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GEOLOGICAL RADIOCARBON DATINGS FROM THE STOCKHOLM STATION

BY

G. LUNDQVIST

STOCKHOLM 1962

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Abstract

The following paper is a summary of the geological datings which have been done during the years 1955—1962 at Stockholm Natural Radiocarbon Station. The main problems comprise interglacial finds, interstadial and Alleröd-layers, land elevation problems, recurrence surfaces and dating of pollen diagrams. We have also started a dating of the first iron production and other facts connected with the first mining.

Introduction

Ever since the Stockholm Station for radiocarbon dating was established in 1955 I have been one of its geological members. Because the Geological Survey of Sweden — together with the Royal Academy of Antiquities — have had priority regarding datings at the station I have had the privilege of getting quite a great number of samples dated. Some of the results have already been published (e.g. G. Lundqvist 1957, 1959, 1960, J. Lundqvist 1957) in different connections.

Though now retired from the Geological Survey and the position at the Stockholm Station I feel it my responsibility to give an outline of my unpublished datings. When necessary the older data are mentioned here.

The geological material dated at the Stockholm Station can be divided into interglacial occurences, interstadial and Alleröd-layers, land elevation problems, recurrence surfaces and dating of pollen diagrams. Moreover, we have studied the first iron production and the age of the mining at Falun, Sweden. A number of miscellaneous datings in different connections are also included.

The Stockholm Station has been set up and led by fil.lic. G. Östlund. During Östlund's absence abroad, especially in the USA, engineer L. Engstrand has been acting head of the Station. The other members of the staff at the Station are engineer L. Lundgren, mrs I. Almstedt and miss B. M. Hellström. My manuscript has been critically read by Jan Lundqvist and corrections to the English of manuscript have been made by P. Padget. To all I express my sincere thanks for their conscientious work.

Review

The investigations published up to now may be, as already hinted, divided into a number of groups of which a short report is given here.

Interglacial deposits. As belonging to this category I have included deposits for which the C14-dating gave more than 30.000—40.000 BP, the hitherto existing limit of the method, as well as deposits which, for many reasons, must be equivalent to these. Definitely interglacial finds that are C14-dated are the spruce at Fryksta (J. Lundqvist 1958), the spruce log from Öje (G. Lundqvist 1955), the Bollnäs find (Eriksson — Halden 1915), the mammoth from Pilgrimstad (Kulling 1945), the clay at Vålbacken (Thorslund 1939), the Boliden deposit (Grip 1949, J. Lundqvist 1955), the Ale find (Fromm 1960) and the ooze at Porsi (G. Lundqvist 1960). All were briefly discussed by G. Lundqvist (1960). The same is true for the following finds, which for different reasons have not been dated with C14: the spruce from the delta of Rättvik (G. Lundqvist, 1951), the find at Ryggesbo (G. Lundqvist 1960), the Härnö find (Munthe 1904), the deposit at Långsele (Sandegren 1948), and the Frösön find (Asklund 1936). Moreover, there is a dated but still unpublished find from Gallejaur at the Skellefte river east of Malå (E. Magnusson).

Thus the number of localities is not insignificant but the datings are made on the organic matter, and therefore it is possible that the geological deposit itself is younger. In some instances the dated material can have been redeposited. Thus the spruces in the Fryksta and Rättvik occurrences are old and the deltas young—finiglacial. It is difficult to say to what extent this experience can be applied generally because the material is often very fragmentary. The explanation is not valid for the occurrences at Öje, Pilgrimstad, Vålbacken and Porsi. There the enclosing layers are intact or lie in such a situation that a redeposition is impossible.

It is probable that there is the same risk as was hinted at above concerning the samples from Ingebäck and Hisingen at the Göta river examined by Brotzen (1961). The radiocarbon datings (fig. 1) indicate in some measure a younger age downward; at 12—13 m below the surface 16040 years BP, and at 55—56 m 15350 BP. The changing ages which are found in the deposit indicate that the sediment must be rich in redeposited material. It must, therefore, be a river sedi-

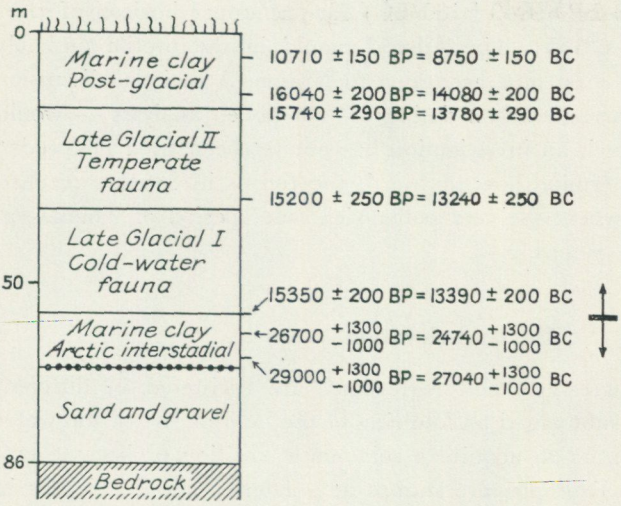


Fig. 1. The stratification at Ingebäck (Göta älv) in southern Sweden, surveyed by F. Brotzen (1961). The distribution of the sediments according to age appears remarkable but the reason is surely that they are river sediments. The stratum from 29000—26700 BP is the first one of this age found in Swedish deposits.

ment. It is such material that has given the age, whilst foraminifera have determined the type of environment.

An important feature of this deposit is the great discordance characterized by a clay layer with coarse sand. Below this layer the datings give in round numbers 10000 years more, namely, $26700 \pm \frac{1300}{1000}$ BP, that is 24—25000 BC. The layer is a marine arctic clay, and Brotzen (p. 147) has correlated this with the Ale find of Fromm (1960) thus: »It was stated to be more than 24000 years BP, but the organic matter may not be older than 29000 years.» For the last statement we have no evidence. Quite the opposite is more probable because the Porsi find situated relatively nearby (G. Lundqvist 1960) gave more than 40000 years. And there it is certainly not a river sediment but a small pool on the mountain heath.

Apart from this the investigation of Brotzen is of great interest because it shows the inadequacy of datings for a correlation of the different old phenomena. Continually we are groping about in the dark with a great number of very important questions. One of these problems we must consider is the age of the different ice streams in Southern Sweden (G. Lundqvist 1961). Unfortunately we have not yet found any stratification allowing a radiocarbon dating to be made. The occurrence at Robertsdal in Skåne (Munthe 1920) appeared very auspicious from a stratigraphical point of view but the radiocarbon dating gave 10980 ± 140 BP (= 8925 ± BC). This is approximately Alleröd time. However, the upper moraine bed may have reached its present position through a landslide. If not, this moraine must be from the Younger Dryas time (G. Lundqvist 1957).

To the same period the material from the classical occurrence at Toppeladugård belongs. The result for the »Alleröd mould» is 12000 ± 200 BP (10040 ±

†— *620901. SGU, Ser C 589. Lundqvist*

200 BC) and 11900±180 BP (9940±180 BC) for the upper horizon of clay-gyttja (T. Nilsson 1959, s. 135). The Alleröd mould in the profile probably marks the beginning of Alleröd time according to Nilsson. A regional discussion of the Alleröd period with radiocarbon datings — not pollen analyses — would be of great interest. But such an investigation has not yet been tried in Sweden and the problem is to determine how far north the forests in Sweden reached during Alleröd time and where the very pollen-rich older period of Thomasson (1935) comes in the time record.

The land elevation

Changes of level, transgressions and regressions, are registered in different ways. Some districts were submerged on lowering of the land or rise of the water level, causing terrestrial strata to acquire a subaquatic position or became embedded among sediments. Examples are stumps at greater or smaller depths in the Baltic. Two of them are dated at 7375±120 and 7145±120 BC (G. Lundqvist 1957). In connection with these a submerged peat at Sörevik SW of Karlskrona may be mentioned. It is situated 4—7 m below the water-level and was dated at 4070±140 BC (T. Nilsson 1959).

There is some discussion as to whether the stumps mentioned were rooted or not. But only a trained frog-man can investigate the critical areas at depths of 30—40 m. Unfortunately, I am too old for such work.

Important for land elevation problems is dating of peat under shore banks, in particular the Ancylus- and Litorina Banks. Classic occurrences are known from Gotland, Öland and the coastal zone of Småland.

Some samples have been dated at 7235±130 BC from beneath the Ancylus beach (at Fröjel on the isle of Gotland) and 5075±110 BC from beneath the Litorina beach (at Ramsås; both in G. Lundqvist 1957). S. Florin (1959, p. 46) obtained a good agreement with the last mentioned result with 5000 BC for a lagoon 'gyttja' in Södermanland.

The material dated up to now is too meagre. It is of special interest to determine the difference in time betwen the surface of the peat and the bottom layer of the bank. For this reason it is necessary to look for occurrences where thin layers of the shore sand alternate with peat. Localities of great interest might be found around Lake Vättern. Outside the town of Huskvarna stumps are found on the bottom but their age has not yet been determined.

In connection with these questions I wish to say that the find of peat under a shore bank at Kärna mosse in Östergötland (Munthe 1922) has now been dated at 5700 BC. Munthe was of the opinion that it was the Ancylus bank but the latter originated about 7200 BC. Nor can it be the Litorina bank which is dated at 5000 BC and is situated on a lower level. Possibly the shore gravel has slid out on to the peat during periods of high water level.

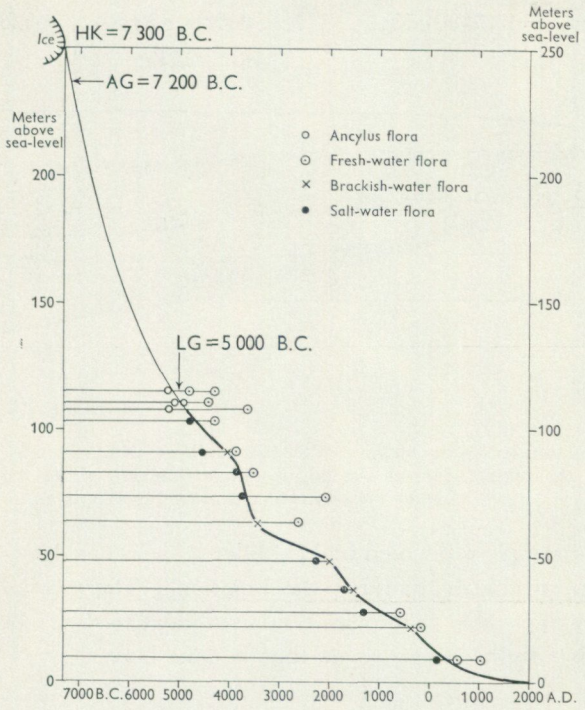


Fig. 2. The upwarping of land in northern Hälsingland from 0 to about 110 m a. s. l. The upper part of the curve (the fine line) is determined from the highest shore line (HK) and the Ancylus limit (AG).

The datings mentioned have given us some definite values of important events in the development of the land elevation but they are insufficient to determine the whole of the process. The development may have been regular or may have proceeded in stages.

For an investigation of these questions we must look for the isolation contacts of many levels within a limited area. The isolation contacts cannot be determined for certain in the field; they must be controlled with diatom flora and such an investigation is time-consuming and expensive.

In northern Hälsingland I have made a tentative survey of this subject. A fuller description will be given in the text to the map of the Quaternary deposits of the county of Gävleborg. The graph of shore displacement for the district refers to the northern part of Hälsingland, the area between Hudiksvall and Bergsjö (fig. 2). It is constructed from 30 radiocarbon-dated samples from 13 levels between 9 and 115 m above sea-level. The oldest sample is from only 5000 BC. In reality this graph registers only 2/3 of the whole of the land elevation curve in this area. The oldest third of the graph is constructed without C14 but with the aid of the Highest shore line (HK) and the ice recession.

The »C14-graph» shows a marked depression between 3000 and 4000 BC. This is determined by four samples, three of which have salt water flora and one with

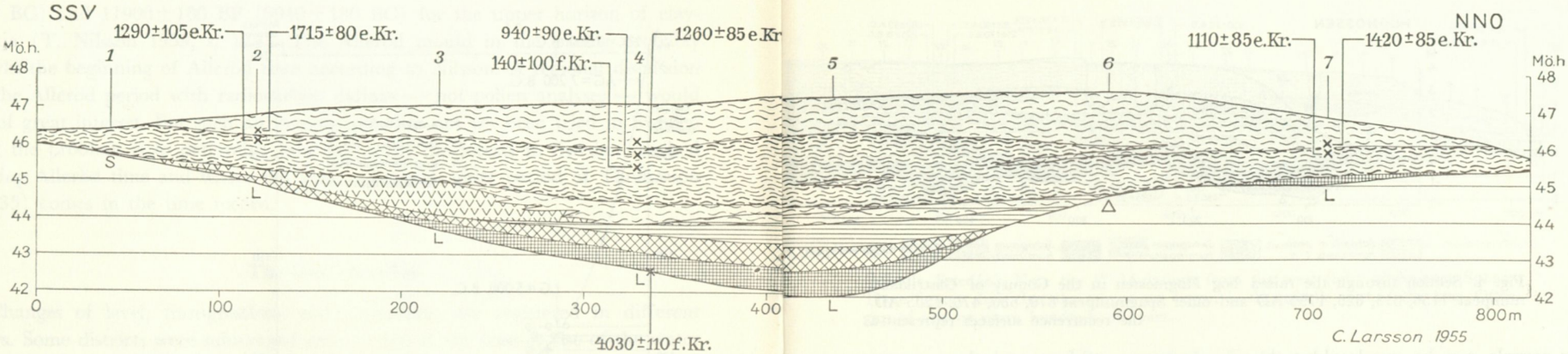


Fig. 3. Section through the bog Lidamossen in the vicinity of Eskilstuna (West of Stockholm). The section shows a bog profile normal for this district. From the radiocarbon datings of the recurrence surface it is clear that the central part of the bog is oldest. The growth of the younger Sphagnum peat has developed from the centre towards the margin. Note that the contact between older and younger Sphagnum peat represents a hiatus. Explanation on p. 10.

a brackish water flora. The last sample is denoted by U. Miller — who has determined the diatoms — as "approximately marking the isolation". The marine element is such that it is nearly impossible to displace the curve more to the right in the diagram, that is towards a fresher water stage, than is done here.

Recurrence surfaces

This conception was introduced by Granlund in 1932, but the phenomenon was well known long ago. It was first observed by Weber (1902) who described a phenomenon in the stratigraphy of the raised bogs. This consisted of an underlying highly humified layer of Sphagnum peat and a younger, only slightly humified layer. Commonly it is implied in the above conception that the peat is a Sphagnum peat. Weber described the phenomenon mentioned as »Die Zweigliederung der Hochmoore» or »Die Grenzhorizont», which Sernander (1909) and L. von Post (1913) translated into Swedish as »gränshorisonten». Both of them were of the opinion that it is a unitary phenomenon and synchronous all over its area of distribution. But it was later realized that the »Grenzhorisont» is quite a heterogeneous phenomenon (G. Lundqvist 1930, Granlund 1931, 1932). And after systematic work it was considered established that we have in Sweden not less than seven different "recurrence surfaces", a new term introduced by Granlund.

These surfaces are: RY I ca 1200 AD, RY II ca 400 AD, RY III ca 600 BC, RY IV ca 1200 BC, RY V ca 2300 BC, RY VI ca 2900 BC and RY VII ca 3700 BC.

They do not all occur in the same bog; it can happen for instance that RY II and III occur in one bog and RY II and IV in another in one region.

Through archaeological and pollen analytical investigations at the lake Käringsjön in the county of Halland Sandegren (1945) showed that RY II becomes younger near the West Coast of Sweden. When we first had the radiocarbon method at our disposal J. Lundqvist (1957) took up an examination of the age of the recurrence surfaces and was of the opinion that there is an age displacement towards the SW. In his investigation almost only the older layers at the recurrence surfaces, the "older" Sphagnum peat, were dated.

The next step was taken on the map sheet Eskilstuna (G. Lundqvist 1959 a) when both types of Sphagnum peat, old and young, were dated. The last mentioned is the thin (5—10 cm) stratum with a huminosity of 5—6 (H 5—6), which is often a transition between the more normal "older" and "younger" types. Thus the vertical distance between the two samples is 5—10 cm, occasionally more. But — most important — the age difference between them can be as large as 400 years (fig. 3). This means that the old bog surface has had nearly its original form during the whole of the time mentioned.

Other investigators (cf Overbeck a.o 1957, p. 65) have reached the same conclusion but it is not clear to me if they have ever followed a long section in a bog. And therefore I wished to know if the recurrence surfaces are synchronous within the whole of a bog, i.e. if all the "old" samples were contemporaneous and likewise the "young ones". This was not the case in the bog Lidamossen on the map sheet Eskilstuna. Instead it was found that the examined samples were younger towards the borders of the bog, which appears quite reasonable.

Within the County of Gävleborg essentially the same results were obtained when the investigation was continued. But it is very remarkable that the recurrence surfaces obtained by the sampling method here used are very seldom of the same age as those previously obtained (Granlund a.o. fig. 5). Sometimes the

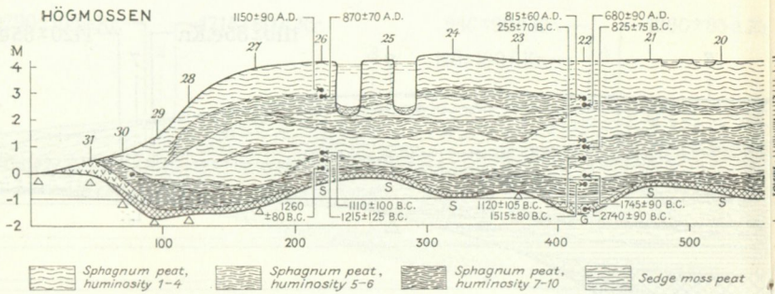


Fig. 4. Section through the raised bog Högmossen in the County of Gästrikland (Middle Sweden). Note the C 14-datings from the west (left) of younger Sphagnumpeat 1150, 815, 825, 1795 AD and older Spagnumpeat 870, 680, 475, 1205 AD. These figures show that the recurrence began in the middle part of the bog. Often the recurrence surfaces represent a gap of one or more hundreds of years.

older sample can be much older than a recurrence surface and the younger sample similarly younger (cf in fig. 5 e.g. RY III in the Högmossen and RY I in the Gränsmyran).

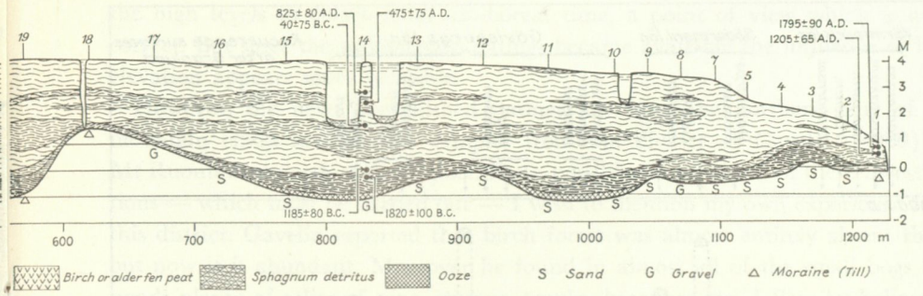
Moreover, in the Högmossen (fig. 4) the different horizons of huminosity, which are here correlated and interpreted as recurrence surfaces, are quite difficult to study. The uppermost appears to be free of objections. The results are as follows:

	BP 26	BP 22	BP 14
Younger Sphagnum peat	1150 AD	815 AD	825 AD
Older » »	870 »	680 »	475 »
Difference	280 years	135 years	350 years

From these results it appears that the older Sphagnum peat, which is the substratum of the recurrence surface, becomes successively younger westwards.

On the other hand the growth upon the dry surface, i.e. the oldest part of the younger Sphagnum peat, is oldest in the central part and successively younger towards the borders. Or in other words the difference in age increases towards the sides. These figures illustrate the progress of the transgression of the bog. In order to avoid misunderstanding attention may be called to the fact that the rate of transgression is certainly quite different in different bogs. It is also evident that more material is necessary for a closer analysis of the course of transgression.

The diagram fig. 5 is quite surprising, the most striking features being 1. that most of the datings fall between the accepted recurrence surfaces, 2. that most of the surfaces are so young — younger than RY II. The samples are naturally too few and from too restricted an area to permit any further conclusions. But the results seem to agree quite well with an opinion which I have earlier expressed, namely, the growth of a recurrence surface occurs when the bog has arrived at a suitable stage of development. Thus it is local conditions which are most significant. Earlier particular emphasis was laid on the climate, but this is certainly only of secondary importance.



Stumps of pine in the mountains

Long ago botanists and geologists began to take interest in occurrences of pine remnants, especially stumps, in the uppermost part of the birch zone (the subalpine zone) and in the zone above the timber line (the alpine zone) in the Caledonian mountain chain. Of special importance are two papers by Axel Gavelin 1909 and 1910. In the first he collected all the material known up to that time. Later Thore C. E. Fries (1913) gave a summary of the finds in Torne Lappmark, and Smith (1920) did the same in Jämtland and Härjedalen. A map of all the occurrences was published in 1944 (G. Lundqvist) and this showed how great was our knowledge of pine remnants in the mountain chain.

However, it was the age of these relics which interested us. Since without the possibility of radioactive dating, they were considered to belong to the warm part of postglacial time. I collected samples for radiocarbon dating from such pines both in the mountains (fig. 6) and in the museums (fig. 7). These samples were from the northern part of Dalarna, from Härjedalen and Jämtland, i.e. from the southern part of the mountain chain. All of them were new finds and not included on my map of 1944. The radiocarbon datings showed that the age varied between about 2000 and about 6000 BC, with a maximum of datings in the older part of the record. Moreover there was a tendency that the relics became younger towards the north. Here they have actually been found at a lower level than in the south.

These datings demonstrated that the earlier opinion (cf Gavelin 1910, p. 33) that the pine stumps in the situations mentioned were from sub-boreal time was quite incorrect. In fact only a small number belong to that time. Gavelin based his opinion upon the works of Sernander but G. Andersson, as was his habit, had quite another opinion, emphasizing the Litorina maximum and thus coming closer to the truth. These very brief remarks regarding earlier opinions of the age problem naturally do not carry any criticism of abovementioned outstanding scientists. They had no dating method, not even the pollen analysis.

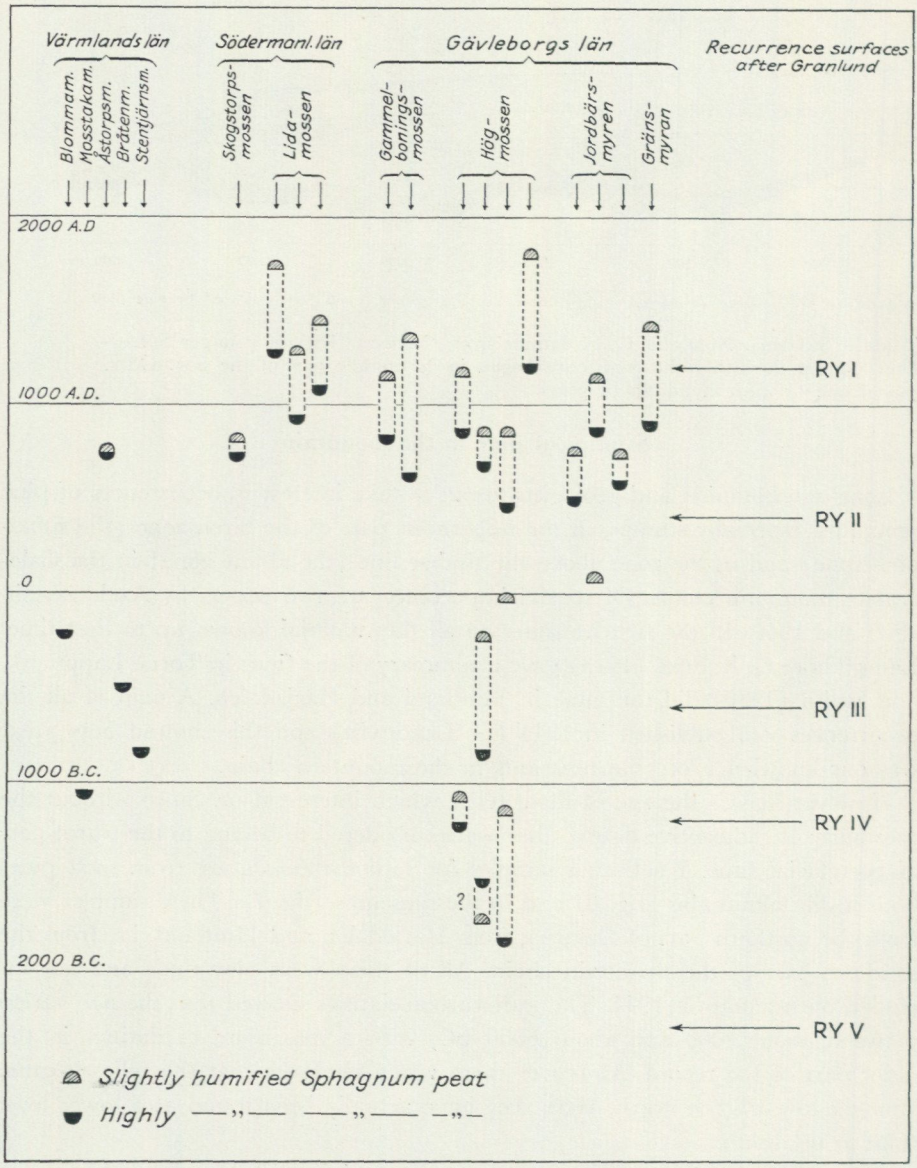


Fig. 5. Diagram showing the datings of recurrence surfaces (grey = younger, black = older Sphagnum peat). The vertical distance between resp. samples in the field is 5—10 cm. The corresponding distance in the diagram shows the age differences. The RY I etc. mark the age according to Granlund. There is a remarkable difference from the radiocarbon results.

The problems regarding stumps and timber lines, have been assiduously discussed about fifty years ago, and in this connection the possible influence of the land elevation upon the lowering of the forest limits was also considered. Gavelin pointed out that the time available was far too short — he considered

the high levels to derive from sub-boreal time, a point of view which is quite correct. But since the radiocarbon datings became available the influence of land elevation appears more probable.

However, the new, unpublished datings are from the northern part of the mountain chain and include samples from the district of Gavelin (1909) on Mt Ruoutevare north of Kvikkjokk. For a possible continuation of these investigations — which must be carried out — I wish to mention my own experience from this district. Gavelin reported that birch forest was almost entirely absent there, but now it is abundant. Moreover he found in almost all of the small bogs and ponds plenty of relics of pine, stumps, trunks, branches etc. I flew by helicopter at low altitude with the map of Gavelin before me. Every detail on the ground was visible but no pine relics were seen. When going on foot I found at last two stumps, but strangely enough these cropped up high above the bog surface. In spite of this the datings gave 6430 ± 100 BP and 6810 ± 110 BP.

Gavelin was a very keen-eyed observer and there is no reason for doubting his information. Therefore it is most probable that the area has become overgrown since his visit. Thus the bogs are very densely overgrown with sedge. Moreover, from Stáloluokta and Melätno (about 60 km NW of Ruoutevare) Selander (1950) mentioned pine relics, but there I had the same bad experience despite favourable localities, though without the use of a helicopter.

From Strimasund I have two stumps from a forest level shown to me by Mr S. af Ekenstam, Hemavan. They were found in the same bog cut on both sides of the road to Norway. The dating results were 4485 ± 80 BP and 2690 ± 80 BP, which is a suggestive age difference.

Through the kindness of the Swedish State Power Board (Vattenfallsstyrelsen) I have got a rich material from the source area of the River Vindelälven. Two stumps are dated and both are from about 6000 BP. One from the vicinity of Lake Tärnasjön (collected by K. Nilsson) is from 3600 BP.

The district south of the Abisko Tourist station is well known from the investigations of Th. C. E. Fries (1913). There are many pine finds there and G. Sandberg at the Abisko Natural Science Station has collected good samples from them, four of which are dated:

St 521	575 m	a.s.	— 6130 ± 115	BP	= 4170 ± 115 BC
St 522	575 »	» »	— 5175 ± 100	»	= 3215 ± 100 »
St 523	530 »	» »	— 3900 ± 80	»	= 1940 ± 80 »
St 520	525 »	» »	— 5620 ± 100	»	= 3660 ± 100 »

Thus the age varies betwen 4000 and 6000 BP and there is a faint tendency for increase in age with greater height above sea-level.

The northernmost stump in my material is collected by G. Ekström at Lake Kelottijärvi NW of Karesuando. Its age is about 5000 BP. It may be mentioned that Fries had quite a rich material from the district more to the north but it has

Fig. 6. A bog above the timber line at mount Anjeskutan, Jämtland. The large root crown in the foreground is dated at 5630±130 BP. After G. Lundqvist 1959.

not been possible to find any samples in his collections. It is also possible to use old samples from museums and in this connection I have a dating of a pine collected by F. Svenonius 1894 from the vicinity of Lake Peskehaure in Lappland. The result is nearly 7000 BP (cf fig. 7).

A review of the new stump material (fig. 9) here only schematically discussed, has given results which correlate well with my earlier results (G. Lundqvist 1959). But considering the old and the new material as separate groups a tendency is found for the new material, from the northern part, to be somewhat younger. This indicates that the old forests showed a displacement in age from somewhat older in the south to younger in the north. And this fact eliminates the possibility that the land elevation had any influence upon the altitude of the timber line in our mountains.

Fig. 7. Pine wood from the collection of the Geological Survey of Sweden. According to the label it is collected by F. Svenonius 18/8 1894. With radiocarbon dated at 6760±160 BP (=4800±160 BC).

In connection with this problem the importance of mass elevation (massupphöjningen) was earlier discussed. This meant that the timber lines rose towards the highest mountains. To some extent this is indubitably so, but when considering the phenomenon in general from south to north the picture is quite different (fig. 10): The height of the country increases towards the north but the timber line decreases. The fact is that the climate should depress it and therefore the mass elevation can have no important influence in regionally respect. If this line of thought is correct the effect must have been the same in what can be called the older end of the curve of distribution, that is from 7—8000 BP. During the first phase of pine immigration it ought to show increasing height towards the present time. As in 1959 I am now astonished at the asymmetry of the curve, a fact that has been accentuated with the addition of the new material. Therefore it is possible that land elevation had some influence upon heights in the south but not in the north. For this reason I return once more to the map of Granlund (1936) "Attempt at a construction of the land elevation isobases for the time from the beginning of the Litorina Sea". Such maps of isobases from other times have shown that the elevation maximum may certainly be displaced,

Fig. 8. On this map the distribution of the material in fig. 9 is shown. The large dots mark the oldest stump in each surveyed area and the time for its growth according to the radiocarbon dating. There is a tendency of the stumps to be somewhat younger in the northern part of the mountain chain, cf fig. 9 the two uppermost rows. After G. Lundqvist 1961.

but on the whole it was always located in approximately the same area. In the present case the southern part of the mountain chain according to the mentioned map has been more influenced than the northern part.

Certainly my C14-material according to present opinion is unusually rich and good but it is insufficient for the problems which have now appeared. Thus I have never more than a few stumps from each district. In fact the stumps from the small bog at Strimasund illustrate clearly that a richer material for observation is necessary. The stump on the one side of the road is from 4485 ± 80 BP

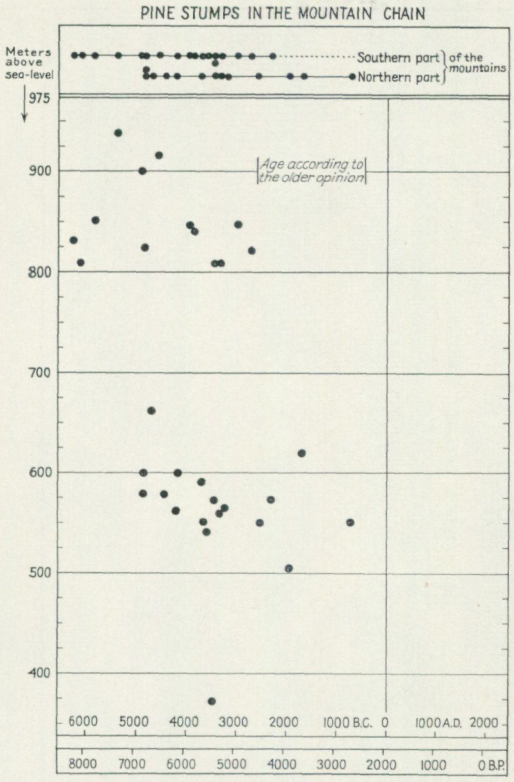


Fig. 9. Radio carbon dated pine stumps in the mountain chain arranged according to height above sealevel and age. The upper two rows show the same material according to the ages only. In the south they are in general older than in the north. »Age according to the older opinion» is quite approximative, a more exact dating was never given than for instance younger stone age or bronze age. The main part of the stumps are much older, to about 3000 years.

and on the other side from 2690 ± 80: thus there is an age difference of about 1800 years. Actually it only implies that pine forest has existed there during the whole of the time mentioned.

Old iron and copper industry

Some attention has also been paid to the early beginnings of the metal industry in Sweden. Interest up to now has been concentrated partly on the production of osmund iron (from lake or bog ore), partly on the first copper mining in the Falun mine. We had ideas about both of them but it seemed appropriate to control the age with the radiocarbon method.

The production of iron. We have long been interested in the age of the first iron production, and the literature about this is quite extensive. For various reasons I especially wish to refer to Grape (1922), Bannbers (1922) and Nihlén (1934) who describe the construction of the foundry and the type of iron melt. Of special interest concerning the melts is the occurrence of charcoal. The age was earlier determined by archaeological finds or pollen analysis. According to Nihlén (1932, p. 208) the results are:

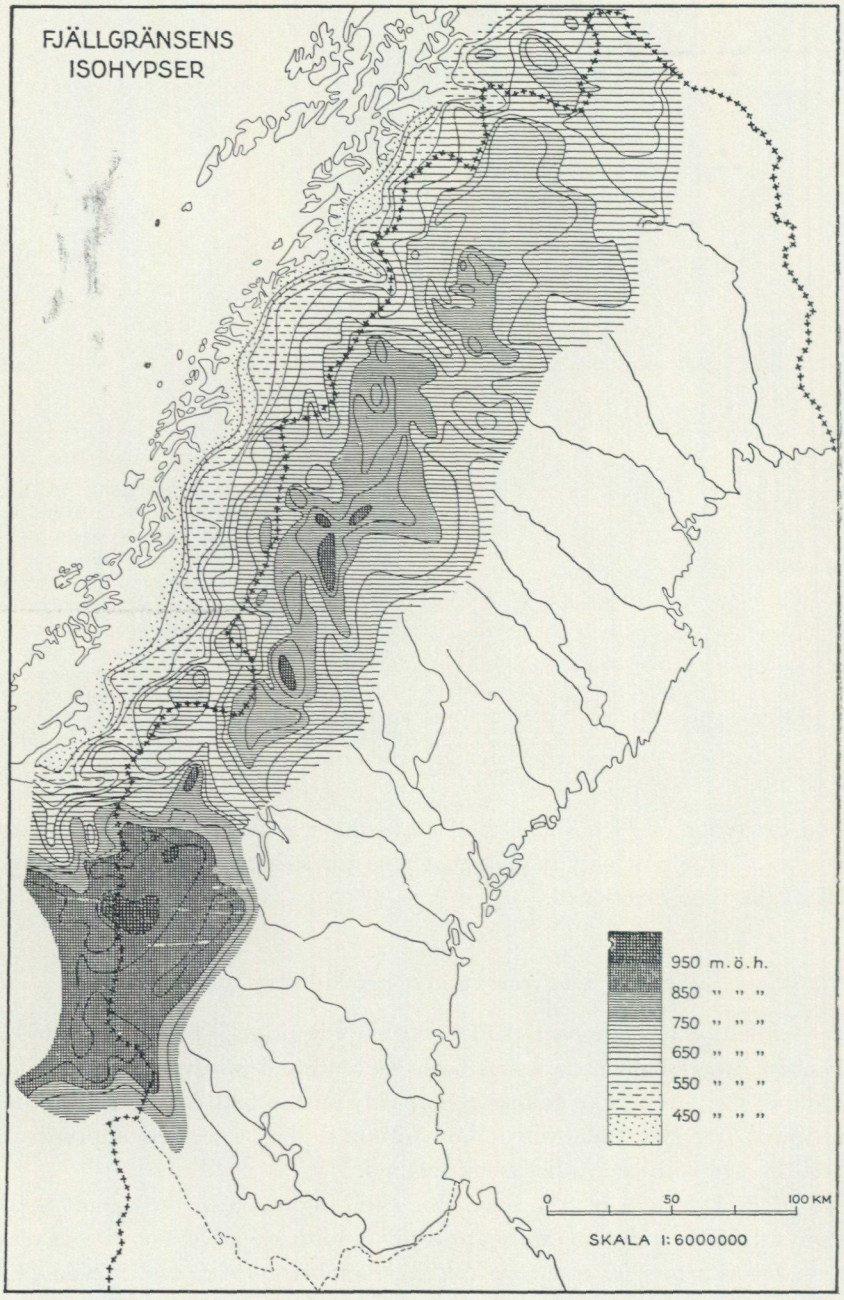


Fig. 10. The isohypses of the timber line in the Caledonian mountain chain and its environs according to the maps of the General Staff. The altitude of the limit increases towards the higher parts of the mountains but it decreases to the north. Cf fig. 8. After G. Lundqvist 1943.

South Sweden 150 BC (locally 200 BC)
Central » 100 BC
North » 3rd century AD

The majority seem to belong to the Migration Period. This opinion refers to Småland, i.e. southern Sweden.

Regarding the county of Gästrikland, Asklund (1934, p. 19) wrote: The occurrence of primitive iron- bearing slag i.e. osmund melt, in the grave-mounds of Gästrikland also connects the wide spread bog-ore working in this region to at least the end of the iron ages.

The method of producing iron from bog-ore and lake-ore was continued up to the middle of the fifteenth century (Asklund). Farther up-country, in the parish of Lima in western Dalarna, this method of iron manufacture was important right up to the eighteenth century. Thus Linné (1734, p. 325) gave us a good description of the method of working at Lima in 1734. The women blew the bellows and also took part in the work at the smithy (scythes which were exported to Norway).

According to Grape (1922, p. 27) the osmund method went out of use in this district in the first half of the nineteenth century. Grape also had an opportunity of speaking with the last person who had worked at the osmund smithy (Fider Anders Pettersson in Nornäs) and who described the method for him.

This is a very brief summary of what we know about the time of early iron manufacture in Sweden. It is clear among other things that it did not begin contemporaneously throughout the country, but was later in the north. Further, it is clear that the primitive iron-working method persisted far into the nineteenth century.

The district which especially interested me was the southern part of the county of Gävleborg, that is, Gästrikland. During geological mapping on the scale of 1 :50 000 in the thirties, many small osmund foundries were found and recorded on the map. Whilst mapping the County we have re-located some of these occurrences and collected material for radiocarbon dating of the foundries. At all localities only the melt is preserved, though displaced. In the most of these melt charcoal is completely destroyed by the fire occurs. We have collected this charcoal and used it for the datings. All the occurrences except for the locality "Gävle" are situated on the geological map sheet Storvik. The results are as follows (the names are working names for the localities).

Nr	Name	age BP		historic age
St 707	Gävle	760 ± 60 BP	=	1200 ± 60 AD
St 640	Dammsjön	1415 ± 130 »	=	545 ± 130 »
St 644	Vall	1640 ± 85 »	=	320 ± 85 »
St 642	Tjärnäshyttan	1860 ± 90 »	=	100 ± 90 »
St 643	Åsmundshyttan	1980 ± 100 »	=	20 ± 100 BC

Thus the foundries began at quite different times ranging from about the birth of Christ to the thirteenth century and according to the literature even into the nineteenth century.

An average calculation — which is statistically unsound because of the incompleteness of the material — indicates that primitive iron production with this method was mostly in use at about the transition from the Roman Iron Age to the Migration Period.

As already mentioned the dating material is quite inadequate for a generalization to be made and is valid for this district only. Thus the result is mostly of importance for the method, but it shows that a regional investigation would be of great interest. Districts which ought to be initially surveyed are Småland and Dalarna. There is no other choice but to date sample after sample until the oldest value is established.

The coppermine of Falun (Falu gruva). For many years there has been a great interest in establishing the time when mining at Falun began. Of very great importance in this respect was an agreement of the 16th of June 1288, by which bishop Peder in Västerås received an eighth part in the "Kopparberget" (translated = approximately the Copper rock). The fortunate fact that melt and waste were tipped out on to a bog situated near the initial area of mining made it possible to use pollen analysis for the dating. I counted on or at least hoped, that peat growth continued right up to the instant when the first waste covered its surface, thus halting growth. In practice the problem was only to date the uppermost layer at some points in the old bog. This first demanded a detailed dating of the pollen diagrams in the vicinity of Falun. From these I finally decided (in 1941) that mining must have begun some time in the eleventh century. This result was obtained from a diagram from Anfarten, the locality closest to the probable initial area. East from this locality the uppermost layer was successively younger.

Few persons believed that mining took place so early and the manuscript lay unpublished until the radiocarbon method could be used when three samples were dated. The uppermost one, from undisturbed peat, gave 850 ± 60 AD and the lowermost from the waste, gave 1080 ± 60 AD. Thus the latter figure was the minimum age of the first mining and confirmed the result of the pollen analysis.

Later, another eleven radiocarbon datings were made at the expense of Stora Kopparbergs Bergslag Inc. However, the sample mentioned above giving an age of 1080 ± 60 AD, is the oldest from more or less disturbed material. At first glance this fact appears peculiar and even suspect. But when knowing the locality it is not so strange, because the Anfarten is situated immediately at the main shaft (Stora Stöten). Thus it is impossible to investigate the westernmost part of the peat and the waste. It fell into the depths probably during the great collapse in 1687. The chances of defining more closely the beginning of mining here therefore appear very slight.

Concluding remarks

In the preceding a short summary is given of some of the more important geological questions investigated at the Laboratory of radiocarbon dating in Stockholm. Of course a large number of datings in connection with other complex and miscellaneous problems have been undertaken too. These are however smaller ones — let me say isolated questions. Naturally it is the more continuous investigations that are of greatest interest. When controlling many data which were long ago considered definitely established it is often found that all data must be redetermined. It is necessary to establish a definite time record for all details in the geological development of the country. It then becomes obvious that only a small number of scattered analyses are of very limited value as they must always be a random selection only. Unfortunately it is necessary to work with whole complex of samples, which makes these investigations time-consuming as well as expensive.

Some questions which appear most urgent at the present are the following:

1. Definite datings of the pollenanalytical levels; this concerns especially the Norrland diagrams in which I wish to call attention to the shape of the *Picea* curve. The displacement in time of certain zone parts towards the mountain chain which I thought I had detected in the diagrams from the county of Kopparberg (G. Lundqvist 1951) must be treated in detail.

2. The oscillations of the tree limits in the mountains, that is, the migrations of the forests, are still only little known. For the present we have only a faint idea about the first appearance of the *Pinus* and its highest limits.

3. The changes of levels. The land elevation curves obviously require much detailed work. Yet these problems on the whole are dependent on the pollen diagrams.

4. The recurrence surfaces have been very much used for datings but they must be controlled much more. My results seem to be discouraging but possibly special circumstances predominate in Norrland. But here I must call attention to the fact that I have got the same results in the vicinity of Eskilstuna (Södermanland). And it is possible to discern the same tendency in Overbeck's et.al. (1957) investigation district.

These questions are related to the study of the climatic development, especially the alternations between dry and humid climate periods.

5. A regional dating and discussion of the osmund workings will certainly give interesting results. But for this purpose much more material must be collected.

When dating these iron melts it is to note that the result, the age, in fact refer to the charcoal. It is a matter of course that it is older than the foundries, but I think the difference is quite insignificant because only young trees were used.

Here only a small number of questions are proposed for revision and this is of course only a small part of the problems of interest. However, even these require a prolonged time for study. And during this time the problems can widen and change according to new experiences. Quite new questions will certainly appear spontaneously in the course of time.

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