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**FIVE RADIOCARBON DATINGS
OF POST GLACIAL SHORELINES
IN CENTRAL SPITSBERGEN**

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Five radiocarbon datings of Post Glacial shorelines in Central Spitsbergen

BY

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IN 1955 the senior author of the present paper established a Late Pleistocene stratigraphical sequence for Billefjorden in central Spitsbergen (Feyling-Hanssen 1955 a). It was done on the basis of shoreline studies and investigation of fossil shells of marine molluscs and cirripeds in the deposits. This standard stratigraphy was later (Feyling-Hanssen 1955 b) successfully applied to the raised features of the area around Kapp Wijk in Dicksonfjorden, to the west of Billefjorden.

Billefjorden is a 32 km long fjord which branches off from Isfjorden towards the NNE. It lies between $78^{\circ} 27'$ and $78^{\circ} 43'$ N. lat., and $16^{\circ} 20'$ and $16^{\circ} 53'$ E. long. in the island of Vestspitsbergen. The most characteristic features of shore topography along the east coast of the fjord are large cusped forelands (see Johnson 1919, p. 325). They are more or less triangular in shape and are prograded in a NNE direction by addition of successive beach ridges. This is caused by the dominant longshore beach drifting to the north produced by the great fetch of southwesterly winds.

When these processes act during periods of constant position of the shoreline, the result will be horizontal beach plains with their surfaces occupied by parallel or subparallel, generally curved, beach ridges of approximately equal crest altitudes, each ridge marking a temporary position of the shoreline during the progradation of the shore.

In Billefjorden, however, the same processes have been operative during a period of emergence, i. e. during a period of negative shift of the shoreline. The resulting beach plains are, therefore, not horizontal, but slope in the direction in which the forelands prograde, the older ridges being more elevated than the younger ones. The gradient of the slope depends on the rate of emergence and the rate of progradation. Every new beach ridge had to form at a lower level than its predecessor and every new

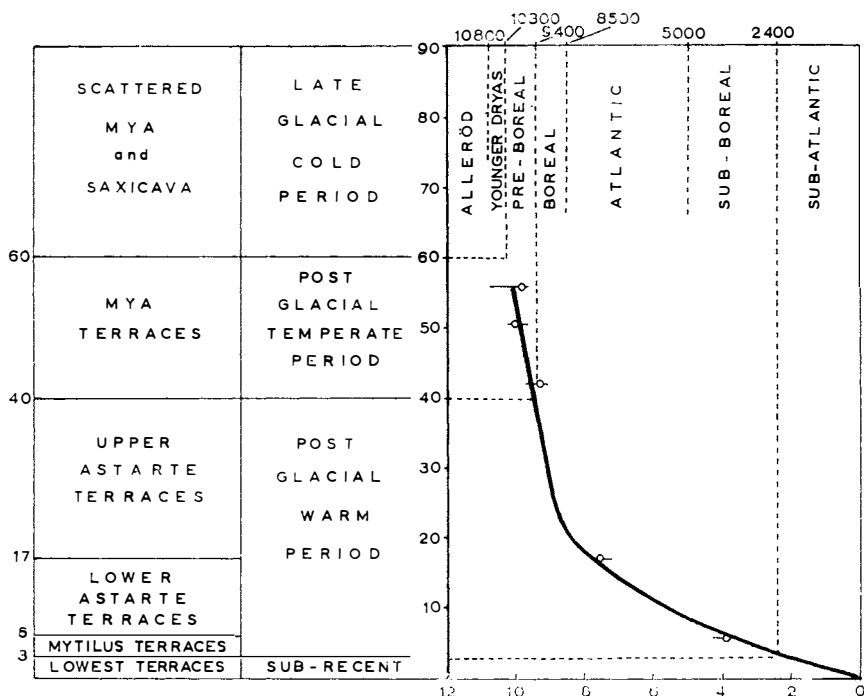


Fig. 1. The stratigraphy of the Billefjorden Late Pleistocene, left (p. 124—125, 129); age and height of the samples (rings), right (p. 127).

lamina in the growing sequence was deposited under a lower sea level than the previous lamina. The beach ridges still mark the temporary positions of the shoreline, but now they record its vertical, as well as its horizontal, movements (Feyling-Hanssen 1955 a, p. 16).

Along the eastern shores of Billefjorden raised sloping beach plains have been cliffed by wave erosion. The cliffs, which cut the plains at approximately right angles to the direction of the beach ridges, reveal continuous incline bedding with alternating coarser- and finer-grained strata, thicker strata with sandy gravel alternating with thinner strata containing silty gravel. The strata have a true northerly dip of 20—25°, i. e. they dip in the same direction as the terrace surface above, and continue through the cliff up to the ridged surface.

Therefore, in collecting fossils from these cliffs, one is, provided the fossils have remained in situ, able to associate every collected specimen with its corresponding sea level, i. e. with the position of the shoreline syn-

chronous with the time at which the specimen was imbedded in the sediment. Even if the specimens were picked at different heights above present-day sea level, as long as they were taken from one and the same stratum, they are of equal age. A stratum represents the temporary position of the sloping beach face or bottom of nearshore zone, and this stratum can, without difficulty, be traced through the cliff up to the surface of the beach plain. Thus, the samples of fossil shells collected during this investigation seem to be exceptionally accurately tied to specific ancient sea levels.

There exist, no doubt, factors tending to diminish the accuracy of the indications provided by the fossils (Feyling-Hanssen and Jørstad 1950, p. 10). The most serious one is redeposition of fossils by streams, waves, currents, or even by solifluction and glacial advance. Such factors were considered in every specific case. Solifluction and glacial advance precluded, fossils were considered to have remained in situ if the size and weight of the biogenic particles (size of fossil specimens or fragments thereof) were of an order of magnitude different from that of the particles of the minerogenic matrix. If, on the other hand, biogenic and minerogenic particles were of approximately equal size, this might, in many cases, prove to indicate that one and the same agency brought them together (Feyling-Hanssen and Jørstad 1950, p. 22, Table I).

The topographical measurements in the field were made using a tachymeter. The heights were referred to local high-water mark and later corrected to an approximate half-tide level so that all heights given refer to mean tide level.

Shorelines, most probably of marine origin, were found up to 90 m, and in Sassenfjorden even up to 96 m, above present sea level. Marine shells were found up to 84.5 m a. s. l.

The period in which the shoreline moved from 90 m to 60 m above present-day sea level was called the *Late Glacial Cold period*. Only two species of marine molluscs were found in the deposits between 84.5 and 60 m, viz. *Saxicava arctica* and *Mya truncata*. Fossils are extremely rare at these levels; in general only scattered shells and fragments occurred.

The period in which the shoreline moved from 60 m to 40 m above present sea level, was called the *Post Glacial Temperate period*. In addition to the two above-mentioned species, 14 new (11 mollusc species, 1 cirriped, 1 echinid and 1 calcareous algae) occurred in the deposits of this period, viz. *Chlamys islandica*, *Mytilus edulis*, *Serripes groenlandicus*, *Macoma calcarea*, *Lepeta coeca*, *Lacuna vincta*, *Littorina saxatilis*, *Lunatia pallida*, *Trophon truncatus*, *Buccinum undatum*, *Buccinum groenlandicum*, *Balanus*

balanus, *Strongylocentrotus* cf. *droebachiensis* and *Lithothamnion* sp. The fossil fauna suggests that the *Post Glacial Temperate period* had a climate slightly more favourable than that prevailing in the area to-day. The fauna of the terraces between 60 m and 40 m a. s. l. is usually dominated by *Mya truncata*, hence they were called *Mya terraces*.

The period in which the shoreline moved from 40 m to 3 m above present sea level, was called the *Post Glacial Warm period*. 39 new species of molluscs and cirripeds, according to the occurrences in the deposits, immigrated to the inner Isfjorden area during this period, among them 7 which now seem to be extinct in Spitsbergen waters, viz. *Heteranomia squamula*, *Volsella modiola*, *Cyprina islandica*, *Zirfaea crispata*, *Emarginula fissura*, *Littorina littorea* and *Omalogyra atomus*. The climatological conditions in the area during this period were assumed to have been decidedly better than those prevailing there to-day, they were most probably similar to those prevailing at present along the coasts of Finnmark and Iceland.

The fossil fauna of the littoral deposits between 40 m and 6 m a. s. l. was found to be characterized by dominant occurrence of *Astarte borealis*. Terraces within this height interval, therefore, were termed *Astarte terraces*. They were further divided into *Upper Astarte terraces*, from 40 m to 17 m a. s. l., and *Lower Astarte terraces*, from 17 m to 6 m a. s. l. Between 6 m and 3 m a. s. l. there occur littoral features which were termed *Mytilus terraces*, because *Mytilus edulis* dominates the fauna in most of them.

The period in which the shoreline moved from 3 m a. s. l. to its present position, was called the *Sub-Recent period*. At these levels the *Warm period* indicators have disappeared from the fossil fauna; even *Mytilus edulis* seems to have abandoned Spitsbergen waters at this time. In very recent time this species seems to have reoccupied the area. A severe deterioration of the climate took place during the Sub-Recent period.

The stratigraphy of inner Isfjorden, in this way established, is illustrated in Feyling-Hanssen 1955 a, Fig. 14.

Five radiocarbon dates.

Dr. A. Rapp, of the University of Uppsala, urged that some of the shell samples from the Late Pleistocene of central Spitsbergen be dated by radiological methods. Five samples were placed at his disposal, and he submitted them for dating to the Radiocarbon dating laboratory of the University of Uppsala, where the datings were carried out by Ingrid Olsson.

Three of the samples were from *Mya terraces* of the *Post Glacial Tem-*

perate period, viz. No. 358, Teltfjellbekken, 56 *m a. s. l.* (Feyling-Hanssen 1955 a, p. 86), No. 349, north of Phantomvika, 50.7 *m a. s. l.* (l. c., p. 75), and No. 326, Myadalen, 42 *m a. s. l.* (l. c., p. 122). Two were from the *Post Glacial Warm period*, viz. No. 350, *Astarte terrace*, Ekholm vika, 17 *m a. s. l.* (l. c., p. 79), and No. 343, *Mytilus terrace*, Mytilusbekken, 5.8 *m a. s. l.* (l. c., p. 66).

As a check, a recent sample was also submitted; it was collected 1952 by the senior author at the recent shore of Tangen, Mushama in Woodfjorden on the north coast of Vestspitsbergen.

This latter sample (U-133) was dated at 400 ± 60 years before present, which is considered to be a normal "age" of the ocean water. Therefore, in order to attain as good an approximation as possible to the real ages, this figure, 400 years, should be subtracted from the other dates.

Every sample was run twice, once the outer layers of what was remaining of the shells after they had been washed with acid, and once the inner parts. The "outer" layers were run as a check in order to detect possible contaminations. These dates are indicated with an "a". The result from the inner parts should be considered as the best approximation to the real ages. These dates have been indicated with a "b". The smaller errors for the "b" samples are, in most cases, due to the fact that these were usually measured during a longer time than the "a" samples. In some cases the amount of material was so small that the gas had to be diluted with CO₂ from an old source to attain the normal working pressure of 3 atm.

The samples from the *Post Glacial Temperate period*:

No. 358 b (U-132):	9840 ± 150	years	B. P.	(inner 50 %)
No. 358 a (U-131):	10460 ± 330	»	»	(outer 15 % removed by washing)
No. 349 b (U-128):	9980 ± 140	»	»	(inner 33 %)
No. 349 a (U-127):	9850 ± 140	»	»	(outer 14 % removed by washing)
No. 326 b (U-124):	9310 ± 200	»	»	(inner 20 %)
No. 326 a (U-123):	9580 ± 170	»	»	(outer 30 % removed by washing)

The samples from the *Post Glacial Warm period*:

No. 350 b (U-130):	7595 ± 110	years	B. P.	(inner 55 %)
No. 350 a (U-129):	7410 ± 160	»	»	(outer 10 % removed by washing)

No. 343 b (U-126):	3810 ± 90	»	»	(inner 55 %)
No. 343 a (U-125):	3985 ± 150	»	»	(outer 15 % removed by washing)

The datings have been carried out with greatest care, and they should be considered as accurate as it is possible to obtain radiocarbon dates from shell material. The results include a correction for isotopic fractionation.

The shoreline displacement.

The recorded dates are certainly too few to give detailed information about the land recovery in central Spitsbergen. We, therefore, intend to do more datings on material from other levels. However, inserted in a height-time diagram the five dates at hand provide a beautiful illustration of the main trend in the negative shift of shoreline during Post Glacial time.

In the diagram (Figure 1) the time is plotted along the abscissa in thousands of years from right to left, zero indicating present time. Heights are plotted along the ordinate in metres above present-day sea level. The b-values of the dates are indicated with rings, the short horizontal lines indicate the range of deviation of a- and b-values together. The age of the recent sample has not been subtracted from the dates.

A definite curve of the shoreline displacement, correct in detail, cannot be constructed on the basis of only five values. However, these five dates provide an important fact about the curve, viz. that it consists of a steeply and a gently dipping part. The preliminary curve which has been drawn in the diagram, illustrates this characteristic form.

The diagram thus informs us about two different parts in the main trend of the negative shift of the shoreline during Post Glacial time in central Spitsbergen: An early part with a very rapid shoreline displacement, and a late part with a slow displacement. In the early part the rate of shoreline displacement was of the order of magnitude 200 cm/century, whereas in the late part the rate was less than a tenth of this, 18—15 cm/century.

It is in this connection necessary to call attention to the results reached by Birkenmajer (1957, 1958) by his so-called "whale method". Birkenmajer found along the coast of Hornsund, in southern Spitsbergen, whale bones up to a height of c. 8 m above present-day sea level, and supposes, without any reservation, that these whales were killed by whalers between the years 1611 and 1640 (Birkenmajer 1957, p. 156). He thus arrived at the conclusion that the bones have been raised to this height in 350 years (1611—

1957), i. e. a land uplift of 2.3 cm per year, or 230 cm per century during these very recent times.

The present authors are not convinced of the legitimacy of this conclusion. The senior author observed whale bones at numerous localities, in Isfjorden as well as on the west and north coasts of the island. They occur at various heights above sea level. Feyling-Hanssen and Jørstad (1950, p. 58) recorded many bones between 3 and 10 m a. s. l. at Gips-
huken, at the junction of Sassenfjorden and Billefjorden, and at Gipsvika, on the north side of Sassenfjorden, they found whale bones 56 m a. s. l. So, even if the whale bones in Hornsund seem to be most frequent at 6—8 m a. s. l., there may be another reason for this than that assumed by Birkenmajer.

Could ruins of oil-cookeries, perhaps, give some guidance in the question? Such ruins were described from the northwestern corner of Spitsbergen (Feyling-Hanssen 1954), where they are situated on the beaches, showing no signs of having been raised after their erection. Ruins at Russekeila in Isfjorden, most probably originating from the whaling period, do not indicate a recent uplift. If ruins of oil-cookeries exist in Hornsund, they should, if Birkenmajer's conclusion is correct, be expected to have been raised, along with the whale bones, to approximately 8 m a. s. l.

In a later paper, Birkenmajer (1958) presented tentative isobases of the Svalbard archipelago (l. c., fig. 1). In doing so he assumed, probably from the above-mentioned occurrence of whale bones at Gips-
huken, that the rate of recent land uplift in Billefjorden is 280 cm per century. This would mean that the shorelines and terraces 9.7—9.8 m a. s. l. in Billefjorden, e. g. at Anservika and Brucebyen, are only 350 years old.

However, according to the radiocarbon dates here presented, the shoreline 5.8 m a. s. l. is 3400—3800 years old, and *the 9.8 m shoreline is most probably more than 5000 years old.*

Among many other samples from Nordaustlandet, the northernmost great island in the Svalbard group, two consisting of whale bone have been dated radiologically by Ingrid Olsson (1959, 1960). They were collected and submitted by Weston Blake Jr.

Cape Twin, Murchisonfjorden, 8 A, 7.5 m a. s. l.:

Organic fraction,	U-109:	6220 ± 110
»	»	U-110: 6380 ± 150
Inorganic fraction,	U-111:	4570 ± 100

Teodolitkollen, Lady Franklinfjorden, 13, 17.6 m a. s. l.:

Organic fraction, U-114: 8270 ± 170

» » U-115: 8530 ± 180

Inorganic fraction, U-113: 6560 ± 170

The organic fraction is the most reliable and in this case the contaminations should give too young dates (Olsson and Blake, in preparation). The land rise of Nordaustlandet is very similar to that of central Spitsbergen. A diagram of the shoreline displacement in Nordaustlandet would give a curve with a smaller slope during the last thousands of years than that of the corresponding part of the preliminary curve for central Spitsbergen.

In the upper part of the diagram, fig. 1, where the stratigraphic units of Blytt-Sernander have been inserted, the terms Younger Dryas and Alleröd are used instead of Arctic and Sub-arctic. The ages of the zone borders are based upon recent radiocarbon dates (i. a. Nydal, 1959; Olsson, 1959). On the left side of the diagram the stratigraphic sequence of central Spitsbergen (Feyling-Hanssen 1955 a) has been added.

From this combination it appears that *the Sub-Recent Period of central Spitsbergen is synchronous with the Sub-Atlantic of Blytt-Sernander. The Post Glacial Warm period of Spitsbergen is identical with the Post Glacial Warm period in Europe* (Firbas, 1954) or the Postglacial Hypsithermal Interval of Deevey and Flint (1957, p. 182—184), embracing the Sub-Boreal, Atlantic and Boreal of Blytt-Sernander. *The Post Glacial Temperate period of central Spitsbergen is most probably synchronous with the Pre-Boreal time of Blytt-Sernander.* No sample from the Late Glacial Cold period has been dated. However, as this period precedes the Post Glacial Temperate period, which seems to be of Pre-Boreal age, *the Late Glacial Cold period of central Spitsbergen, at least a part of it, is of Younger Dryas age.*

Shorelines occur in Billefjorden up to 90 m a. s. l., in Sassenfjorden even up to 96 m. We do not know the rate of shoreline displacement during these early stages. It seems, however, to be a reasonable assumption, that it was scarcely more rapid than during Pre-Boreal time. Therefore, our Late Glacial Cold period of central Spitsbergen most probably at least partly also coincides with Alleröd time. It could be mentioned, without being considered as evidence of analogous conditions in Spitsbergen, that

Two Creeks (Alleröd) as well as the Valdres maximum (Younger Dryas) are supposed to be periods of rapid crustal uplift in northern U. S. A. and southern Canada (Flint 1953, 1956).

As already mentioned by Feyling-Hanssen (1955 a, p. 36), the occurrence of high shorelines far into Billefjorden suggests an extension of the glaciers during the Late Glacial Cold period not very different from the present. This is certainly a quite surprising suggestion about Younger Dryas time in inner Isfjorden. It could probably be explained by low precipitation and perhaps also by the fact that the higher sea level in itself constituted a limiting factor to the advance of glaciers. It is also not certain that an arctic area, like Spitsbergen or Greenland, necessarily to any considerable degree, had to be more arctic during the ice ages than it is to-day. On the other hand, the rapid land uplift, which indisputably took place in central Spitsbergen during Pre-Boreal and Boreal time, should be assumed to represent the isostatic readjustment in connection with the vanishing of a considerable ice load. Such an extra ice load seems, however, not to have existed in the inner Isfjorden area in Younger Dryas time.

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