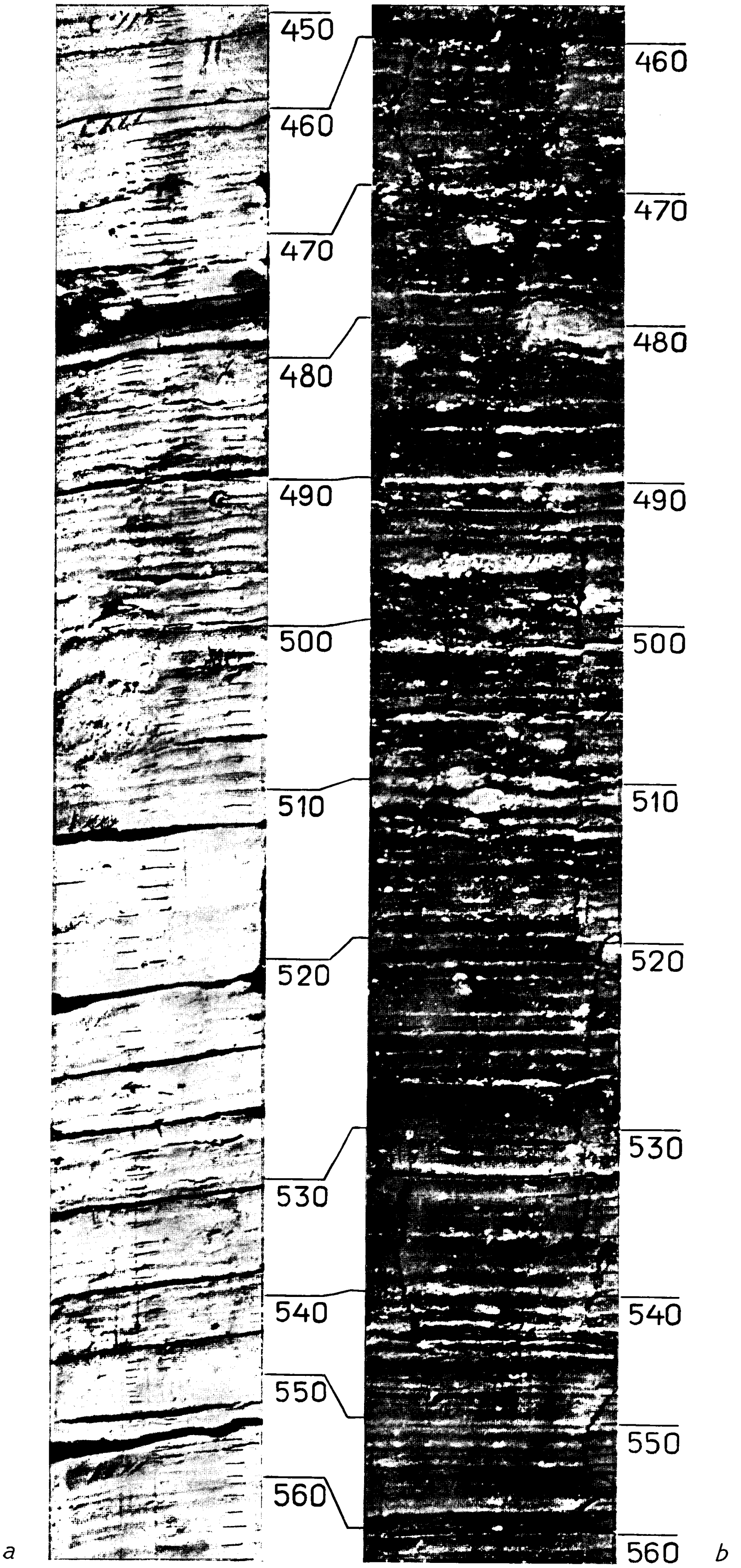
Unusual amount of micro-boulders, mostly calcareous.

When measured by binocular × 20, with due consideration to thickness disturbances by the boulder-nodulae, the varve graphs obtained were found to be mutually comparable, so that varves of the same years could be identified in a and in b.

Confer Pl. 81, Ockelbo Special, where the respective graphs are presented together with other varve series of the same age, measured in the field. The micro-varves are magnified by 10, while the macro-varves, measured on a field-section, are given by $^1/_2$ of natural size.

Micro-measurement and dating by G. De Geer and E. H. De Geer, 1939.

Natural size.

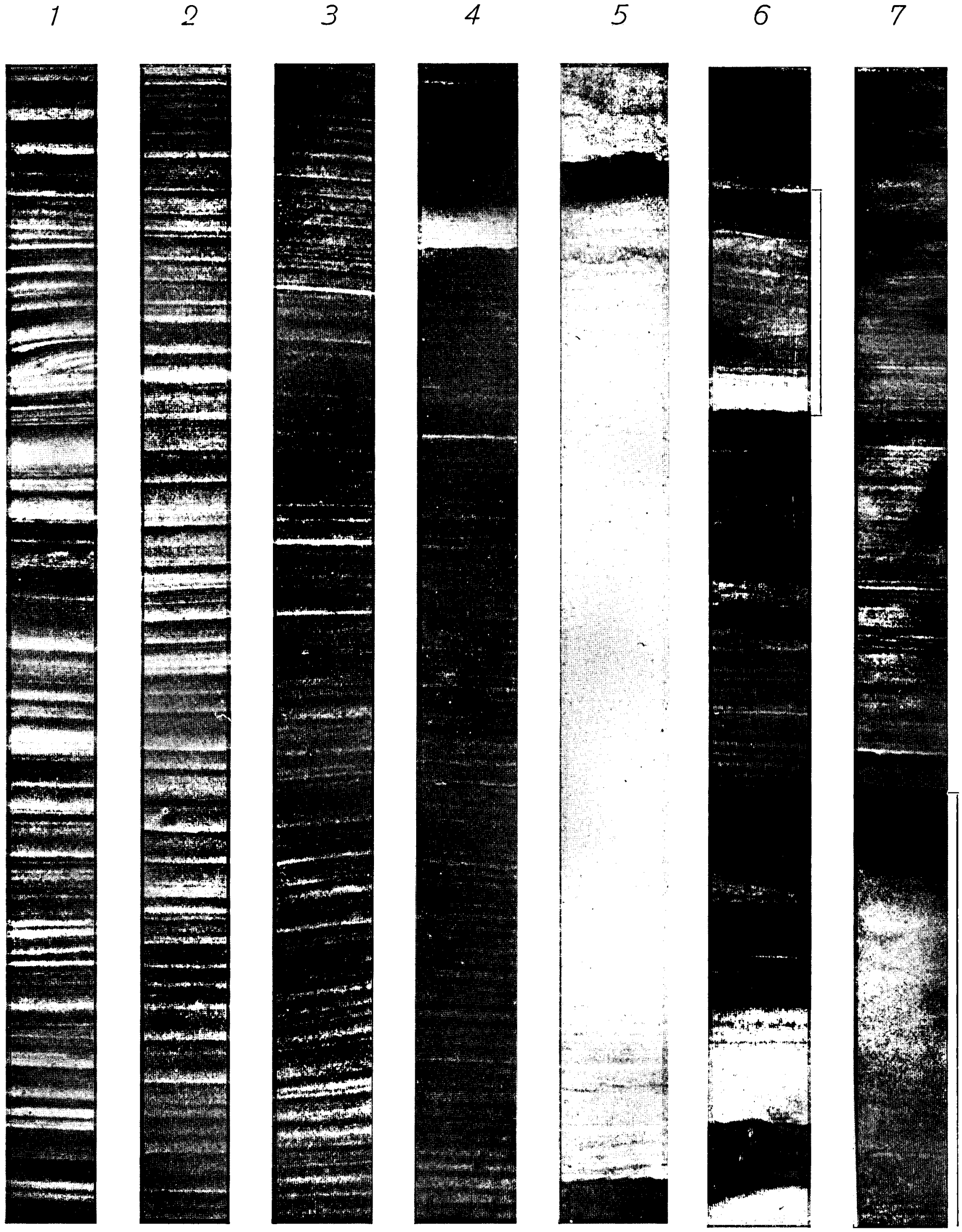


Dated micro-varves from Uppsala and Gävle with micro-boulders. 1 : 1.

Pl. 51.

Localities Indal, Me 7 a and 7 b, W side of river, facing Bjällsta farm. Specimen No. 7 taken by G. De Geer in 1912, specimens 1—6 by C. Caldenius 1939, some 500 m farther north, series micro-measured by C. Caldenius and E. H. De Geer. Several drainage varves, the one in No. 5 being probably from some adjoining ice-lake.

In No. 6 and 7 the Zero varve occurs, not very thick in this distal part of the Indal valley, however up to 27 cm in locality Me 7 a (spec. 7), of which the postglacial micro-varves above the Zero-varve are represented graphically in the Main Time Scale, Pl. 75.



Varve series from Indal, Me. Lowermost varves to the left. Various sandy giant drainage varves among the series of micro-varves. 1—6, from one locality; 7, some 500 m apart. In specimens 6 and 7, the Zero-varve.

1 : 3.

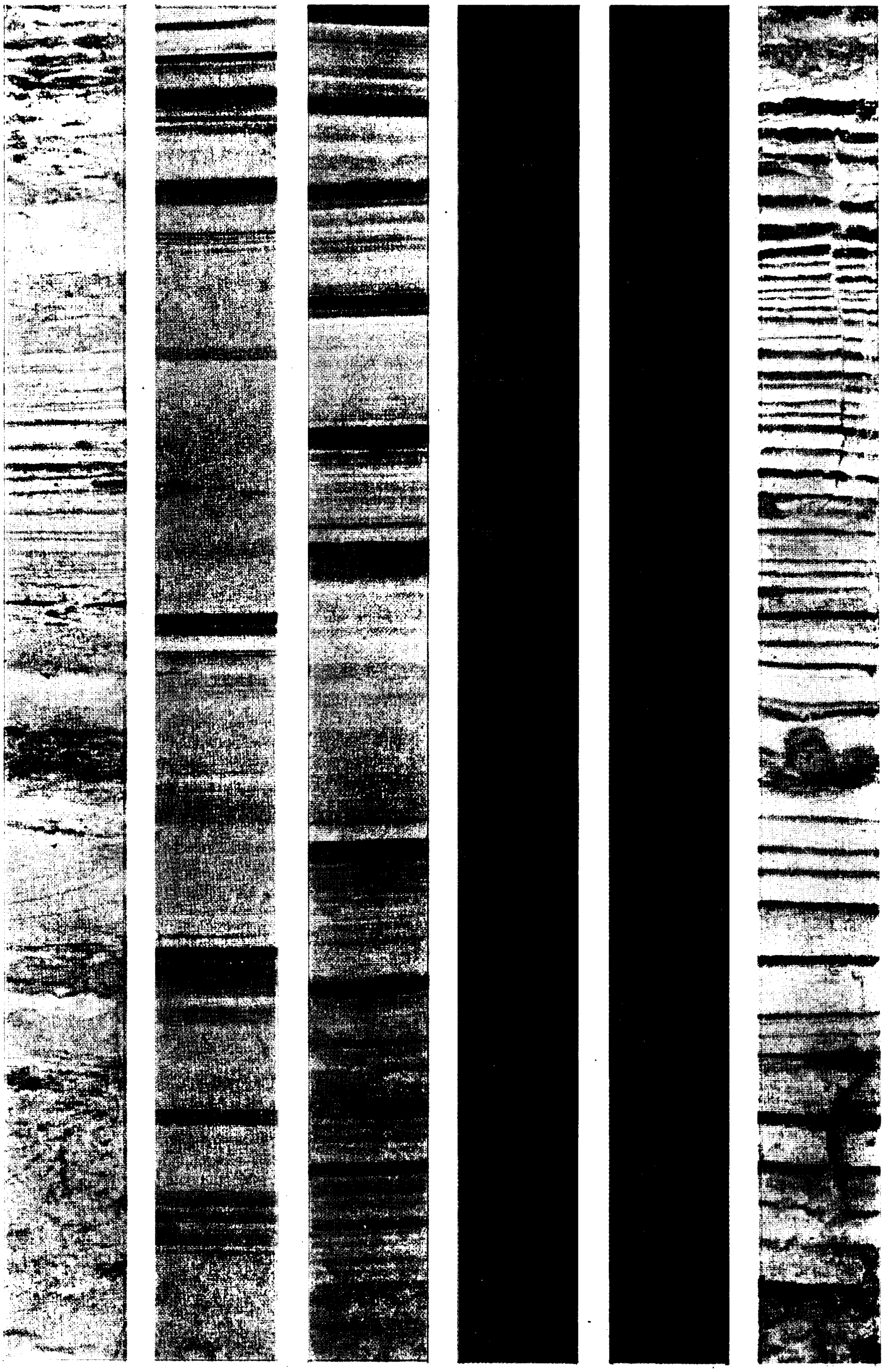
Pl. 52.

Varves from Scandinavia, II.

1. Ragunda, Jl., Lake varves, topmost horizon, thickened by locally current-eroded material. Two varves only in the specimen. Lowermost: bed of rolled clay-granulae. Middle dark: winter-horizon with plant-remains, varve-limit. Uppermost: similar horizon just below next varve-limit. About year + 3000. G. De Geer, 1911.
2. Ragunda, Jl. Postglacial lake varves of clearly varved character. C. Caldenius, 1915.
3. Frösön Island in Lake Storsjön, near Östersund, Jl. Finiglacial ice-lake varves. Graph, Pl. 85, 2. G. De Geer, 1906.
4, 5. Tierp, Bredäng, N. Uppland. Two specimens taken for control measurements, Up. 34 a. Graphs in the Time Scale, Pl. 77, and in Division S, Pl. 72. C. Caldenius, 1937.
6. Isojoki, Finland. Graph in the Time Scale, Pl. 77, Fin. 3. M. Sauramo, 1931. Confer Pl. 49.

Size 2:5.

1 2 3 4 5 6

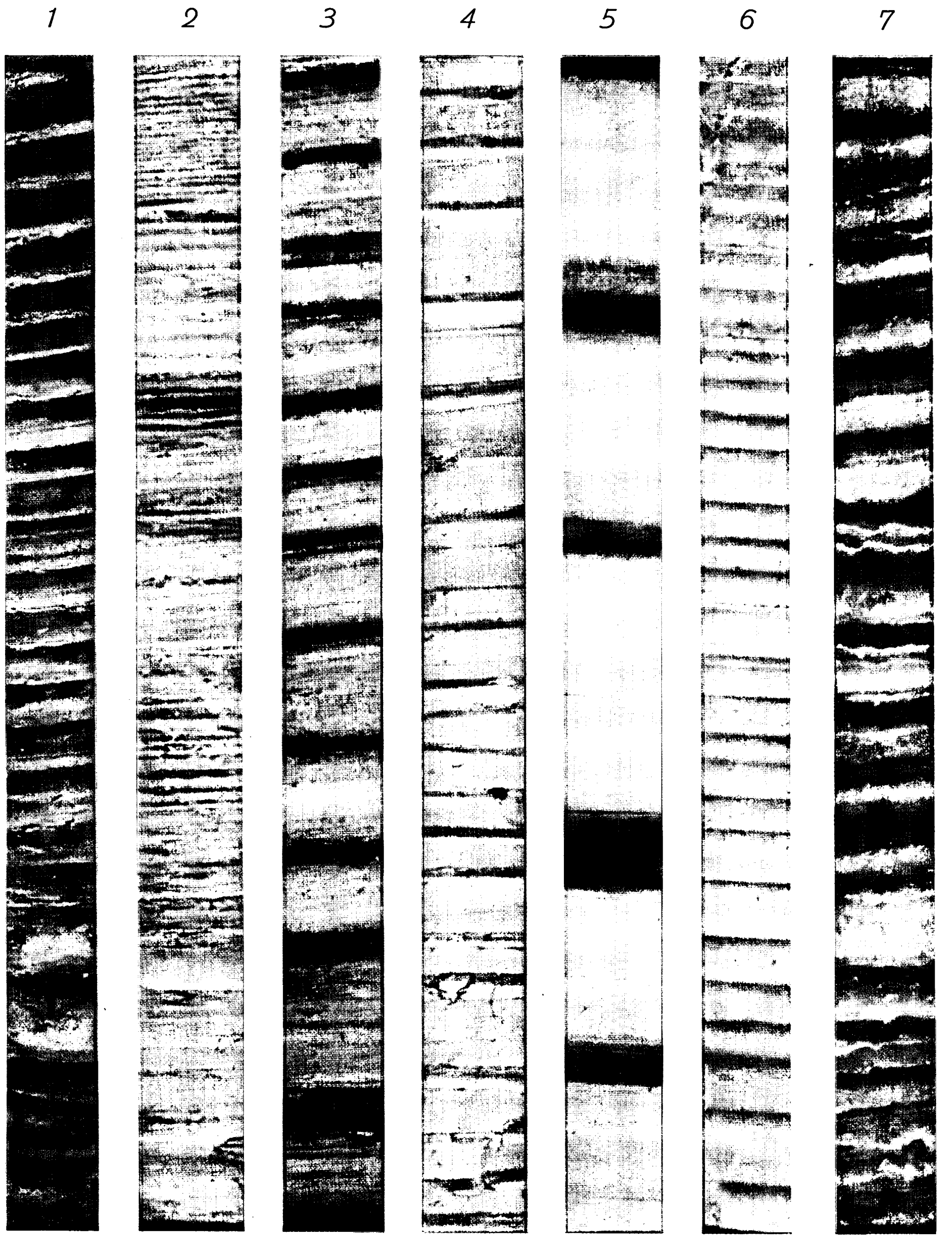


Pl. 53.

Varves from other continents.

1. Essex Junction, N. Y. Varves -1150—-1176 (Pl. 78). G. De Geer, 1920.
2. Beach Ridge, Ont., Canada. Varves of Gotiglacial age. E. Antevs, 1920.
3. Walkerton, Ont., Canada. Varves of Finiglacial age (c. -726—-738). R. Lidén, 1920.
4. S:t Albans, Vt., U. S. A. Varves of Finiglacial age (c. -950—-982). E. Antevs, 1920.
5. Lago Corintos, Argentina. Varves of Finiglacial age (c. -931—-935). C. Caldenius, 1927.
6. Lago Buenos Aires, Argentina. Varves of Finiglacial age (c. -821—-850). C. Caldenius, 1927.
7. North Bay, Ont., Canada. Varves of Finiglacial age (c. -740—-760). R. Lidén, 1920.

Size 1:3.


1
2
3
4
5
6
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Plates.

In the Text.

Glacial varved sediments.

Glacial marks and walls.

Stockholm region.

Dated varve localities.

Scandinavia.

Text-figures.

CONTENTS.

Tryckt den 5 augusti 1940.

Uppsala 1940. Almqvist & Wiksells Boktryckeri-A.-B.

Errata.

P. 83, line 5 fr. below, for: 90, read: 96.
» » » 4 » » » 70 » 60.
Pl. 18 » 8 » » » 70 » 60.
(S:t Erik bottom varve most nearly —876 b. Z.)
Pl. 25, line 1 fr. above, for: 1040, read: 1041.
P. 241, Stockholm region, Participants, add: O. Kulling and G. Troedsson.
P. 255, line 6 fr. below, for: p. 218, read: p. 251.
Pl. 49, lowest line, for: 8, read: 7.