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Gerard De Geer – a pioneer in Quaternary geology in Scandinavia

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Abstract The paper presents a pioneer in Quaternary geology, both internationally and in Scandinavia – the Swedish geologist and professor Gerard De Geer (1858–1943). This is done, first by highlighting one of his most important contributions to science – the varve chronology – a method he used to describe the Weichselian land–ice recession over Scandinavia, and secondly by the re–publication of a summary article on Gerard De Geer's early scientific achievement in 1881–1906 related to the Baltic Sea geology, written by his wife, Ebba Hult De Geer.

Keywords *Gerard De Geer• Clay varves • Varve chronology • Glacial and Postglacial• Quaternary geology • Baltic Sea*

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INTRODUCTION

It is unfortunately becoming more common in scientific papers that authors do not cite original sources of the methodology, observations and interpretations that their studies are based on. In many cases, the references are to very recent articles dealing with similar issues, which at best have correct references to the original sources. But the lack of proper citations and circular references prevents the reader from verifying the facts involved, and may lead to serious, uncontrolled permutations in ideas. This practice is scientifically inaccurate and indicative of shortcomings in both procedure and understanding of the need to always be referred to the original sources of methodology and interpretations. These deficiencies in the referencing technique occurring in many, perhaps all, scientific disciplines – geology is no exception.

Geological research is, arguably, dependent on a very close contact with original sources since most historical "experiments" in nature are not possible to repeat and often require extensive effort to document. The archive function of literature diminishes if referencing is surficial. The good news is that it has never

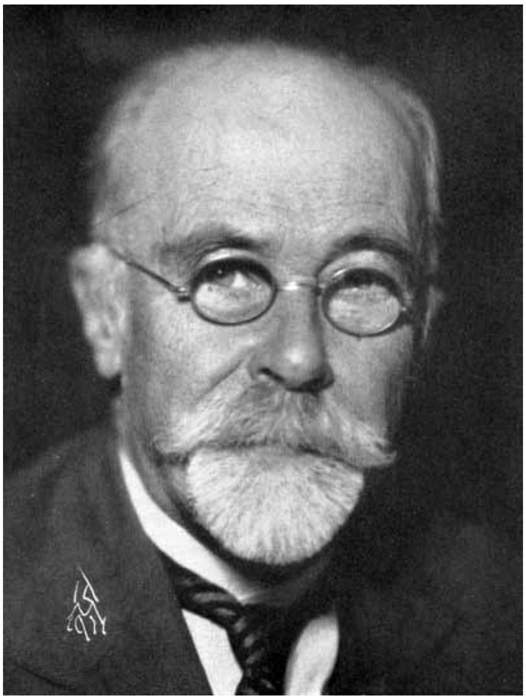

Fig. 1 Gerard De Geer (2 October, 1858–23 July, 1943). Photo courtessy of the Geological Survey of Sweden.

been so easy as today to find and access original sources, thanks to the Internet connectivity of our world and increasingly innovative IT programs for literature search and data mining.

In order to help limit the shortcomings of current bibliographic trends, Baltica has chosen to start publishing classic articles of important scientists in various Earth science disciplines. These are articles that have had a significant impact on scientific knowledge and methodology, as well as a major impact on our understanding of developments within the Baltic field of interest – the geology of the Baltic Sea and surrounding coastal states.

The following paper presents a pioneer in Quaternary geology, both internationally and in Scandinavia – the geologist and professor Gerard De Geer (1858–1943). This is done by re–publication of a summary article on Gerard De Geer's early scientific achievement in 1881–1906 related to the Baltic Sea geology, written by his wife, Ebba Hult De Geer, also a prominent geologist.

GERARD DE GEER – A BRIEF BIOGRAPHY

Baron G. De Geer is called as "the father of the clay varve chronology". After his university studies De Geer was employed by the Geological Survey of Sweden (SGU) in 1878. The Survey he left for a professorship (1897–1924) in General and Historical Geology at the Stockholm University. At the same university he served as a Rector from 1902 to 1910 and as vice chancellor from 1911 to 1924. Before that he was a member of the Swedish Parliament Lower House from 1900 to 1905. From 1924 until his death in 1943 he founded and built up and was the head of the Geochronological Institute at the Stockholm University. De Geer also had time during the period 1882–1910 to carry out six expeditions to Svalbard for the study of glaciers and their movements.

Gerard De Geer reached international fame not least through his studies of varved clay, its connection to the glacier annual variation in sedimentation supply that gave rise to two distinct layers—a summer layer and a thin dark winter layer—together forming an annual varve. By measuring the thickness variation of the varves he managed over time to build up a chronology of the Weichselian land–ice recession over Scandinavia. The importance of this chronology to geology and other sciences was shown very clearly in the introduction to Carl Grimberg's book Swedish history: *Swedish people's wonderful stories*, part 1 (Grimberg 1921). Where Grimberg states that De Geer's discovery (published 1912) is *"one of the Swedish natural science's most magnificent results"*, which for the first time demonstrated *"how far back Sweden's land was habitable"* (more than 12 000 years BP). This knowledge was based on De Geer's glacial chronology, coupled with one of his pupils established postglacial varve chronology in

Fig. 2 Varved glacial clay exposed in an intersection during construction of the motorway (E4), approx. 3 km east of Gamla Uppsala, Sweden. Photo by J.O. Svedlund, 2005.

Ångermanälven river valley in central Sweden (Lidén 1911, 1913, 1938).

The latter chronology was based on the sediments formed after the Scandinavian ice sheet had retreated from the interior portions of the Ångermanälven river valley, which at that time was a fjord with a delta forming at the river mouth. Through land uplift by isostatic movement after the recession of the inland ice, the outlets of the rivers and delta formation moved successively from the highest coastline, HK (in Swedish: *Högsta Kustlinjen*) (see definition, *inter alia*, Cato 1982) down to the present level of the Bothnian Sea. This regression created the postglacial varved sediments along the modern river valley with a surface that more–or–less forms a continuous sloping delta plane from the highest coastline, down to the present outlet of the river in the Bothnian Sea. Lidén's postglacial chronology in its entirety was published much later, after his death (Cato 1998), and was also successfully connected with the present (Cato 1985, 1987, 1992).

SCIENTIFIC IMPACT OF DE GEER'S IDEAS

De Geer began in the decades 1920's and 1930's to spread the knowledge and application of the clay varve chronology outside of Sweden, through his and his pupils' studies in other parts of the world that had been glaciated, such as the Alps, the Americas, the Central Africa, the Himalayas, and New Zealand. In his great summed work *Geochronologia Suecica, Principles* (De Geer 1940), published some years before his death, he tried through tele–connection to clarify the global melting process of the last ice age. The ability for tele–connections, however, was questioned and never received scientific acceptance, due to the varying climatic conditions of the continents. The clay varve chronology based on each individual glaciated area was, however, a great success, along with De Geer's description, among other things, of the genesis of annually formed end moraines (commonly termed *"De Geer moraines")* and glaciofluvial eskers, as well as pioneering studies of the highest coastline in Sweden that showed the land areas of today that once were covered by the sea and later emerged, by isostatic rebound of the Earth crust. All this is only part of the epoch–making research he carried out.

By respecting the original source of ideas, such as with varve chronology, we are also able to reinstate the potential and uncertainties that all methods include. Documented varve sequences by De Geer and others may well provide input for new modeling efforts. Understanding of complex climatic systems is one of the great modern challenges, and new perspectives, statistical tools and data resolution may provide valid comparisons and insights, reminiscent of De Geer's notorious tele–connections. Since science is build mainly upon borrowed ideas both the original intent of these ideas and the new synthesis of new interpretations can complement each other if properly referenced. In this light it is motivated, once more, to highlight the importance of G. Dee Geer's contribution to modern Quaternary geology, well done by Ebba Hult De Geer's 1963 review of her husband's early contributions to the Baltic research.

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G. DE GEER'S PART IN EXPLORING THE HISTORY OF THE BALTIC SEA

by

EBBA HULT DE GEER, Stockholm

Abstract

This research deals with seven main topics concerning the Baltic Sea, mainly as listed in the Bibliographia De Geeriana (GFF 40, 1918, pp. 811—852):

(1) 1881. The early tectonic formation of the Baltic depression
(2—3) 1881. A postglacial land sinking discovered
(4) 1881. The Åland bedrocks and Baltic leading boulders
(5) 1894. The isobases established through E Baltic research
(6) 1906. The ice recession from the S Baltic to Mid-Gotland
(7) 1906, 1912. The clay varve recession from the E Swedish gotiglacial Standard Line, with 200 years of recession in Gotland, supplying fixed years.

Introduction

Although he never directly studied the Baltic basin as such, De Geer's research in Sweden often touched upon this ancient outlet for glacial ice and water. The Baltic, besides being a basin a valley at different times, has also been a branch of the sea for long periods.

In 1881, at the age of 23, De Geer published no less than four papers on three topics, all to do with the Baltic Valley. Unfortunately, these were in Swedish and it is hoped that the present paper will help to make them better known. In these works he (1) outlined the history of the Baltic from its first foundation through tectonic bedrock movements, marked by the Cretaceous of NE Scania, (2) demonstrated similar but slighter movements through observations in the region of Ronneby spa, Bleking, and (3) proceded to the Åland islands, limiting the Baltic basin to the North. He then put forward the theory of **erratic leading boulders,** a term introduced in 1884, proving the course of the Baltic ice currents. In a later investigation, 1893—94, he continued his study of the changes of level in SE Finland, on the Carelian isthmus and the Estonian coast, and combined this with previous work in an E Baltic region to give a more penetrating account of the bedrock movements, the lateglacial MG, the Ancylus stage, and the Litorina stage could be revised through isobases, which made their course more certain (printed with maps, 1896).

Particular topics treated by De Geer

(1) THE CRETACEOUS OF SCANIA

(B. No. 1) In 1881 De Geer published a paper (1), (GFF 5, 395—402) on the early formation of the Baltic depression, called: **On the succession of layers within the Cretaceous of NE Scania.** There are three localities described: (1) a well section at Truedsttorp, (2) Hanaskog big quarry, nearly 60 m^2 and 10 m deep, and (3) a temporary small section near the church at Qviinge. (1) consisted of coarse gravel-lime, extremely rich in fossils, mainly with *Belemnitella subventricosa.* Sven Nilsson and N. P. Angelin had already found this species to be older than the so-called sand-lime with *B. mucronata,* which is dominant in (2), where the fossils become sparser higher up, denoting shallower water, i. e. a final stage of the warm Cretaceous sea; this was also the case with (3). Later, De Geer (Ibid, 6, 1885, p. 478) found one specimen of *Actinocamax quadratus* and hoards of *Act. mamillatus,* together with *Ostrea* sp. and, in the upper part of the walls, one specimen only of *Act. quadratus* and another one on the talus at the foot of the wall. Much later, in 1932, De Geer and I found yet another *Act. verus* at the foot of the northerly fault scarp of Mt Hallandsås. This shell was crooked and flattened, as if squeezed in the fault movement and thus a palpable example of De Geer's statement in 1885 that „the Cretaceous formation within our country stands in close connection with the present relief of our surface topography" (GFF 7, p. 479).

This find is thus a clear evidence of a series of vertical bedrock movements in Scandinavia, which caused the complex sinking that led to form the Baltic basin. De Geer also pointed out that present lakes in NE Scania elongated in N—S, with cretaceous layers in their southerly parts and Archean heights surrounding their northerly ends, represent parts of the Cretaceous broken shore.

(B. No. 15) Caves had since long been found in the chalk. In 1886 De Geer described The **Balsberg Cave** (GFF 1886, 8, 3—4). It consists of two big halls (the S one 40 m long and 5 m high, the N one 20 m long and 12 m from its lowest to its highest point). It had been visited earlier by Retzius, Linné and Wasser, and the latter made a map of it published by Liewen in Sv. Vet. Ak. Handl., 1732. De Morgan visited another part of the caves, described in Mém. Soc. Géol. de France, with a sketch. In the narrow channel between the halls the water stood at 15 m a. s. in 1885, when De Geer mapped these caves on a bigger scale and found that the layers were greatly weathered, especially along

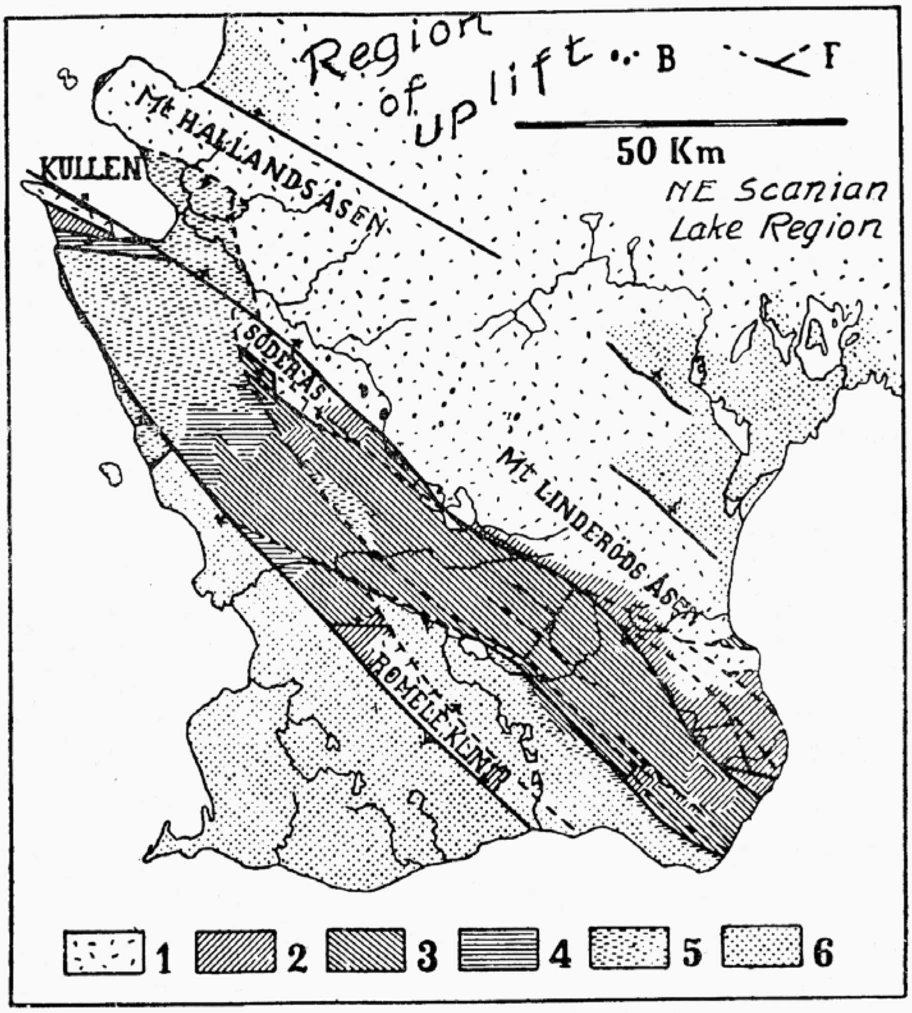


Fig. 1. Geological map of Scania. 1. Archean. 2. Cambrium and Ordovician, 3. Silurian, 4. Triassic, 5. Jurassic, 6. Cretaceous. F.—faults. The arrows point at the lowered side. B-Basalt. After SGU and Nathorst, from W. Ramsay 1909

The South region of Scandinavia: in Tertiary time a great tectonic monoclinal block by a strong elevation along the W side and a mild fall off towards the East. Here the S limit of the Cretaceous Sea is seen by a straight fault line along Mt Linderödsåsen, but its N shore sagged by fissure valleys S—N into the Archean, often occupied by lakes. The Åhus sandstone at the Hanö Gulf may be a littoral level of the late Cretaceous Sea. (From W. Ramsay, Geologins grunder, 1912)

fissures. The chalk is deposited collaterally to the Archean rock walls, so that the relation of a lime layer to the Archean gives no information as to its age. The cave entrance was evidently opened by Man for the purpose of exploiting the lime. This explains why no bones of Tertiary or Pleistocene mammals have been found there.

(B. No. 20) In 1887 (GFF 9, 287—306, Tafl. 8: map and sections) De Geer published a thourough description of **The Cave of Barnakälla,** a by him discovered chalk locality in Skåne, extremely rich in fossils.

(B. No. 27) In 1889 he wrote a paper on **The Scanian lakes and their formation.** He regarded the NE Scanian Cretaceous plain and the Gulf of Hanö as delimited to the SW by a great fault line and in the North by several N—S fissures, which ought to be as old as the diabase eruptions (jotnian) and in any case older than the cretaceous layers. He also regarded the hillocky surface of the Archean as a result of the secular weathering which to a great extent took place before the deposition of the chalk. On the N side of the plain, finally, ice currents eroded the loose weathered gravel and the chalk deposited at the southern side, thus digging out lake basins. To sum up, there are lakes of erosion formed in hollows and valleys, originating from weathering, fissures and probably also faults.

(B. No. 14, 1885) De Geer discovered kaolin at the NE end of Lake Råbelöv in 1885 (Flackarp, Fig., p. 736) and then (Ibid. GFF 7, 734—740) summed up his studies on this topic in a paper **On kaolin and other remains of weathering within the Cretaceous system** (GFF 7, 734—740), where he wrote (p. 740): „It seems possible to assume that the Cretaceous on the whole was deposited during a land sinking, while the weathered Archean was redeposited along the shores, where beds of conglomerate and shell-limestone gravel with *Actinocamax mamillatus* were gradually formed. As the sinking proceeded, these deposits were covered in turn with *mucronata* lime, while simultaneously along the new shores the formation of shell lime continued, perhaps still marked by *Actinocamax mamillatus*. The small differences between the faunas should then depend partly on different age, but partly also on the different bathymetric extension of certain layers. If, as Nathorst claims, the Åhus sandstone is the youngest member of the series, it may be regarded as a remains of the shore deposits formed when the region rose out of the Cretaceous Sea". And this now lies near the shore of the present Baltic Sea. Closely after the Bibliographia printed (in GFF 40, p. 872—885) De Geer developed his theme **On the origin of the Scanian peninsula,** describing its limits as collective horsts. And a year later (Ibid. 41, p. 529—538), he mentions *Actinocamax verus* as here above, broken and squeezed by the market faulting as well Mt Hallandsås as all of Scania's other mid-senonian collective horsts.

(2—3) GEOLOGICAL OBSERVATIONS AT RONNEBY

(B. No. 2, 3, 6; 1881, 1882) After starting in 1881 by this prelude from an introductory stage in the history of the Baltic depression, De Geer's next work dealt with an adjacent region in Bleking, only 65 km E of Mt Balsberget and 70 km E of the town of Kristianstad.

In 1879, the board of the spa at Ronneby, which is renowned for its chalybeate water and its bathing gyttja, commissioned the young

D e G e e r to investigate the properties of their spa. He reported that the soils consist of nine superjacent beds, from top to bottom: (1) brown outwash („svämsand"), (2) gyttja, (3) peat, (4) upper sand, (5) clay, (6) lower sand, (7) varved marl, (8) till, and (9) glacifluvial sand („hvitå -sand"), or perhaps weathered till.

The mineral water was taken mainly from the upper sand but also from the large deposits of gyttja. To reveal the stratification some 200 borings were made to a depth of 3 meters, and many chemical analyses were made of the water by D e G e e r and others. To D e G e e r's great surprize he found a buried river bed, 50 m wide, winding through the bed of marl at a depth of 5—7 m. This was the Ronneby river, which some time after the glaciation ran in a different course from the present. This discovery was of a great principal significance, as it proved the existence of a land surface, evidently older than the lower sand, between the deposition of the two clays, i. e. between the varved marl (7) and the upper clay (5). Until then the two clays were believed to belong to one and the same land depression with but a slight elevation for the sand. The upper clay was the now well-known type of unvarved, grey postglacial clay spotted with black biotic remains.

(B. No. 7, GFF 6, 1882) In a paper called **On a postglacial land sinking in South and Mid-Sweden** this young postglacial land sinking was thouroughly discussed by D e G e e r (pp. 149—162). He mentions (p. 154) that during his reconnoitrings around Penningby in NE Uppland (1878—79) he had noted no less than ten localities, evenly distributed over that areas, with „lower sand" in a similar position. The sand was 0.36 m thick and the younger clay 0.47 m.

The young land sinking remained unnamed, however, until 1886, when the shell of *Litorina* was mentioned, apparently for the first time, in the Swedish literature, by G. L i n d s t r ö m (GFF 8, p. 265), who refers the *Litorina litorea* in Gotland to the 80-feet shore as during the first postglacial landsinking, while following or last sinking only reached 50 feet above the present sea level. In Dec. 1887 A. V e s t e r b e r g spoke about his find of *Litorina* and *Limnaea* in one and the same locality. No *Yoldia* was found in all South Baltic region. H. M u n t h e mentioned his find of *Ancylus fluviatilis* in Gotland. D e G e e r held there could have been an icedammed lake from the last Baltic ice current. G. Holm (GFF 1888, 10, 364) said that his find of *Ancylus* gravel in an open situation was quite similar to those by Dr F r. S c h m i d t within *Ancylus* layers in Estonia and Island Ösel, discovered in 1887.

(4) THE BEDROCKS IN ÅLAND AND DRIFT BOULDERS FROM THERE

(B. No. 4, GFF 5, 1880—81) In 1880 D e G e e r was appointed by the director of the Geological Survey of Sweden, Professor O. T o r e l l, to undertake a week's surveying in Åland. He found it a rhombic, broken land block, reposing on a base 40—50 m below sea level. W of Åland was a deep channel, greatest depth 274 m and the highest point on land was 132 m a. s.; the greatest difference in height was therefore 406 m.

Åland's rock structure is monotonous — great masses of crystalline rocks, lacking parallel structure, and dikes of pegmatite. According to professor Wiik, they could be shown to be older than the Silurian, if that formation were found on the bottom of the Lumpar fjärd. This was in fact done in about ca. 1945, by B. Asklund and O. Kulling (GFF 48, 498—511). De Geer gave a detailed description of the different Åland rocks. They are mostly red, meat-coloured. The Rapakivis have smaller „eyes" of Plagioclase and are thus easy to discern from those of Finland. The quartzporphyries have a fine-grained, reddish brown matriz and are best recognized by the outstanding drop-like, grey Quartz individuals. The Åland granite is light red with crystalline Orthoclase. The granite appears in different-sized massives in various parts of the islands. It occurs between Hulta and Bomarsund on the E coast, striking N—S between higher massives of rapakivi. Wiik considers that the granite generally occurs in four such N—S directed domes, thus forming the most important topographical lines of the islands. De Geer complains of a lack detailed maps and these still seem to be lacking do-day.

All of Åland's rocks (except the finegrained granite) are easy to distinguish from those in S and Middle Sweden, and they are therefore extremely valuable in the study of the spreading of erratic boulders. Only one place in Sweden (Härnösand) and one in Norway (Holmestrand) have rocks that might be taken for an Åland boulder; the eyes of Finland rapakivi are bigger and of lighter colour.

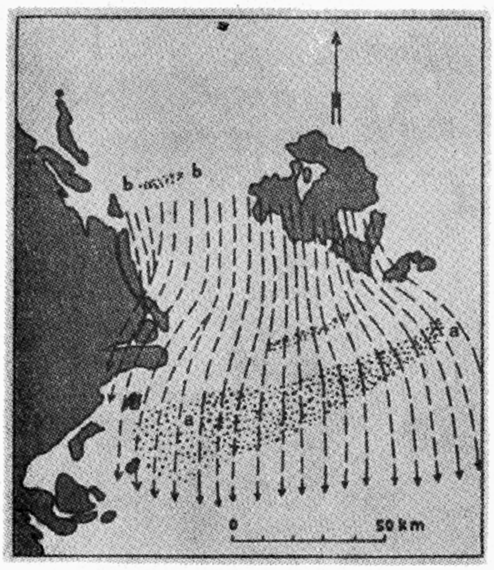
In Åland all striae refer to a single system. They enter the island from due N and run across it in a more or less southerly direction. On the W side they turn a little to the West. Evidently they belong to the Baltic ice current which, coming from Ångermanland, followed the S part of the Botnic valley and fanned out from its entrance. It is unlikely that the ice came from Gävle or Dalecarlia. The cambrian and silurian erratics common all over Åland therefore probably come from N Sweden, or perhaps mainly from the bottom of the Baltic. Other common extraneous boulders in Åland include Hyperite, which is thought to have come from Ångermanland.

To judge from the direction of the striae, Åland boulders ought to occur in Dagö and Ösel as well as S of the Riga Gulf and Düna. But it may not be easy to separate the boulders brought to the Baltic countries by the different ice currents, for close SE of Åland the boulders all went in about the same direction. But surely, if boulders from Åland can be demonstrated farther inland in East Baltic Area and Russia, the E limit for their occurrence should coincide more or less with the easternmost direction of the older ice currents, as the younger ones are known to have followed the valley of the Baltic.

(B. No. 11, GFF 7, 1885) The W limit for spread of Åland boulders seems to be in the south part of the Uppland skerries, as reported by N. O. H o l s t and listed by D e G e e r together with all localities he had found or heard of until 1885 (GFF 7, 464—466). This is an affix to his paper **On the**

Fig. 2. The distribution area of Åland leading boulders. Lines of spread by K. Richter, 1934. Dots-Åland boulder localities, in all 14, reported by De Geer in 1881. In 1885 he had 82 localities, of which 12 on the outer skerries of the SE Uppland coast were reported by N. O. Holst

second extension of the Scandinavian land ice where, for the first time the Finnish and Norwegian big endmoraines are as contemporary combined on a map (C. f. Tafl. 12, 13), but he erroneously added a far too extended ice lobe in the whole length of the Baltic Valley, a fancy which he soon abandoned. Instead there is sketched by G. F r ö d i n (1956), according to soundings, a crossgoing threshold from Svenska Björn to Sarjeva. It is tempting there to imagine a surficial cover of till material on top of the flat bedrocks. But Frödin is quite aware of the flat, monoclinal slope of the pre-Cambrian peneplane, which he shows by detail maps (Fig. 36, 37), only admitting that these rock sills might have had a retarding influence on the ice movement. In a time of climatic halts such as those of the Salpausselkäs, it seems not unlikely that such sills should be able to locate the halts, apt to occur where the calving influence was absent — and the Salpausselkä ridge however must pass somewhere in these regions.



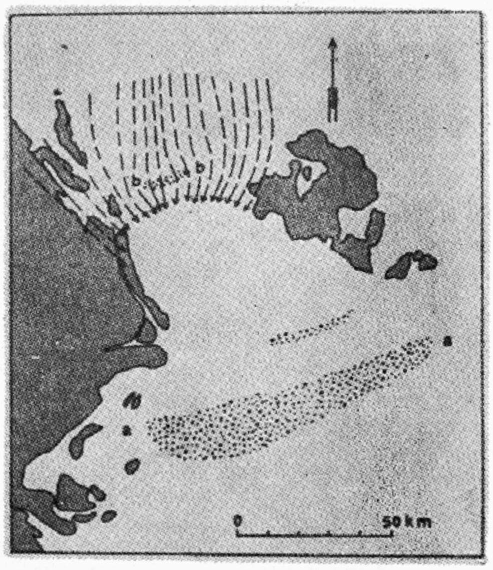


Fig. 3. The opinion of the differential flows in the basin of Åland (after G. Frödin, 1956). Sketch from observations of striae, given here as showing the impossibility of Åland boulders reaching the Uppland shore through glaciers alone. Such a westerly situation seems only be gained by help of icebergs drifting along the successive iceborders. Now observed in Uppland are, as to Frödin, only Jotnian and Cambro-Silurian boulders, but none of the Åland bedrocks. This, however, strengthenes De Geer's opinion of a great drift of icebergs westwards from the Åland Sea, due to various finds in the Stockholm region

De Geer 1881, declares that on the whole the W limit for the spread of Åland erratics and hence for the extension of the Baltic ice would soon be better known, if Swedish, Danish and English geologists gave the matter the attention. The regions considered include, except the SE outer skerries of Uppland, Öland, E Bleking, Scania, Mid-Germany, Sjaelland, Jutland, and possibly NE England. Concerning Åland boulders known to De Geer, he reports that at Rüdersdorf he and at Eberswalde Prof. Torell, each found a boulder of Finnish rapakivi, which are rare in NW Germany. He mentions finding Åland boulders at Ronneby, possibly brought from the skerries as rubble stone, and at Malmö, where they may have come with pavement material. The same is the case with the Åland boulders at Berlin. All the erratics found elsewhere by De Geer were in glacial clay, those of Rüdersdorf from upper till, of which they comprised 0.5%.

These erratics should prove to be only a small beginning. They all followed an ice stream which was more or less influenced by the Baltic valley. Those in Saxony and Silesia may have been deposited directly or they may have been carried to the plains at first and then have been swept to the sides by a later current. In the former case the ice current must have proceeded at a height of 400 m a. s. (H. Credner, Z. d. geol. Ges. 1880, 579).

While De Geer left the boulders for the varves, many others continued and especially V. Milthers in Denmark made that study his life's work in a surprisingly splendid way, by means of a minimum number of boulders. In Germany a great **Geschiebeforschung** was developed by methods always more refined. As introductor of the term **Leitgeschiebe** is generally mentioned J. Korn (1927). Further progress is made by K. Richter, J. Hesemann and lately G. Lüttig.

(5) ON PLEISTOCENE CHANGES OF LEVEL IN THE GULF OF FINLAND

(B. No. 64, GFF 16, p, 639—655, 1894) When in 1893 De Geer wanted to study the Pleistocene changes of level on the east side of the Baltic, he found it most practical to do so in the regions round the Gulf of Finland. For one thing, a great deal of basic work had been done there by the Geological Survey of Finland and in Russia and Estonia mainly by Dr Friedrich Schmidt; for another, a series of excellent maps was available, and finally the open till-covered regions E and S of the Gulf of Finland might have highly favored the formation of typical shorelines at the limits of transgression. Moreover there was the important question of a connection with the White Sea.

In December 1893, at the Geological Society in Stockholm, De Geer presented a map of his results with his points of observation, 21 for the highest coast line and 20 for the postglacial sea between the Gulf of Finland and Ladoga Lake (GFF 15, 1893, p. 537—518, and also 1894, here above). He received friendly cooperation from the foremost specialists in each country — Director Sederholm in Finland, Dr Tschernyschev in Russia and Dr Schmidt in Estonia.

The highest shoreline (MG) was measured within two regions: (1) near Lahti (about 152 m) and (2) on the Karelian isthmus, 55—24 m. From W of Perkjärvi rystn (3) to Rasmitelevo (10) E of Petrograd there was a straight, magnificent terrace forming the highest shoreline, 6 m hight and 6 km long, and on lower levels there were shorelines and beaches from both Ancylus and Litorina. The former may have led to the White Sea at 80 (83) meters.

The other points were:		The Late-glacial Sea:
(11—14)	SW of Peterhof, 4 km	30 m
(14)	Piersal	48 „

(15)	Ösel, highest point	(58°21′N)	50 m	
(16)	Irgen, Courland	57 38	38 „	
(17)	E Windau L. Pussen	57 22	32 „	
(18)	Alschwangen	56 56	28 „	with land sculpture
(19)	Libau	56 33	21 „	„ „ „
(20)	Rutzau	56 08	15 „	wall 25 km long
(21)	NO Polangen at the frontier to Germany	55 56	11 „	

These important features appear very clearly in the Russian topographic maps.

The Ancylus limit. At several places near Onega Inostranzev found terraces 50 m above the lake, i. e. at 83 m a. s., so that it is very probable that this lake was combined with the Baltic lake. Stjernvall's find of only *Mytilus* and *Tellina* (not *Cardium*) was much overrated, however. As described by Tschernyschev, they may elucidate the relation between the Scandinavian and a possible „interglacial" depression.

At Brigitten, Reval, MG lies at 60—80 m and the limit of the shell-bearing Ancylus layers at ca. 45% of this level. At **Kunda** the peatbog lies 50% of MG, where Nathorst found a big beach at 56 m a. s., damming a lagoon in which he discovered arctic plant remains in Estonia.

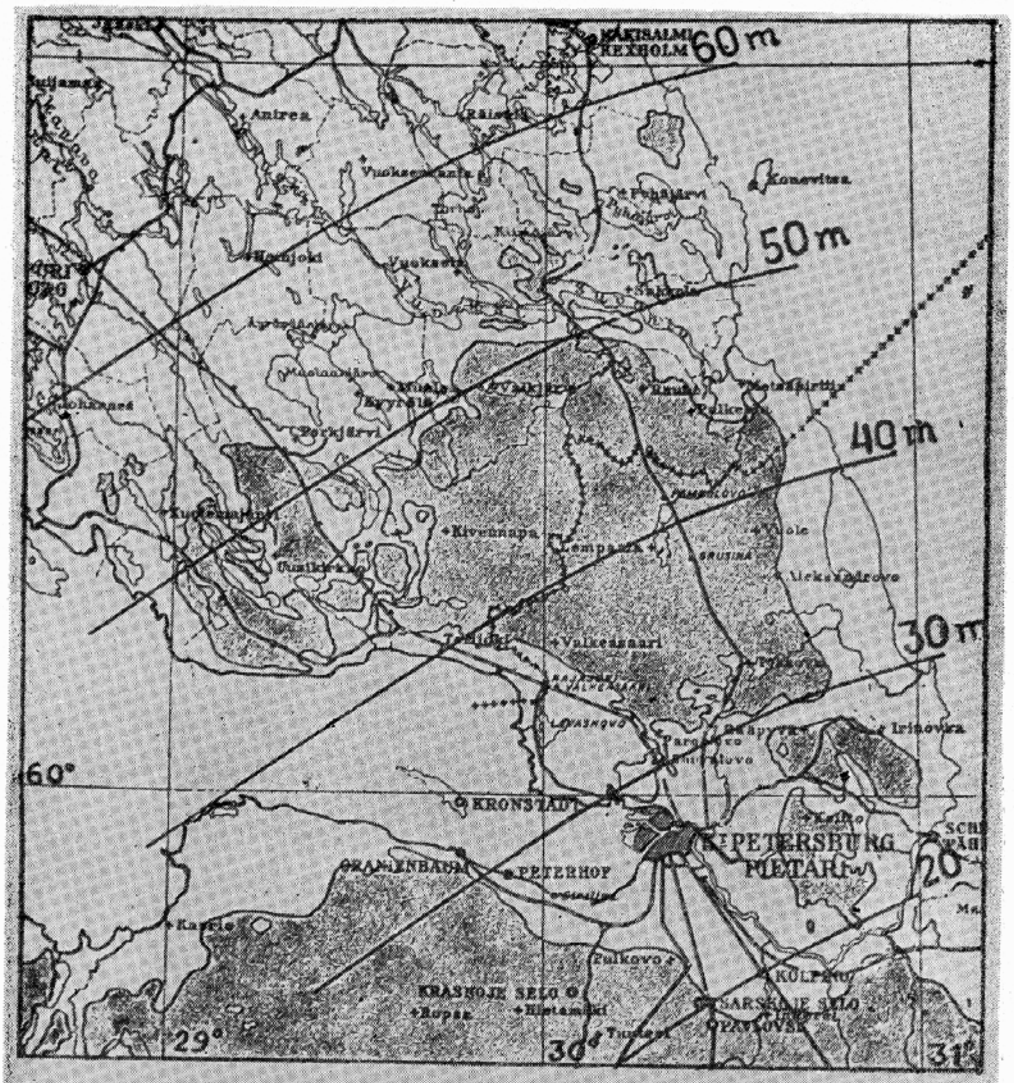
The Postglacial or Litorina limit. The study was drawn up as follows: To determine the level of the extreme limit at:

1. F. Schmidt's renowned shell localities in Ösel and Estonia
2. to establish the isobases from the Swedish side
3. using 2. to seek out the continuation of this transgressional limit on the soil-covered shores of the Gulf of Finland and regions inland.

Already, when reconnoitring on the Karelian isthmus, guided by H. Berghel, De Geer found, during a steamer voyage on Lakes Vuoksen-Suvanto, a shoreline at a higher level than the low watershed between Lake Vuoksen and the Gulf of Finland. De Geer supposed this elevated terrace of abrasion to be marine, forming the postglacial limit, and thus showing that Ladoga even in postglacial time stood in connection with the sea. Schmidt's great knowledge of shells meant that postglacial isobases could be established for this region. Apart from the lateglacial limit, here called the second or upper Neva terrace, only one level exists in these regions, namely the lower or first Neva terrace. This is clearly to be seen both in maps and in nature, as running almost uninterruptedly along the whole length of the plain, inner shores of the Finnish Gulf, rising to 17 m at Seivistö in the NW. It forms a prominent terrace of abrasion, and its general level, its gradient and its relation to the isobases show that it must be the immediate continuation of this lower Neva terrace.

The northernmost locality of this level is Palakahia, just at the divide on the Karelian watershed. According to Sederholm it lies at 17,4 m

a. s. between Lakes Oissenlampi, 14.7 m, and Menämänlampi, 16.2 m a. s.; as the level of the main terrace is 33 m a. s., the strait which joined Ladoga Lake to the sea at the maximum of P. G. must have been only 15 meters



Isobasen der Uferfläche B III, sowie die Verteilung des Festlandes (grau) und des Wassers (weiss) während derselben.

Fig. 4. The highest shore-line of the inner Gulf of Finland, formed in B III (Sauramo), a late stage of the Baltic Ice Lake, slightly higher than the MG. (From Ramsay, W., 1928, Fennia 50, No. 5, 1—21.)

deep and rather narrow. Since all the water from Vuoksen streamed through this strait, no marine molluscs could have lived there.

The 21 m terrace at Vuoksen could not possibly have belonged to the PG at Patakahia. De Geer later found that Böthlingk had measured this level long ago and assigned it to a water-level in Suvanto-Vuoksi earlier than and higher than the oldest known, before the drainage of 1818. As the threshold is only 4 m higher than the divide to the Baltic in the direction of Viborg, this should be a direct proof of Ramsay's assumption that Vuoksen once had its outlet to the west, instead of as now to Ladoga at Taipale.

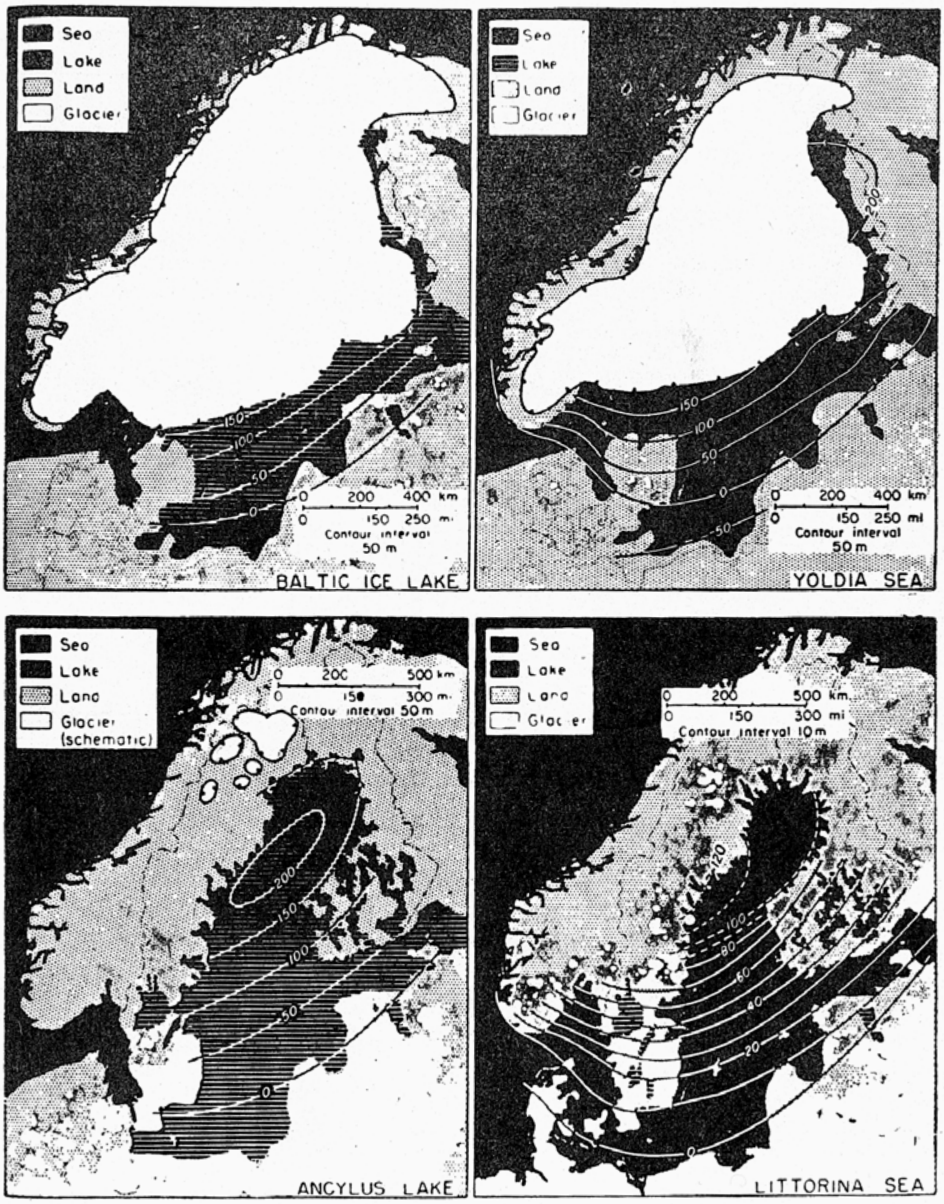


Fig. 5. The suceessive stages of Late-glacial uplift, with isobases combined from De Geer, Högbom, Munthe, Sauramo, Ramsay a.o. (From R. F. Flint, 1957, after E. Fromm in Atlas över Sverige, 1953.)

At the Geological Society, Stockholm, a month before, Gunnar Andersson had communicated seven postglacial localities levelled by Berghell, without knowing of De Geer's values. They fit excellently, Andersson's peat is postglacial and e. g. not Ancylus. At the S shore of Ladoga, Inostrantsev found the oak, to have been common and thriving during the postglacial maximum. The 39 species found in somewhat younger layers include, besides, birch and pines, also alder, hazel, spruce and, a dominating tree, the „summer-oak".

Together with skeletons and toils, including a whole boat of oak, 44 species of vertebrates were found, for instance ourochs (bison), wild bear, beaver and sable as well as the puffin *(Mormon arcticus)* which no longer exist in these regions; the boar for example only stretches to 55°N. The silure or sheet-fish, now most common in S. Russia, was found in plenty and seems to have immigrated from the East. Also a sea-dog was found and rein deer, „which still exists living on a peatbog S of Ladoga".

From the description it is clear that the stoneage climate was somewhat milder than the present one and that here, as I have tried to show earlier the immigration of both Man and the oak took place during the same big postglacial land sinking.

Böthlingk mentions a layer of peat, formed by water plants and covered by clay, which he regards as indicating an ancient higher water level in the Neva. He also mentions, as does Pallas, a boat of oak and remains of human bones and reeds, which were found below clay and a layer of stones, evidently cobble, in the channel to the castle of Strelna, 17 km W of Petrograd on the shore of the Gulf. Inostrantsev also mentions that oak is not uncommon in the „alluviums of the Neva" and has been found in borings in Petrograd. Pallas also found a boat of oak, when a dock was built at Kronstadt.

Since all these finds lie below the P. G. and since, moreover, Strelna and Kronstadt lie outside the alluvium of the Neva, it is presumable that they were all made in marine, postglacial sediments. In this connection it may be mentioned that Tschernyschev has found submarine ridges, in his opinion beaches, outside Terijoki in the Gulf of Finland. If he is right, this should prove a land elevation, probably corresponding to the Ancylus elevation in Sweden.

It is interesting that these repeated changes of level are most pronounced in the periphery of the region of land elevation, and most probably further evidence is to be found in Courland and the inner part of the Gulf of Riga.

(6) ON THE LAST BALTIC ICE CURRENT

a) Retreat within the S part of the Baltic valley

(B. No. 161, GFF 28, 419—421, 1906) The limit of the upper Baltic moraine in Scania seems to curve around the south side of Mt Romeleåsen (Holmström). Visiting Oxie in 1888, De Geer saw that the landscape which on the topographic maps appear to be hillocky, consists in fact of **Durchragungen** or push moraines. Its extension in a curve parallel to the coast N of Ystad denotes that it was once the limit of the last Baltic ice current. This seems to have overrun the whole of Sjaelland (Ussing) and reached the moraines described by V. Milthers in the NW part of the island. During its final retreat, the melting within the Baltic Valley, no doubt because of calving, proceeded considerably more quickly than on land.

Consequently the iceborder, which from Halland via N Skåne and Mid-Bleking goes in a curve to the narrowest part of Kalmar sund (now called the Göteborgsmoraine) there forms a fine series of endmoraines,

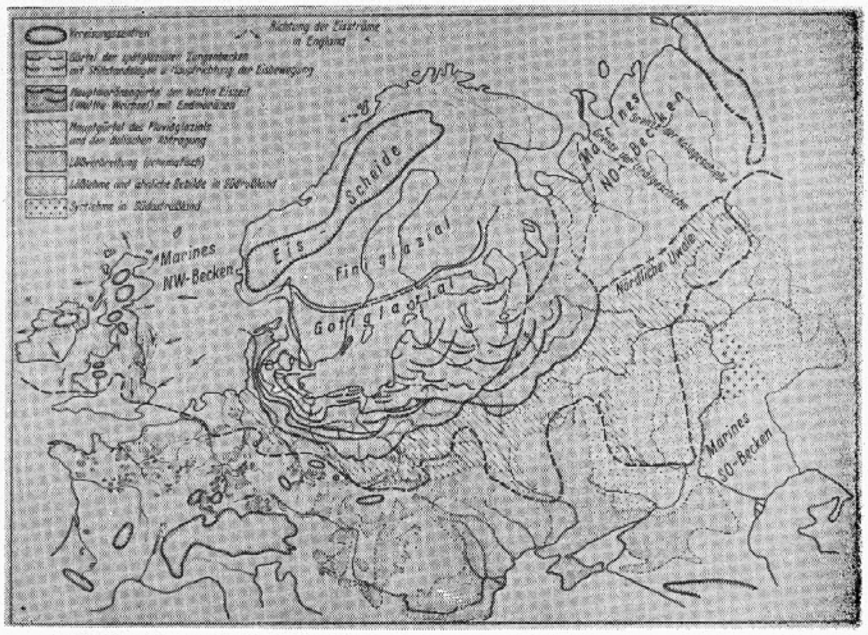


Fig. 6. This map on the Quaternary glaciations of Europe, centrated on the east Baltic regions, is given here in the hope of soon obtaining some C-14 dates from the central parts of Russian Plain. On those wide plains there may surely have been many great oscillations, and the Kalmar moraine, expected to be found near Perguba, may perhaps like the Salpausselkä moraines in Mid-Sweden, be so subdivided as not to present a striking aspect. Its situation is however likely to be there, but in Sweden that stage appears mostly by flat plains of sandy marginal terraces
(From K. Richter, 1934).

partly as shoals on the bottom of the sund, so that the striae of this iceborder fan out from NE-SW to straight N-S and then to NW-SE. „The limit of the Baltic ice in E Scania cannot have curved to the NW before at Blåherremölla (Maglehem) and therefore was not more than half a degree of latitude S of the iceborder just mentioned, which thus eastwards within the Baltic Valley must have retired incomparably more rapidly".

These words, written by De Geer in 1906, outline the mode of ice release within the S Baltic Valley from the Danish islands towards Gotland-Courland (e. g. Ronneby—Kalmar—Roma—Pernau (Pärnu)—Onega and, in an earlier stage, Rörum—Libau (Liepaja)—Riga). This includes, for the NO ice in N Scania: stagnation or a very slow retreat along the Belt line, E, with the Gribskov glacier broadly expanding from the Rönne valley to east central Sjaelland, there probably pushing against the Kattegat ice, then during the lake period 15 000—14 000, holding this position, first perhaps with dead ice along its east side, and then with a series of meltwater lakes, confronting the border of the NO ice (Data 119, Fig. 1, 1962).

This glacier's role as a transit passage to the Rönne valley, now expired and the transfer was taken over by the far deeper strait of Öresund. But in the pocket of Skelder bay and Engelholm plain the Kattegat ice could readvance from the NW, at the Langeland cold maximum damming the Rönne lakes.

Then came the Langeland retreat N-S in Öresund, while at about 13 000 in the low Baltic, extensive new lakes or straits were formed between the Baltic ice and the S Scanian land. During the Bölling mild climate the Baltic ice now thinned and may have broken up by calving, as Bornholm acted as a barrier to the deep ice of the main Baltic. But even this main ice evidently became thinner from vertical melting, as it broke up so far that the marked iceborder of 12 300, i. e. the Gothenburg moraine, is fixed in Gotland, as far as time is concerned, by the oldest varve dates just N of Roma, and topographically by long, straight moraines, rather low and flat which extend from the Gotland coast to its center. These moraines are bordered by equally extensive peatbogs with outlines as straight as the moraines themeselves (see topographical map sheets). Forming a right angle S of Roma, the easterly moraine goes due SE, thus denoting a lobe of ice projecting into the main basin of the East Baltic valley. In the center of this lobe there is the Kullenberg deep boring Nr. 141.

b) Retreat from Gotland-Kalmar to Stockholm-N.Uppland

N of Roma starting through persevering measures by G. Erdtman (as well as finishing northwards with such by R. Liden), the ice retreat is registered in scattered groups of varve localities all up to Fardume (12 km NE Slite). These seem to give a total of some 200 years across 30 km of retreat, i. e. rather equal to that in Småland close N of the Kalmar moraines. In Sweden, from Kalmar NNW along an easterly valley, by Standart Line F to Linköping, than ENE by help of Ss I to (Herrhamra) Nynäs, by Divisons A-G to Stockholm, and by H-S past Uppsala to N Uppland (c. f. 1912, in B. No. 214 and 1940, Data, 82, Geochronologia Principles, K. V. A. Handl. Bd. 18, 6). Further, by EHDG: s fixed teleconnections (in GFF 65, 1943 and in 76, 1954, and 79, 1957, maps Fig. 1, resp. in Fig. 2), there comes out that while Sub. Ss enter Finland far E of Hangö, it is Ss I that forms the pointed cape called Hangö Udd and enters Sweden close S of Nynäs in 10 650 B. P. Conclusively also E. Nilsson's southermost bottenvarv in Åland is by De Geer (1940, p. 257 and Pl. 79) dated — 912 B. Z. = 9712 B. P., where by the Baltic basin (Ibid. Pl. 63, 65, 68 and Data, 109, Fig. 1), as counted from East Sjaelland, was in 3 300 years definitely laid free of the land ice.

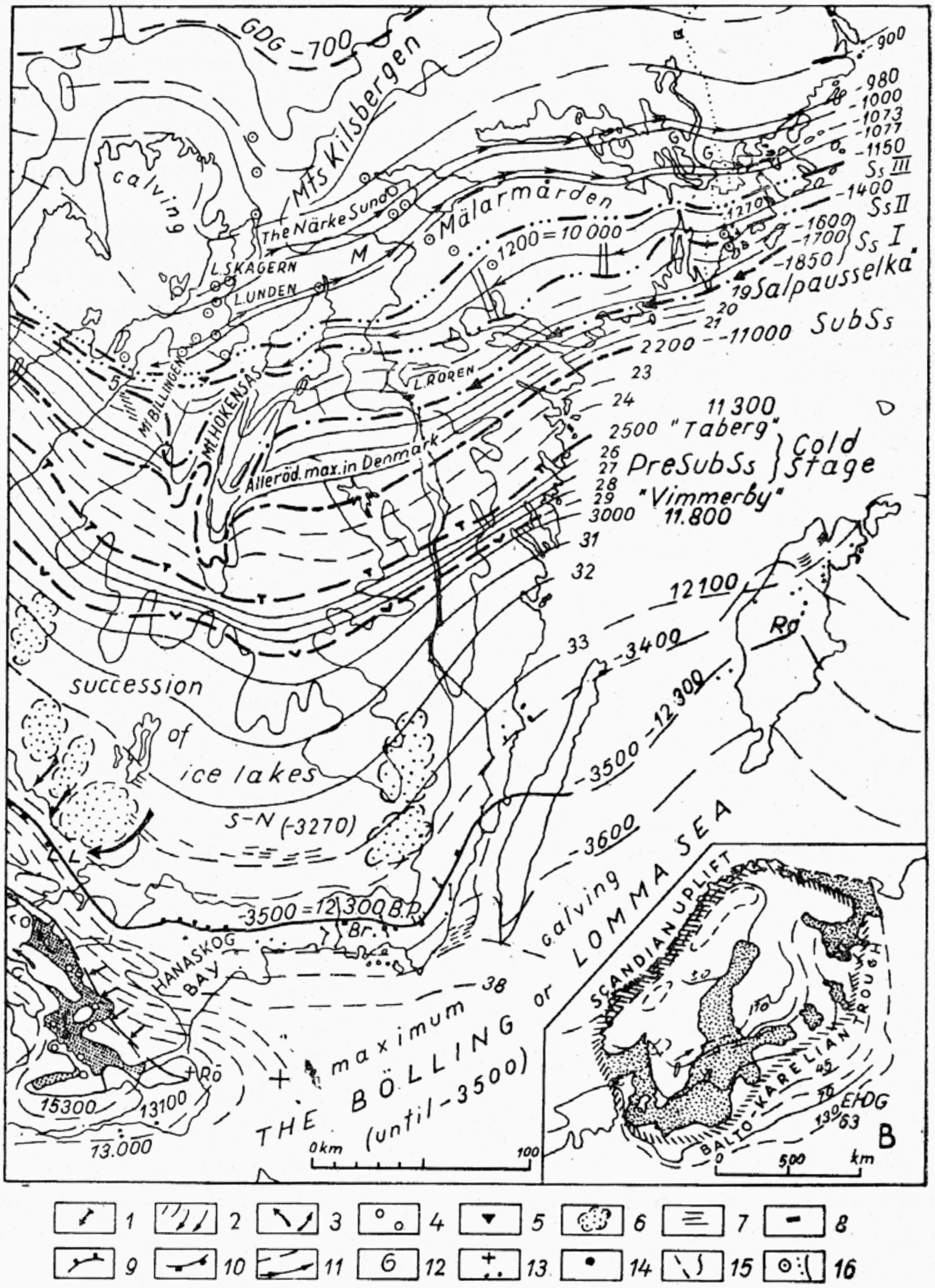


Fig. 7. G. De Geer's map of the last deglaciation in S. Sweden and adjoining areas. EHDG 1962.

Legend

1. striation, *2.* ice movement, *3.* water courses, *4.* localities with *Gammarus pulex*, *5.* glacial overriding, *6.* deadice fields, *7.* end moraines, *8.* transverse ose, *9.* submarginal moraines, *10.* extramarginal rand delta, *11.* saltwater inflow, *12.* loc. with *Yoldia arctica*, *13.* varve measurements, *14.* varve series showing the „LANX", *15.* eskers (Åsar), *16.* core boring and standard varve line

LANG: Langeland; Low: Low Baltic Gl.; Laholm, Lejeby E. F. G. (Madsen 28); T: Tyringe; V: Vanåsfors; M: Mysen; Gr: Grefsen ridge; Rö: Rörum; Va: Valer; K: Koster; Go: Gothenburg; Ud: Uddevalla; R: Lake Rönne; Ro: Roma; Sk: Skara. —3270: southernmost dated ice lake

CONCLUDING REMARKS

For lack of linguistic ability, I am unfortunately rather ignorant of what happened in the SE Baltic during the last ice retreat. Still, an excellent paper by V. Gudelis (1960) has recently afforded a welcome opportunity of acquiring such knowledge. His English text is made all the more valuable by his prominent application of De Geer's varve method. In 1956 I tried to interprete and review the works of Germans and Poles in may paper on the last glacial retreat in the Baltic Valley.

Of those glacial events the most dramatic must have been the catastrophic drainage of the icedammed lake of the Lower Visla, which suddenly dropped 20 meters to the level of the Baltic. (Orography and glaciation in the Baltic valley. Cahiers géol. 35—36, Mars-Mai 1956).

In **Nordosten** (edited by N. Creutzburg, 1931), there are several papers of great value concerning the lower valleys of the Visla and the Pregel. There is also the Bayreuther map with several morainic stages, which I provided with tentative dates in round numbers. R. Galon (1934), finally reports the levels of the sea during the past successive sinking of the icedammed lake, right to the great break through, when an outlet for the Visla to the Baltic was opened for good. But even so, essential information is still lacking. We do not, for instance, know where the iceborder was at the time of the break through. Thanks to De Geer's varve datation at Grudziądz, 15 300 B. P., as a starting point, it seems to me that it may have been at the present Gulf of Danzig and round about 13 000 B. P. This is in Mid-Bölling time, when the climatic maximum might have mellowed the ice and filled many fissures with meltwater. If I am not mistaken, there should be a total lowering of 70—75 meters from the highest water level, though for the final drainage there may have been 40 meters down to the Baltic level at that time. And this must have occurred in lateglacial, early gotiglacial time (early Mid-Bölling), when the westerly iceborder was rapidly breaking up along the south Scanian shore, from Öresund to Hanö bay and farther east. The most important task now is to take some varve measures, preferably at 4 localities by intervals along the Visla valley N of Grudziądz, onto the northernmost bed of „Deckton", shown in my map, Fig. 3 (from Bayreuther). After B. Halicki nobody seems to have measured varves in Poland. Yet science should be curious to know whether these varves show any likeness to those in nearby Lithuania, so carefully measured by V. Gudelis and his collaborators. Geochronology calls for a revived spirit of exploration in the SE corner of the Baltic.

To the prominent volume — Collectanea Acta Geologica Lithuanica — issued at the XXI Session of the International Geological Congress, 1960, there are all papers given in English. So by R. Tarvydas there is given a modern map of all the types of leading erratics and their spread to the SE, while the present author wanted to mark out the early findlings of De Geer, which lie farther SW. Except V. Gudelis work, to which

I may return on another occasion, the paper by J. Dalinkevičius is of a special interest to me, as treating **The main features of the tectonic development of the southern Baltic countries** (Coll. Acta Geol. Lithuanica, Vilnius, 1960, p. 137—150. Figs 1—12). By the discreet, uniform style of the maps, this author illustrates his work of the varying process of sedimentation all from the transgression of the Lower Cambrium through the ages on to the Cretaceous, Tertiary and even Pleistocene times. There he achieved to link up with the young events of the big elevations of the Baltic shield. Interesting are the enormous depositions of coally-sandy sediments of several tens of meters during the Oligocene. Apparently the areas of erosion were the elevated parts of the S slope of the Baltic shield, with Paleozoic beds stretched down upon it. Finally, the big elevations in the Quaternary created the Baltic trough as a consequence of warping.

This little paper, reviewing the first eager steps taken by the young De Geer some 80 years ago, when the initiatives to take up something really new opened great perspectives, will I hope give a feeling of „nearness" to those days and their connection with the great work still waiting to be done by new, young individuals with a fresh, enthusiastic spirit.

ADDENDUM

1. As to the South Baltic ice, only the following may here be mentioned. In Poland, 14 varve localities measured by R. Sandegren are in his Journal (of 1927, n. p.) reported as covered by the zone L 4 (also called layer A), as to him appearing: in 7 cases as **glacifluvial sand**, in 3 cases as **sandy moraine** (thus 10 of sand) and in 4 cases as „moraine", yellow or brown.

De Geer has annotated his doubts that this should be real moraine or till. He considered the whole L 4 to be glacifluvial sand, i. e. the final phase of the Langeland or Middle Baltic stage, which lasted from ca. 15 000 to ca. 13 000 B. P. It seems quite reasonable that this could also correspond to the glacifluvial sand, mentioned by V. Gudelis (1960, p. 255) as throughout covering the mighty clays of the Middle Lithuanian stage (e. g. in the basin of Kaunas—Kaišiadorys). This may signify the most natural explanation of Zone L 4.

2. G. De Geer in September 1887 even entered on Speleology, when discovering the grottow of Barnakälla in NE Scania. It is by him discribed in GFF 9, 287—306, map and profiles, Tafl. 8. Its very narrow entrance almost invisible, but it gave a good record of the Cretaceous fauna (122 sp.).

[Manuscript received March 22nd, 1963]

ANTEIL G. DE GEERS AN DER ERFORSCHUNG DER OSTSEEGESCHICHTE

von

EBBA HULT DE GEER

ZUSAMMENFASSUNG

Der Verfasser bestrebt sich die wichtigsten Arbeiten von Prof. Gerard De Geer über die Entwicklung des Ostseeraumes im Spät-und Nacheiszeit zusammenfassend darzulegen. Die folgenden Fragen sind eingehend betrachtet worden:

1) Die frühtektonische Entwicklung der Ostseemulde. 2) Nacheiszeitliche Landsenkung. 3) Das Grundgebirge Ålands und die Leitgeschiebe der Ostsee. 4) Die gehobenen Uferlinien im Ostbaltikum (im Bereich des Finnischen Meerbusens) und 5) Der Rückzug des Ostseeeisstromes von Schonen über Gotland — Kalmar bis Stockholm — N Uppland.

Zum Schluss werden die neuesten Forschungsergebnisse zur Warwenchronologie in Litauen, Polen und Deutschland vorläufig erörtert.

ВКЛАД Г. ДЕ ГЕЕРА В ИЗУЧЕНИЕ ИСТОРИИ РАЗВИТИЯ БАЛТИЙСКОГО МОРЯ

ЭББА ХУЛЬТ ДЕ ГЕЕР

РЕЗЮМЕ

В данной статье автор рассматривает вкратце основные работы профессора Герарда Де Геера, относящиеся к развитию района Балтийского моря в поздне- и послеледниковое время. Следующие вопросы освещаются подробнее:

1) Раннетектоническое развитие впадины Балтийского моря. 2) Послеледниковое погружение суши. 3) Коренные породы Аландских островов и руководящие валуны Балтийского моря. 4) Приподнятые береговые линии Балтийского моря (в пределах Финского залива). 5) Отступание балтийского потока материкового льда со Скандии через Готланд—Кальмар до района Стокгольма и северного Упланда.

В заключении статьи затрагиваются некоторые результаты новейших исследований хронологии ленточных глин в Литве, Польше и Германии.