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PETER HAGEVOLD

Trykt desember 1977

M/V POLARSIRKEL bryter ettårs-isen ved barrieren før landsetting på Riiser-Larsen-isen av ni mann fra Den norske Antarktisekspedisjonen 1966/77 (se artikkel, s. 327).

M/V POLARSIRKEL breaking annual ice by the barrier prior to disembarkment at the Riiser-Larsen-isen of nine men from the Norwegian Antarctic Research Expedition 1966/77 (see article p. 327).

Photo: K. REPP

Innholdsfortegnelse

Notiser:

Development patterns of gypsum/anhydrite in Lower Permian sediments of central Spitsbergen — a suggested classification

By ØRNULF LAURITZEN

Contents

Abstract

This paper deals with the gypsum/anhydrite-bearing strata of Lower Permian age from the central parts of Spitsbergen, and suggests a classification of the major types of evaporite occurrence as observed in the field. Five major types of gypsum/anhydrite-bearing structures are presented, and three of these major types are again divided into subtypes. Two of these subtypes, the gypsum/anhydrite-bearing stylolites and "megafissures" are described for the first time.

Introduction

Few descriptions of the gypsum/anhydrite-bearing strata of central Spitsbergen have been published. The results presented in this paper are obtained from fieldwork in this area (see key map, Fig. 1) during the field seasons 1975 and 1976. My work has been restricted to the Lower Permian sediments bounded upwards by the Brachiopod Chert of GEE, HARLAND, and MCWHAE 1953 (the Kapp Starostin Formation of CUTBILL and CHALLINOR 1965). All my observations on gypsum/anhydrite-bearing rocks in this area are restricted to the Gipshuken Formation of CUTBILL and CHALLINOR (1965) or the "Upper Gypsiferous Series" of Lower Permian age of GEE, HARLAND, and MCWHAE (1953).

HOLLIDAY (1966) studied nodular gypsum and anhydrite rocks in the Billefjorden region, but most of his observations are from older beds of Middle Carboniferous age, belonging to the "Lower Gypsiferous Series" of GEE,

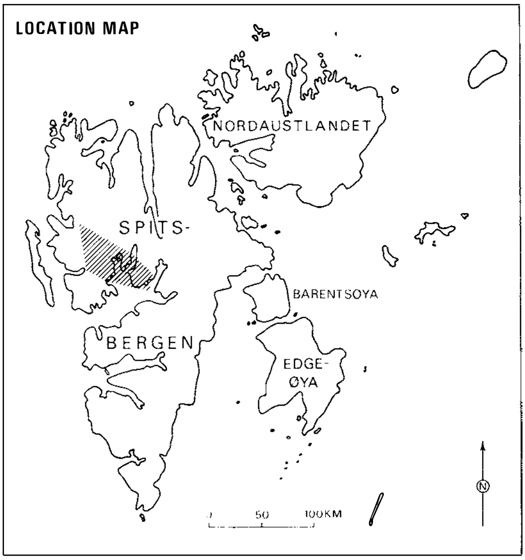


Fig. 1. *Key map showing the investigated area (shaded).*

HARLAND, and McWHAE (1953) or to the Ebbadalen Formation and a part of the Minkinfjellet Member of CUTBILL and CHALLINOR (1965). HOLLIDAY (1966) also examined the Gipshuken Formation at Skansbukta in order to compare what he saw there with his observations from the Middle Carboniferous strata.

The area studied in this paper lies within the north-west to south-east trending basin described by CUTBILL and CHALLINOR (1965), and the sections studied form a traverse from Garwoodtoppen by Kongsfjorden as the westernmost locality, via Palatiumfjellet, Kolosseum and Kapitol, across the northern parts of Dicksonland to Skansbukta (Billefjorden) in the east.

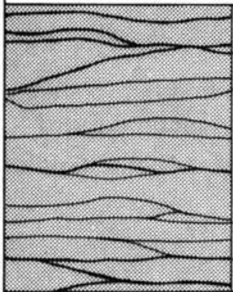
Systematic description

After studying some of the gypsum/anhydrite outcrops within the investigated area, I felt a great need for a classification system of all the different features observed. In order to classify the structures as seen in cross-section in the field, I erected five major types, three of which could again be divided into subtypes. It is clear, however, that transitional forms of development between these major types do occur. The five major types observed are:

I. Continuous beds
II. Nodules
III. Infillings in cracks and fissures
IV. Infillings in fossils
V. Separate crystals

TYPE I. CONTINUOUS BEDS

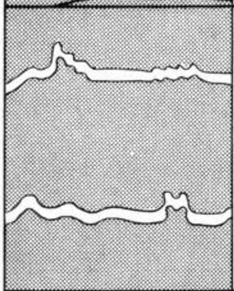
Gypsum/anhydrite developed as continuous beds, parallel or subparallel to the bedding of the host rock.



Ia. Veins

1-5mm thick veins, mostly parallel to the bedding. Often found in a coarsegrained, partly dolomitized rock. Often situated above the beds richer in sulphates.

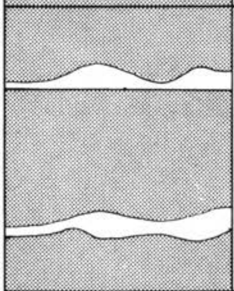
See Fig. 6.



Ib. Stylolites

Stylolitic surfaces now intruded by sulphatic material and pressed apart because of crystal growth. Undulating, often with peaks. Thickness 1mm to 2cm.

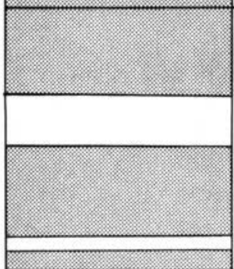
See Fig. 6.



Ic. Undulating beds

Beds where one or both of the bounding surfaces are undulating, often giving a ripple-like appearance in cross-section. Normal thickness 1–10cm.

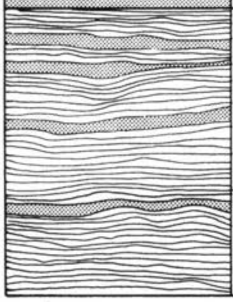
See Fig. 7.



Id. Regular beds

Almost constant thickness laterally in each bed and bedding planes parallel. From several cm to several m thick. Both pure sulphate and intermixtures with carbonate material.

See Fig. 8.



Ie. Laminated beds

Host rock and gypsum/anhydrite in sequences with light and dark sulphates and host rock in equally thick laminae. Thickness of each lamina often less than 1mm.

See Fig. 9.

Fig. 2. *Continuous beds and subtypes.*

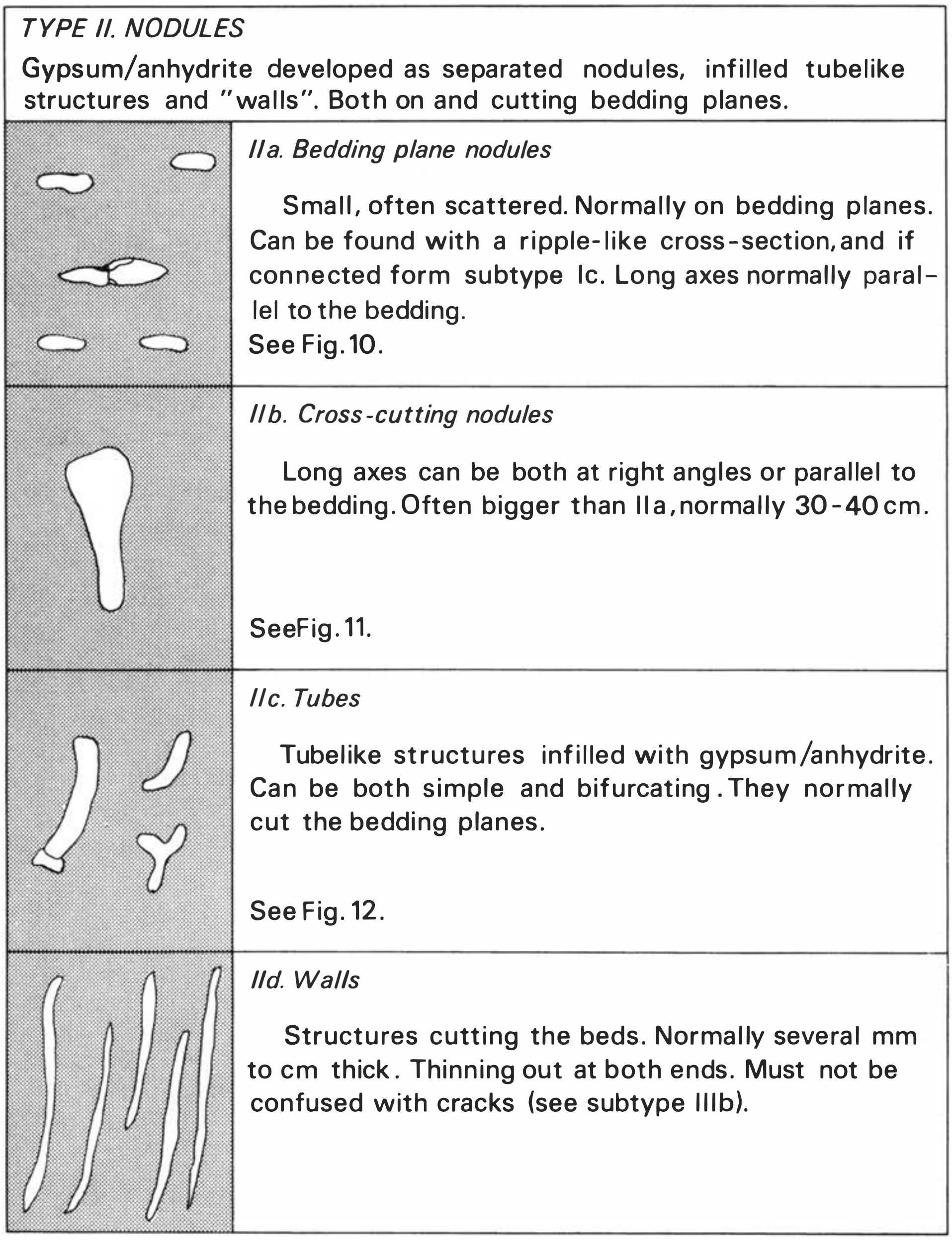


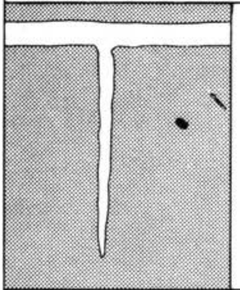
Fig. 3. *Nodules and their subtypes.*

I. *The Continuous Beds* have parallel to subparallel bounding surfaces, but their most characteristic feature is their lateral continuity. There is, however, great variation both in size and shape. This major type can be divided into five subtypes (see Fig. 2).

Ia. *Veins.* The smallest subtype are here called veins, and they are normally only a millimetre thick. They appear mostly as single laminae with vertical

TYPE III. CRACKS-AND FISSURE INFILLINGS

Both large and small scale infillings of gypsum/anhydrite occur throughout the sulphatebearing strata.



IIIa. Megafissures

Fissures found in cliff-sections with a height of 50-75m.

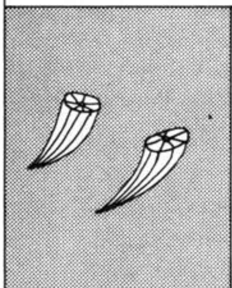
See Fig. 5.

IIIb. Small scale cracks

Small scale infillings in cracks. Very often only a few cm thick and long. Normally located below thick regular beds.

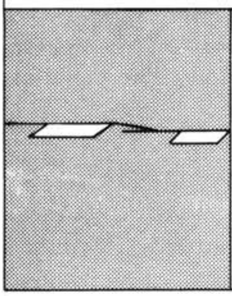
See Figs. 13 and 14.

TYPE IV. FOSSIL INFILLINGS



Infillings of gypsum/anhydrite in hollows and chambers in fossils. Can be seen both in macro- and micro-fossils.

TYPE V. CRYSTALS



Well developed single crystals or clusters of crystals where one crystal plane or more is seen.

Fig. 4. *Cracks and fissure infillings with subtypes, fossil infillings and crystals.*

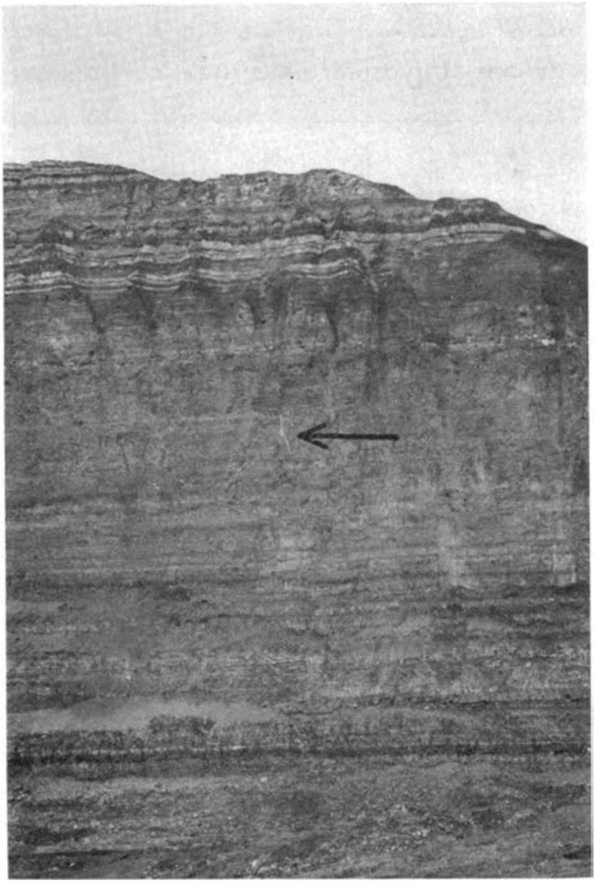


Fig. 5. *The gypsum/anhydrite beds as seen in outcrop, here at the top of a section at the south-eastern end of Kolosseum. The black arrow points towards a megafissure (subtype IIIa) which can be followed downwards from the sulphate beds into the underlying Tyrellfjellet member.*

separation of a centimetre or two, but they often interconnect laterally. They can easily be detected because solution of the evaporites on the surface of the outcrop produces distinctive empty veins. Other types exist together with the veins, but the most common co-occurences are either other types of continuous beds or nodules. Veins often occur above thicker sulphate beds. On Fig. 6, veins can be seen above the upper and below the lower stylolite, and smaller nodules can be seen in the upper part of the figure. The veins are here seen in a host rock of partly dolomitized biopelmicrite.

Ib. *Stylolites.*[1] One of the most peculiar subtypes of gypsum/anhydrite strata observed are the stylolites, and to my knowledge stylolites with gypsum or anhydrite have not been described previously, at least not from Svalbard.

[1] Ever since stylolites were first described by KLÖDEN (1828) these features have attracted geologists' attention, and many different explanations have been given for their origin. Today, however, there is almost general agreement on their production by pressure-solution (PARK and SCHOT 1968). These authors believe that stylolites originate during various stages of carbonate diagenesis, although BATHURST (1958) noted that pressure-solution must act before complete reduction of pore-space by cementation has taken place.

Films of other minerals are often found associated with stylolites, and these are normally

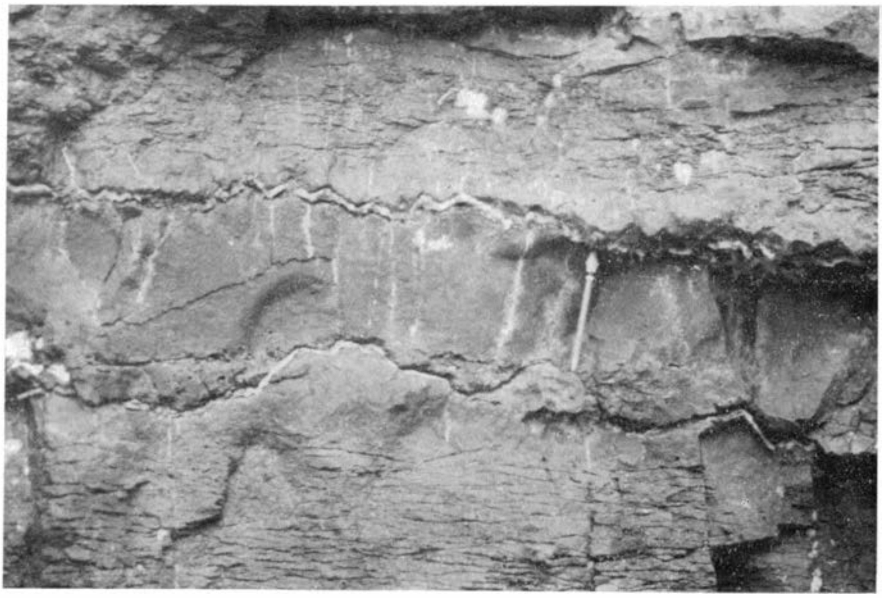


Fig. 6. *Veins (subtype Ia) and stylolites (subtype Ib) as seen in a section on the southern flanks of Gangerolvfjella. The veins are situated above the upper and below the lower stylolite in a host rock of partly dolomitized biopelmicrite. The massive bed between the stylolites is a dolomite with only the fossil fragments preserved as calcite.*

The thickness of these layers varies from less than a millimetre up to one or two centimetres, and according to the classification of PARK and SCHOT (1968) represent horizontal stylolites parallel or nearly parallel to the bedding of the rocks. See Figs. 2 and 6.

Ic. *Undulating beds.* These beds have a "ripple"-like appearance in cross-section, specially when the thinnest parts of the beds are only a few millimetres thick. Such beds are, however, linked together also at their thinnest point, and laterally discontinuous occurrences would be classified as nodules (see type II). The normal thickness of these beds is 1–10 centimetres, but also here there are variations. See Figs. 2 and 7.

Id. *Regular beds.* Regulary beds of gypsum/anhydrite have more or less constant thickness laterally, and bedding planes are parallel. Individual bed thicknesses show great variation, from a few centimetres to several metres (greatest observed thickness 15 m). These beds can be composed of pure

referred to as insoluble residue. Coal films (STOCKDALE 1945) are also known. In the Lower Permian of Spitsbergen such detrital films occur in association with the gypsum/anhydrite-bearing stylolites, and in some rare cases thin films of asphalt are observed together with the sulphate mineralization on these surfaces. This was first observed by myself in western Dicksonland (see Fig. 6), and a colleague (ROTHÉ pers. comm.) observed the same phenomenon at Skansbukta in Billefjorden.

Fig. 7. *Undulating beds (subtype Ic) here giving a "ripple-like" appearance in cross-section.*

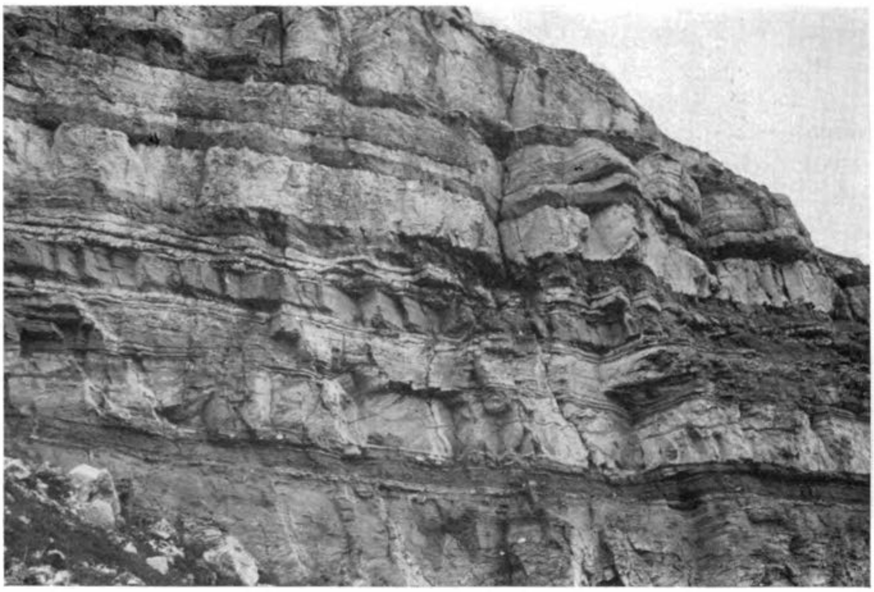
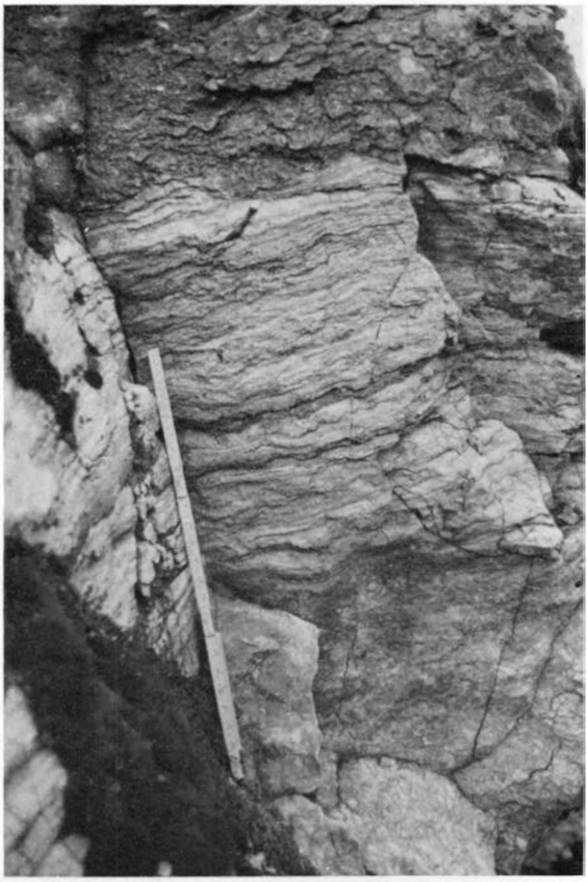


Fig. 8. *Regular beds (subtype Id) as they appear in steep cliffs. Individual bed thicknesses show great variations.*

Fig. 9. *Laminated beds (subtype Ie) here developed in an undisturbed sequence of less than a metre. The overlying beds contain walls (subtype IId) in a regular bedded host rock.*



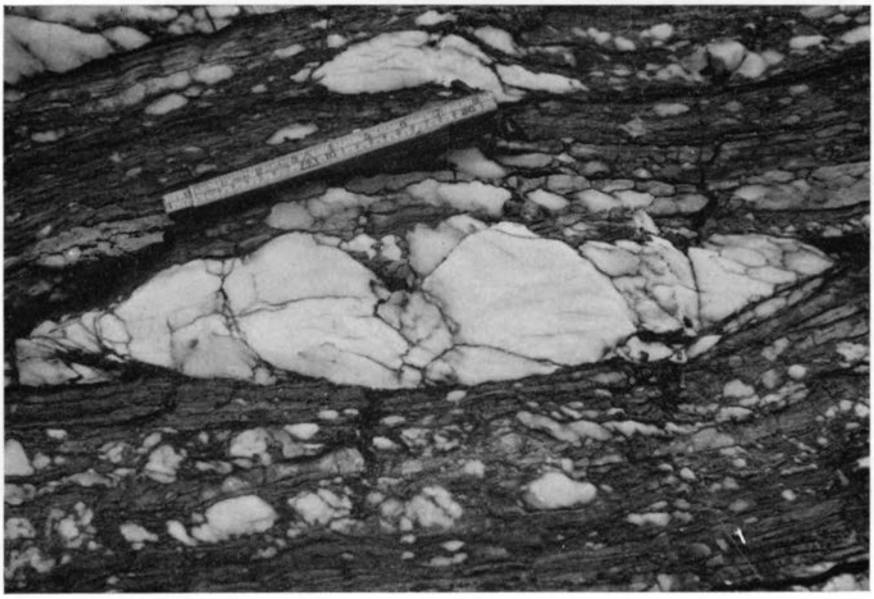


Fig. 10. *Bedding plane nodules (subtype IIa) as they normally appear with long axes parallel to the bedding of the host rock.*

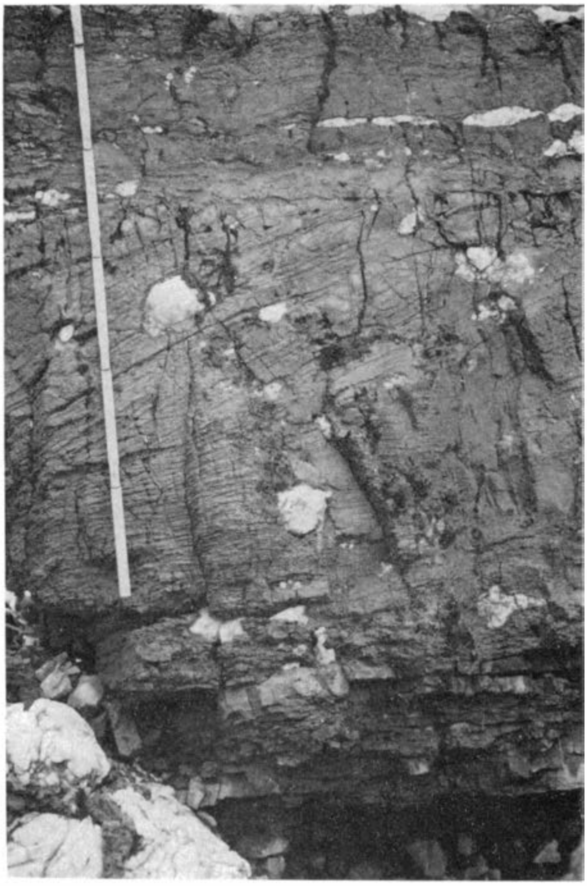


Fig. 11. *Cross-cutting nodules (subtype IIb) here clearly cutting the bedding of the host rock which is here a cross-bedded limestone. Their long axes are often, but not always, at right angles to the bedding.*

sulphates or of sulphates with ghosts or inclusions of carbonate material, and so-called chicken wire structure is not uncommon. See Figs. 2 and 8.

Ie. *Laminated beds.* To this subtype belong beds with a finely laminated appearance, where thin laminae of gypsum/anhydrite intercalate with the carbonate material of the host rock. The appearance is very similar to that seen in algal mats. Although the thickness of the individual laminae component rarely exceeds a millimetre, the total thickness of such beds may extend several metres without interruption by other bedtypes. See Figs. 2 and 9.

II. *Nodules* of gypsum/anhydrite are defined as separated small to large irregular bodies, separated from each other by host rock. The nodules are found both restricted to bedding planes and as features cross-cutting the same planes. It is natural to define four subtypes. See Fig. 3.

IIa. *Bedding plane nodules.* This subtype is one of the most common features seen, and variation in both shape and size is great. They vary from less than a centimetre in cross section up to about a metre in apparent diameter, and thickness varies in proportion to diameter. Bedding planes are often seen to

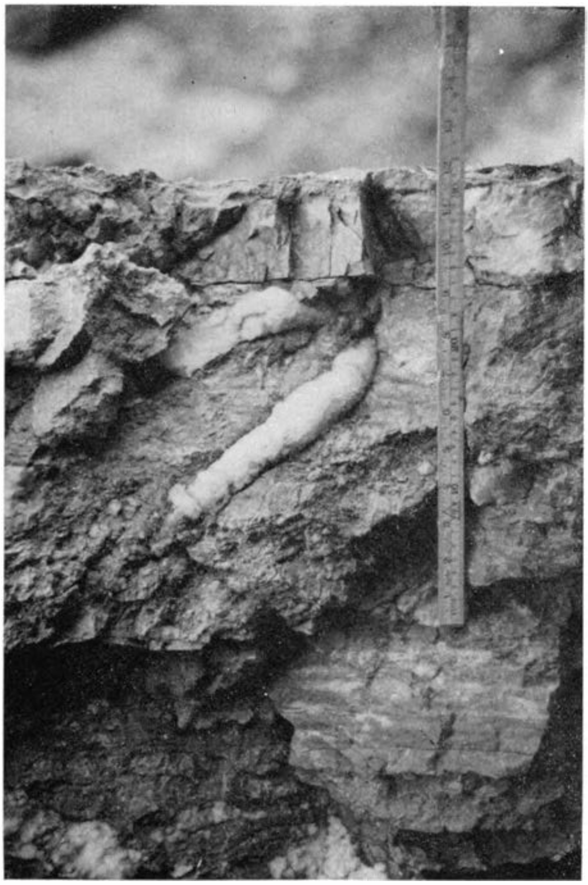


Fig. 12. *The tubes (subtype IIc) figured here, show the typical features of such structures, although these are somewhat longer than usual.*

have been pushed apart from each other by the growth of the nodules. See Figs. 3 and 10.

IIb. *Cross-cutting nodules.* This subtype can be very similar to the subtype just described (IIa), except that they cut the bedding planes. Both size and shape are highly variable, but they tend to have a more vertical trend in the host rock than the former subtype. They are also normally bigger than subtype IIa, and a size of 30–40 centimetres is about the average, although both smaller and much bigger forms are common. See Figs. 3 and 11.

IIc. *Tubes.* Nodules of this subtype are cross-cutting like subtype IIb, but their shape and form are much more tubelike, with almost circular cross-section and constant diameter throughout their whole length. They are often found bifurcating. The diametres of the tubes vary from less than a centimetre to about 10 centimetres, and they can extend for more than a metre through the host rock. See Figs. 3 and 12.

IId. *Walls.* This subtype displays a peculiar shape; bedding planes are cross-cut as in the two former subtypes. Thin walls extend through the host rock, but end blind in a point at both ends. They are reminiscent of the

Fig. 13. *Small scale cracks (subtype IIIb) extending downwards from a thick regular evaporite bed.*

infillings one finds in cracks and fissures (see subtype IIIb), but because of their termination patterns, I prefer to regard them as nodular structures. They are normally only one millimetre to one centimetre thick, and vertically they can be followed for half a metre or more. Their most common vertical length is 30–40 centimetres, and they appear in swarms where they completely dominate the rock. See Fig. 3.

III. *Cracks- and fissure-infillings* with gypsum/anhydrite are located beneath regular sulphate beds and extending downwards into the underlying sediments, but physical contact with the beds above is not always exposed. Infillings in cracks where no overlying regular gypsum/anhydrite beds occur are also found. This major type can be divided into two subtypes.

IIIa. *Megafissures.* These are large scale infillings in cracks that cut the succession for tens of metres. They can easily be seen in steep cliffs, and the vertical extent of this type has been measured to 50–75 metres. The width at the top of these megafissures are several metres, and they taper to a point downwards. See Figs. 4 and 5.

IIIb. *Small scale cracks.* This subtype is the most abundant of these two, and

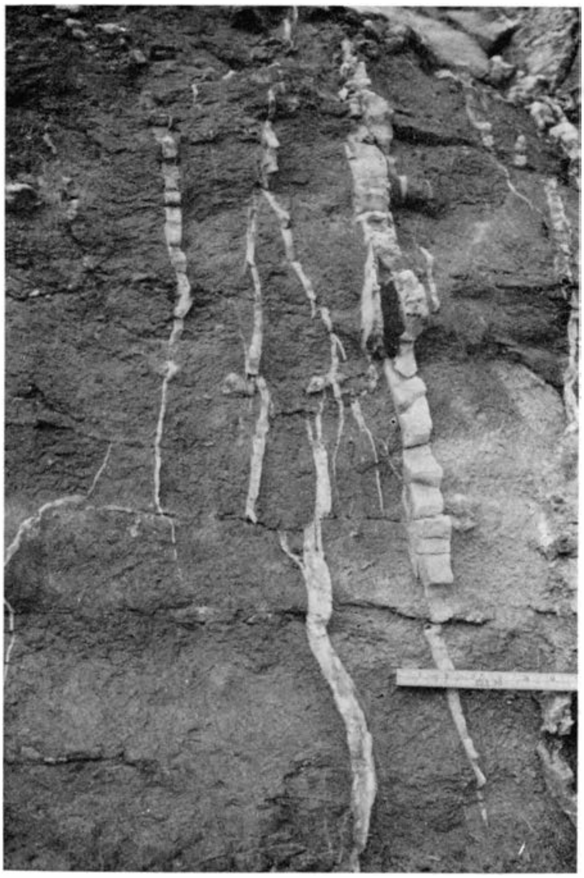


Fig. 14. *Small scale cracks (subtype IIIb) without any visible connection to sulphate beds above.*

they normally extend downwards from the bottom of a thicker continuous bed (subtype Id). They also occur as separate, vertical bodies, without any visible connection to the sulphate beds above. Thickness and length normally only a few centimetres. See Figs. 4, 13, and 14.

IV. *Fossil infillings* are found throughout the gypsum/anhydrite bearing sequence, and gypsum/anhydrite is then located in the natural hollows or chambers in the fossil material. This can both be seen in macrofossils in hand specimens and in microfossils in thin section. See Fig. 3.

V. *Crystals* with well developed planes are found from time to time, but are not common. When seen they occur in very porous carbonate sediment, along small fault planes or other places where crystal growth was not inhibited by lack of space.

Discussion

The evaporites exposed in this area today consist of partially gypsified anhydrite in host rocks of various carbonate sediments. Most of the carbonates are dolomites or partially dolomitized limestones, and preliminary thin-section studies suggest that almost all stages of dolomitization are present. Sulphate crystals are commonly seen to be growing at the cost of dolomite (see also HOLLIDAY 1968), but the opposing process may also be seen with dolomite replacing sulphate. These relationships suggest a diagenetic origin for at least some of the Lower Permian sulphates, an origin also suggested by HOLLIDAY (1966) for the Middle Carboniferous sulphate beds.

Gypsum is the most abundant mineral in modern calcium sulphate deposits (BLATT, MIDDLETON, and MURRAY 1972), but ancient rocks generally contain anhydrite in the deep subsurface, while gypsum is found in the shallow subsurface and in outcrops. This is also true on Spitsbergen, where mining of the Lower Permian sulphates was stopped as more and more anhydrite was encountered at depth.

It is generally accepted that calcium sulphate rocks generate from brines, and brines can develop either by evaporation of sea- and groundwater, or by solution of calcium sulphate minerals from pre-existing rocks. I have observed no signs of deformation which would suggest either increase or loss of volume in the gypsum/anhydrite beds of Lower Permian age. If these evaporites had originally been formed as gypsum, some deformation of the host rock would be expected because of the reduction in solid volume accompanying the transition from gypsum to anhydrite. As this is not seen, primary formation of anhydrite may be indicated, a feature also noted by McWHAE (1953) and HOLLIDAY (1967) in the Middle Carboniferous beds.

Whatever the originally formed mineral, the question remains as to the processes producing these evaporites, and some of the structures described herein may help to solve this problem. The evaporites could represent either (a) precipitates from a standing body of water, (b) precipitation product within the vadose zone, or (c) later stage diagenetic products formed by the solution of pre-existing rocks.

The laminated beds (subtype Ie) show features normally associated with primary precipitation from a standing body of water (BLATT, MIDDLETON, and MURRAY 1972), while the chicken wire structure often found in the regular beds is often produced by precipitation within the vadose zone. The various other kinds of nodules and the fossil infillings may also have formed at this stage. Such features as infillings in cracks, fissures and in stylolites may result from later diagenetic processes. The solution of pre-existing rocks may provide the source for such later features, and many examples are known of breccias thought to result from the collapse of overlying beds caused by the solution of evaporites. Such breccias also occur in the present succession (e.g. the Klotten Breccia Member in the north of the area), and if these represent solution phenomena, the resulting sulphate solution may have been the source for some of the late diagenetic mineralization phenomena described here.

This paper is meant to be a preliminary report, and only deals with the descriptive features of the gypsum/anhydrite beds; I hope that future work in the area will lead to a detailed reconstruction of the formation of this evaporite sequence.

Aknowledgements

I am deeply indebted to Dr. DAVID WORSLEY at the Paleontological Museum in Oslo, for helping me with the English text and for his criticism and help in preparing this paper. Thanks also to Mr. ESPEN KOPPERUD who prepared the drawings. I would also like to thank my field assistants from these two summers, Miss RANDI REE, Mr. JAN ERIK STRAND and Mr. JAN VOLLSET.

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Investigations on the Carboniferous and Permian stratigraphy of the Torell Land area, Spitsbergen

By EIGILL NYSÆTHER[1]

Contents

Abstract

New stratigraphic evidence from the Permo-Carboniferous rock sequence in Torell Land north of Hornsund, has permitted a better correlation than hitherto of the sediments in the Hornsund area with those around Isfjorden. It is suggested that a general regression of the sea from the Hornsund-Sørkapp High took place, starting in the Gzelien Stage of Upper Carboniferous and extending through the Kungurian Stage of Lower Permian. The transgression then initiated continued without pronounced break into Lower Triassic.

[1] Geological Institute, Avd. A, University of Bergen.

Introduction

The area of Palaeozoic and Mesozoic sediments between Hornsund and Bellsund is one of the least investigated areas in Spitsbergen. The area is mountainous and has extensive ice and snow cover which make access to the rare outcrops very difficult.

The area between Bellsund and Kopernikusfjellet was first investigated by ROZYCKI in 1934 and the results of his work were published in 1959. He recognized the existence of varicoloured clastics, carbonates and chertified rocks as belonging to the Permo-Carboniferous rock sequence.

In 1958 BIRKENMAJER visited the area between Kopernikusfjellet and Hornsund and described two sequences of Permo-Carboniferous age which he termed the Treskelodden Beds (youngest) and the Hyrnefjellet Beds. The material collected by BIRKENMAJER was further investigated by Polish scientists and the results were published in various papers between 1960 and 1968.

Also other workers have contributed with descriptions and interpretations of the Permo-Carboniferous rocks in the Hornsund area. Interested readers are referred to BIRKENMAJER (1964) on details concerning these publications.

This paper presents the results of the Norsk Hydro/Aker Drilling Company geological expedition to the area in 1970. During this expedition two profiles, the Drevbreen and Ostra Bramatoppen sections, through the Permo-Carboniferous rock sequence were measured which throw new light on the Carboniferous and Permian stratigraphy in the area.

These two localities have to my knowledge never been visited and described before, although one of them (Ostra Bramatoppen) is shown on one of ROZYCKI's sketches from the area. Their location is shown in Fig. 1.

Regional Geology and Structure

The substrate upon which the Upper Palaeozoic sediments were deposited is composed of metamorphosed pre-Cambrian to Cambro-Silurian sediments and intrusives that were deformed during the Caledonian orogeny. These rocks are found exposed in the westernmost part of the area.

Devonian rocks are known with uncertainty from the area, but Lower Carboniferous terrigenous sediments outcrop in small areas at the head and mouth of Hornsund. Whether the limited distribution of these rocks is depositional, i.e. caused by the original basin configuration, or they are remnants of a pre-Middle Carboniferous episode of blockfaulting and erosion, is not known.

(?) Middle Carboniferous sediments were apparently deposited on an uneven surface since thick local developed red-coloured conglomerates of presumably this age have been found at several localities along the foldbelt between Hornsund and Bellsund (ORVIN 1940; ROZYCKI 1959).

In Upper Carboniferous greater parts of the area were transgressed and uniform sedimentation initiated. The area remained a stable block up through the lower part of Upper Permian but received less sediment than the area

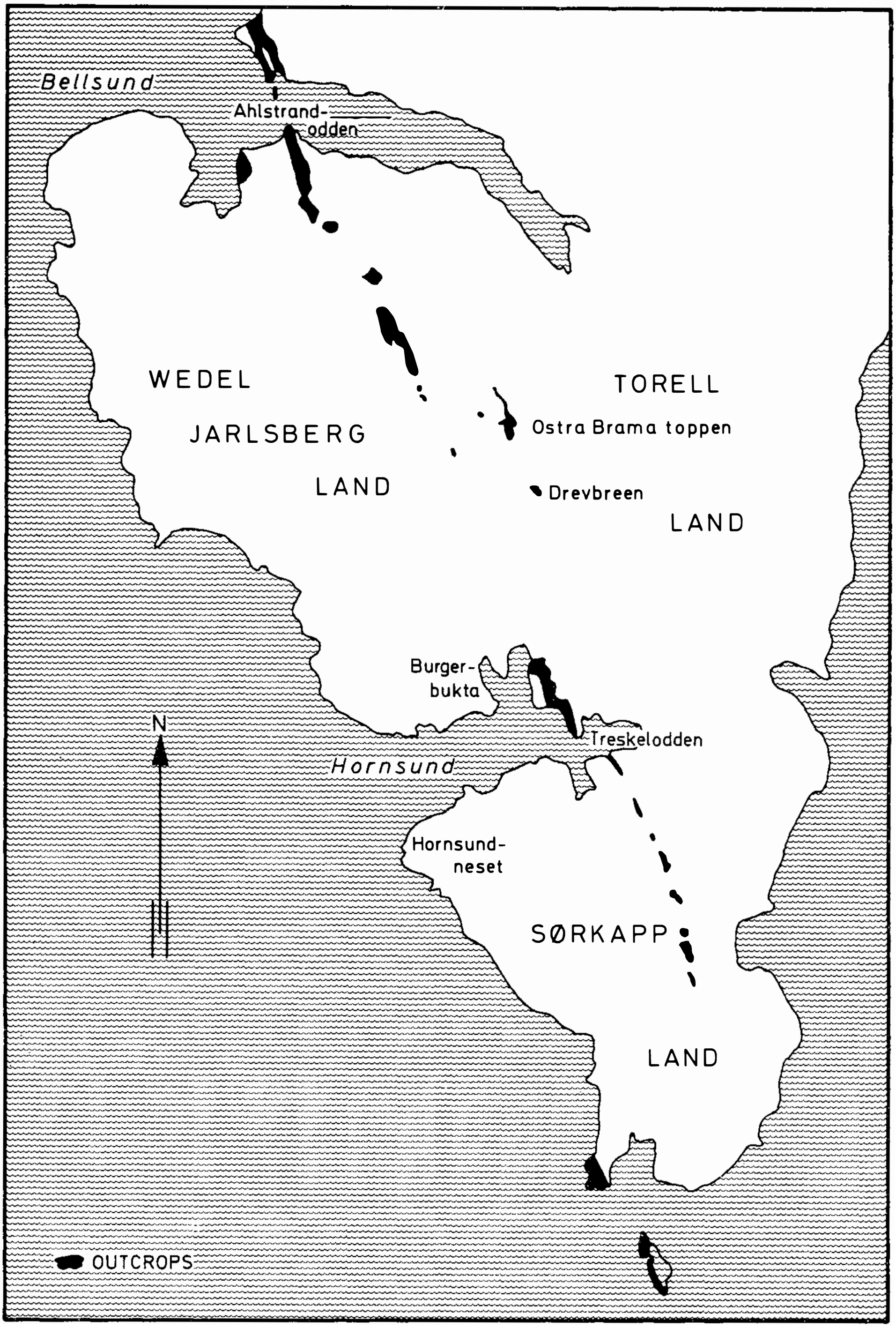

Fig. 1. *Location map showing distribution of Middle Carboniferous–Permian outcrops in the area between Bellsund and Sørkapp, and the position of the sections investigated.*

around Isfjorden further north. The sediments are also considerably more sandy here.

The younger sediments of the area are little known as most of these were eroded during the Tertiary episode of tectonism and uplift.

The Permo-Carboniferous sediments are found outcropping in a narrow foldbelt between Hornsund and Bellsund from where they dip eastward and disappear beneath a cover of younger rocks of the Spitsbergen syncline. The foldbelt was formed as a response to pressure from the west during Lower-Middle Tertiary.

Thrust sheets that are genetically related to the folding phase can be seen west of the foldbelt and along its western margin. These sheets have in some instances carried Palaeozoic and Mesozoic sediments eastward from their original site of deposition which complicates a palaeogeographic reconstruction of the facies distribution.

The Sections

The Drevbreen section totalling 388 m is exposed on a mountain ledge on the southern extremity of the Polakkfjella range. The section starts above the Drevbreen glacier and is overlain conformably by sediments of Triassic age.

The beds have a N 20 W° strike and an east dip of 10–40°. It is bounded on the north by a normal E-W striking fault that has brought the sequence in contact with Triassic sediments.

The section is lithologically tripartite with a 180 m thick carbonate-sandstone sequence at the base, a 69 m thick carbonate-evaporite sequence in the middle and 95 m of limestones, sandstones and chertified rocks at the top. The lower and middle sequences are separated by a 44 m thick scree-covered area.

On lithological grounds it seems reasonable to correlate the two uppermost sequences with the Gipshuken Formation (oldest) and the Kapp Starostin Formation of the Isfjorden area (CUTBILL and CHALLINOR 1965).

The lower part of the section (here called the Drevbreen Beds) bear a striking resemblance with the Treskelodden Beds as described by BIRKENMAJER (1960). However, it seems that only the lower part of the sequence at Drevbreen correlates with the Treskelodden Beds. The upper part thus seems to form a new lithostratigraphic unit.

At the Ostra Bramatoppen locality only the uppermost sequence with limestones, sandstones and chertified rocks is exposed. The section is limited by scree at its base and overlain conformably by Triassic sediments. Its thickness is 176 m.

Because it is inaccessible at Ostra Bramatoppen, the topmost 32 m of the sequence was measured and described at Waveltoppen, 1 km further north. The two localities are situated on the steep east flank of a flat topped anticline. The beds strike in a N 15° W direction and dip 20–25° to the east.

At this locality most of the exposed sequence must be allocated to the Kapp Starostin Formation. The section is probably more complete at the southern

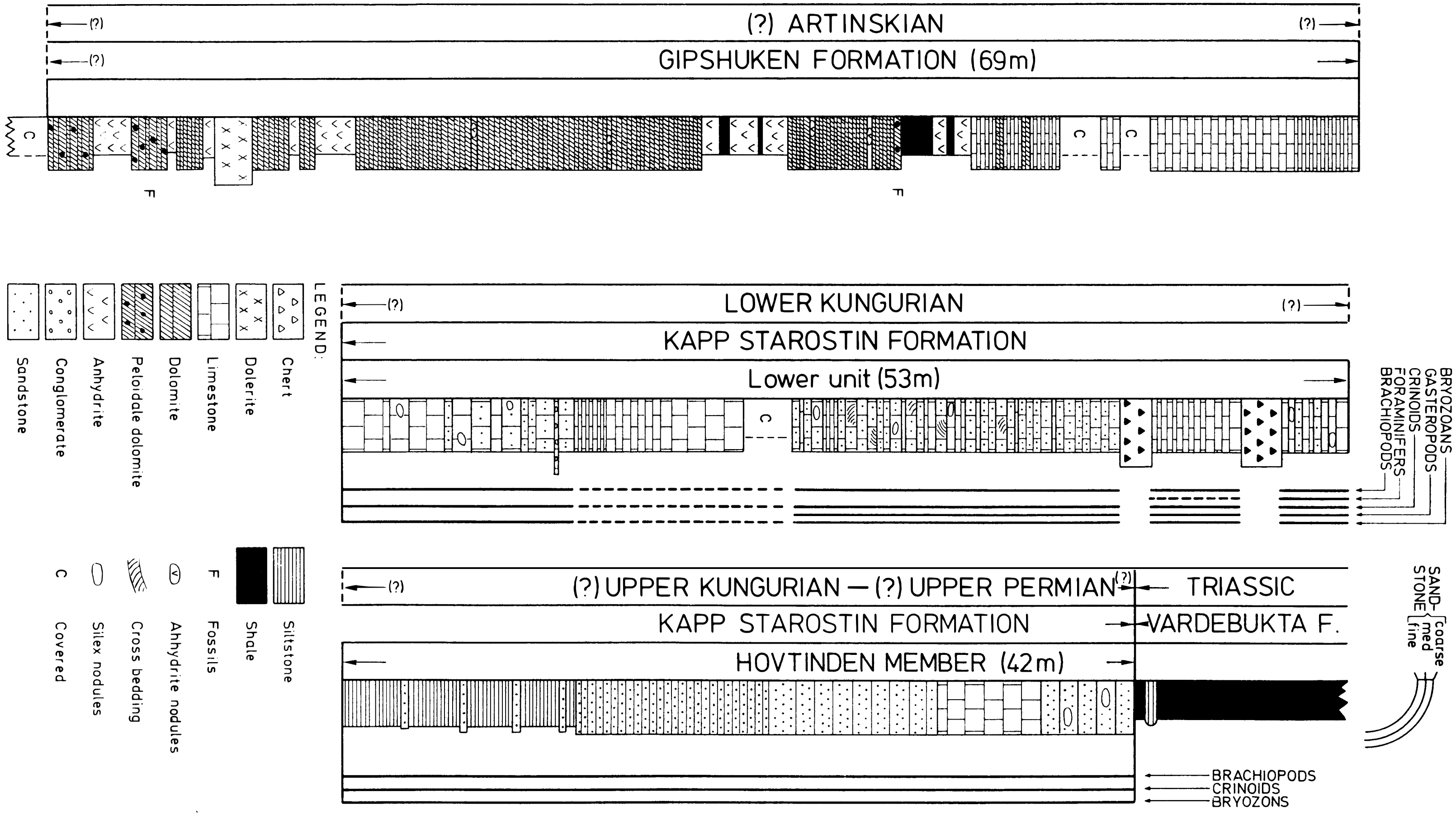

Fig. 2. *Drevbreen section; the Drevbreen Beds.*

extremity of the Ostra Bramatoppen range where sediments supposedly belonging to the Gipshuken Formation were observed. This locality was not visited by us, however.

Stratigraphy and age

The Drevbreen Beds (*Fig. 2*)

This sequence of carbonates and sandstones belongs to a litho-facies from near the westcoast of Spitsbergen which has been recognized by many earlier workers in the area. In only one case has any detailed description been made of the rock-sequence, however, and a general lack of significant fossils has only permitted a rough time-stratigraphic correlation between the localities. The age given to the facies range from Middle Carboniferous to Lower Permian.

The most thorough and detailed description and interpretation of the facies have been given from a locality in Hornsund by K. BIRKENMAJER and various other Polish geologists from 1960 through 1968. BIRKENMAJER's investigation resulted in the recognition of two sequences which he termed the Hyrnefjellet Beds (oldest) and the Treskelodden Beds. These informal names were later formalized by CUTBILL and CHALLINOR (1965) and the sequences given the status of formations. This move by the two authors is in my opinion somewhat unfortunate since the Treskelodden Beds is overlain by an important unconformity and the boundary between the two formations only vaguely defined by BIRKENMAJER which could make litho-stratigraphic correlations difficult or even impossible. I shall therefore in this paper use the term Beds as originally suggested by BIRKENMAJER.

BIRKENMAJER and CZARNICKI (1960) from a study of the brachiopod fauna suggest a possible Upper Carboniferous age for the Treskelodden Beds, while LISZKA (1964) after a study of foraminifer and FEDOROWSKI (1964, 1965) after a study of corals contained in the Treskelodden Beds, assigned a Lower Permian age to the rocks. CUTBILL and CHALLINOR (1965) also give a Lower Permian age for the Treskelodden Beds but do not support this by any faunal evidence.

An investigation by M. LYS (in preparation) on a rich fusilinid fauna collected by me from the lower part of the carbonate-sandstone sequence at Drevbreen, revealed an Upper Carboniferous (Gzelian) age for most of these. However, in the uppermost limestone-bed that contained fusulinids he suggested a possible transition from Gzelian to Asselian affinities of the fauna, which would indicate the Carboniferous-Permian boundary.

From the above it should follow that the lower part of the carbonate-sandstone succession at Drevbreen is of the same age as, or older than, the Treskelodden Beds.

The Hyrnefjellet Beds which contain neither carbonates nor fossils, were tentatively assigned an Upper Carboniferous age by BIRKENMAJER (1969) while CUTBILL and CHALLINOR (1965) correlated them with the Tyrellfjellet Member of the Nordenskiöldbreen Formation of Lower Permian age.

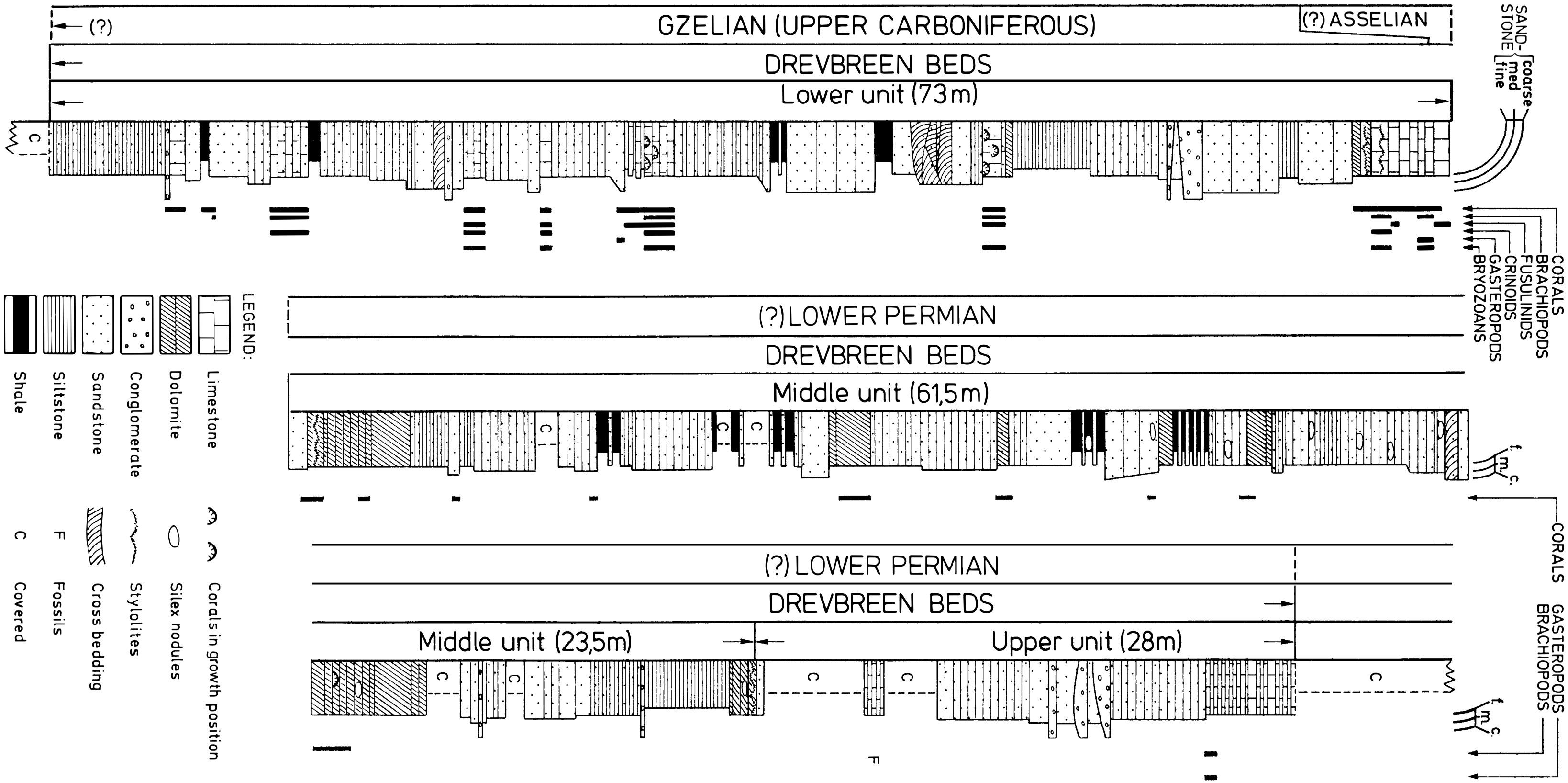

Fig. 3. *Drevbreen section; Gipshuken Formation and Kapp Starostin Formation.*

Gipshuken Formation (*Fig. 3*)

Approximately 69 m of the possible equivalent of the Gipshuken Formation is exposed at Drevbreen. Its base is covered with scree and it is overlain by limestones and chertified rocks of the Kapp Starostin Formation. The possible recognition of this formation which is previously not reported south of Isfjorden, is based on the existence of anhydrites and dolomites in the sequence occupying the stratigraphic position immediately below rocks from the Kapp Starostin Formation.

No identifiable fossils were found in the rocks to help determining the age of the formation, although remnants of organisms were disclosed in thin sections of the dolomites.

The Gipshuken Formation has been assigned a possible Artinskian age by CUTBILL and CHALLINOR (1965). The reference to the present sequence as being equivalent with the Gipshuken Formation is not in conflict with this age determination as the sequence is sandwiched between rocks of Gzeliar-Asselian age (Drevbreen Beds) and Kungurian age (Kapp Starostin Formation).

As the formation base is not exposed, we do not know its real thickness nor the nature of the transition to the Drevbreen facies below. Of importance in this connection is the existence of cellular dolomite in the scree between the two sequences. As this specific rocktype is not known from the sequence above, cellular dolomites most logically will be found in situ underneath the cover which indicates that the lower limit of the Gipshuken Formation should be extended somewhat downwards.

Kapp Starostin Formation (*Fig. 3*)

This formation is 95 m thick at Drevbreen and at least 141 m thick at Ostra Bramatoppen. Its lower boundary at Drevbreen is determined at the base of a 12 m thick sandy biosparite with abundant remnants of brachiopods. The upper boundary is with terrigenous clastic deposits of Triassic age.

At Ostra Bramatoppen the position of the lower boundary remains uncertain as it may be hidden in the scree-covered area below the exposed sequence. There exists, however, a distinct massive limestone with abundant brachiopods near the base of the sequence, the base of which I have tentatively used as the lower limit for the formation there.

The Kapp Starostin Formation is composed of three members in the Isfjorden area (CUTBILL and CHALLINOR 1965). From the base upwards these are: the Vøringen Member which is a massive limestone with a prolific brachiopod fauna; the Svenskegga Member with siltstone, shale and limestone; and the Hovtinden Member which is composed of silicified shale, siltstone and sandstone, which is often glauconitic.

In the present area only two facies are recognized: an upper unit composed of chertified siltstone and sandstone with glauconite and a lower unit that

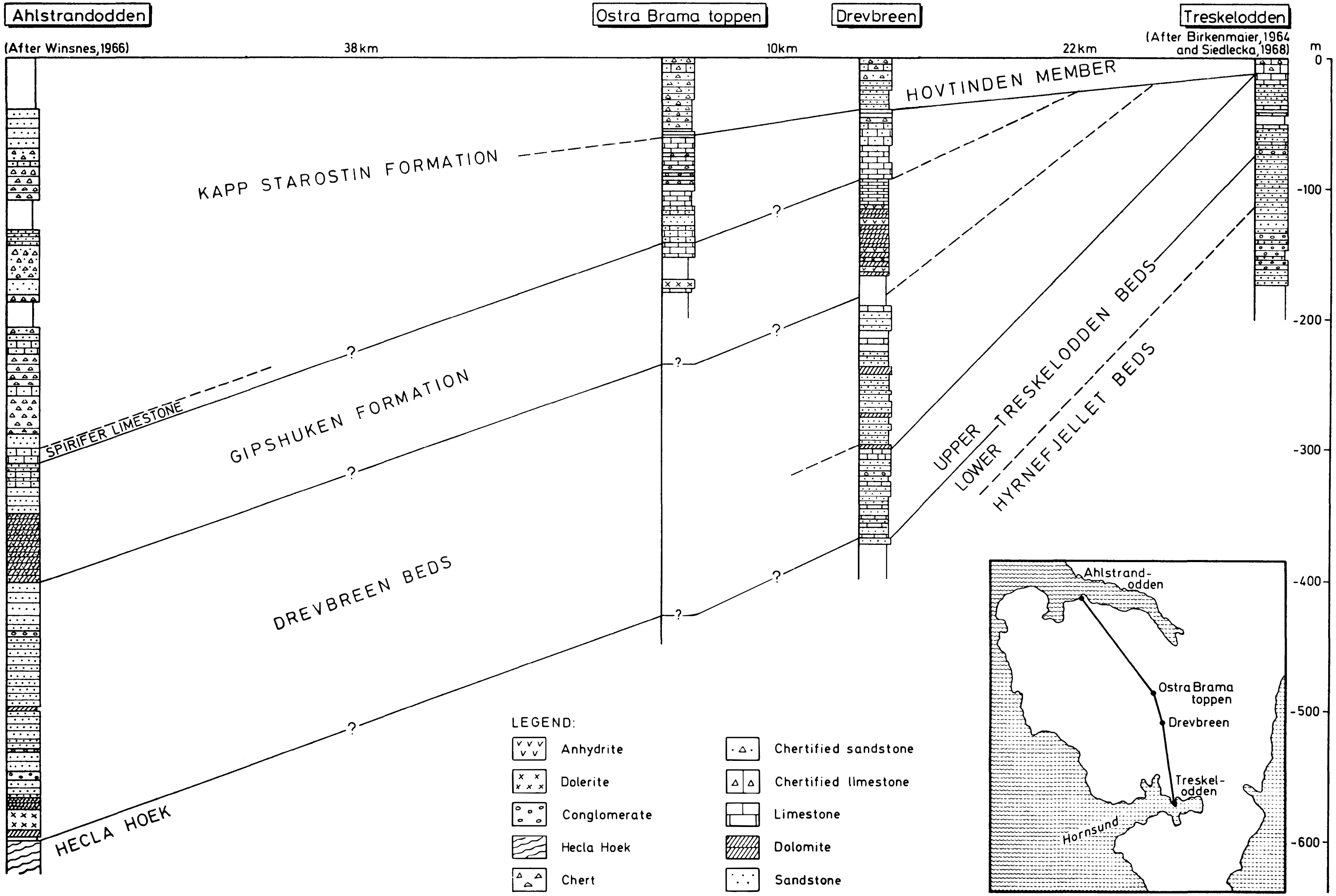

Fig. 4. *Cross-section through the Permo-Carboniferous rock-sequence between Bellsund and Hornsund.*

includes sandy limestone with abundant remnants of bryozoans and brachiopods and interbedded with some sandstones, conglomerates and pure chert layers. The upper unit may well be equivalent with the Hovtinden Member based on its composition of chertified terrigenous clastics whereas the lower unit can not be subdivided on lithological grounds.

Fig. 4 shows the thickness variation of the formation within the study area. There is a notable continuing increase of the formation thickness from Treskelodden northwards to the Bellsund area.

A Kungurian age has been confirmed by M. LYS (in preparation) for the upper part of the lower unit at both localities. This compares well with the age of the Kapp Starostin Formation in the Isfjorden area.

Description

The Drevbreen Beds

These rocks have a characteristic overall light yellow colour which helps in distinguishing them from the light-coloured, younger Permian sediments and the dominantly dark-coloured Triassic sediments in the area.

The succession consists of alternating sandstones, siltstones, limestones and dolomites with subordinate amounts of conglomerates and shales, of which the terrigenous clastics make up 75%, the carbonates 20%, and 5% is covered (see SIEDLECKA 1968, for a comparison with the Treskelodden Beds).

A more or less well defined cyclic pattern is developed in the lithologic sequence in that carbonates and terrigenous sediments alternate in a regular manner. Each cycle starts with a carbonate which in turn is overlain by a terrigenous clastic sequence of a generally upward coarsening character. On top of the uppermost clastic bed follows a new carbonate, and so on.

Similar cycles have been recorded in the Upper Carboniferous Yoredale series of northeast England (MOORE 1959) and more locally by BIRKENMAJER (1960) from the Upper Carboniferous Treskelodden Formation in Hornsund, and by BARBAROUX (1967) from the Middle Carboniferous Leinstranda Formation of Brøggerhalvøya.

Altogether 16 cycles starting with a carbonate layer, have been recognized although it shall not be excluded that some of the shale/silt beds sandwiched between sandstones may be of the same importance as the carbonates in reflecting the initiation of a new cycle.

On the basis of the type of carbonate present, it has been possible to divide the sequence into three units:

1. The lowermost 70 m. Here the carbonate is nearly exclusively limestones which display abundant remnants of life including corals, fusulinids, gasteropods, brachiopods, bryozoans and crinoids.
2. The next 83 m. This unit is characterized by dolomites and the total absence of limestones. Some of the dolomites are silicified and many

display a vuggy appearance. In the upper half of the unit is found abundant red-coloured silex- and dolomite-filled geodes probably reflecting an infill of similar vugs as those present below. Corals are the only fossils collected.

3. The topmost 27 m of the sequence. Here the carbonates are all limestones some of which are slightly bituminous. The corals are now apparently gone; instead a sparse fauna consisting of bivalves and gasteropods is observed. Also here we see silex in the form of nodules; their colours have now turned black and white, however, indicating the presence of organic material in the sediments.

Except for the lowermost 6 m of unit 1, which consists of red-coloured, very fine-grained sandstone, the different terrigenous clastic rocks are very much alike in the three units with respect to colour, composition and texture. The sandstones and siltstones have colours in shades of brown, yellow and grey and are primarily well sorted unimodal sediments. The dominant detrital component is quartz whereas rock fragments composed of chert, quartzite and quartzschist with minute flakes of sericite, are common constituents. Feldspar is present but is apparently not common. Heavy minerals are rare and consist generally of well rounded zircon and tourmaline grains. Detrital carbonate grains have been observed in a few thin sections. These fragments must not be confused with remnants of fossils that occur abundantly in some of the sandstones. The cement in the rocks is sparry calcite (lower and upper unit) and fine-textured dolomite which is found primarily in the middle unit, but scattered well developed dolomite rhombs have also been seen in unit 1. Some chertcement is also present in rocks from unit 2.

The sandstones vary from thin to thick bedded with a few zones of medium-scale cross-stratification. The conglomerates occur as lenses or well defined thin beds in all three units. They are composed of well-rounded quartz, chert and quartzite pebbles which are usually less than 3 cm in diameter. Their matrix is generally medium-grained quartz-sand (coarse-grained sand is rare in the sequence).

The shales have a green to dark-grey colour and an important content of siltsized detritus. The dominantly light colours probably indicate absence of organic material.

The carbonates in the lower unit are always rich in fossil fragments and quartz sand. The texture of the calcite is invariably sparry. In some of the beds corals are aligned with their long axis probably pointing in the direction of the prevailing current at the time of deposition.

In the upper unit framework components like quartz sand and fossil fragments make up only a small proportion of the limestones. Instead these rocks show a churned appearance that are interpreted in terms of reworking of the sediments by organisms. The texture is micritic, but isolated spots of sparry calcite may be related to burrow-fill or recrystallized fossil-fragments.

The pure dolomites are all confined to unit 2. They have a dominantly micritic appearance in thin-section with a varying but commonly important content of quartz sand. Fragments of fossils are sparse. The bedding of the dolomites is from thin to thick, the thicker beds being very resistant to erosion.

Gipshuken Formation

The formation contains dolomites (51%), limestones (26%), anhydrites (19%), and shales (4%). The percentages in brackets give their relative mode of abundance. Also present is a dolerite sill, approximately 2 m thick. The dolomites are confined to the middle and lower parts of the formation. Between the two anhydritic zones, the dolomites are dark grey micritic rocks, laminated to thin-bedded, with small vugs filled with anhydrite. Within the anhydritic zones, some of the dolomites are rich in quartz sand and dolomitized ooids and peloids, others have a regularly laminated appearance. Anhydrite cement is common in the oolites and peloidal rocks. Abundant nodular anhydrite is found within the dolomites in the upper zone.

The limestones which are limited to the upper one-third of the formation show a general increasing coarseness towards the top from micrites to biosparites. The colour ranges from dark grey in the micrites to grey-black in the biosparites; the darkening of the biosparites probably reflects an increasing content of organic matter in the latter. The internal structures are dominated by fine laminations, but small-scale ripplemarks and convolute bedding have also been recorded.

The anhydrites occur as beds or nodules, the beds being from 30 cm to 2 m thick, the nodules up to 1 m in diameter. Both very pure anhydrites and anhydrites rich in clay occurring as claylenses or shalepartings, have been seen. The anhydrite beds occur in two zones separated by a 18 m thick sequence of micritic dolomite.

The shales are grey-green in colour and occur in up to 2 m thick units between the anhydrite beds in the upper anhydrite zone. They split along a paper-tnin lamination.

Kapp Starostin Formation

The lower unit of the formation, which is 53 m thick at Drevbreen and at least 78 m thick at Ostra Bramatoppen, consists of light to dark grey dominantly sparry limestones, often with abundant fossil remains and quartz sand. The bedding is from thick to thin. Sand and well rounded pebbles of quartz and chert are sometimes concentrated to form distinct beds. These are most prominent at Ostra Bramatoppen where two conglomerates, 0.8 m and 1.4 m thick, are interbedded with the limestones.

The dark coloured limestones owe their colour to a bitumenous content. Many of the sandy limestones display cross-bedding in beds about 5–10 cm thick. The orientation of these crossbeds seems to indicate varying directions of sediment transport.

Except for the limestones and conglomerates, several chertlayers also form distinct rock units within this sequence. The chertlayers are maximum 1.8 m thick and have white to yellow to grey colours. Internal structures are not seen in the pure cherts, but they often contain inclusions or lenses of sandstone and limestone from which they may have been derived by replacement. A thin lignite horizon is interbedded with the limestones at Ostra Bramatoppen.

The fossil content of the limestones show a rich macrofauna of brachiopods, bryozoans and echinoderms with some gasteropods and corals in certain layers. Thin sections reveal the existence also of foraminifers.

In the upper unit (Hovtinden Member), we get a lithology very different from what we see in the lower unit. The rocks are now composed of silicified siltstones and very fine-grained sandstones with a few interbedded sandy limestones. The colours are grey-brown to black, and there is enough glauconite concentrated in certain layers to give the rocks there a green tinge.

Debris of brachiopods, bryozoans and echinoderms is still a common constituent of the rocks. The trace fossil *zoophycos* is observed in the lower part of the upper half of the unit at each locality.

This member shows a coarsening-up character in that silty beds are concentrated in the lower part of the succession and sandstones in the upper part. At each locality there is a 6 m thick chertified limestone with abundant fossil-remains situated approximately 5 m below the termination of the formation. Thin sections of this reveal a fauna composed of brachiopods, bryozoans, echinoderms and sponge spicules. The unit is 42 m thick at Drevbreen and 62 m at Ostra Bramatoppen.

Sedimentary environments and diagenesis

The Drevbreen Beds

The lithology and the biotic constituents of the limestones in unit 1 clearly suggest that open but shallow marine conditions prevailed during the deposition of these rocks.

In unit 2 the carbonates are all dolomites. The abundance of corals in these rocks, however, points to a secondary origin for the dolomite, the original carbonate being calcite and/or aragonite. It can therefore not be excluded that also other organisms inhabited the seabottom at the time of deposition, but that their remains were later obscured by the dolomitization process. It is thus possible that the depositional environment did not differ considerably from that in unit 1 although the rocks were possibly deposited closer to the shore as will be explained later.

The absence of dolomites in the units above and below indicates that the dolomitization process is stratigraphically controlled and that the dolomites are of early diagenetic origin. It is here suggested that the regressional phase that was initiated shortly after the deposition of each carbonate layer created restricted lagoonal environments in the nearshore area with the deposition of anhydrites or gypsum out of solution. The sulphates were later dissolved as the terrigenous deposits advanced across them while the Mg-rich brines that were another result of this process had already converted the underlying limestones to dolomite, a process that could not be reversed. It is possible that the commonly occurring vugs in rocks from this unit originally were anhydritic nodules which later on were dissolved.

Most of the terrigenous beds do not give any definite clues as to their origin. Deltaic and fluvial environments were probably not important in contrast to what appears to have been the case in the Treskelodden Beds (BIRKENMAJER 1964) due to the absence of channels and other current structures. A deep water origin of the beds is also rejected since there is no positive evidence for this and because of their proximity to shallow water carbonates. My conclusion is therefore that the major part of the terrigenous clastic sediments were deposited in a nearshore and paralic environment but that some beds may represent partly reworked fluvial-deltaic sediments.

The absence of any noticeable deltaic influence on the sedimentation is also an important aspect in terms of an understanding of the cyclic sedimentation in the sequence. I think we can immediately conclude that this cyclicity was not brought about by the changing courses of river distributaries as advocated for the similar Yoredale sequence by MOORE (1959). I would rather favour BIRKENMAJER's (1964) interpretation of similar cycles in the Treskelodden Beds as being formed by fluctuations in sea level resulting from periodic accumulation and melting of ice caps in the polar regions.

Gipshuken Formation

Gradually increasing marine restriction in the shelf area after the deposition of the Drevbreen Beds resulted in the deposition of relatively pure carbonates and anhydrites. The abundance of interbedded dolomite and anhydrite in the lower two-thirds of the formation is suggestive of prevalence of restricted lagoonal and/or supratidal environments.

The dolomites probably originated under fairly similar conditions to those suggested for the Drevbreen Beds although some of them may be connected with a supratidal environment. Even though the deposition also in this case took place close to a shoreline, we do not see the influence of terrigenous material in the sequence. This is probably connected with a termination of the process(es) that caused the eustatic sea level changes, but there may well also have been a climatic factor involved due to the regional appearance of evaporites at this stratigraphic level.

The upper third of the formation displays dominantly limestones which suggest a return to a more open marine environment. However, the presence of some anhydrite cement in one of the rock-samples investigated points to an intermittent return to more restricted environments.

Since this formation has not been investigated in any detail it has not been possible to forward any hypothesis as to the subenvironments within the dominant restricted environment.

Kapp Starostin Formation

The bioclastic facies of the lower member points to deposition in a shallow nearshore environment where fluctuating currents and waves produced cross-bedding in the limestones and mixed the skeletal debris there with terrigenous material derived from a nearby shore or river mouth bar. The upward coarsening chert and quartz conglomerates may be interpreted as beach deposits that migrated across the nearshore facies.

In view of their coarse-grained nature and mode of deposition, the sediment probably had a high original intergranular porosity that ultimately became filled with a sparry matrix.

Sparry limestones with a small amount of organic remains and a negligible amount of quartz probably originated as micritic rocks, and may have been deposited under lagoonal conditions or on the foreshore.

We thus see that during the deposition of this member both low- and high-energy bottom conditions were present in a nearshore environment.

With the initiation of deposition of the Hovtinden Member the sea transgressed across the eastern part of the Hornsund-Sørkapp High and the water apparently deepened. The presence of very fine-grained glauconitic clastics that show no sign of directional current structures and the presence of the trace fossil *zoophycos* indicate a relatively quiet-water offshore type environment with low rates of sedimentation. Abundance of skeletal debris and burrows that penetrate the glauconitic sand, point to oxidizing conditions during the deposition of the sediment.

Both members of this formation are rich in silex but its occurrence is somewhat different in the two cases which may be related to different states of diagenesis of the members at the time of emplacement of the silex.

In the lower member, the silex or chert is distributed as lenses, nodules and beds in the limestones, whereas it does not seem to be important as a cementing agent or porefill. On the other hand, both the limestones and sandstones in the upper member have important silex cement in addition to some carbonate cement. Only rarely are chert nodules found and bedded chert does not exist. These differences may be explained as follows.

The limestones in the lower member were exposed to fresh water shortly after the deposition, which initiated early calcite cementation of the rocks. Subarial exposure is indicated by the occurrence of lignite in the sequence. When later the chertification process started there was no available porespace for precipitation and the silex was deposited as lenses or beds by replacement of the host rock along bedding planes.

In the case of the Hovtinden Member, the sandstones and the few limestones there were probably *not* cemented by calcite prior to the introduction of the silex, which easily penetrated all rocks and cemented these. Most of the silex was used for this purpose and few silex nodules were formed.

The origin of the silex may be due to dissolution of sponge spicules from the Hovtinden Member. Remnants of such are abundant in some of the thin sections investigated.

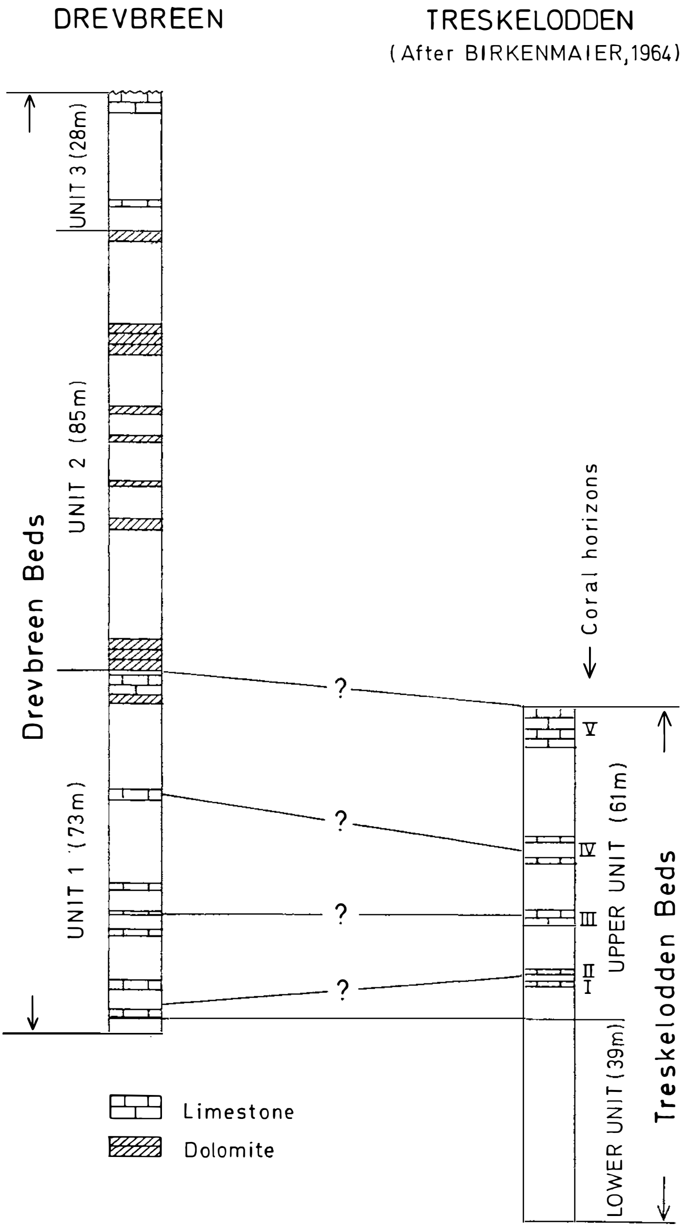

Fig. 5. *Lithological correlation between the Upper Treskelodden Beds and unit 1 of the Drevbreen Beds.*

Litho-correlation within the Drevbreen Beds

The 180 m thick carbonate-sandstone sequence at Drevbreen (the Drevbreen Beds) has strong lithological resemblance with the 60 m thick upper part of the Treskelodden Beds in the Hornsund area. There are, however, reasons not to consider the Treskelodden Beds just a condensed version of what we see at Drevbreen. Firstly, the carbonates at Treskelodden are all limestones whereas at Drevbreen both limestones and dolomites have been found. Secondly, the thickness of the individual cycles in the two places are of the same order, but there are 16 of these at Drevbreen and only 5 in Hornsund. Moreover, there exists a good correlation between the limestones of unit 1 at Drevbreen and the limestones of the Treskelodden Beds both with respect to the internal spacing of beds and the total thickness of the two sequences correlated (Fig. 5). This puts all of the Treskelodden Beds at the level of unit 1 and below this, but not above.

The limit between the assumed equivalent of the upper and lower part of the Treskelodden Beds is tentatively put on top of the 6 m thick red-coloured basal sandstone at Drevbreen which compares well with a similar development in Hornsund.

ORVIN (1940) described a sequence of rocks at Burgerbukta, 10 km north of Treskelodden, which has strong affinities with the Drevbreen facies. By a correlation of this sequence with the Treskelodden Beds it appears as if all of this formation is represented at Burgerbukta. In addition, however, a 40 m thick dolomitic sandstone is added on the top of the sequence at Burgerbukta. This increase in thickness is in accordance with BIRKENMAJER's mention of the Treskelodden Beds being of the order of 150–170 m north of Treskelodden. He does not give the reason for this increase, however. The existence of dolomitic cement in the sandstone is of great importance in this connection since it points toward deposition under conditions similar to those found in unit 2 at Drevbreen. This would strengthen our assumption that the Treskelodden Beds are indeed equivalent to unit 1 and older rocks of the Drevbreen Beds and that the whole or part of unit 2 compares with the topmost sandstone at Burgerbukta.

If we compare the facies of the sediments of unit 1 at Drevbreen with the supposed equivalent sediments at Treskelodden, the Treskelodden Beds, we see that even though the sandstones have a more continental affinity at Treskelodden, the depositional environment for the carbonates shows no detectable variation. On the other hand, unit 2 at Drevbreen shows a lateral variation of facies from interbedded dolomite and sandstone at that locality to pure sandstones at Burgerbukta which indicate that a dominantly continental environment had been permanently established at this location.

The change in lithology between units 1 and 2 at Drevbreen seems therefore to have more than local importance and possibly reflects both a restriction in the area of deposition as well as a restriction with respect to water-circulation in the shelf area during the deposition of unit 2.

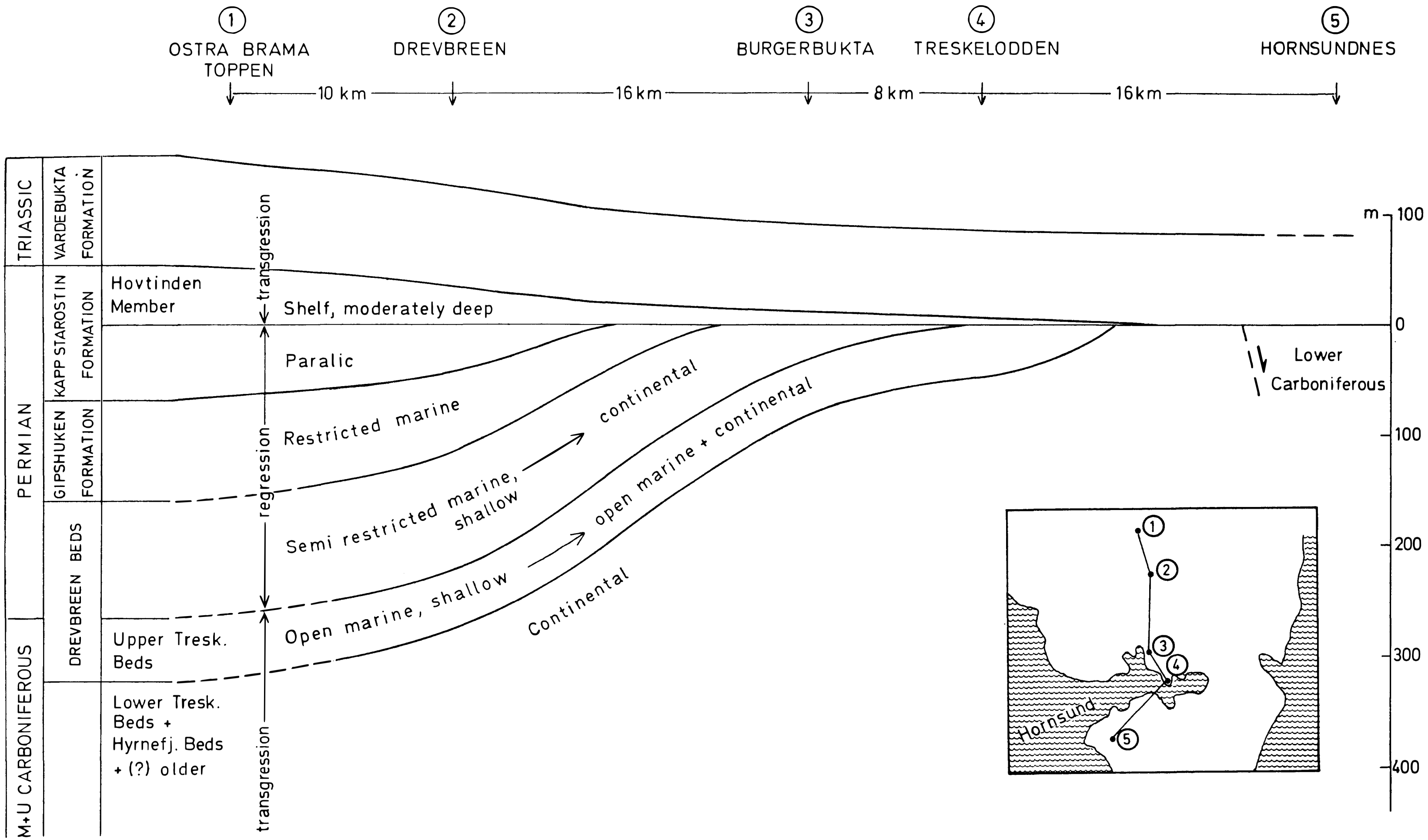

Fig. 6. *Schematic interpretation of the transgressive–regressive phases in the Permo-Carboniferous rocksequence; the Torell Land – Hornsund area.*

It is thus possible that the non-existence of unit 2 at Treskelodden and its reduced thickness at Burgerbukta are primary features rather than being any indication of later erosion.

Transgressive and regressive phases

The major transgressive and regressive phases that occurred during the Upper Carboniferous and Permian had apparently an overall much less pronounced effect on the sediments than the minor regressions and transgressions reflected by the small scale cyclicity in the Drevbreen Beds. It is only by a consideration of the onlap-offlap style of the different formations at the basin margin that the existence of these major phases becomes apparent.

The transition from the continental deposits of the Hyrnefjellet Beds to the marine-continental facies of the Treskelodden Beds is certainly transgressive. Above the Treskelodden Beds an episode of offlap and consequently regression of the sea started on the east flank of the Hornsund-Sørkapp High. The whole sequence up to and including the lower member of the Kapp Starostin Formation can be regarded as part of an overall regressional sequence (Fig. 6). The regression was probably accompanied by only minor erosion in the Hornsund area as the sedimentary record at Drevbreen and Ostra Bramatoppen displays no evidence of any important nearby source area at this time.

With the deposition of the dominantly terrigenous Hovtinden Member the sea again started to transgress the Hornsund-Sørkapp High, a transgression that continued into the Triassic. The recognition of this transgressive phase is in my opinion of importance in assessing the character of the transition from the Permian to the Triassic in Svalbard. This transition zone was for a long time believed to include an important hiatus comprising the upper part of Lower Permian and all of Upper Permian. With the re-examined fossil fauna now including species from the Kungurian Stage of Lower Permian, this gap has been somewhat narrowed but still one lacks a confirmed record of fossils between the Kungurian Stage and the Griesbachian Stage of Lower Triassic (TOZER and PARKER 1968).

It is also possible that the difference in lithology across the transition zone has led to an overestimation of the importance of the gap between the two systems. In fact, while looking at the original composition of the rocks, the Hovtinden Member has stronger affinities with the terrigenous clastic Triassic rocks than with the dominantly limy Permian rocks. In this connection it is of interest to note that the third formation from the bottom in the Triassic succession, the Botneheia Formation, is as cherty in parts of the investigated area as is the Hovtinden Member.

It is apparent that the depositional style that commenced with and was responsible for the upward coarsening nature of the Hovtinden Member, continued and repeated itself several times during the Triassic. The four formations recognized there are all of this nature.

The question now arises as to whether this depositional style which was initiated during the Permian is likely to have terminated after the deposition of the Kungurian Beds and then continued again in early Triassic. According to the stratigraphical scheme of TOZER and PARKER (1968) there appears to have been no appreciable halt in the sedimentation after the deposition of each Triassic formation. In view of this it may be reasonable to assume only a relatively minor hiatus, if any, also between the Permian and Triassic deposits.

Acknowledgements

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I am also indebted to Mr. K. BJØRLYKKE who offered valuable criticism of the manuscript and to Mr. R. J. STEEL who corrected the English language.

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Observations on some Cretaceous and Tertiary sandstone bodies in Nordenskiöld Land, Svalbard

By RONALD J. STEEL[1]

Contents

Abstract

Field measurements on the Helvetiafjellet (Lower Cretaceous) and Battfjellet (? Eocene/Oligocene) Formations in Nordenskiöld Land, Svalbard, suggest that these contain sandstone bodies of two contrasting types of coastline, namely deltaic and beach-dominated coasts, respectively.

Within the former a variety of distributary channel, levee-crevasse splay, crevasse channel and other interdistributary bay sequences are described and their lateral variation within a limited area is illustrated. Within the latter a number of offshore, barrier bar, coastal lagoon, tidal channel and tidal flat sequences are documented within what is interpreted as a major Tertiary regressive episode.

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The main parameters used here for distinguishing between these two types of coastal succession are epsilon cross-strata, herringbone cross-strata, "beach" lamination, wave-generated ripple lamination, degree of bioturbation, bimodal size sorting and overall vertical organization.

Introduction

Sedimentological field measurements on the Helvetiafjellet (Lower Cretaceous) and Battfjellet (? Eocene/Oligocene) Formations in northern Nordenskiöld Land, Svalbard (Fig. 1), suggest that these contain sandstone bodies

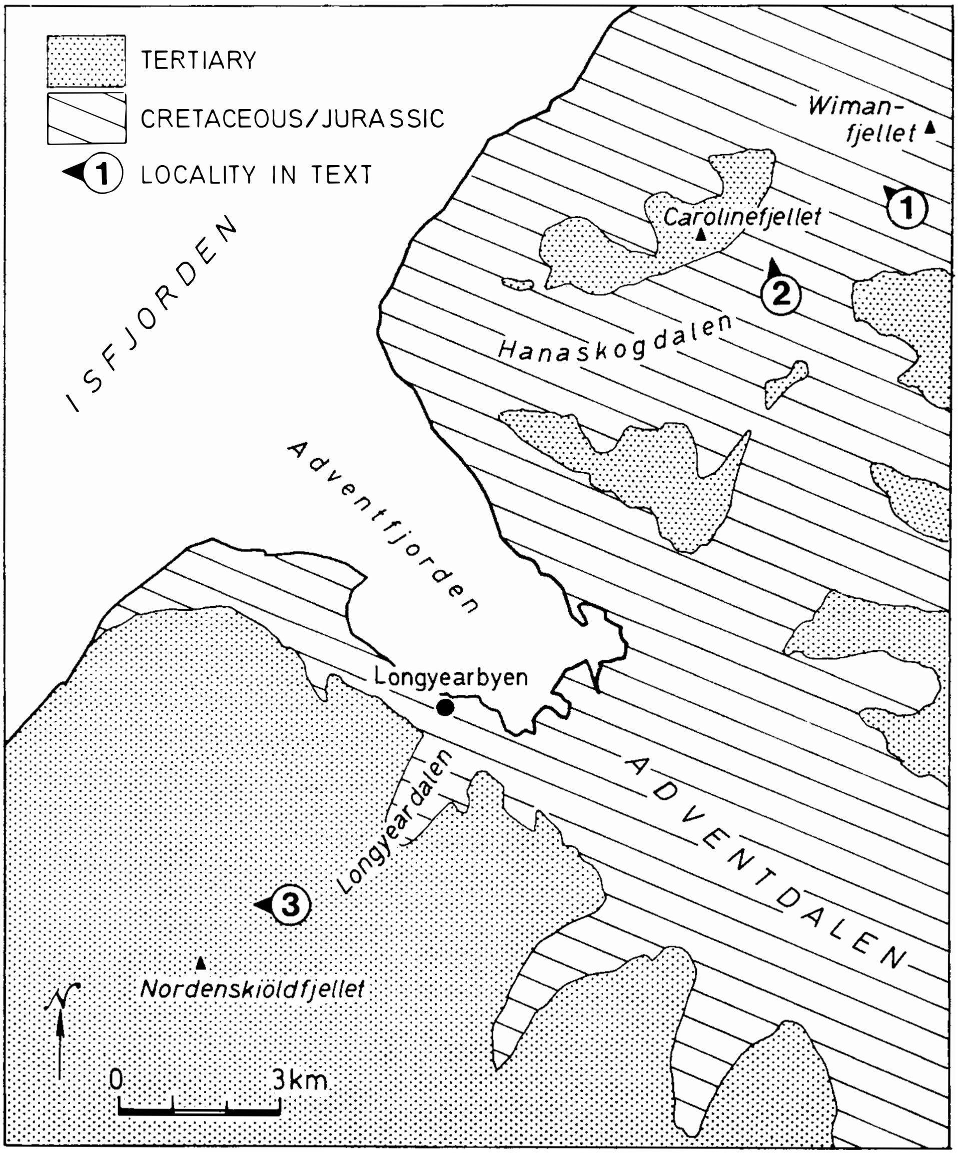

Fig. 1. *Simplified geological map of the area around Adventdalen, showing the localities where the Cretaceous and Tertiary sequences have been examined.*

representative of two quite different types of coastline, namely deltaic and beach-dominated coasts, respectively. The observations recorded here, measured during the summer of 1976, are preliminary in as much as they are taken from only a small number of localities, and are therefore not necessarily typically representative of these Formations in their full lateral development. The vertical profiles are, however, representative of the sedimentation history at these localities, and are used here to illustrate some of the principles of using field measurements for interpreting sedimentology and palaeogeography.

Helvetiafjellet Formation

The Helvetiafjellet Formation is a well-known sequence of sandstones, shales and coal seams (NATHORST 1913; HAGERMAN 1925; PARKER 1967; MAJOR and NAGY 1972; SMITH and PICKTON 1976) of probable Barremian age (PCHELINA 1965).

It was formally divided into two members, a lower Festningen Sandstone Member and a Glitrefjellet Member, by PARKER (1967), although any meaningful subdivision of the succession outside the type area is somewhat dubious, since there has existed some confusion about the delimitation of a "Festningen Sandstone" both prior to (e.g. compare NATHORST 1913 and HAGERMAN 1925) and after PARKER's work (compare MAJOR and NAGY 1972, and SMITH and PICKTON 1976). The cause of the difficulty in recognizing a Festningen Sandstone Member, a rapid lateral facies variation within the Helvetiafjellet Formation, was suggested by SMITH and PICKTON (1976) and is neatly illustrated in Fig. 3, where two measured profiles less than 3 km apart, can scarcely be matched. In Fig. 3 incidentally, the most prominent and most laterally persistent of the sandstone bodies within the Formation is the uppermost, not the lowermost one.

Previous interpretation of the Helvetiafjellet Formation has mostly been made only at a generalized level, e.g. non-marine, deltaic (SMITH and PICKTON 1976), on the basis of the coal seams, plant remains and non-marine bivalves, although in a more detailed analysis from a locality on Sørkapp Land, EDWARDS (1976) made an interpretation in terms of fluvial fining-upward cyclothems. EDWARDS (1976) raised the pertinent question as to why the upwards transition from the quiet water marine shales of the Rurikfjellet Formation to the non-marine fluvial sandstones of the Helvetiafjellet Formation often appears to be rather abrupt in Svalbard, although he demonstrated in Sørkapp Land the presence of a likely sandy shoreline facies in an intermediate position, at the top of the Rurikfjellet Formation. The present study of the Helvetiafjellet Formation is on Carolinefjellet and Wimanfjellet in the neighbourhood of MAJOR's (1963, **in** MAJOR and NAGY 1972) type section on Helvetiafjellet (Fig. 1). It is argued below that although the Helvetiafjellet Formation is dominated by fluvial deposits the resultant sandstone bodies are of coastal (deltaic) type and

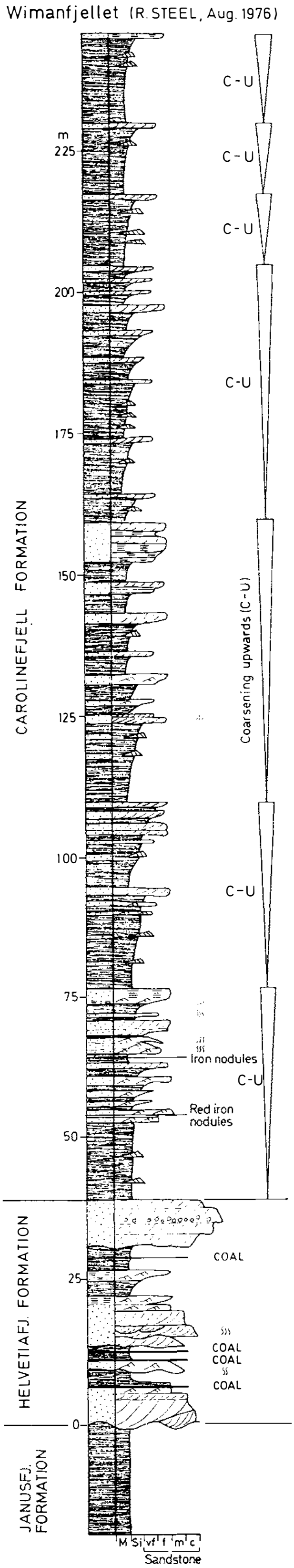

Fig. 2. *The Helvetiafjellet Formation shown within the context of the underlying and overlying sequences on Wimanfjellet. Only part of Carolinefjellet Formation is shown. For legend see Fig. 3.*

the intervening sequences of fines show signs of marine influence. Consequently any abrupt marine/non-marine transition on this area may be less impressive than it appears.

Helvetiafjellet Formation on Wimanfjellet and Carolinefjellet

Detailed logging of Helvetiafjellet Formation on Wimanfjellet and Carolinefjellet shows the sequence to be almost 40 m thick there (Figs. 2, 3). The boundary with the overlying marine Carolinefjellet Formation is sharp at both localities, but the boundary with the underlying marine Janusfjellet Formation is sharp at the former and transitional at the latter locality (Fig. 3). The most prominent feature of the succession is the presence of three multistorey sandstone bodies, varying from 6 to 9 m in thickness, separated from each other vertically by sequences of mudstones/siltstones, fine sandstones and coals (Fig. 3). It is argued below that the coarsest sandstones were deposited in fluvial distributary channels and that the mudstones and coals accumulated in quieter adjacent areas, probably in interdistributary bays. A more detailed look at the vertical organization of the lithologies suggests the following three basic types of sequence:

1. *Distributary channel sequences*

These are the main sandstone bodies. They are constructed from tens of planar or trough cross-stratified sets, some of which are good examples of epsilon type (ALLEN 1965a), showing trains of ripples directed along the strike of the

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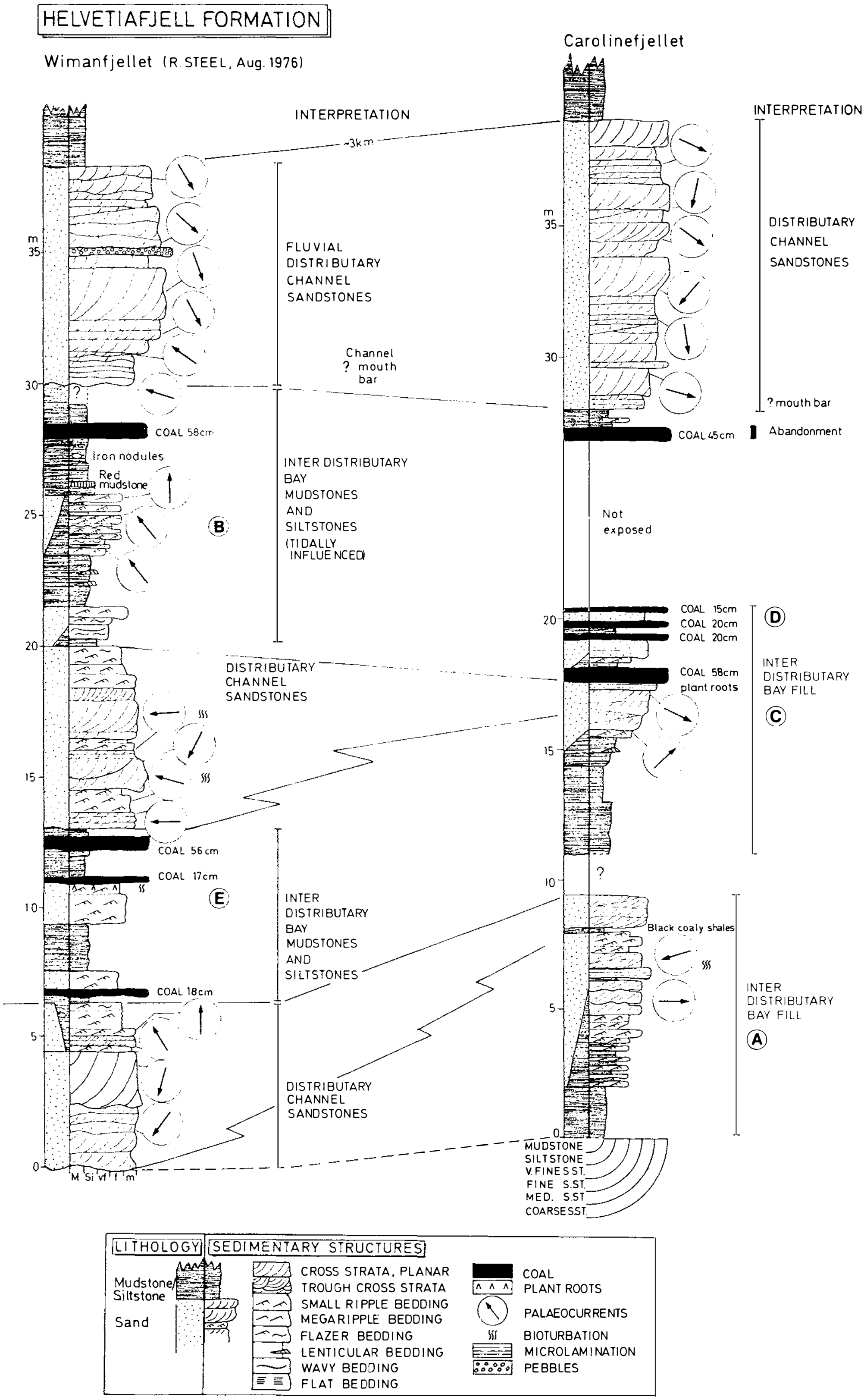
Fig. 3. *Details of lithology, structure and palaeocurrents within Helvetiafjellet Formation on Wimanfjellet and Carolinefjellet. The letters A-E refer to more detailed interpretation shown on Fig. 5.*


HELVETIAFJELL FORMATION
Wimanfjellet (R. STEEL, Aug. 1976)
Carolinefjellet
INTERPRETATION
~3km
FLUVIAL
DISTRIBUTARY
CHANNEL
SANDSTONES
Channel
? mouth
bar
COAL 58cm
Iron nodules
Red
mudstone
INTER DISTRIBUTARY
BAY
MUDSTONES
AND
SILTSTONES
(TIDALLY
INFLUENCED)
B
DISTRIBUTARY
CHANNEL
SANDSTONES
COAL 56cm
COAL 17cm
E
INTER
DISTRIBUTARY
BAY
MUDSTONES
AND
SILTSTONES
COAL 18cm
DISTRIBUTARY
CHANNEL
SANDSTONES
M Si vf f m
DISTRIBUTARY
CHANNEL
SANDSTONES
? mouth bar
COAL 45cm
Abandonment
Not
exposed
COAL 15cm
COAL 20cm
COAL 20cm
D
COAL 58cm
plant roots
INTER
DISTRIBUTARY
BAY FILL
C
?
Black coaly shales
INTER
DISTRIBUTARY
BAY FILL
A
MUDSTONE
SILTSTONE
V. FINE S.ST.
FINE S.ST.
MED. S.ST.
COARSE S.ST.
LITHOLOGY
SEDIMENTARY STRUCTURES
Mudstone/
Siltstone
Sand
CROSS STRATA, PLANAR
TROUGH CROSS STRATA
SMALL RIPPLE BEDDING
MEGARIPPLE BEDDING
FLAZER BEDDING
LENTICULAR BEDDING
WAVY BEDDING
FLAT BEDDING
COAL
PLANT ROOTS
PALAEOCURRENTS
BIOTURBATION
MICROLAMINATION
PEBBLES

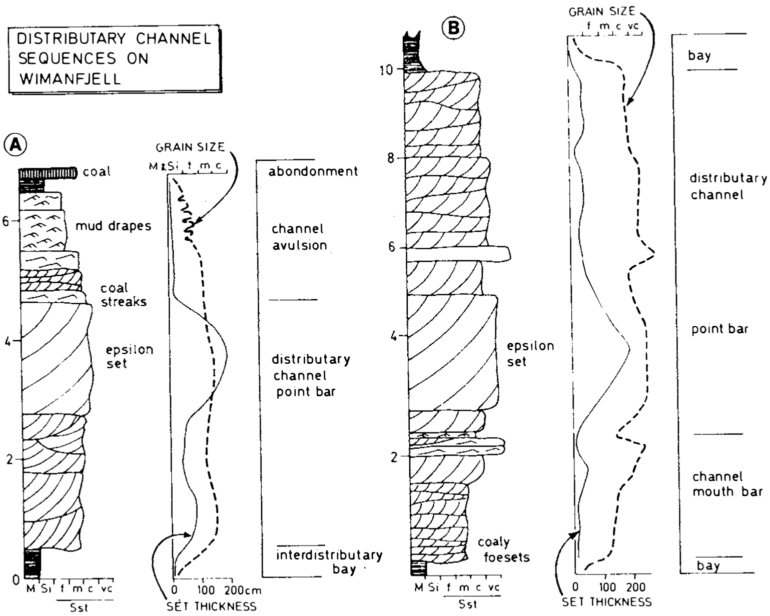


Fig. 4. *Details, with interpretation, within some of the distributary channel sandstone bodies within the Helvetiafjellet Formation on Wimanfjellet. See Fig. 3 for legend.*

major foresets or accretion surfaces. Most of these sequences do not show a simple fining-upwards (compare with Sørkapp Land observations of EDWARDS 1976) but rather an initial coarsening and thickening-upwards of sets followed by a fining and thinning-upwards of sets in the upper half of the bodies (Fig. 4). Some of the sequences are more complex, with repeated coarsening-upwards/thickening-upwards sequences or a more random vertical organization (Fig. 3). Some of the sandstones are well bioturbated and there are occasional conglomerates.

Epsilon cross-stratified sets are well-known from point bars in fluvial (e.g. LEEDER 1973) or fluvio-deltaic (e.g. ELLIOTT 1975) sinuous channels. These sandstone sequences here in Helvetiafjellet Formation, laterally discontinuous and separated from each other by coals and dark shaley mudstones, are interpreted in terms of delta plain distributary or major crevasse channel fingers which prograded out across mouth bars (basal coarsening-upwards) into the adjacent interdistributary bays. The degree of fining-upwards at the top of the channel sequences may reflect the subsequent rate of channel abandonment or avulsion at that point (Fig. 4a).

The fact that each of these sandstone bodies within the Formation here has a

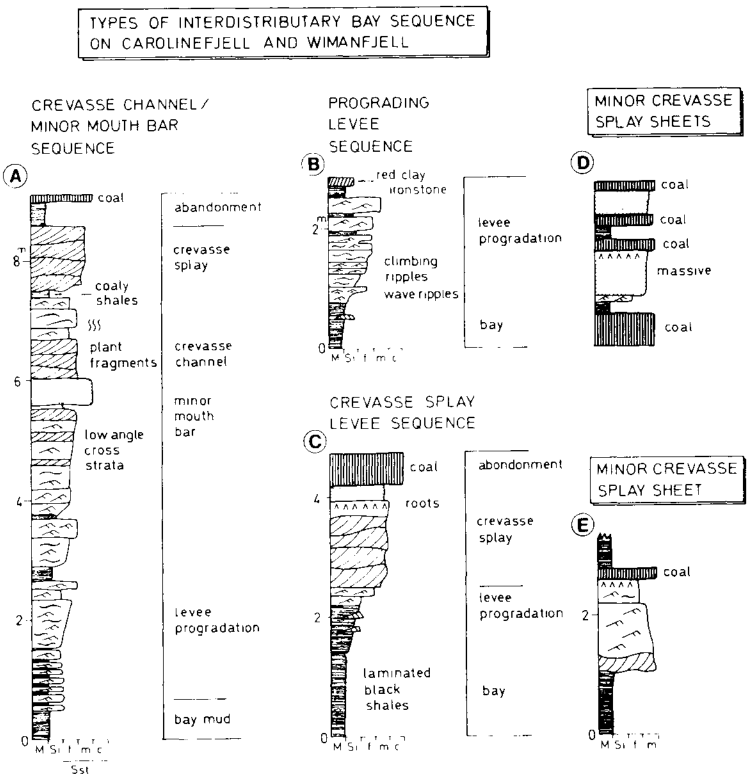


Fig. 5. *Details, with interpretation, within some of the interdistributary bay fill sequences in Helvetiafjellet Formation. See Fig. 3 for legend.*

similar appearance and origin further indicate that it may be neither necessary nor desirable to formally subdivide the succession into members here.

2. *Levee-crevasse splay or crevasse channel sequences*

There are a number of heterogeneous sandstone sequences often showing a distinct coarsening-upwards from mudstones and siltstones with a gradual influx of sharp-based, mud-draped, ripple laminated sandstones up to planar or trough cross-stratified sandstone sets. Such sequences can vary from 1 m to 7 m in thickness, are commonly capped by a coal seam and usually appear to have accumulated from currents which were directed oppositely or at a high angle to the direction of flow in the main distributary channels (Fig. 3). The coarsest, cross-stratified sets at the top of these sequences are generally much more thinly bedded than the sandstones in the main sequences (compare Figs. 4 and 5).

Because the sequences have a considerable amount of interbedded fines, it is thought that they are only partly dominated by flood incursions from the main distributary channels. The common wavy and lenticular bedding and abundant mudstone drapes indicate rapidly fluctuating current strength with common periods of sedimentation from suspension. Similar coarsening-upwards sequences are known from both modern (e.g. COLEMAN et al. 1964; OOMKENS 1970) and ancient (e.g. ELLIOTT 1974) delta plain deposits, where crevassing, commonly related to levee progradation, has caused periodic flooding of sediment from the main distributary channels out into the interdistributary bays. The probable lateral correlation of two sequences of this type on Carolinefjellet with two coarser grained distributary channel sequences on Wimanfjellet, together with the palaeocurrent patterns, supports this notion (Fig. 3). Variation in the type of developed sequences would be expected depending on whether the crevassing was sudden and temporary into the bay (e.g. Fig. 5 d, e), was related to levee progradation (Fig. 5b, c), or was channellized and semipermanent, possibly associated with minor mouth bar development (e.g. Fig. 5a) (see also ELLIOTT 1974).

3. *Interdistributary bay sediments.*

Interdistributary bays have been broadly defined by COLEMAN et al. (1964) as the areas between deltaic distributaries. They may, therefore, be open to the sea or may be partly or completely closed, as coastal lakes or lagoons. In as much as interdistributary bay infilling is dominated by flood-generated incursions from the distributaries, either by overbank flooding, crevassing or by channel avulsion (Fig. 5) (ELLIOTT 1974), the previously described levee-crevasse sequences are bay-fill elements. In addition, however, bay conditions may be quiet or ponded, may be subject to vegetative and subaerial processes (ALLEN 1965 b), or may be subject to tides, passing shorewards into tidal flats (VAN ANDEL 1967), or to wave processes (COLEMAN and GAGLIANO 1965). In the Helvetiafjellet Formation, the coal seams, dark mudstones and occasional ironstone nodules lying between the sandier sequences are considered to represent the quieter bay conditions, or those parts of the bay furthest from the distributary channels. The very common lenticular, wavy (Fig. 5) and flazer bedding in the lower parts of bay-fill sequences, together with the contrasting palaeocurrent directions between these deposits and the main channel sandstones (Fig. 3), suggests that the bays may have been tidally influenced, and therefore at least partly open to the sea.

Discussion

On the basis of the present examination of the Helvetiafjellet Formation, in the neighbourhood of its *type* section, together with a review of previous published observations, the following suggestions are made:

1. The Helvetiafjellet Formation here is made up of a series of sandstone bodies which are, locally at any rate, not laterally persistent. A comparison of Fig. 3 with Fig. 2 of SMITH and PICKTON (1976) shows clearly that the total number of these sandstone bodies present vertically in the sequence across northern Nordenskiöld Land varies considerably. In

addition, the uppermost of the sandstone bodies here is thicker, coarser and more laterally persistent than any of the underlying ones (Fig. 3), although palaeogeographically they may have similar significance. These features suggest that an attempt to identify or map a unique "Festningen Sandstone Member" throughout the region will be unsuccessful.

2. In this area, neither the sand bodies themselves nor the sand sequences together with the intervening fines can be interpreted simply in terms of fining-upwards fluvial sequences. On the contrary, coarsening-upwards dominates in both the fine members and coarse members of the succession. An interpretation in terms of delta distributary and crevasse channels and interdistributary bays implies a coastal situation. Bedding types and palaeocurrents in the bay sequences further suggest tidal influence in places, although the Formation is very much dominated by flood-generated discharge from the distributaries. Possibly analogous channel and sheet sandstone bodies are presently forming in a variety of distributary channels, crevasse channels, crevasse splays and mouth bars of the Mississippi Delta (Fig. 6 A, B). The analogy between the Helvetiafjellet Formation and the Mississippi Delta is deliberately taken no farther than this level, in a comparison of subenvironments. Until the formation is studied in its full lateral development it will not be possible to comment on the geometry of the delta lobes or on the delta type represented.
3. The deltaic coast interpretation made for the Helvetiafjellet Formation here is consistent with the likely offshore marine nature of the overlying and underlying formations. There is clearly an important regression involved at this level throughout much of Svalbard (HAGERMAN 1925; ORVIN 1940), though the details of the palaeogeography are far from clear, as yet. At one of the logged localities here (Carolinefjellet) there appears to be no abrupt lithological change between the base of Helvetiafjellet Formation and the underlying Janusfjellet Formation, another indication of likely marine influence in the Helvetiafjellet Formation bays. At other localities in Svalbard this junction is commonly abrupt, although considered conformable (HAGERMAN 1925; PARKER 1967).

Battfjellet Formation

General

The Battfjellet Formation (FLOOD et al. 1971) is one of the least known portions of the Tertiary succession in the Spitsbergen trough (Fig. 7). In the area examined here (Fig. 1), it consists of a sequence of mainly siltstones and sandstones which have structures and lithological organization suggestive of deposition in a marginal marine area. It is important to note that the formation is not a discrete stratigraphic unit which is uniform and easily definable over a

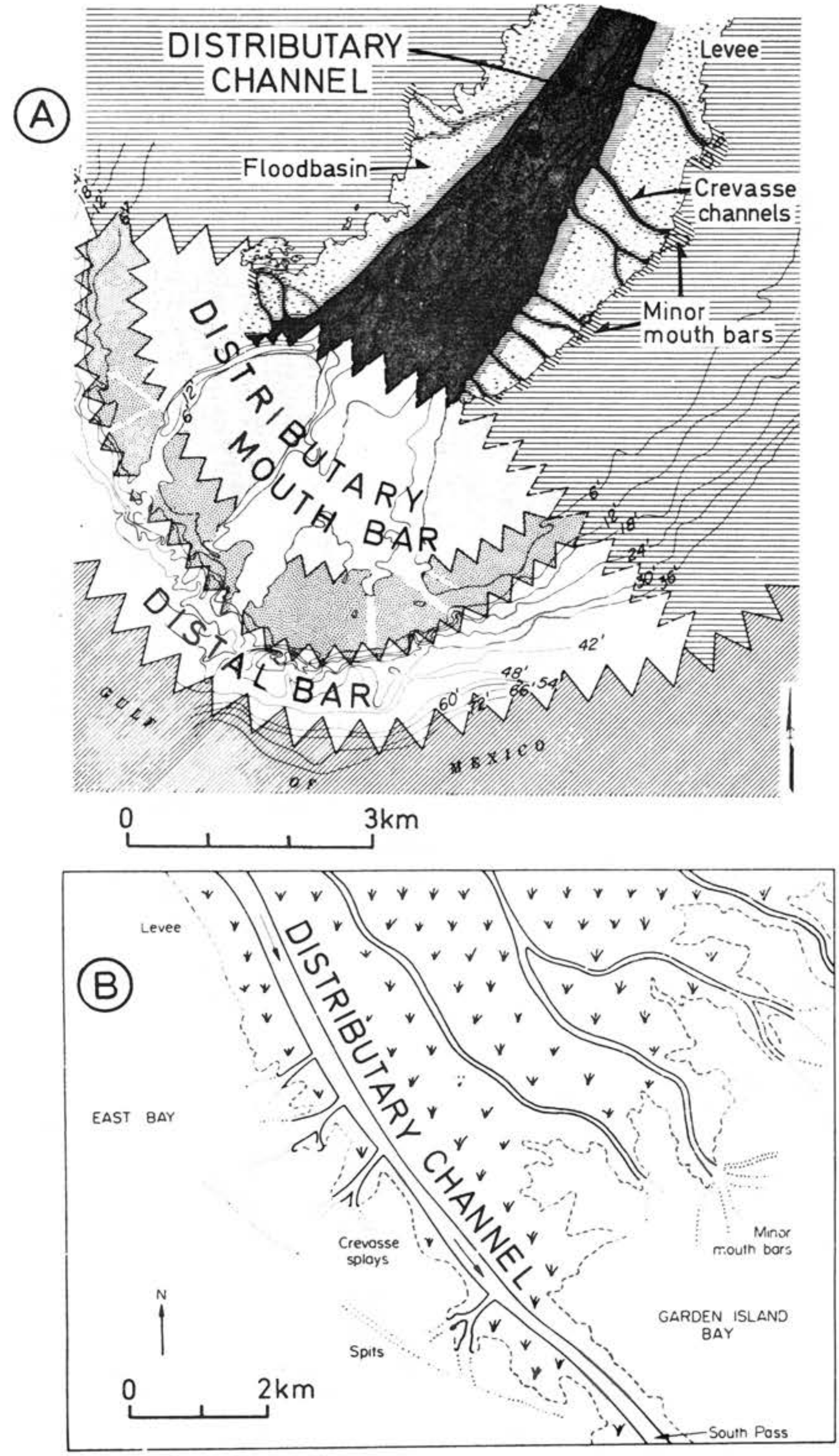


Fig. 6. *The distribution of areas of distributary mouth bar, minor mouth bar, levee, crevasse channel, crevasse splay and interdistributary bay sedimentation on the South-West Pass (A) and South Pass (B) of the modern Mississippi Delta (from* BERNARD *et al. 1970, and* ELLIOTT *1974).*

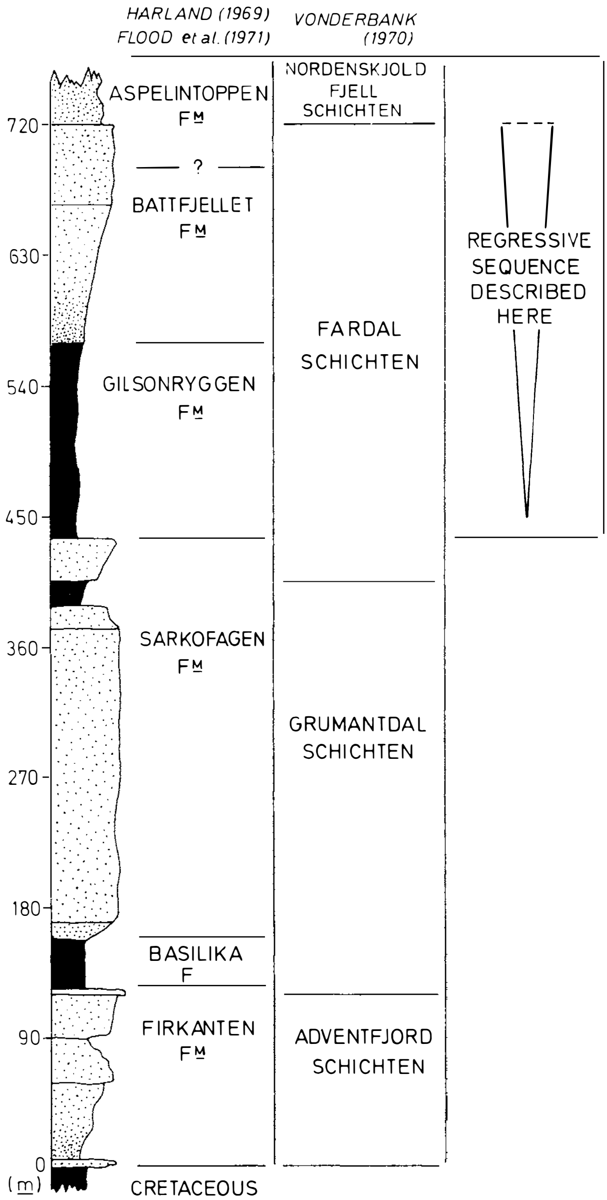
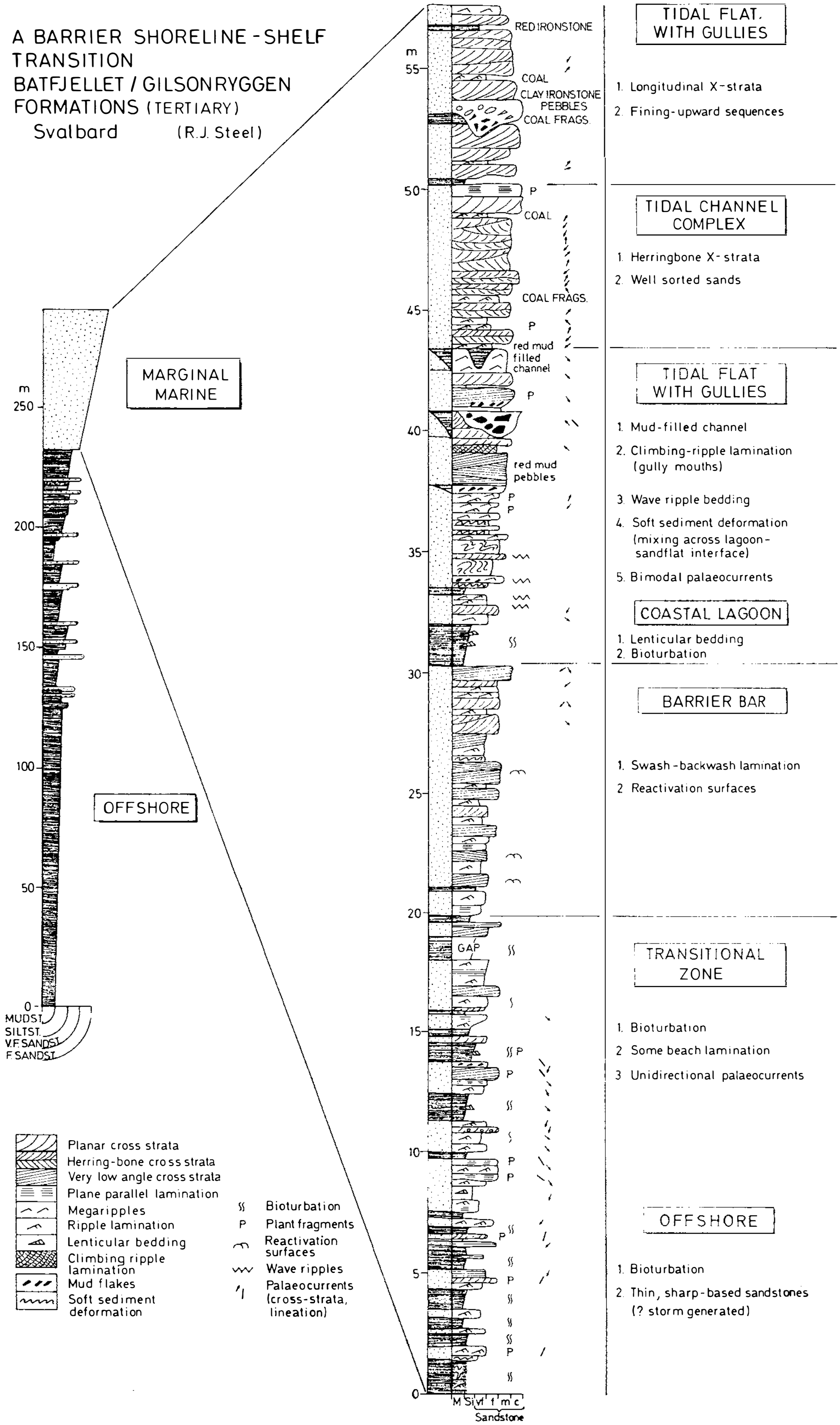


Fig. 7. *A simplified profile through the Tertiary succession in the northern part of Nordenskiöld Land, showing the different formation boundary positions for the two main classification systems. That portion of the succession described here is also shown.*

widespread area. It clearly grades downwards into the shales of the underlying Gilsonryggen Formation and upwards into the (?) fluvial Aspelintoppen Formation (Fig. 7). In this sense these three formations are closely related vertically, probably interfinger laterally and together form an important regressive succession in the central Tertiary trough.

Previous descriptions of the Battfjellet Formation have been brief and interpretations made only at a very generalized level, e.g. shallow marine, estuarine (MAJOR and NAGY 1972; KELLOGG 1976). Many workers have noted that this



A BARRIER SHORELINE - SHELF TRANSITION
BATFJELLET / GILSONRYGGEN FORMATIONS (TERTIARY)
Svalbard (R.J. Steel)
MARGINAL MARINE
OFFSHORE
m
250
200
150
100
50
0
MUDST.
SILTST.
V.F. SANDST.
F. SANDST.
Planar cross strata
Herring-bone cross strata
Very low angle cross strata
Plane parallel lamination
Megaripples
Ripple lamination
Lenticular bedding
Climbing ripple lamination
Mud flakes
Soft sediment deformation
Bioturbation
Plant fragments
Reactivation surfaces
Wave ripples
Palaeocurrents (cross-strata, lineation)
RED IRONSTONE
COAL
CLAY IRONSTONE PEBBLES
COAL FRAGS.
COAL
COAL FRAGS.
red mud filled channel
red mud pebbles
GAP
M Si vf f m c
Sandstone
55
50
45
40
35
30
25
20
15
10
5
0
TIDAL FLAT. WITH GULLIES
1. Longitudinal X-strata
2. Fining-upward sequences
TIDAL CHANNEL COMPLEX
1. Herringbone X-strata
2. Well sorted sands
TIDAL FLAT WITH GULLIES
1. Mud-filled channel
2. Climbing-ripple lamination (gully mouths)
3. Wave ripple bedding
4. Soft sediment deformation (mixing across lagoon-sandflat interface)
5. Bimodal palaeocurrents
COASTAL LAGOON
1. Lenticular bedding
2. Bioturbation
BARRIER BAR
1. Swash-backwash lamination
2. Reactivation surfaces
TRANSITIONAL ZONE
1. Bioturbation
2. Some beach lamination
3. Unidirectional palaeocurrents
OFFSHORE
1. Bioturbation
2. Thin, sharp-based sandstones (? storm generated)

formation has more well-developed stratification compared to the other Tertiary formations (including NATHORST (1910) in his naming of the sequence as "Flaggy sandstone series"). KELLOG (1975, p. 476) made an important large-scale observation concerning lateral variation and the diachronous nature of the formation, in noting that some sandstone beds and groups of beds die-out laterally after having formed very large-scale "foresets".

The type section for the formation, on Battfjellet is found some 20 km to the SE of the section described here. It has been measured and described by MAJOR (in MAJOR and NAGY 1972).

Battfjellet Formation on Nordenskiöldfjellet

The Gilsonryggen-Battfjellet succession with detailed measurements through the uppermost, sandy 60 m of the Battfjellet Formation, as seen on Nordenskiöldfjellet (Fig. 1), is shown in Fig. 8. The sequence as a whole shows a general coarsening-upwards. A number of lithofacies divisions have been made from the base of the succession upwards, representing segments of progressively more shorewards aspect.

1. *Offshore-transitional zone sequences* (0–245 *m, Fig.* 8)

From the base of the succession up to a level of about 130 m there is a monotonous sequence of dark, silty marine shales with occasional scattered chert pebbles. There is a gradual incoming of sharp-based, often bioturbated very fine-grained sandstones, which can be ripple-laminated, massive or show soft sediment deformation. One of the first of these sandstone beds shows well-developed recumbent folding (Fig. 9). Towards the top of this zone sandstone beds become thicker and more frequent, often forming small (2–5 m), coarsening-upwards sequences in which lenticular bedding passes up through ripple lamination to plane parallel lamination or very low angle cross-stratification. The uppermost portions of such sequences often have an abundance of well-oriented plant fragments, well-developed asymmetric wave-rippled cappings (Fig. 10), and can have thin conglomeratic horizons. Palaeocurrents measured from cross-stratification, ripple lamination, parting lineation and plant fragment orientations show that sediment transport in this zone was largely towards SSW–SSE (Fig. 8).

The fine-grained nature of the sediment, occasional marine fossils (LIVŠIC 1965; VONDERBANK 1970) and frequent thorough bioturbation suggest an offshore depositional site for this zone. The thin, sharp-based sandstone or siltstone beds are likely to have been storm-generated but the frequent wave-rippled cappings emphasize shallow water depths. The upwards increase in the sandstone/shale ratio marks an approach to the shoreline, with indiivdual small coarsening-upwards sequences being a result of offshore shoaling, perhaps

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Fig. 8. *Details of lithology, structure, palaeocurrents and interpretation through the Gilsonryggen and Formations Formations on Nordenskiöldfjellet.*

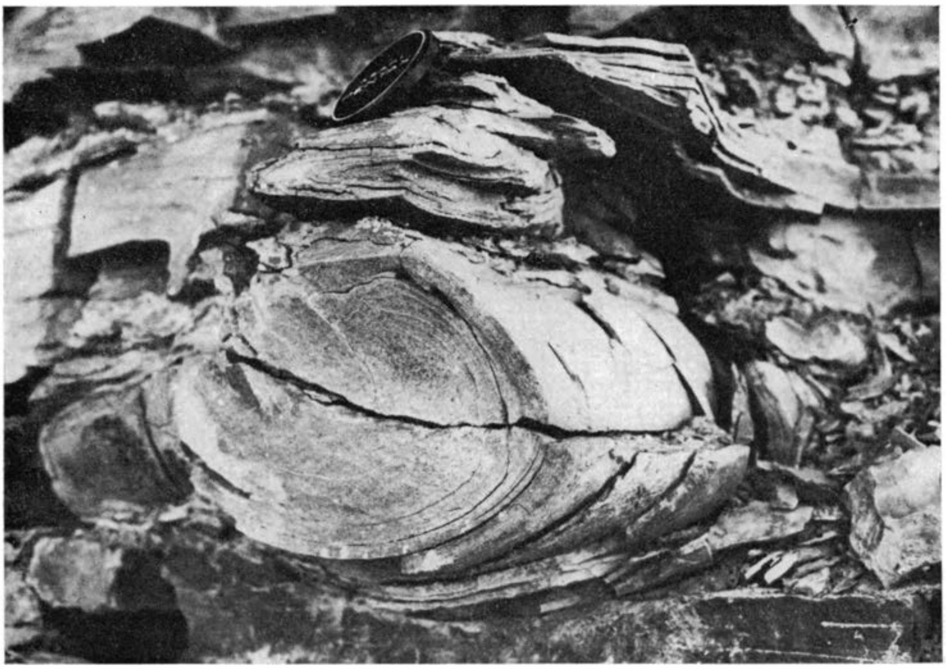

Fig. 9. *Soft sediment folding within sandstone beds near the base of Battfjellet Formation on Nordenskiöldfjellet. Lens cap is 5 cm in diameter.*

with occasional emergence where plane parallel lamination or low angle cross-strata are developed. Some typical depositional sequences developed in these zones of shoaling are shown in Fig. 10.

2. *Barrier bar sequence (245–256 m, Fig. 8)*

This sequence is characterized by a coarsening upwards within well-sorted sandstones, a scarcity of mudstone/siltstone and plane parallel lamination or very low angle cross-stratified sets within which individual foresets become thinner upwards (hummocky cross-strata of HARMS 1975) (Fig. 10). Relatively thin, rippled, very fine-grained sandstone interbeds are not uncommon. Sandstone sets very commonly have prominently rounded megarippled upper surfaces.

The absence of fines in this 10 m sequence suggests a high energy regime compared to the underlying succession, and probably the location of some type of bar. The dominance of plane parallel or low angle strata, suggestive of a beach zone, indicates that the bar was probably emergent, and that the coarsening-upwards, a culmination of a much larger scale coarsening-upwards (Fig. 8), resulted from the seawards progradation of a barrier bar. The overall coarsening-upwards of the succession reflects, in a general way, a gradient of

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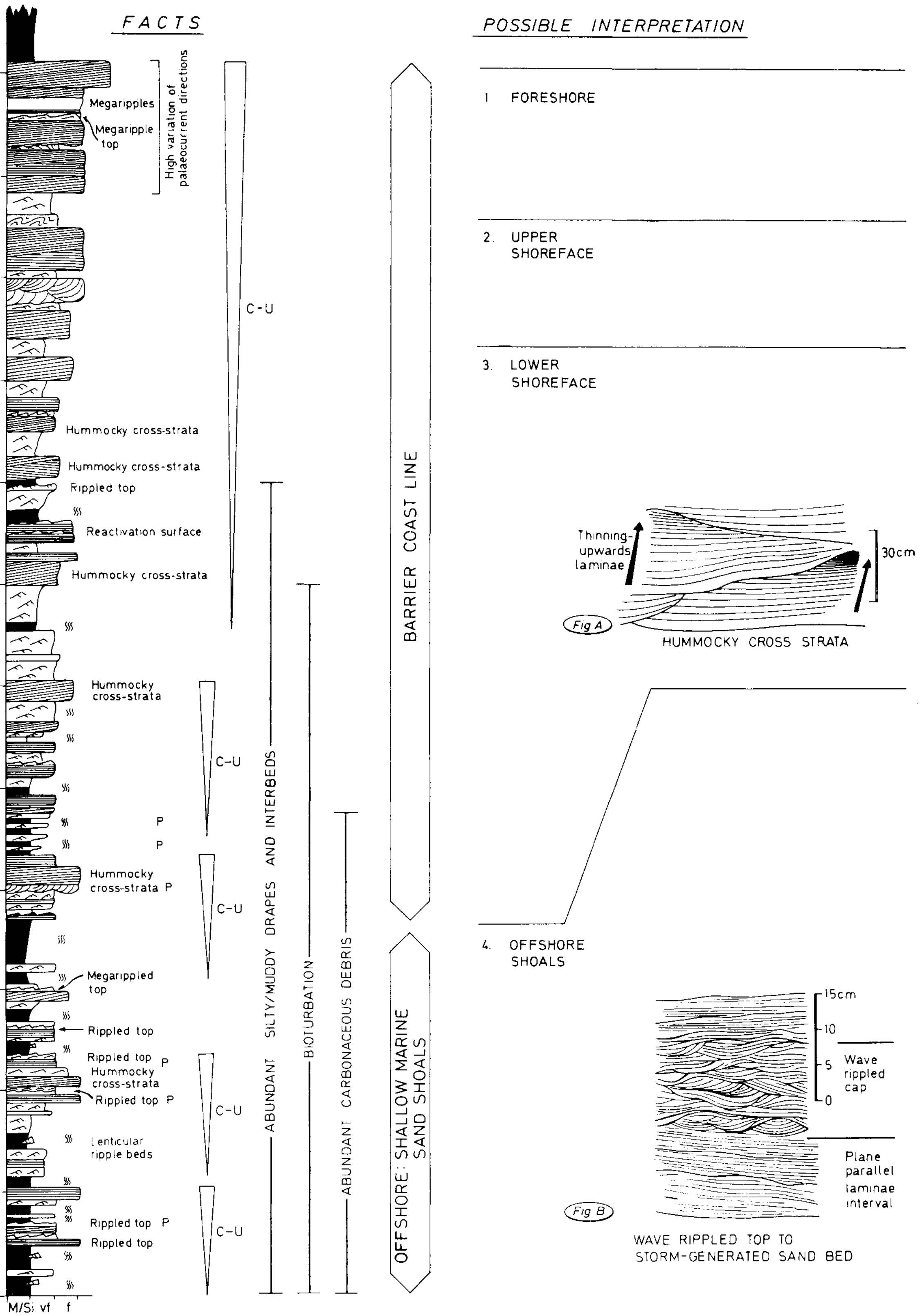
Fig. 10. *Details of subsequences and interpretation within the barrier bar/transition zone of Battfjellet Formation on Nordenskiöldfjellet. For legend see Figure 8.*

BARRIER BAR — TRANSITIONAL ZONE



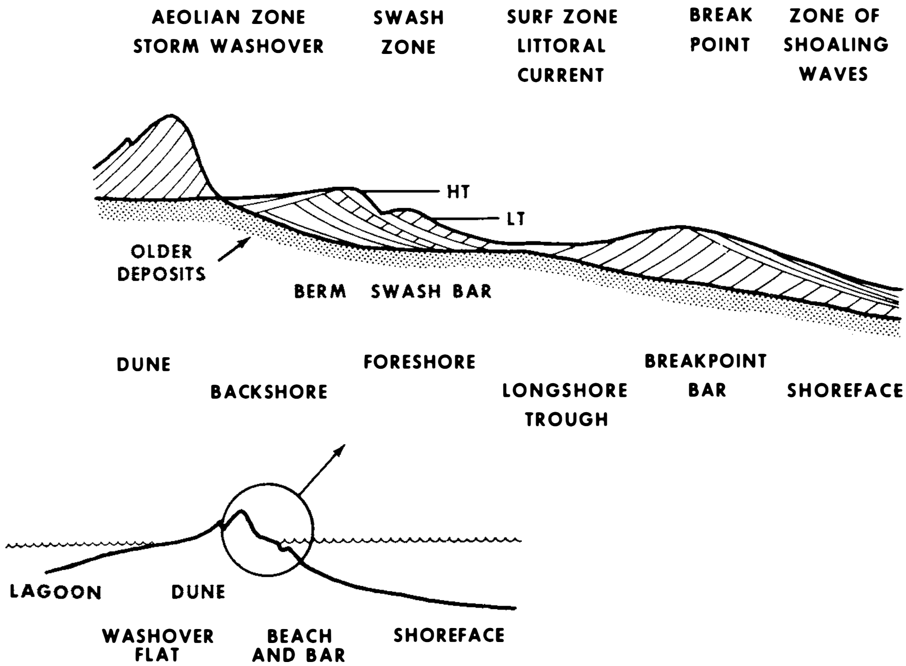


Fig. 11. *Morphology of the open coast and its hydraulic provinces (modified after* Swift *1976).*

shorewards increasing grain-size at any level in time. The slope and grain size gradients of modern shorefaces, occurring mainly in the zone of wave-driven flow, have been generally considered to be a response to the regime of shoaling waves seawards of the breakpoint (Fig. 11), in which depth, as a function of distance from shore, is itself a function of littoral wave power, sediment discharge and grain size (Johnson 1919; Wright and Coleman 1972; Swift 1976).

A fourfold division has been tentatively made within this succession, a subdivision largely predictable from the morphology of modern shorelines (e.g. Clifton et al. 1971), or from well documented ancient sandy shorelines (e.g. in the Upper Cretaceous of the Rocky Mountains; Weimar 1960, Howard 1966).

a) *Foreshore deposits* are identified in the uppermost (2–4 m), coarsest part of the sequence (Fig. 10). They are dominated by plane parallel lamination and by very low angle cross-stratification which have characteristics similar to those of the swash cross-strata on modern foreshores (see Thompson 1937). Sets of such cross-strata here have a high palaeocurrent variance and are sometimes capped by megaripples.

b) *Upper shoreface deposits* of somewhat similar character but with more steeply dipping cross-strata, sometimes of trough form, are interpreted in terms of (?) longshore bar development. Interbedded rippled fine sandstones (Fig. 10) presumably formed in the channels adjacent to these bars.

c) *Lower shoreface deposits* are more variable in grain size, have more interbedded fines and have less frequent cross-stratification. A particular type of cross-strata occurs in which sets are irregularly bounded, low angle foresets become distinctly thinner upwards in the set, and are often capped by silt or mud (Fig. 10). These sets resemble the hummocky cross-strata of HARMS (1975) and so may have been generated by storm waves and bottom surges in shallow offshore regions.

d) *Farther offshore* and beyond the deeper parts of the shoreface, storm-generated, laminated and hummocky strata become enveloped by thick amounts of well bioturbated mudstones and siltstones. In this transitional zone there was periodic growth of offshore sand shoals on which wave-generated megaripples or, more commonly, ripples (Fig. 10) developed. REINECK and SINGH (1971) note that in the lower shoreface and beyond, on many coasts, sediment is moved mainly during storms and the bottom surface is normally abundantly covered by wave ripples, although these latter are commonly destroyed during subsequent storm events.

3. *Coastal lagoon – tidal flat sequence (256–269 m, Fig. 8)*

This sequence, in contrast to the underlying well sorted, barrier bar sandstones, is remarkable because of the poorly sorted nature of its sediments. More accurately, there is a spectacular interbedding of very well sorted, megarippled sandstones with very poorly sorted, often clearly bi-modal sediments. This contrast is highlighted by a colour (white-yellow) alternation and by the soft sediment deformation in many of the bi-modal (yellow) beds (Fig. 12 B-D). The well sorted (white) sandstones are dominated, in further contrast, by well developed, wave generated ripple and megaripple bedding (Fig. 12 C). Associated with these deposits, especially low in the sequence, there are mudstones showing in places paper-thin lamination, thorough bioturbation or wavy/lenticular sand layers. Higher in the sequence there are a number of large (>1 m deep) channels which are filled with red mudstone or mudstone blocks (Fig. 12 D). These are associated with sandstones with climbing ripple lamination and low angle cross-stratification.

This part of the succession has been interpreted in terms of a coastal lagoon with associated tidal flats/beaches primarily because of its mixture of well-sorted and poorly sorted deposits and because of its stratigraphic position between a barrier bar sequence and a tidal channel complex (Fig. 8). Tidal lagoon/barrier bar coastlines of the type envisaged here are well known from the present day (Fig. 13). About 13% of present coastline and up to 50% of the eastern coast of the U.S.A. south of New York is of this type (ZENKOWITCH 1969; PHLEGER 1969).

In the present sequence (as in modern coastal lagoons, e.g. see WARME 1971) the poor sorting or bi-modality of some of the deposits is due to a mixing of lagoonal muds with storm or river-introduced, well sorted sands. The mixing evidently took place by loading and slumping caused by the reversed density gradients set up by this interbedding. Such gradients were probably exag-

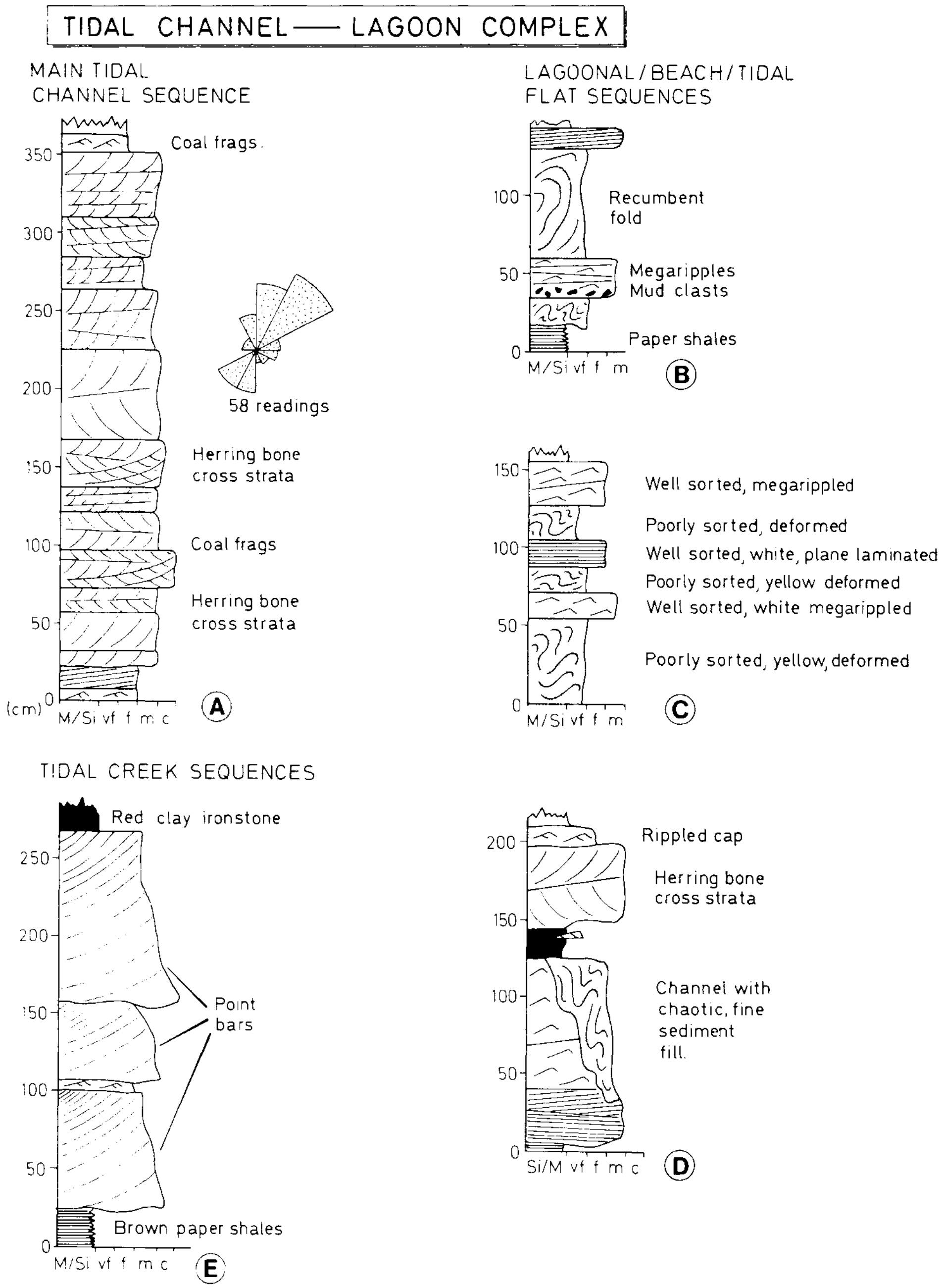


Fig. 12. *Details of lithology, structure and interpretation within sequences in the tidal channel/lagoon complex. Occasional occurrences of paper-thin shales probably indicate locally closed lacustrine areas.*

gerated by further sorting and winnowing of the sands by wave action, as is evident from the well developed wave-generated structure in most of the undeformed sandstones. Bi-modal palaeocurrents in some of the sandstones together with the overlying tidal channel complex clearly indicate that the lagoon was open to the sea.

The large mud-filled channels are further evidence of a tidal lagoon environment because high velocity tidal currents functioning within the quiet water environment of a lagoon may typically create channels which are later recipients of suspension-deposited sediment (MASTERS 1967).

Despite the local abundance of plant debris and coal fragments at certain levels in the sequence (Fig. 8) it is uncertain as to whether there was direct fluvial input, on the landward side of the lagoon. Much of this debris may well have been introduced by longshore drift from a more distant delta system (e.g. as along the barrier coast of the Gulf of Mexico, Fig. 13 B, D) or, on the other hand, the present sequence plus the overlying tidal channel complex could be interpreted in terms of a tidal delta-lagoon complex (eg. see Gulf Coast example, Fig. 13 C). One problem with the latter interpretation is that this sequence does not cut down erosively into the underlying barrier sequence, as might be expected, in places, if it represented a tidal delta/inlet complex.

4. *Tidal channel complex* (*269–276 m, Fig. 8*)

This sequence is composed of mainly well sorted, medium grained sandstones with many good examples of herringbone cross stratification and an overall bimodal palaeocurrent pattern (Fig. 12 A). Many of the cross-stratified sets have concentrations of coal fragments along their toes and in the coarse grained sandstones at the top of the sequence there are concentrations of plant debris. In the lower part of the sequence there are some finer, rippled interbeds.

This sequence together with the underlying sequence has the four main characteristics necessary for its acceptance as tidal flat or tidally dominated deposits (see GINSBURG 1975):

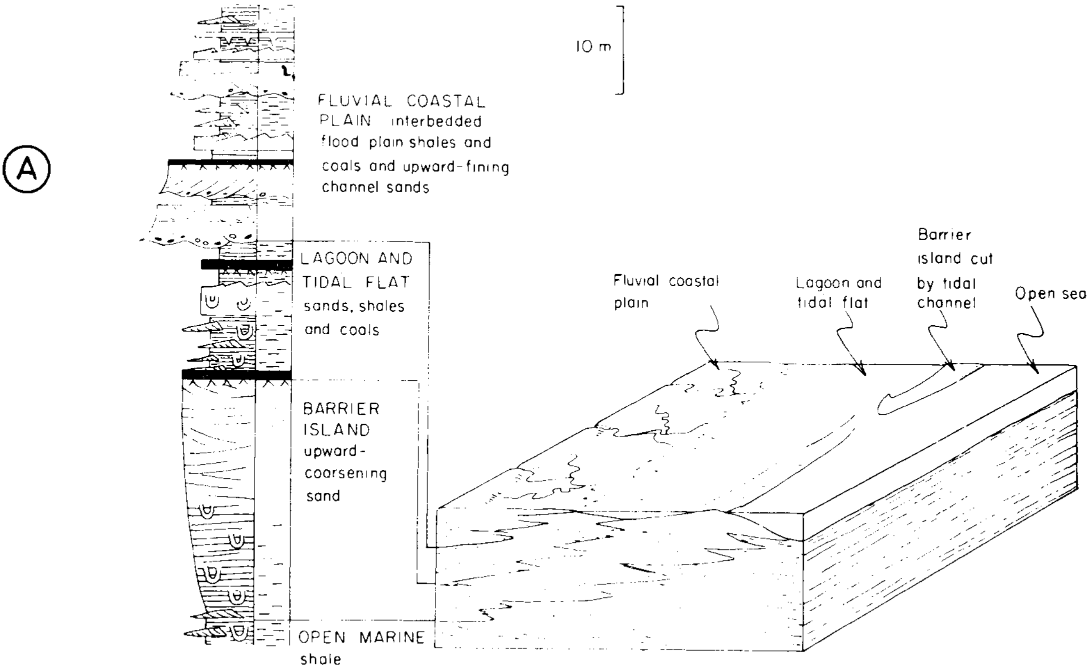
(a) Evidence of rapid reversals of depositing currents; herringbone cross-stratification.

(b) Evidence of alternating slack water and strong currents on a small scale; flazer/lenticular bedding.

(c) Evidence of intermittent subaerial exposure; plant debris, coal beds.

(d) Evidence of alternating erosion and deposition; mud-filled channels, intraformational conglomerates, winnowed (wave rippled) sand beds.

In addition, the stratigraphic context of this part of the succession, with the underlying offshore and barrier beach sandstones and the overlying fluvial sediments (Aspelintoppen Formation, MAJOR and NAGY 1972), establishes beyond doubt the importance of tidal currents in its development.



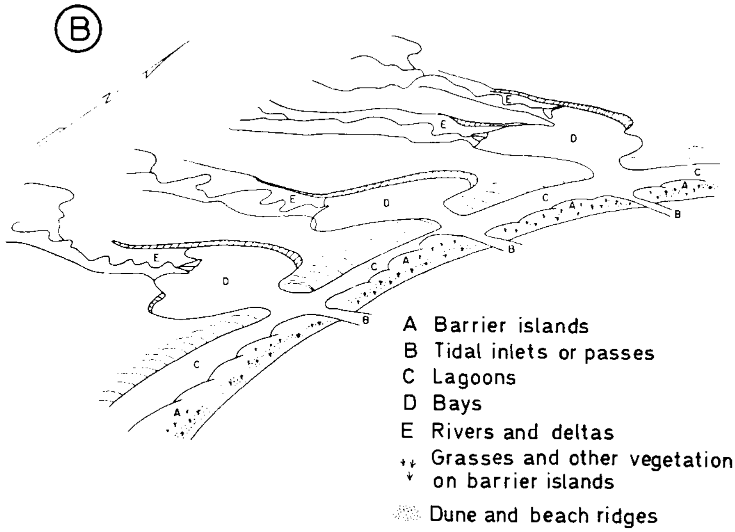
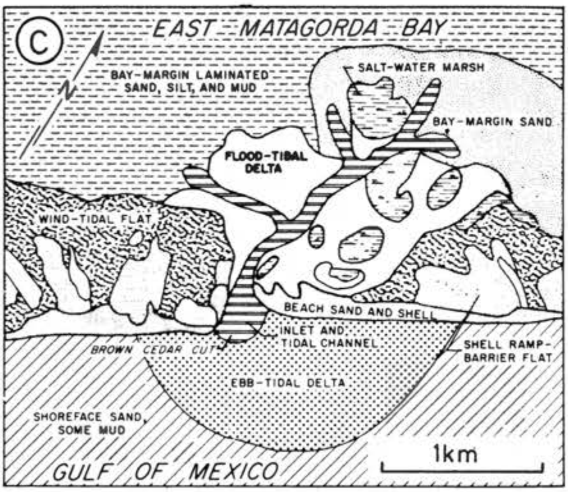


Fig. 13. (A) *A model of the sedimentary environments, facies and vertical profiles produced by a seawards prograding barrier island complex (from* Selley *1976)*, (B)–(D) *examples of modern barrier island/lagoon/bay complexes from the Bay City* (C) *and Corpus Christi* (D) *areas of the Texas Coastal Zone (from* Brown *et al. 1976 and* McGowan *et al. 1976).*


C
EAST MATAGORDA BAY
N
BAY-MARGIN LAMINATED SAND, SILT, AND MUD
SALT-WATER MARSH
BAY-MARGIN SAND
FLOOD-TIDAL DELTA
WIND-TIDAL FLAT
BEACH SAND AND SHELL
INLET AND TIDAL CHANNEL
BROWN CEDAR CUT
SHELL RAMP-BARRIER FLAT
EBB-TIDAL DELTA
SHOREFACE SAND, SOME MUD
GULF OF MEXICO
1km

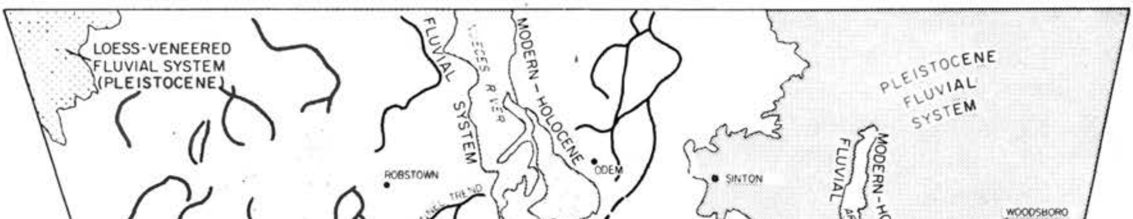

LOESS-VENEERED FLUVIAL SYSTEM (PLEISTOCENE)
FLUVIAL SYSTEM
NUECES RIVER
MODERN-HOLOCENE
PLEISTOCENE FLUVIAL SYSTEM
ROBSTOWN
ODEM
SINTON
WOODSBORO
FLUVIAL SYSTEM
MODERN-HOLOCENE
ARANSAS RIVER
DISTRIBUTARY CHANNEL TREND
PLEISTOCENE FLUVIAL-DELTAIC SYSTEM
TAFT
CHILTIPIN CREEK
NUECES BAY
CORPUS CHRISTI
MISSION BAY
GREGORY
COPANO BAY
MARINE REWORKED DELTA SEDIMENTS
OSO CREEK
CORPUS CHRISTI BAY
MODERN MARSH SYSTEM
PORT BAY
OSO BAY
STRANDPLAIN SYSTEM
ARANSAS PASS
ROCKPORT
REDFISH BAY
PLEISTOCENE BARRIER -
MODERN BAY - ESTUARY - LAGOON SYSTEM
LAGUNA MADRE
ARANSAS BAY
TIDAL FLAT
MODERN BARRIER SYSTEM
PORT ARANSAS
MODERN OFFSHORE SYSTEM
0 5 10 15
Scale in miles

Fig. 13 (D).

5. *Tidal flat sequence (276–284 m, Fig. 8).*

This sequence, like the underlying sequences, has examples of herringbone cross-strata, coal debris concentrations, and mud-filled channels. For these reasons it is likely to represent an area still influenced by tidal currents. However, the relative scarcity of herringbone cross-strata compared to the underlying sequence and the more common presence of red/brown paper shales and of thinning and fining-upwards sandstone sets (? longitudinal cross-strata of tidal creek point bars, Fig. 12 E) suggests an area dominated by tidal channels or creeks, but on the flank of, or on a quieter area lateral to the main tidal channel complex.

Discussion

The Tertiary history of infilling of the Svalbard Trough will be understood only after a thorough facies and palaeocurrent analysis of all of the depositional elements. For these reasons the writer agrees in principle with the attempt of VONDERBANK (1970) to subdivide the Tertiary succession into genetic units, but disagrees with the position of his boundaries. Work presently in progress by a sedimentology group at the University of Bergen (Geological Institute, Dept. A.) strongly suggests that, (1) the conglomerates at the base of VONDERBANK's Grumantdal Schichten (1970, Fig. 2) are of fluvial origin (K. KALGRAFF pers. comm. 1976) and would therefore have been more appropriately placed at the top of his Adventfjord Schichten, and that (2) the coarse sandstones at the base of VONDERBANK's Fardal Schichten (1970, Fig. 2) are of a nearshore tide-dominated deltaic facies (A. DALLAND pers. comm. 1976) and should logically be placed at the top of his Grumantdal Schichten. A disadvantage of the more widely accepted, so-called non-genetic stratigraphic classifications of the Svalbard Tertiary succession of, for example, FLOOD et al. (1971) or of LIVŠIC (1967), is that formation boundaries placed within regressive sequences (e.g. especially the Basilika/Sarkofagen and the Gilsonryggen/Battfjellet boundaries of FLOOD et al. 1971) are somewhat arbitrarily placed and are therefore difficult to define and difficult to recognize outside of the type area. It may have been preferable to leave a formal stratigraphic classification until the succession is better mapped, documented and understood, both in its lateral and vertical development within the Svalbard Trough.

Contrasting types of coastal sandstone bodies

It has been argued above that by means of a series of simple field measurements on ancient sandstone bodies together with an awareness of the structural and textural characteristics of the sand accumulating in particular modern environments we can go a considerable way towards reconstructing detailed palaeogeography. In the examples discussed above there has not been sufficient lateral control to establish a regional palaeogeography but rather models based largely on sedimentation time-trends have been constructed, in the belief that those environments which are laterally associated with each other geographically, often become associated in a vertical sequence (see WALTHER 1894; VISHER 1965).

In the present study two particular sandstone sequences have been chosen because they illustrate some of the principles used to distinguish between sandstone bodies built on a fluvial-dominated (deltaic) coastline from those constructed along a wave or tide-dominated (barrier beach) coastline. A summary of what is considered to be the main points of contrast are as follows:

1. In the Helvetiafjellet system the coarsest sandstones are dominated by cross-stratification, some of which have the character (epsilon-type) of point bar cross-strata. In the Battfjellet system most of the coarsest sandstones are dominated by very low-angle cross-stratification (beach type) or by herringbone cross-strata (tide-generated).
2. In both the Helvetiafjellet and Battfjellet systems the finer sandstones are commonly rippled, but in the former case current ripples dominate, while in the latter wave-generated ripple lamination is extremely common.
3. The finest sediments of the Battfjellet Formation (offshore mudstones) are more thoroughly bioturbated than those (bay mudstones) of the Helvetiafjellet Formation, and in the latter system coal beds are common.
4. In general the sandstones of the Battfjellet Formation are better sorted than those of the Helvetiafjellet Formation, although there are also specific instances (lagoonal deposits) of extremely poorly sorted sediments in the former system.
5. The vertical organization of the Battfjellet Formation can be best understood in terms of an offshore-barrier beach-lagoon-tidal channel complex palaeogeography (Fig. 13), with probable major thinning of sandstones in a direction at right angles to the nearest shoreline (see also Fig. 9 of KELLOGG 1975). The sandstone bodies of the Helvetiafjellet Formation appear to thin in a direction at right angles to the main palaeoflow, as would be expected of distributary sandstones in a river dominated delta system (Fig. 6).

Acknowledgements

I thank my colleagues in Bergen, particularly KNUT BJØRLYKKE, for discussions about the Cretaceous and Tertiary sequences in Svalbard. I am also grateful to Norges Teknisk-Naturvitenskapelige Forskningsråd for financially supporting the work and to ELLEN IRGENS and MASAOKI ADACHI for drawing the figures.

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The stratigraphical significance of a marine vertebrate fauna of Rhaetian age, Kong Karls Land

By DAVID WORSLEY[1] and NATASCHA HEINTZ[1]

Contents

Abstract

Marine vertebrate fossils are reported from hitherto unknown strata of Rhaetian age which outcrop on Kongsøya: the find of a well-articulated skeleton with apparent plesiosaurian affinities is of special interest. The vertebrate-bearing sequence suggests a greater similarity between the stratigraphy of Kong Karls Land and other localities than has previously been recognized, and the sequence is assigned to a new stratigraphical unit (the Kapp Koburg Member). The regional implications of the find are briefly discussed.

Introduction

Several sections through the Mesozoic succession of Kong Karls Land were sampled in the course of Norsk Polarinstitutt's summer expedition of 1973 as a part of the Institute's contribution to the Barents Sea project. Palynological studies of samples collected on Kong Karls Land are described by BJÆRKE (1977). In the course of field work on Kongsøya, WORSLEY logged a section which contained both dispersed marine vertebrate remains and a relatively complete skeleton. In addition to the intrinsic value of such a find, this section is of interest as it supplements the recent description by SMITH, HARLAND, HUGHES, and PICKTON (1976) of the geology of Kong Karls Land. These workers defined their basal Svenskøya Formation as consisting of 'dominantly sandy, continental beds' and suggested a Rhaetian to Sinemurian age for the unit. As indicated in this contribution, the vertebrate-bearing marine section on Kongsøya underlies rocks assigned by SMITH et al. (1976) to the Svenskøya Formation, and this has wider implications for interpretations of the Mesozoic stratigraphv of eastern Svalbard.

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Our tentative descriptions of the vertebrate remains are based on photographs taken in the course of field work and on isolated bones and loose blocks which were collected. The section was found two days before the end of the field season and it was impractical to initiate large scale excavations of the whole skeleton in the limited time available. We hope that this paper will stimulate interest in the find and so further our efforts to secure the skeleton for more detailed palaeontological investigation.

Stratigraphy

SMITH et al. (1976) defined and described two laterally equivalent members of the Svenskøya Formation, viz. the Mohnhøgda Sandstone Member of Svenskøya and the Sjøgrenfjellet Sandstone Member of Kongsøya, the latter with its type section on the northwest face of Hårfagrehaugen (Fig. 1). Both members were interpreted as non-marine deposits, and the presence of thin coal seams and plant fragments was noted. Palynological preparations of samples from Hårfagrehaugen supported this interpretation as they contained neither acritarchs nor dinoflagellates. This feature is also characteristic of the samples collected from this part of the succession in 1973 (association B of BJÆRKE 1977).

The Sjøgrenfjellet Sandstone Member is however underlain by a marine succession not noted by SMITH et al. (1976). This is exposed in low coastal cliffs east of Kapp Koburg; these exposures are probably covered by snow or ice throughout most summers. The section terminates uppermost in strata correlated in the field with the lowermost non-marine beds seen on the north-western slopes of Hårfagrehaugen, an interpretation supported by palynological analyses.

Exposures in the immediate vicinity of Kapp Koburg show friable sandstones with some cross-bedded units indicating current flow to N, NW and W. Occasional large irregular concretions contain plant fragments displaying a pronounced E-W lineation. These beds have an observed thickness of approximately 8–10 m, but their relation to the figured section is obscure.

The sequence containing vertebrate remains (Fig. 1) constitutes a 36 m thick coarsening-upwards unit. The lower 13 m consists of poorly consolidated mudstones with minor silty interbeds. Occasional vague moulds after decalcified bivalves are seen in the mudstones. Thin sideritic beds are often associated with well-rounded bone fragments. Palynological preparations from this part of the section contain both spores, marine acritarchs and dinoflagellates (association A of BJÆRKE 1977). The overlying 16 m of the section forms a coarsening-upwards sequence with a gradually increasing component of thin silt- and sandstone interbeds showing well-developed lenticular and wavy bedding. Sideritic beds contain vertebrate remains, and bones also fill the bases of small erosive washout structures. One sandy bed contains a sideritic concretion which encapsules the reptile skeleton described below. This coarsening-upwards sequence culminates in a 2 m thick massive sandstone which is

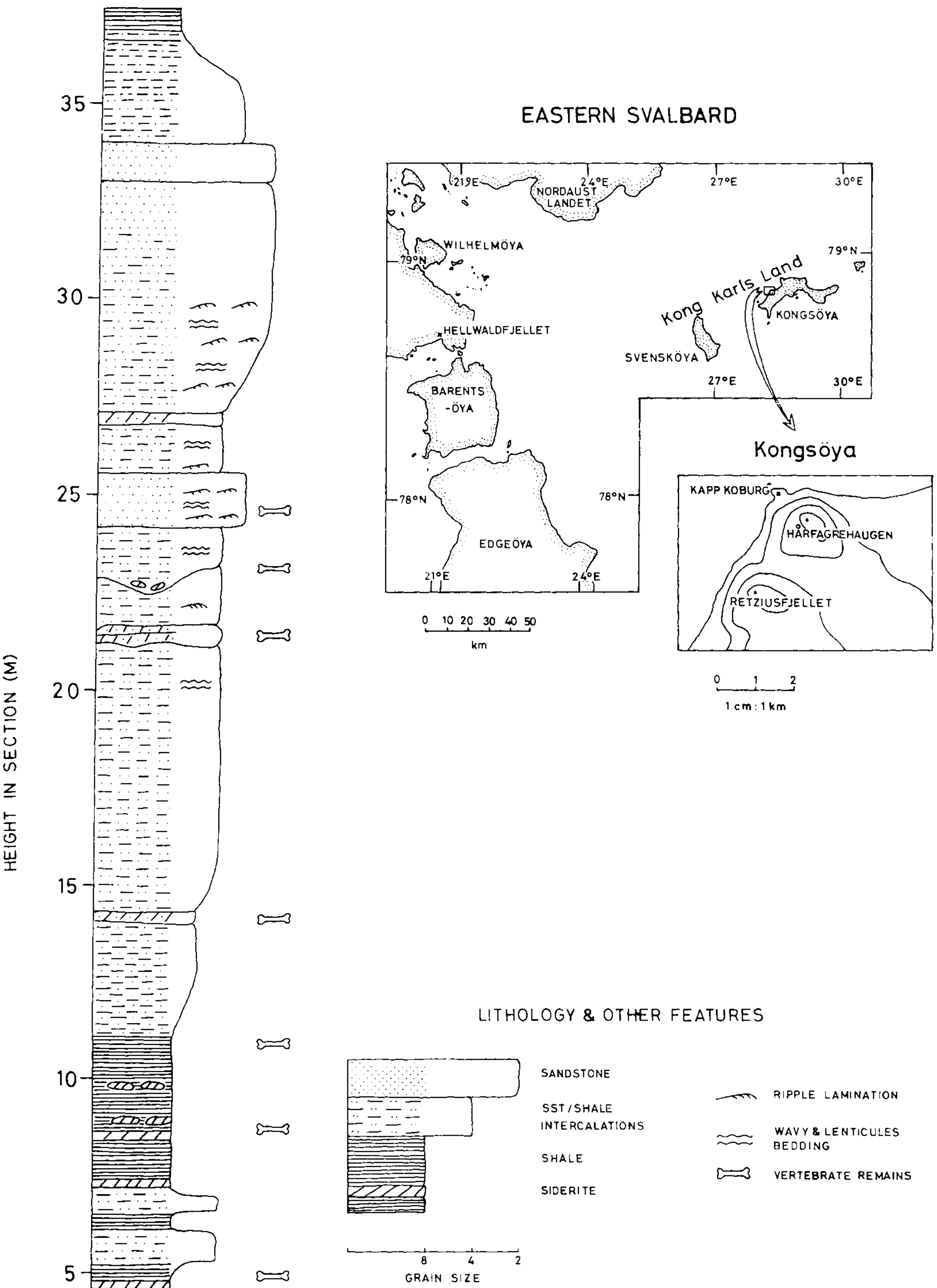

Fig. 1. *Type section of the Kapp Koburg Member in outcrops approximately 1 km east of Kapp Koburg, Kongsøya. The accompanying map shows most of the localities mentioned in the text.*

overlain by thin siltstones and mudstones. These fine rapidly upwards into mudstones characterised by non-marine palynomorphs (association B of BJÆRKE).

The coarsening-upwards sequence which dominates this section is interpreted as representing a marginal marine environment phasing up from offshore muds through the transitional zone into barrier sands. This is overlain by lagoonal shales which can be assigned to the Sjøgrenfjellet Sandstone Member of SMITH et al. (1976). Isolated skeletal elements may represent storm-lags deposited in the transitional zone and the whole skeleton was apparently buried by the mass transportation of sands in this environment. The marine sequence can be clearly distinguished from the overlying beds, and we therefore suggest the establishment of a new lithostratigraphical unit: the Kapp Koburg Member, with type section as in Fig. 1. The unit is probably covered by scree on Svenskøya and the 'Arnesenodden Shale Bed' of SMITH et al. (1976) contains a similar palynological association to that seen in the Kapp Koburg Member of Kongsøya.

Vertebrate remains

The vertebrate remains from Kongsøya can be grouped as follows:

Numerous isolated skeletal remains, occurring at several horizons in the lower 25 m of the section,

a large, relatively well-articulated reptile skeleton found in a sideritic sandstone concretion lying partially exposed in the section,

small fish teeth discovered in disaggregated preparations of thin laminae, apparently containing winnowed material.

Tentative descriptions of these fossils are presented here, and their biostratinomical significance is briefly discussed.

Isolated skeletal remains

The isolated bone material which has been studied comprises the remains of nine vertebrae, numerous ribs and gastralia, two fragments of what is presumably a humerus, one phalange bone, one tooth, a large flat bone (presumably a girdle element), and a few unidentifiable bones.

All the nine vertebrae have a typical ichthyosaurian form (see ZITTEL 1918; SWINTON 1965; and TATARINOV 1965). The largest vertebra is 18 cm wide and 6.5 cm thick at its circumference; the figured specimen (Fig. 2A) is 14.5 cm wide, 15 cm high and 5 cm thick. Five of the vertebrae are well-rounded and partly broken. No vertebrae less than 11 cm wide are present in the collection, and no neural arches are found.

The greater part of the collection comprises fragments of ribs and presumably also of gastralia. The individual fragments are mostly only a few centimetres long, but in some cases it is possible to piece together several fragments; the largest bone thus obtained is approximately 35 cm long. However, this specimen is broken at both ends and shows a quite even thickness, so that it seems reasonable to assume that it represents only a part of a considerably longer

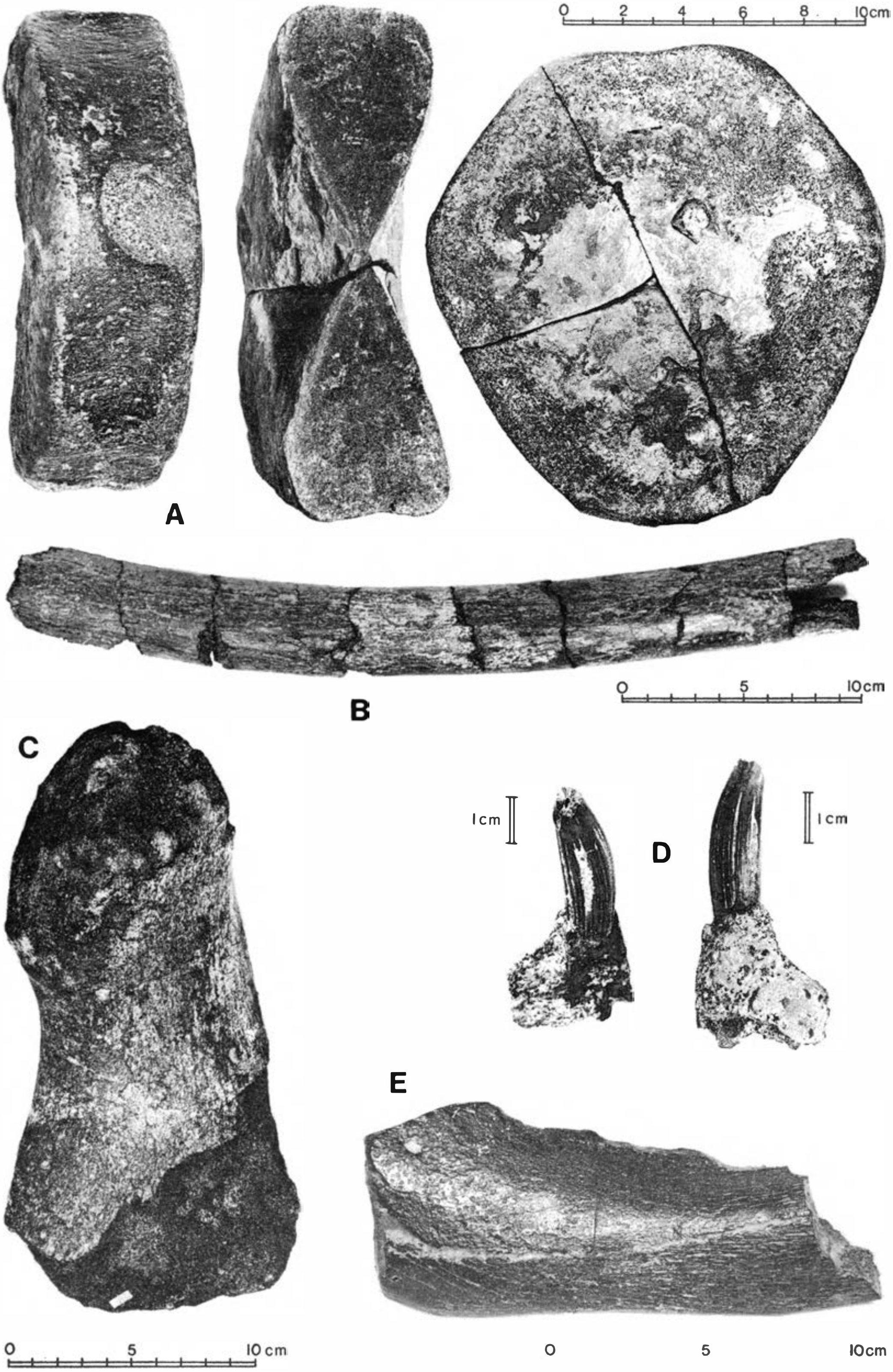

Fig. 2. *Isolated skeletal remains*

A. *Ichthyosaurian vertebra* (*PMO A* 37429)

B. *Fragment of plesiosaurian rib* (*PMO A* 37430)

C. *Plesiosaurian humerus* (*PMO A* 37431)

D. *Tooth* (*PMO A* 37432)

E. *Unidentified fragment* (*PMO A* 37433) bone (Fig. 2 B). This bone is oval in cross-section (4 cm in height and 3.5 cm in breadth). This is representative of one type of ribs seen, and the largest of these measures 5 × 4.5 cm in cross-section.

Other ribs and/or gastralia are much thinner, with cross-sections measuring 4 × 2 to 2.5 cm. Several of these bones show a difference in surface structure along their central parts, where the texture is in places somewhat coarser than usual. Some also show a distinct groove along the longitudinal axis of the bone. Neither the proximal nor distal ends of any of the ribs or gastralia are seen, features which would enable a precise assignment of the material. However, on the basis of the general appearance of these bone fragments it seems reasonable to assume that the collection comprises ribs of both ichthyosaurs and plesiosaurs as well as gastralia of the latter group.

One of the two bones presumed to be part of a humerus is depicted in Fig. 2C. The total length of this fragment is approximately 25 cm. It is broken at both ends, but the general shape of the joint at the proximal end is preserved; this shows the characteristic more rounded shape of a plesiosaurian humerus (Romer 1956). The distal extremity is broken off, leaving no trace of the joint which articulated with the following two bones, viz. the radius and ulna. The other bone which may also be a piece of a humerus is a flat, almost square fragment (approximately 16 × 14 cm and 6 cm thick), which must have been a part of the distal end of a large humerus.

The phalange is 5 cm long, and 3.2 cm wide at one joint surface; the other joint is broken off. This bone has the elongated shape typical of a plesiosaurian phalange (Romer 1956).

The tooth (Fig. 2D) is 3.2 cm long, but it has originally been a little longer, as the outermost tip is broken off. The tooth appears to have been sharply pointed and its greatest width is at about the middle of the present fragment where it is 1.2 cm in diameter. The tooth is a little curved and shows longitudinal grooves on the surface, owing to infolding of the enamel.

The last bone to be mentioned from this collection is a fragment approximately 15 cm long and 7 cm in greatest width (Fig. 2E). It is absolutely flat on one side and slightly curved on the other. However, as both ends of the bone are broken, it is not possible to assign this to any particular skeletal element.

In summary, although the fragmental nature of the bones prevents any precise identification, these skeletal elements suggest the presence of both plesiosaurian and ichthyosaurian remains.

The large skeleton

The large reptile skeleton seems to be relatively well-articulated and occurs in a sideritic sandstone concretion which apparently encapsules the trunk and possibly also the neck and the cranium of the skeleton (Fig. 3A).

The concretion is approximately 4.5 m long, and mainly the abdominal region of the skeleton is exposed. Here one can see longitudinally exposed the coarse ribs, a black phosphatic mass (presumably representing the gastric contents), and the oval cross-sections of what are considered to be the gastralia.

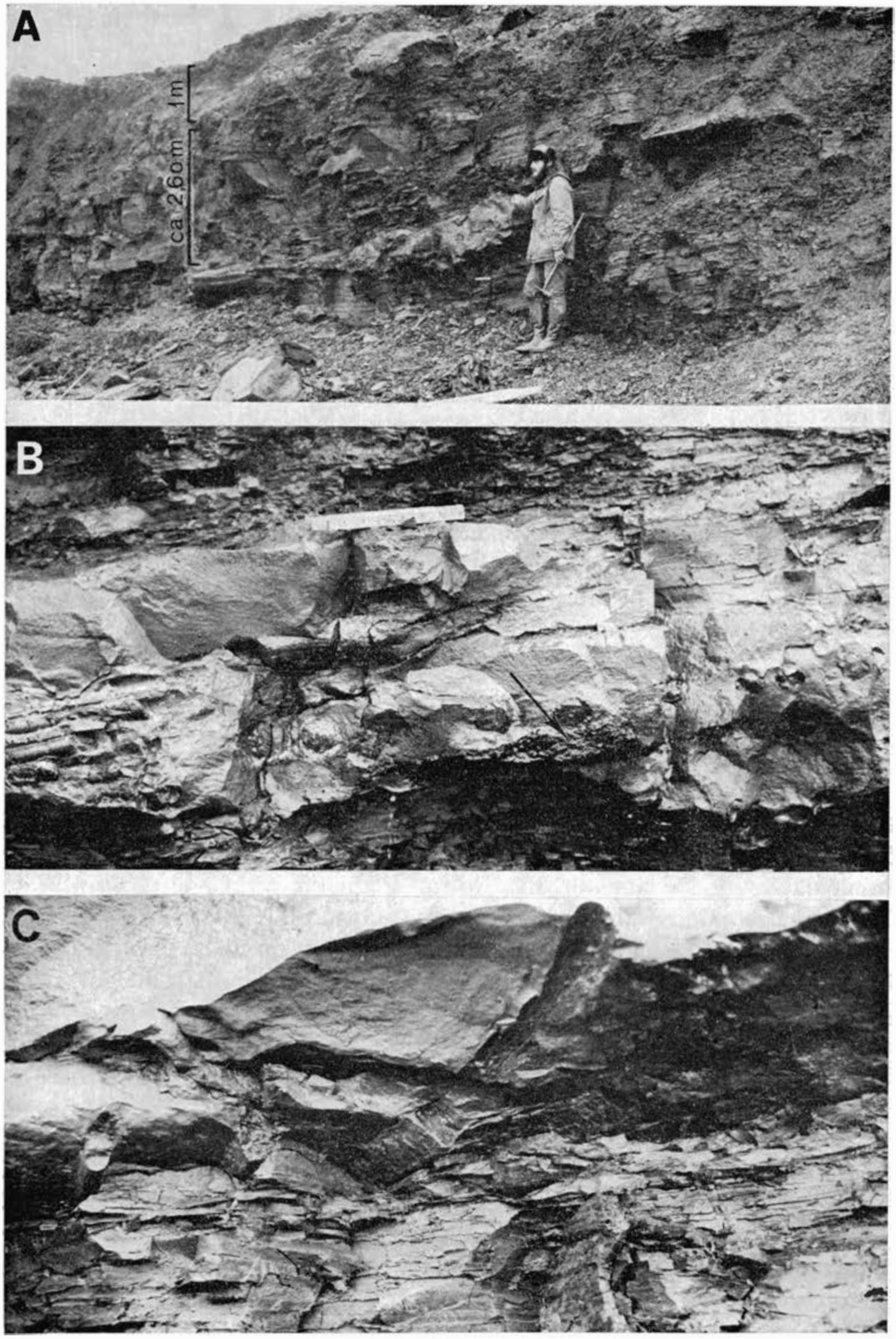

Fig. 3. *Large reptile skeleton*

A. *Sideritic sandstone concretion surrounding the skeleton as exposed in the cliff section*

B. *Detail from the trunk of the skeleton showing ribs, black gastric mass (arrowed) and cross-sections through the gastralia*

C. *Near view showing parallel alignment of gastralia on the concretion's lower surface.*

When found in 1973 parts of the skeleton had already been removed by cliff-erosion. This process is enhanced by the friable nature of the sediments surrounding the concretion (the major cementing agent of the "standstones" appears to be permafrost).

Only scanty remains of plesiosaurs have been recorded from the Triassic of Svalbard (WIMAN 1916; COX and SMITH 1973; WORSLEY 1973), and this find is therefore of great interest. It is hoped that the skeleton may be secured in the near future in order to facilitate more detailed studies. However, on the basis of the material and photographs now available it seems reasonable to assume that this does represent the remains of a plesiosaur; the general configuration of the skeleton and the presence of plesiosaurian bones in the other collections would support this tentative conclusion.

Fish teeth

The fish teeth have so far been only briefly studied. They are all small, but show varied affinities. Three common elements are characteristic fragments of dipnoan toothplates, tricuspate teeth of elasmobranch type and several typical labyrinthodont teeth (all sharply pointed and somewhat curved). Most of the teeth are simple pointed cones, with no visible special features (OBRUČEV 1964).

The biostratinomy of the vertebrate remains

The two contrasting types of preservation of the reptilian remains in the section can be interpreted in light of the actuopalaeontological studies of SCHÄFER (1972) in the North Sea. Seals and most whales sink to the seafloor immediately after death, but they re-emerge at the surface after a few days because of inflation of the body cavity by decompositional gases. The inflated corpse may float for several weeks before total disintegration strews disarticulated skeletal elements over the subjacent sea-floor. Individuals may of course die in intertidal areas, and corpses may strand in this environment; in either case prolonged exposure will produce disintegration and reworking of the individual skeletal elements. The isolated bones seen throughout the lower 25 m of the Kongsøya section may have such an origin. The apparent pre-depositional abrasion and rounding of these remains suggests appreciable tide- and storm-influenced reworking, prior to the final depositional of individual bones. The preservation of the well-articulated skeleton suggests rapid burial either of a newly dead individual which had sunk to the sea floor or of a corpse stranded in the intertidal zone (burial of the inflated corpses of modern marine invertebrates may often produce well-ordered skeletal remains). The position of the skeleton in the coarsening-upwards motif described above suggests either shallow subtidal or low intertidal environments. Burial of a newly dead individual would be expected to result in the subsequent collapse of overlying sediment around the skeleton after decay of the animal's soft parts, but the sandstone which surrounds and infills the skeleton appears to be relatively well-laminated. A tentative interpretation suggests the burial of a stranded individual in the intermediate stages of decay when skeletal elements were still articulated.

The relatively complete preservation of the gastric mass in this skeleton does not necessarily indicate immediate post-mortem burial. SCHÄFER (1972) noted that the stomachs of seals are resistant to decomposition, and the gastric contents of both ichthyosaurs and plesiosaurs are common even where the disorder of the skeletal elements suggests appreciable post-mortem decay (e.g. see POLLARD 1968, Fig. 1). The gastric mass seen in this skeleton is a discrete entity in approximately the position the stomach would occupy during life. The stomach contents seem to consist of both carbonised and phosphatic remains. The reader is referred to POLLARD (1968) who reviews the food resources and possible digestive mechanisms producing such remains.

Summary

The vertebrate fauna is interpreted as representing the thanatocoenosis of a rich and varied fish and reptile fauna which inhabited the shallow seas covering eastern Svalbard during the Rhaetian (see also below). The fauna is dominated by the reworked remains of marine reptiles which have been drifted on-shore after death.

Regional implications

The vertebrate-bearing sequence described above has not been reported from Kong Karls Land previously. The new information provided by the Kapp Koburg Member has significant implications for our interpretation of the sedimentational history of eastern Svalbard in the late Triassic and early Jurassic.

The non-marine beds of the Svenskøya Formation were suggested by SMITH et al. (1976:222) to show a similar facies to "parts of the De Geerdalen Formation of Spitsbergen", although they also noted the younger age of the Kong Karls Land unit. The presence of the older marine beds described here modifies the concept of the Svenskøya Formation, and more generally suggests the need for a reconsideration of the stratigraphical scheme which has been proposed for rocks of this age in eastern Svalbard (SMITH 1975; SMITH, HARLAND and HUGHES 1975; and SMITH et al. 1976). See also Fig. 4.

The combined Kapp Koburg and Sjøgrenfjellet Members of Kongsøya show striking lithological similarities to sequences of a broadly similar age on Wilhelmøya, Hellwaldfjellet and Hopen. Using type sections from Wilhelmøya, WORSLEY (1973) defined the Wilhelmøya Formation to include strata interposed between the fluviodeltaic sediments of the late Triassic De Geerdalen Formation and the marine shales of the middle Jurassic Agardhfjellet Formation. WORSLEY also suggested that the youngest rocks exposed on the island of Hopen show a comparable development to the Wilhelmøya Formation. At that time most of this interval was thought to be represented by hiatus in central Spitsbergen; for example the fluviodeltaic De Geerdalen unit in its type area

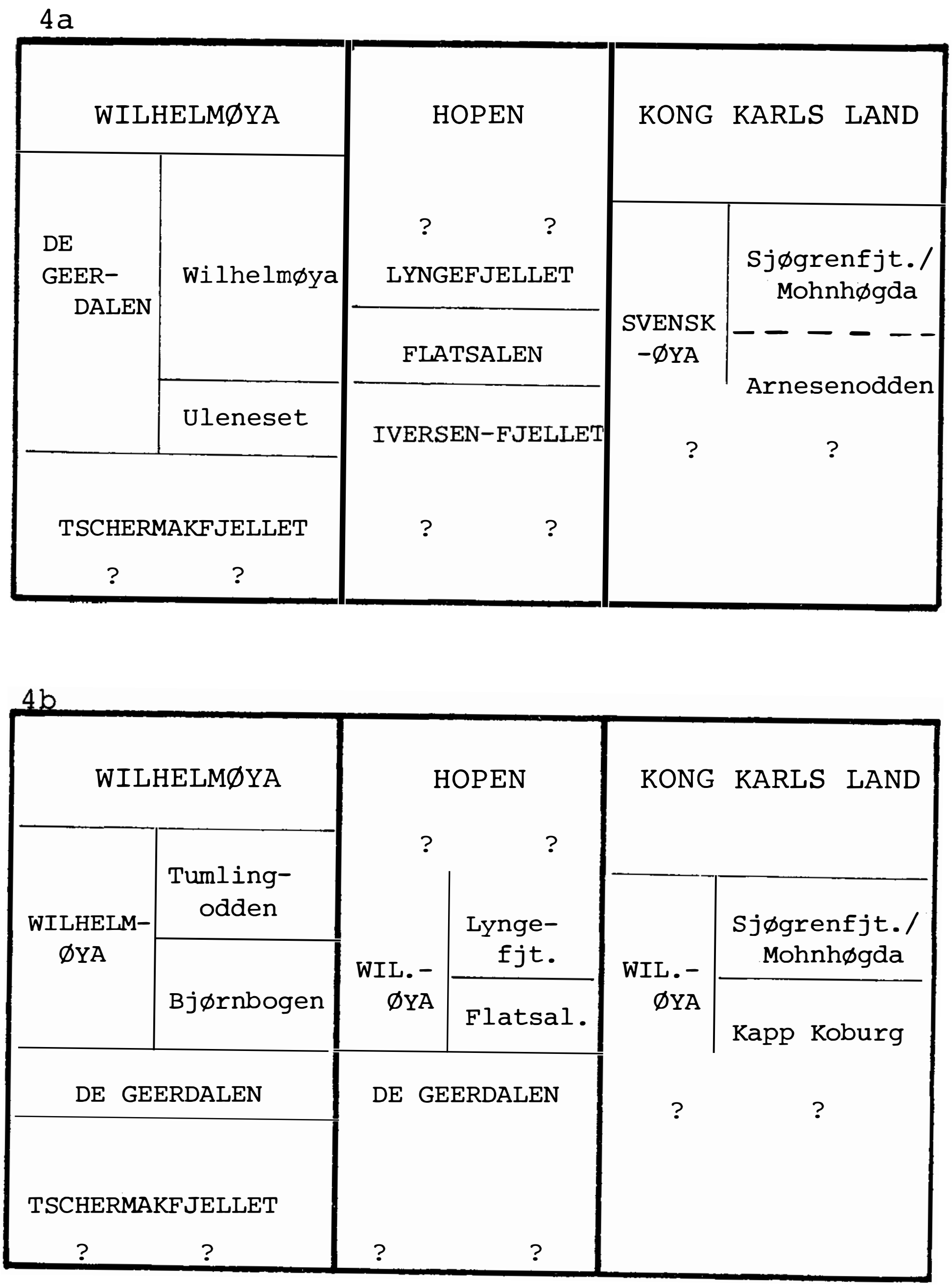

Fig. 4. *Alternative lithostratigraphical schemes for units assigned to the Kapp Toscana Group of Wilhelmøya, Hopen, and Kong Karls Land. Formational names are printed in capital letters, and lower ranking units in normal type letters.*
4 a: *The scheme summarized by* SMITH *et al.* (*1976: Table 5*).
4 b: *The scheme suggested in this contribution.*

was thought to be directly overlain by the "Lias conglomerate" (Brentskardhaugen Bed, PARKER 1967), a supposition which formed the basis for the definition of the top of this unit (the De Geerdalen Member of BUCHAN et al. 1965). The Brentskardhaugen Bed contains a remanié fauna suggesting a Toarcian or younger age; elements of this fauna occur in the uppermost parts of the Wilhelmøya Formation of Wilhelmøya and Hellwaldfjellet, this feature being an important factor in the ensuing nomenclatorial proposals.

The substance of WORSLEY's observations on Wilhelmøya was supported by the more detailed studies of SMITH (1975), although SMITH reduced the Wilhelmøya Formation to member rank. The unit was then grouped within the De Geerdalen Formation, apparently so as to retain the accepted upper limit of this formation at the remanié fauna noted above. SMITH et al. (1975) introduced two new formational names for the rocks on Hopen considered by WORSLEY to be equivalent to his Wilhelmøya Formation. This procedure was adopted as the authors considered "this long-range correlation unjustifiable in view of the probable lithological variation of these marginal marine sediments" (SMITH et al. 1975: 19). The resultant scheme is summarized and compared to the rocks of Kong Karls Land in SMITH et al. (1976: Table 5) where a broad correlation is suggested of the Svenskøya Formation of Kong Karls Land, the combined Flatsalen and Lyngefjellet Formations of Hopen, and the lower parts of the Wilhelmøya Member of Wilhelmøya. This scheme (with the possible exception of the anomalous ranking of the various units) is justifiable if:

the lower boundaries of these units cannot be shown to represent a regionally significant and mappable horizon,

these sequences do show appreciable lithological variation regionally, and

the previously defined stratotypical upper limit of the De Geerdalen Formation is retained.

The base of the Wilhelmøya unit on Wilhelmøya is marked by a sandstone with extraformational pebbles (a sufficiently distinctive horizon that BUCHAN et al. (1965) misinterpreted this as the Brentskardhaugen Bed). Comparable beds on Hopen show winnowed horizons with concentrations of quartzitic granules and sideritic oolites, features which seen in relation to the underlying succession suggest a significant sedimentological (if not stratigraphical) "event" in the succession at this level. The lower boundary of the Kapp Koburg Member of Kongsøya is not seen, but the member's lower components are similar to the beds overlying the clear lithological marker horizons on Wilhelmøya and Hopen. In all three localities marine shales with vertebrates and bivalves contain similar palynomorph associations of a Rhaetian age (BJÆRKE and MANUM 1977; BJÆRKE 1977). These palynomorph associations are markedly different from those found in the underlying De Geerdalen fluvoi-deltaic sequence. We interpret these shales as indicating a transgressive episode with a wide regional extent, an interpretation supported by the work of BJÆRKE and DYPVIK (1977) which suggests the occurrence of a conglomerate and marine shale sequence between the De Geerdalen and Brentskardhaugen units in their type areas.

The shales of Wilhelmøya, Hopen, and Kongsøya coarsen upwards into sandstone complexes which are petrographically distinct from the De Geerdalen coarse clastics, a distinction which enabled EDWARDS (1975) to identify these sandstones over large areas of the Barents shelf. This sandstone component *does* show regional variability because of varying progradational processes in the different areas, and more detailed sedimentological studies are needed before this facies mosaic can be fully interpreted.

The regional extent and distinctive character of these sediments appear to warrant their grouping in a unit clearly distinguished from, and not included within, the De Geerdalen Formation. The adoption of a Wilhelmøya unit with formational rank to encompass these strata may be disputed because of the accepted definition of the De Geerdalen Formation's upper limit; however, the work of BJÆRKE and DYPVIK (1977) provides a new and significant dimension to this discussion. If, as their data suggest, the De Geerdalen Formation has been misinterpreted in its type area, a complete redefinition of existing terminology is necessary, and there may be no nomenclatorial justification for the suppression of the Wilhelmøya unit's formational status.

Regional use of the Wilhelmøya Formation as a lithostratigraphical unit may serve to elucidate the sedimentational history of eastern Svalbard during an eventful period. Within this formational framework locally defined members may be useful, especially in view of the sedimentological variability shown by the upper parts of the formation. We therefore propose:

Wilhelmøya: re-establishment of the Wilhelmøya Formation, essentially as described by WORSLEY 1973, but with two components, viz. the Bjørnbogen and Tumlingodden Members (the former incorporating WORSLEY's "basal" and "transitional" members).

Hopen: grouping of the Flatsalen and Lyngefjellet Members (reduced from formational status) within the Wilhelmøya Formation (as suggested by BJÆRKE and MANUM 1977).

Kong Karls Land: suppression of the Svenskøya Formation of SMITH et al. (1976) and inclusion of the Kapp Koburg Member and the Sjøgrenfjellet and/or Mohnhøgda Members in the Wilhelmøya Formation.

Sassenfjorden: provisional use of the informal terminology suggested by BJÆRKE and DYPVIK (1977) prior to further investigations.

It is apparent that increasing knowledge of the lower Mesozoic succession in eastern Svalbard necessitates a critical re-investigation of the Triassic/Jurassic boundary throughout the archipelago. The Svalbard Research Group at the University of Oslo hopes to study relevant sections in the Festningen, De Geerdalen, Brentskardhaugen, Agardhfjellet and Sørkapplandet areas in the course of 1977. Meanwhile we hope that the approach which we have outlined may provide a reasonable framework for future work and discussion.

Acknowledgements

Field work was carried out by WORSLEY while employed by Norsk Polarinstitutt, and several members of the 1973 expedition contributed to the results presented here. Materialforvalter KÅRE BRATLIEN first discovered reptile bones; THOR SIGGERUD with several members of the expedition worked enthusiastically under difficult conditions to retrieve as much of the vertebrate material as possible. Fruitful exchanges (and friendly disagreement) on stratigraphical problems with M. B. EDWARDS, D. G. SMITH, and colleagues in Oslo are gratefully acknowledged. The technical assistance of L. KRAVIK, B. OPPI, and A.-K. PUNSVIK has been invaluable.

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Mesozoic Palynology of Svalbard — II

Palynomorphs from the Mesozoic sequence of Kong Karls Land

By Tor Bjærke[1]

Contents

Abstract

Rhaetian, Jurassic and Lower Cretaceous beds on Kong Karls Land have been investigated palynologically. 90 samples were studied and 116 species of spores, pollen, dinoflagellates and acritarchs are recorded. Six associations of palynological assemblages are recognized on the basis of 77 selected species. 107 species are illustrated.

The sequence on Kong Karls Land is referred to the Wilhelmøya, Agardhfjellet, Rurikfjellet and Helvetiafjellet Formations described from Wilhelmøya and Spitsbergen.

Spore and pollen assemblages from the lower part of the sequence are closely similar to Rhaetian assemblages in NW Europe. This part of the sequence is correlated with the Flatsalen and Lyngefjellet Members, Wilhelmøya Formation, on Hopen, Svalbard. Middle and Upper Jurassic dinoflagellate assemblages compare with assemblages reported from Arctic Canada.

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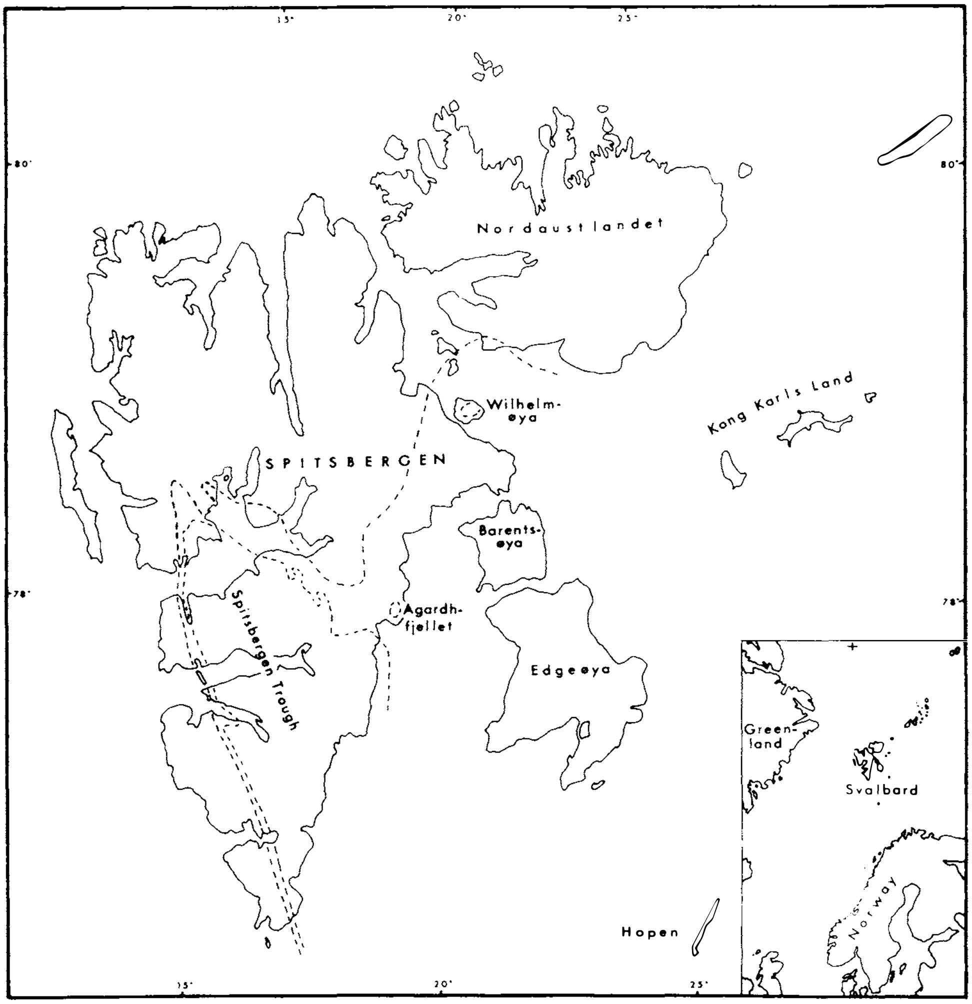


Fig. 1. *Map of Svalbard (1 :4 mill.) showing extent of Mesozoic rocks (outer broken line) and the base of the Jurassic (inner broken line).*

Introduction

This is the second contribution in a series of papers which will deal with the Mesozoic palynology of Svalbard and the northern part of the Norwegian shelf. Increasing interest in the geology of these areas requires a refined biostratigraphic zonation which will make a correlation possible between the sediments in the offshore areas and the established stratigraphic column in Svalbard. Only during the last few years palynological information from the Mesozoic of Svalbard has become available and little is yet published.

The present paper illustrates diverse assemblages of spores, pollen, dinoflagellates and acritarchs from Kong Karls Land, and gives the stratigraphical distribution of 77 selected species. Dating and correlation with other localities are discussed. Taxonomic aspects of the assemblages will be dealt with in a subsequent publication.

Acknowledgements

The investigation was carried out at the Paleontologisk Museum and Institutt for geologi, University of Oslo, as part of a research project aimed at palynological investigations of the Norwegian continental shelf and adjacent areas supported by the Norwegian Council for Scientific and Industrial Research (NTNF). Thanks are due to Dr. S. B. MANUM who initiated the investigations.

The samples were collected by Dr. D. WORSLEY and Mr. Ø. LAUTEN, members of the Norsk Polarinstitutt Svalbard Expedition 1973. The fieldwork was also financially supported by the Norwegian Council for Scientific and Industrial Research, Continental Shelf Division.

I should like to thank Dr. D. WORSLEY (Paleontologisk Museum, University of Oslo), cand. real. J. NAGY and cand. real. H. DYPVIK (Institutt for geologi, University of Oslo), and Dr. M. B. EDWARDS and G. BELL (Continental Shelf Institute, Trondheim) for helpful discussion and comments on the manuscript.

Geological setting

Pioneer work on the geology of Kong Karls Land was carried out by NATHORST (1901, 1910). SMITH, HARLAND, HUGHES and PICKTON (1976) described in detail a number of sections on Svenskøya and Kongsøya (Figure 2) and they established an elaborate stratigraphical nomenclature.

The sedimentary rocks of Kong Karls Land represent part of the Mesozoic platform deposits of the eastern Svalbard area (Figure 1). The Mesozoic sequence is deeply eroded in this area and Kong Karls Land is the only place where Jurassic and Cretaceous beds are exposed east of the Spitsbergen Trough. However, equivalent beds are thought to have a greater extention in offshore areas (NAGY 1973; EDWARDS 1976; BJÆRKE and THUSU 1976).

The Middle and Upper Triassic is thickest in eastern Svalbard but during the Jurassic the axis of maximum sedimentation moved westwards and the Jurassic and Cretaceous beds are most completely developed in the Spitsbergen Trough. The succession on Kong Karls Land is a condensed sequence, probably representing a marginal development closer to the positive area of Nordaustlandet.

The sequence on Kong Karls Land shows an overall similarity with those described from Wilhelmøya and Spitsbergen. In spite of this, SMITH et al. (1976) established three new local formations. However, it will seem more appropriate to use the formations defined elsewhere in Svalbard also on Kong

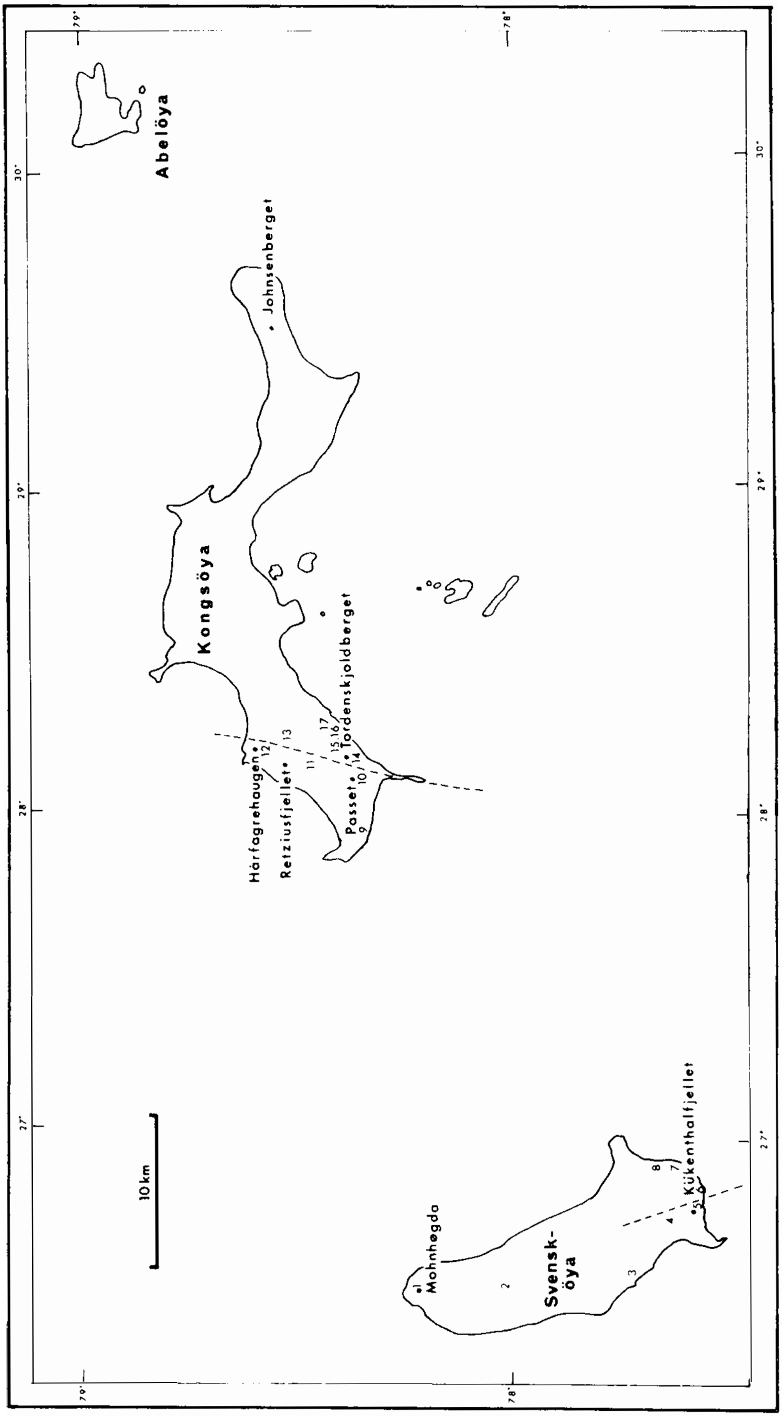


Fig. 2. *Map of Kong Karls Land. Broken lines indicate faults suggested by* NATHORST *(1901). Numbers (1—17) indicates location of sections described by* SMITH *et al. (1976).*

Karls Land, and to define local units only on the level of members (see Figure 4).

The oldest beds on Kong Karls Land are marine black shales and siltstones, the Arnesenodden Shale Bed of SMITH et al. (1976) (Figure 4). There is no evidence for the presence of the De Geerdalen Formation (Triassic) as described from Edgeøya and Barentsøya (FLOOD, NAGY and WINSNES 1971). The Wilhelmøya Formation (WORSLEY 1973) was regarded as a member of the De Geerdalen Formation by SMITH (1975) and SMITH et al. (1976). This obscures the fact that the development of the Wilhelmøya Formation on Wilhelmøya as well as on Hopen and Kong Karls Land is different from that of the De Geerdalen Formation on Spitsbergen, Edgeøya and Barentsøya.

Above the Arnesenodden Bed are found approximately 200 m of sandstones with interbeds of shale and silt and some thin coal and ironstone horizons. These beds are regarded here as part of the Wilhelmøya Formation.

The sandstones are overlain by marine black shales and clays of the Agardhfjellet Formation. In some localities on western Kongsøya (Figure 2, localities 16 and 17) and at Johnsenberget, eastern Kongsøya, calcareous sandstones, shales and siltstones are found above the Agardhfjellet Formation. These are described as the Tordenskjoldberget Limestone Member on western Kongsøya and are probably equivalent to the Rurikfjellet Formation of Spitsbergen (SMITH et al. 1976).

The continental series with interbeds of lavas belonging to the Helvetiafjellet Formation is the youngest formation on Kong Karls Land unconformably overlying the older beds (Figure 3).

There are several breaks evident in the sequence. A major hiatus occurs between the Agardhfjellet Formation and the overlying Rurikfjellet/Helvetiafjellet Formations (Figure 3). The youngest horizon dated within the Agardhfjellet Formation is of upper Oxfordian or lower Kimmeridgian age, while the oldest beds overlying this formation, the Tordenskjoldberget Member, Rurikfjellet Formation, is of Lower Cretaceous, probably Valanginian age (SMITH et al. 1976, p. 218). This break is probably a parallel to the disturbances recorded at the Jurassic-Cretaceous boundary in Spitsbergen (PARKER 1966; SMITH et al. 1976, p. 230). There is probably also a break between the Rurikfjellet Formation and the Helvetiafjellet Formation.

The relationship between the Wilhelmøya Formation and the Agardhfjellet Formation is not clear because of lack of age control. The lower part of Agardhfjellet Formation is probably of Callovian age (see p. 96), but the age of the upper part of the Wilhelmøya Formation is not known. Palynological evidence indicates that it is certainly of early Jurassic age and an upper Lower Jurassic nonsequence is therefore possible.

For more detailed information on geology and earlier paleontological work in the area, the reader is referred to SMITH et al. (1976).

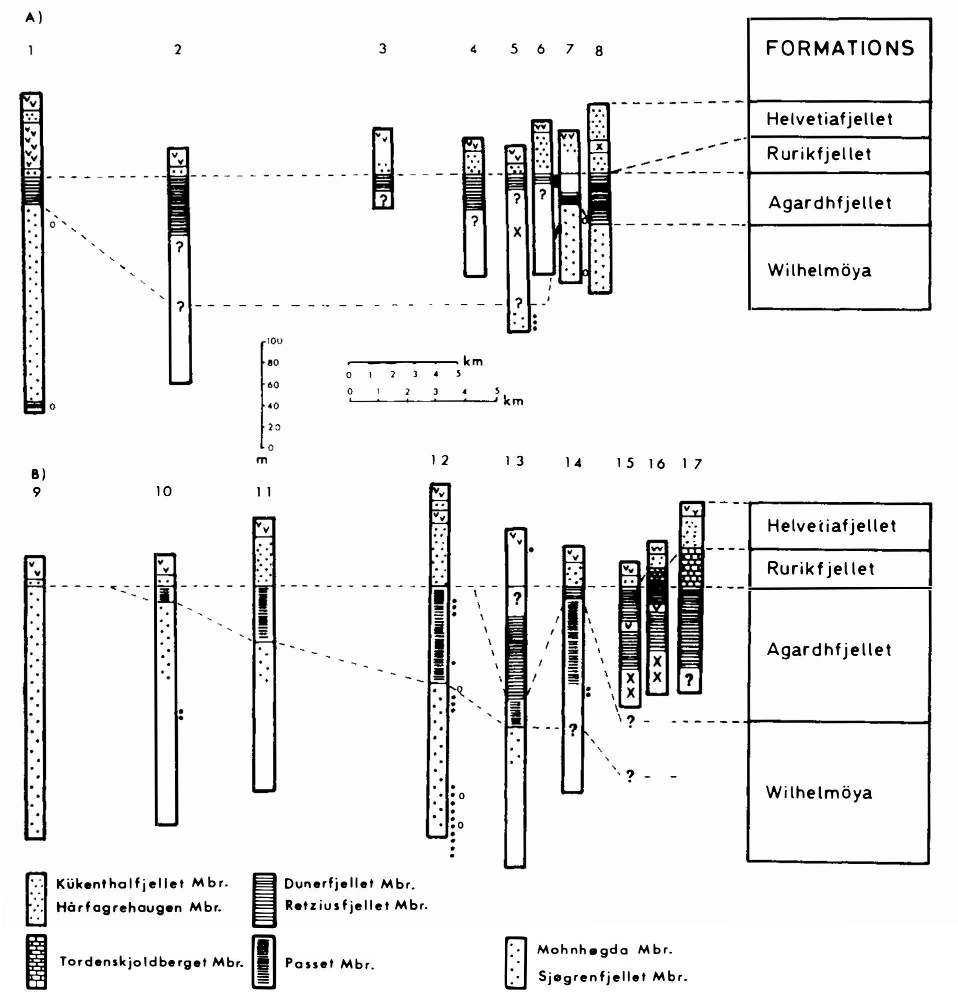


Fig. 3. *Sections from A : Svenskøya and B : Kongsøya (from* SMITH *et al. 1976). Numbers refer to locality numbers in Figure 2. Approximate sampling levels indicated by black dots, position of samples investigated palynologically by* SMITH *et al., open rings.*

Material

The samples investigated in the present study cover most of the lower part of the sequence, while only isolated samples are described from higher up the sequence. Material from the Rurikfjellet Formation was not available for the present study. The material consists of surface samples.

From Hårfagrehaugen, Kongsøya (Figure 2, locality 12) three series of samples were studied, one from a section along the shore east of Hårfagrehaugen and two from the northwestern slope of Hårfagrehaugen between 34 and 86 m and 139 and 155 m, respectively. Samples are from shale and silt lithologies. Further up the sequence one sample from 180 m and three samples from 222 to 226 m were also investigated. From Retziusfjellet (Figure 2, locality 13) one sample from just below the basalts, belonging to the Helvetiafjellet Formation, was investigated.

Three samples from Passet, Kongsøya, were also studied, one from locality 10 at 90 m and two from locality 14 at 100 m.

In addition to these samples from Kongsøya, 12 samples from Svenskøya were studied. Five samples were from locality 5 between 2 and 10 m and seven samples from locality 6 between 50 and 70 m (Figure 2).

Palynology

Methods and presentation of data

Preparation followed standard techniques using HCl, HF, short oxidation with HNO_3 and sieving (15μ net). Some residues were separated into two size-fractions to obtain a higher concentration of dinoflagellates (15—50μ and more than 50μ). The residues were mounted as strew preparations in glycerol jelly and sealed.

All palynomorph species identified are listed in Table I and the vertical range of 77 selected species is given in Table II. Six characteristic palynomorph associations were recognized (Table II, A—F).

Table I

Index of species

Sporomorphs

Alisporites microreticulatus REINHARDT 1964, assoc. A, Pl. 5, Fig· 9.
Annulispora bicollateralis (ROGALSKA) BJÆRKE & MANUM 1977, assoc. A, Pl. 2, Fig. 20.
Annulispora folliculosa DEJERSEY 1959, assoc. A, B, Pl. 2, Fig. 21.
Annulispora sp., assoc. A, Pl. 2, Fig. 26.
Apiculatisporis globosus (LESCHIK) PLAYFORD & DETTMANN 1965, assoc. B, Pl. 1, Figs. 23, 24.
Apiculatisporites parvispinosus LESCHIK 1955, assoc. B, Pl. 1, Fig. 13.
Aratrisporites fimbriatus (KLAUS) PLAYFORD & DETTMANN 1965, assoc. B, Pl. 4, Figs. 3, 6.
Aratrisporites laevigatus BJÆRKE & MANUM 1977, assoc. B, Pl. 4, Fig. 4.
Aratrisporites macrocavatus BJÆRKE & MANUM 1977, assoc. A, B.
Biretisporites potoniei DELCOURT & SPRUMONT 1955, assoc. A, B, Pl. 1, Fig. 3.
Biretisporites cf. *spectabilis* DETTMANN 1963, assoc. B, Pl. 1, Figs. 11, 12.
Calamospora nathorstii (HALLE) KLAUS 1960, assoc. A, B, Pl. 1, Fig. 1.
Camarozonosporites aulosenensis SCHULZ 1967, assoc. F, Pl. 2, Fig. 9.
Camarozonosporites laevigatus SCHULZ 1967, assoc. A, B, Pl. 2, Fig. 12.
Camarozonosporites rudis (LESCHIK) KLAUS 1960, assoc. A, B, C, D, Pl. 2, Figs. 10, 11.
Cavatoretisporites obvius BJÆRKE & MANUM 1977, assoc. A, Pl. 2, Fig. 7.
Caytonipollenites pallidus (REISSINGER) COUPER 1958, assoc. A, B, C, D, E, Pl. 5, Fig. 5.
Cerebropollenites mesozoicus (COUPER) NILSSON 1958, assoc. C, D, E, Pl. 5, Fig. 12.
Cingulizonates rhaeticus SCHULZ 1967, assoc. A, B, Pl. 3, Fig. 6.
Circulina meyeriana KLAUS 1960, assoc. B
Chasmatosporites apertus NILSSON 1958, assoc. B, C, Pl. 4, Fig. 10.

Chasmatosporites hians NILSSON 1958, assoc. A, B, C, Pl. 4, Figs 11–14.
Cicatricosisporites australiensis (COOKSON) POTONIÉ 1956, assoc. F, Pl. 5, Figs. 13, 14, 18.
Cicatricosisporites cooksonii BALME 1957, assoc. F, Pl. 5, Fig. 20.
Cicatricosisporites perforatus (BARANOV, NEMKOVA & KONDRATIEV) SINGH 1964, assoc. F, Pl. 5, Fig. 15.
Classopollis harrisii MUIR & v.KONIJNENBURG–v.CITTERT 1970, assoc. A, B, C
Conbaculatisporites hopensis BJÆRKE & MANUM 1977, assoc. B, Pl. 1, Fig. 22.
Conbaculatisporites mesozoicus KLAUS 1960, assoc. B, Pl. 1, Figs. 14, 15.
Concavisporis sp., assoc. B, Pl. 1, Fig. 7.
Corollina torosus (REISSINGER) CORNET & TRAVERSE 1975, assoc. C, D, Pl. 6, Figs. 1–3.
Cyathidites australis COUPER 1953, assoc. A, B, C, D, E, F, Pl. 1, Figs. 4, 9, 10, 20.
Densosporites fissus (REINHARDT) SCHULZ 1967, assoc. B, Pl. 3, Fig. 4.
Dictyophyllidites mortonii (COUPER) DETTMANN 1963, assoc. A, B, Pl. 1, Figs. 5, 8.
Duplexisporites problematicus PLAYFORD & DETTMANN 1965, assoc. A, B, C, D, Pl. 2, Figs. 27, 31.
Ginkgocycadophytus granulatus DEJERSEY 1964, assoc. B, Pl. 4, Fig. 1.
Ginkgocycadophytus sp. assoc. A, Pl. 4, Fig. 5.
Heliosporites reissingerii (HARRIS) MUIR & v.KONIJNENBURG–v.CITTERT 1970, assoc. A, Pl. 1, Fig. 18.
Kyrtomisporis speciosus MÄDLER 1964, assoc. A, B, C, D, E, Pl. 2, Figs. 29, 32.
Kyrtomisporis sp., assoc. A, Pl. 2, Fig. 28.
Leptolepidites verrucatus COUPER 1953, assoc. A.
Limbosporites lunbladii NILSSON 1958, assoc. B, Pl. 2, Figs. 30, 33, 34.
Lycopodiacidites microrugulatus (SCHULZ 1967) n.comb., assoc. A, B, Pl. 2, Fig. 1.
Lycopodiacidites rugulatus (COUPER) SCHULZ 1967, assoc. A, B, C, Pl. 3, Fig. 12.
Lycopodiumsporites cf. *austroclavatidites* (COOKSON) POTONIE 1956, assoc. A, Pl. 2, Fig. 8.
Lycopodiumsporites semimuris DANZÉ-CORSIN & LAVEINE 1963, assoc. A, B, C, D, E, Pl. 2, Figs. 2, 3.
Marattisporites scabratus COUPER 1958, assoc. B, Pl. 1, Fig. 19.
Neoraistrickia truncata (COOKSON) POTONIE 1956, assoc. C, Pl. 5, Fig. 16.
Ovalipollis limbata (MALJAVKINA) POCOCK & JANSONIUS 1969, assoc. A, B, C, D, Pl. 4, Figs. 9, 16.
Ovalipollis ovalis (KRUTZCH) POCOCK & JANSONIUS 1969, assoc. A, B, Pl. 4, Fig. 15.
Perotrilites sp., assoc. A, Pl. 4, Fig. 2.
Platysaccus sp., assoc. C, Pl. 5, Fig. 10.
Podocarpites sp., assoc. E, Pl. 5, Fig. 11.
Polycingulatisporites crenulatus PLAYFORD & DETTMANN 1965, assoc. B, Pl. 3, Fig. 10.
Polycingulatisporites cf. *densus* (DEJERSEY) PLAYFORD & DETTMANN 1965, assoc. B, Pl. 3, Fig. 9.
Polycingulatisporites mooniensis DEJERSEY & PATEN 1963, assoc. B, Pl. 2, Figs. 24, 25.
Polycingulatisporites sp., assoc. B, Pl. 3, Fig. 8.
Protodiploxypinus gracilis SCHEURING 1970, assoc. A, B, Pl. 5, Fig. 6.
Protodiploxypinus macroverrucosus BJÆRKE & MANUM 1977, assoc. B.
Protodiploxypinus microsaccus BJÆRKE & MANUM 1977, assoc. A, B.
Protodiploxypinus minor BJÆRKE & MANUM 1977, assoc. A, B, Pl. 5, Figs. 3, 4.
Protodiploxypinus ornatus (PAUTSCH) BJÆRKE & MANUM 1977, assoc. B, Pl. 5, Figs. 7, 8.
Protodiploxypinus sp., assoc. B, Pl. 5, Figs. 1, 2.
Retusotriletes mesozoicus KLAUS 1960, assoc. B, Pl. 1, Fig. 6.
Ricciisporites tuberculatus LUNDBLAD 1954, assoc. A, B, Pl. 4, Fig. 7.
Rugulatisporites sp., assoc. A, B, Pl. 2, Fig. 6, Pl. 3, Fig. 7.
Selagosporis mesozoicus SCHULZ 1967, assoc. A, B, Pl. 2, Figs. 14, 19.
Sphagnumsporites clavus (BALME 1957) n.comb., assoc. A, Pl. 2, Fig. 4.
Sphagnumsporites psilatus (ROSS) COUPER 1958, assoc. F, Pl. 2, Fig. 5.
Sphagnumsporites sp., assoc. A, B, Pl. 1, Fig. 2.
Stereisporites perforatus LESCHIK 1955, assoc. A, B, C, D, Pl. 2, Fig. 13.
Striatites sp., assoc. B, Pl. 4, Fig. 17.
Striatoabietites aytugii VISSCHER 1966, assoc. A, B.
Taeniasporites rhaeticus SCHULZ 1967, assoc. A, B.

Uvaesporites argenteaeformis (BOLCHOVITINA) SCHULZ 1967, assoc. A, B, Pl. 1, Figs. 16, 17.
Velosporites sp., assoc. A, B, Pl. 3, Figs. 11, 13, 14.
Verrucatosporites scabratus BJÆRKE & MANUM 1977, assoc. B, Pl. 4, Fig. 8.
Zebrasporites interscriptus KLAUS 1960, assoc. A, B, C, Pl. 2, Figs. 17, 18.
Zebrasporites laevigatus SCHULZ 1967, assoc. A, B, Pl. 2, Fig. 16.

Marine species

Adnatosphaeridium caulleryi (DEFL.) WILLIAMS & DOWNIE 1969, assoc. D, Pl. 9, Fig. 4.
Baltisphaeridium spp., assoc. A, C, D.
Canningia minor COOKSON & HUGHES 1964, assoc. D, Pl. 8, Fig. 2.
Canningia ringnesii MANUM & COOKSON 1964, assoc. D, Pl. 7, Fig. 10, pl. 8, fig. 1.
Sp. Indet., assoc. E, Pl. 9, Fig. 6.
Chlamydophorella sp., assoc. D, Pl. 7, Fig. 7.
Chytroeisphaeridia chytroeides SARJEANT 1962, assoc. D, Pl. 7, Figs. 3, 5, 6.
Cleistophaeridium tribuliferum (SARJEANT) DAVEY et al. 1966, assoc. E.
Fromea sp. A, assoc. D, Pl. 7, Figs. 1, 2.
Gonyaulacysta cf. ambigua (DEFL.) SARJEANT 1969, assoc. E.
Gonyaulacysta cladophora DEFLANDRE 1938, assoc. D, E, Pl. 9, Figs. 1—3.
Gonyaulacysta eisenackii DEFLANDRE 1938, assoc. D, Pl. 9, Fig. 5.
Gonyaulacysta jurassica DEFLANDRE 1938, assoc. D, E, Pl. 8, Fig. 6.
Gonyaulacysta jurassica var. *longicornis* (DEFL.) GITMEZ 1970, assoc. E, Pl. 8, Figs. 4, 5.
Leptodinium sp. A, assoc. E, Pl. 8, Figs. 7, 8.
Lithodinia sp. A, assoc. E, Pl. 10, Figs. 1—4.
Micrhystridium sp., assoc. A, C, D.
Nannoceratopsis pellucida (DEFL.) EVITT 1961, assoc. D, Pl. 10, Fig. 6.
Prolixosphaeridium granulosum (DEFL.) DAVEY et al. 1966, assoc. E.
Pareodinia ceratophora (DEFL.) GOCHT 1970, Assoc. D, E, Pl. 6, Fig. 8.
Pareodinia evittii (POCOCK) WIGGINS 1975, assoc. D, Pl. 6, Figs. 4, 5, 6, 9.
Pareodinia sp. A, assoc. D, E, Pl. 6, Fig. 11.
Pareodinia sp. B, assoc. D, E, Pl. 6, Fig. 12.
Pareodinia sp. C, assoc. D.
Pareodinia sp. D, assoc. D, Pl. 6, Fig. 10.
Pareodinia sp. of WIGGINS 1975, assoc. D.
Pterospermopsis australiensis DEFLANDRE & COOKSON 1955, assoc. A, C, Pl. 10, Fig. 7.
Rhaetogonyaulax rhaetica (SARJEANT) HARLAND et al. 1975, assoc. A.
Sirmiodinium grossi WARREN 1973, assoc. D, E.
Spiniferites sp., assoc. D.
Tasmanites sp., assoc. D, Pl. 9, Fig. 7.
Tenua hystrix EISENACK 1958, assoc. E, Pl. 8, Fig. 3.
Tenua verrucosa SARJEANT 1968, assoc. D, E, Pl. 7, Figs. 8, 9.
Tenua sp. A, assoc. E, Pl. 7, Fig. 11.
Tenua sp. B, assoc. D, Pl. 7, Fig. 4.
Veryhachium reductum DEUNFF 1954, assoc. A, C.

Table II

Vertical distribution of selected palynomorph species on Kong Karls Land and the stratigraphical position of palynomorph associations A through F.

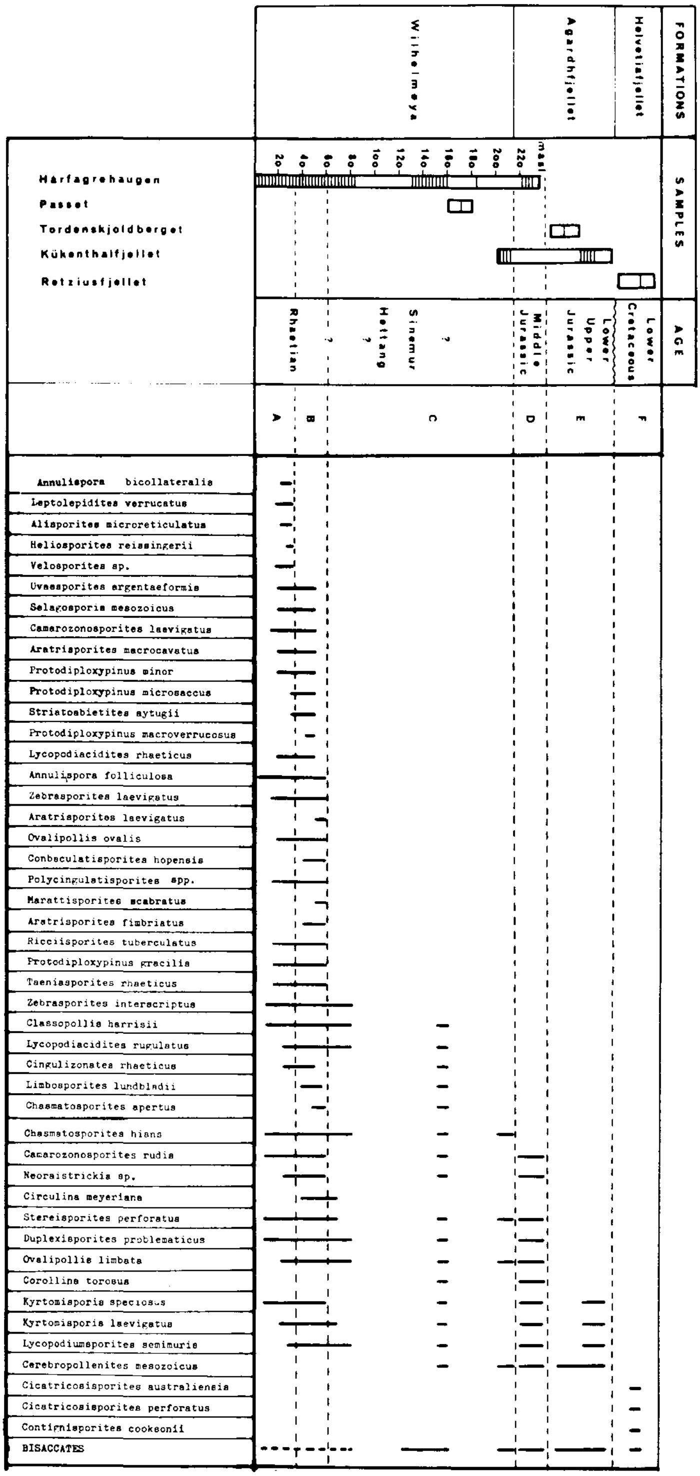
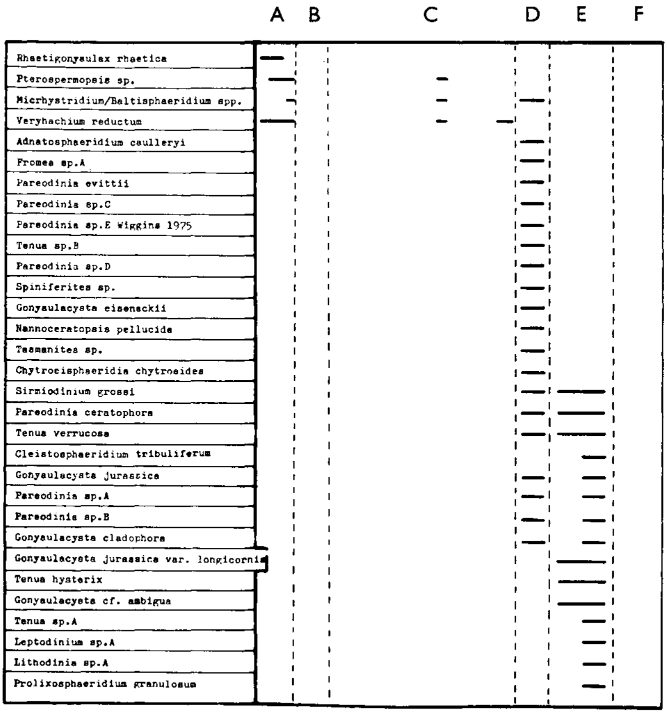


Table II, cont.



Preservation and productivity

Nearly all of the 90 samples investigated yielded identifiable palynomorphs. Sporomorphs of good preservation were rare in the diverse assemblages of association A. Following CUSHING's (1967) classification of preservation, assemblages of association A showed typically *corroded* and *broken* grains. Assemblages of association B and C contained mostly *well preserved* grains.

The sporomorphs of association D and E, mostly bisaccates, were *degraded* and *corroded* and almost impossible to identify. The marine species showed a variation between *degraded* and *corroded* and *well preserved* grains.

Palynomorphs from the assemblage of association F were mostly *well preserved*, though a number of *broken* sporomorphs were observed.

The degree of thermal alteration judged from the colour of organic matter in un-oxidized material is 2.0 to 2.5 (Staplin index, STAPLIN 1969).

Palynological associations

A composite section has been worked out on the basis of the presumed stratigraphical relationships between the individual sections. In Table II the ranges of 77 selected palynomorph species are indicated against this composite section. Six palynomorph associations (A—F) of stratigraphical significance for this section from Kong Karls Land are recognized.

Association A including assemblages from the shore cliff section northeast of Hårfagrehaugen (locality 12) is characterized by diverse spore and pollen assemblages associated with *Micrhystridium* spp., *Veryhachium reductum*, *Pterosper-*

mopsis sp., and *Rhaetogonyaulax rhaetica*, indicating a marginal marine environment. The marine facies in this part of the sequence was not observed by SMITH et al. (1976).

Association B recorded from samples betwen 34 and 60 m on the northwestern slope of Hårfagrehaugen and from samples just above those belonging to association A in the shore cliff section, lacks the marine elements of association A, but shows similar spore and pollen assemblages. The first appearance of *Aratrisporites fimbriatus*, *Limbosporites lundbladii*, and *Circulina meyeriana*, probably controlled by facies, also characterizes this association.

Association C is introduced by the disappearance of several characteristic Rhaetian spore and pollen species at approximately 60 m. No samples were available from the interval between 86 and 139 m, but most of the species occurring between 60 and 86 m are also found between 139 and 155 m. The first appearance of *Cerebropollenites mesozoicus* at 139 m is considered to be of stratigraphic importance. The reappearance of marine species like *Pterospermopsis* sp., *Micrhystridium* spp., *Baltisphaeridium* spp., and *Veryhachium reductum* indicates a return to marine conditions at 139 m.

Assemblages of association D are found in the three samples taken at 222 and 226 m on Hårfagrehaugen. Middle Jurassic dinoflagellate assemblages are recorded from this interval. *Pareodinia evittii*, *P.* sp. C, and *P.* sp. D together with *Nannoceratopsis pellucida* form characteristic elements in these assemblages. Association D is completely different from associations A, B, and C as only a few spore and pollen species were observed. Bisaccates, however, are abundant in assemblages of association D.

Association E from Kükenthalfjellet, Svenskøya (locality 6), is characterized by another association of dinoflagellate assemblages. The appearance of *Gonyaulacysta jurassica* var. *longicornis*, *Tenua hystrix*, *Cleistosphaeridium tribuliferum*, *Prolixosphaeridium granulosum*, and *Lithodinia* sp. gives this association a younger aspect than assemblages of association D. Both association D and E represent marine environments.

Association F is based on one assemblage only, recorded from Retziusfjellet just below the basalts (locality 13). This assemblage is dominated by bisaccate pollen and only a few stratigraphically important species were noted, *Cicatricosisporites australiensis*, *C. perforatus*, and *Contignisporites cooksonii*. SMITH et al. (1976) reported several reworked "Rhaeto-Liassic" palynomorph species from this horizon. Our assemblage is, however, typically autochthonous.

Age and correlation

Associations A and B

Associations A and B include assemblages closely similar to Rhaetian assemblages known from NW Europe and Arctic Canada. In Arctic Canada no detailed zonation of the beds at the Triassic-Jurassic boundary has been established, but the assemblages of associations A and B are comparable with those from the upper part of the Heiberg Formation (Upper Triassic —? Lower Jurassic) (McGregor 1965; Felix 1975; Fisher and Bujak 1975). The detailed palynological subdivisions of the Rhaeto—Liassic beds in Europe established by Schulz (1967), Orbell (1973), Morbey and Neves (1973), and Lund (1976) are partly inconsistent and can not be applied regionally because of the influence of facies on the distribution of palynomorphs.

The occurrence of *Stereisporites bicollateralis*, *Heliosporites reissingerii*, *Selagosporis mesozoicus*, *Camarozonosporites laevigatus*, *Lycopodiacidites rhaeticus*, *Polycingulatisporites circulus*, *Aratrisporites fimbriatus*, *Ricciisporites tuberculatus*, *Lycopodiacidites rugulatus*, *Cingulizonates rhaeticus*, *Limbosporites lundbladii*, *Camarozonosporites rudis*, *Ovalipollis limbata*, and *Rhaetogonyaulax rhaetica* in association A and B strongly suggests an upper Rhaetian age for these beds.

The intervals studied were tentatively referred to the sections described by Smith et al. (1976) in Figure 3. There is some uncertainty as to the position of the sampled intervals relatively to these sections because sampling was carried out before this stratigraphical terminology was established and no complete section was obtained during sampling. Further, the exact position of the sections

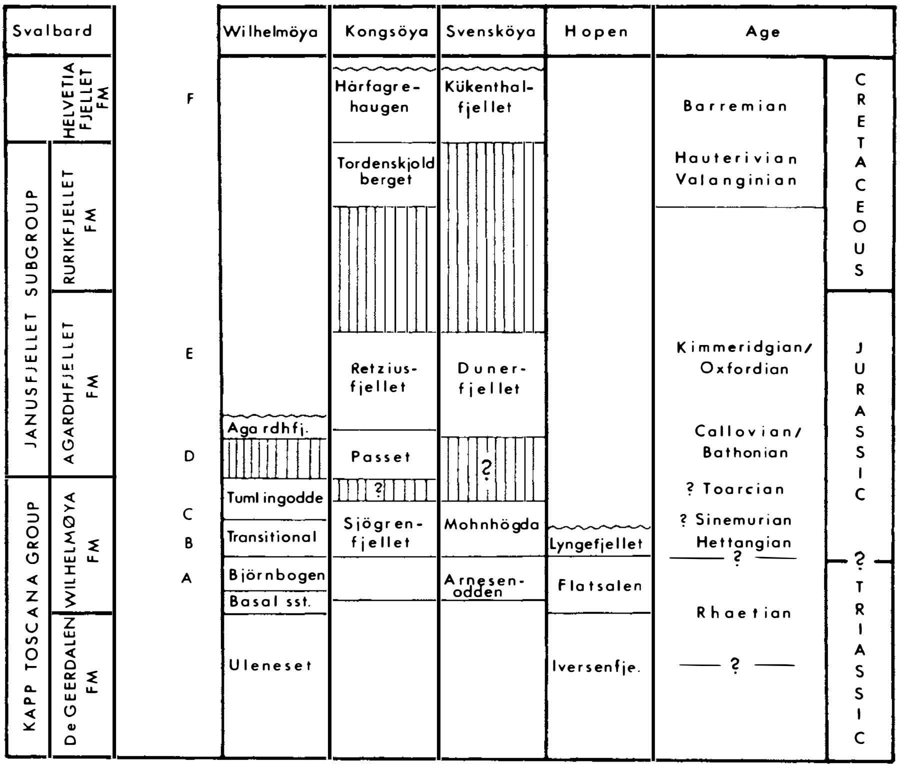


Fig. 4. *Lithostratigraphical units in the Upper Triassic, Jurassic and Lower Cretaceous of Svalbard. Suggested age and correlation of sequences on Wilhelmøya, Kong Karls Land and Hopen. All local units are at the level of members. Letters A through F incidate position of palynomorph associations described in the text.*

described by SMITH et al. is not known since heights above sea-level were not given, However, if my interpretation is correct, association B occurs in the Sjøgrenfjellet Member, here regarded as part of the Wilhelmøya Formation (Figure 3, section 12), while association A is recorded from the beds just below this member, a unit probably correlative with the Arnesenodden Bed, described from Svenskøya by SMITH et al. (1976) (Figure 3, lower part of section 1). This is supported by the palynological data given by SMITH et al. Of the nine species listed by SMITH et al. from the Arnesenodden Bed (Sample H 3072, Table 4), six belong to association A. The species recorded by SMITH et al. from Sjøgrenfjellet Member at Hårfagrehaugen (Sample C 4395, Table 4) are all found within association B.

The assemblages of association A on Kong Karls Land are almost identical to assemblages described from the Flatsalen Member, Wilhelmøya Formation on Hopen (SMITH et al. 1975; BJÆRKE 1975; BJÆRKE and MANUM 1977). This allows a correlation between the two areas (Figure 4). The change to the non-marine facies of association B probably corresponds stratigraphically to the transition from the Flatsalen Member to the Lyngefjellet Member on Hopen. Palynological information from the Lyngefjellet Member is not sufficient for a confident correlation, but the first appearance of *Limbosporites lundbladii* reported by SMITH et al. (1975) from this member on Hopen, supports this view.

Association C

The age of association C is difficult to establish from the available data. The disappearance of several Rhaetian spore and pollen taxa and the first appearance of *Cerebropollenites mesozoicus* suggest that we are in the lowermost Jurassic. The assemblages of association C come from the upper part of the Wilhelmøya Formation, probably corresponding to the upper part of the Sjøgrenfjellet Member of SMITH et al. (1976). Unfortunately no palynological information is available from the type section of the Wilhelmøya Formation. The grey clay described by WORSLEY (1973) from Wilhelmøya (middle part of the Tumlingodden Member) containing belemnites, is probably younger than the upper part of the Sjøgrenfjellet Member as indicated in Figure 4.

Association D

Association D is of Middle Jurassic age and contains assemblages similar to those described by JOHNSON and HILLS (1973) from the upper part of the lower Savik Member, Savik Formation, in Arctic Canada. It is recorded from beds probably belonging to the Retziusfjellet Member, Agardhfjellet Formation, just above its base at Hårfagrehaugen. NATHORST dated this unit as Callovian. No palynological information is yet available from Jurassic beds elsewhere in Svalbard.

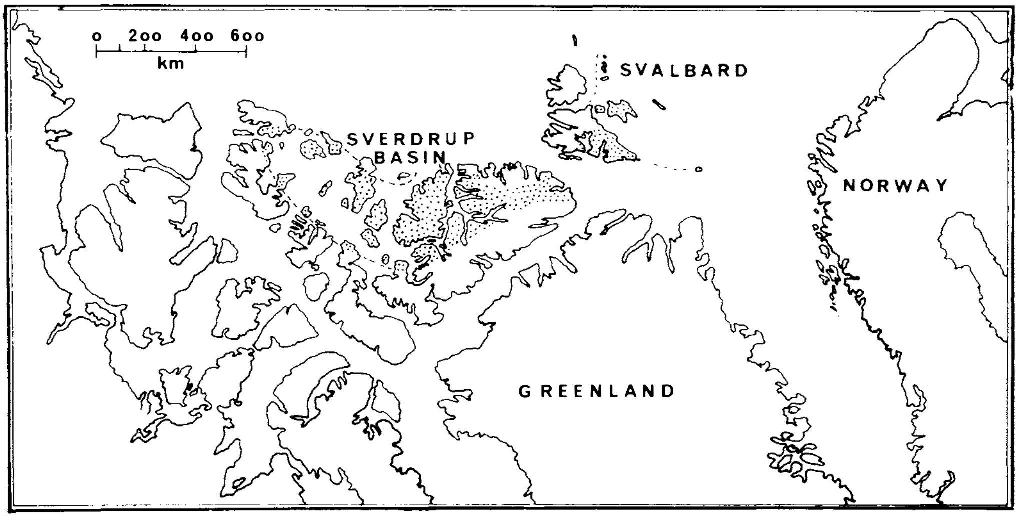


Fig. 5. *Position of Svalbard in relation to the Sverdrup Basin, Arctic Canada, prior to the Tertiary continental drift.*

Association E

Association E is established on the presence of dinoflagellate assemblages from the Agardhfjellet Formation on Svenskøya (Figure 3, section 6), probably belonging to the Dunérfjellet Member of SMITH et al. (1976). The appearance of *Gonyaulacysta jurassica* var. *longicornis*, *Tenua hystrix*, *Cleistosphaeridium tribuliferum*, and *Lithodinia* sp. suggests an Upper Jurassic age and compare with assemblages described from the upper Savik Member, Savik Formation, in Arctic Canada (JOHNSON and HILLS 1973). The Dunérfjellet Member has previously been dated as Oxfordian—Kimmeridgian on the basis of ammonites (NATHORST 1910; BLÜTHGEN 1936; SMITH et al. 1976).

Association F

Association F assemblage from the Hårfagrehaugen Member, Helvetiafjellet Formation, gives no definite information on the age, but it is of Lower Cretaceous, probably Barremian age.

The position of Svalbard in relation to Arctic Canada prior to the Tertiary continental drift is shown in Figure 5. It appears quite probable that Svalbard formed a continuous eastern extension of the Sverdrup Basin during the Mesozoic. As further information on palynomorph ranges accumulates, a detailed correlation should become possible between the two areas.

Stratigraphical conclusions

The oldest beds on Kong Karls Land are of Rhaetian age. They are correlated with the Flatsalen Member, Wilhelmøya Formation, on Hopen, and may also be correlated with the Bjørnbogen Member on Wilhelmøya (Figure 4). These beds were deposited in a marginal marine environment.[1]

[1] These beds correspond to the Kapp Koburg Member, a unit introduced by WORSLEY & HEINTZ (this vol., pp. 69—81).

Above the lower shale unit follows an approximately 200 m thick sequence dominated by sandstones. Palynomorph assemblages indicate a transition to non-marine environment at the base of the sandstone unit (Sjøgrenfjellet Member, Wilhelmøya Formation). Some thin lenses of clay higher up in the sequence produced palynomorph assemblages indicating marine influence. The age of this unit is probably lowermost Jurassic.

The sandstone unit is overlain by Middle and Upper Jurassic clays and shales referred to the Agardhfjellet Formation. Dinoflagellate assemblages from the lower part indicate a Middle Jurassic age in agreement with previous dating based on macrofossils. Dinoflagellates from the upper part is of Oxfordian or Kimmeridgian age, also in agreement with previous dating.

There is a significant break in the sequence in the Upper Jurassic and Lower Cretaceous, caused by uplift and erosion. The continental sandstones and lavas of the Helvetiafjellet Formation (?Barremian), overlie unconformably the Wilhelmøya and the Agardhfjellet Formations (Figure 3). In some places a calcareous sandstone and shale unit is found below the Helvetiafjellet Formation. This unit is of Lower Cretaceous (?Valanginian) age and probably correlative with the Rurikfjellet Formation in Spitsbergen (SMITH et al. 1976).

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PLATES

All figures x 500 unless otherwise stated. Coordinates given for Plates 1 to 5 refer to the Reichert microscope 359.091 belonging to Paleontologisk Museum, University of Oslo, coordinates given for plates 6 to 10 refer to the Leitz Dialux microscope 68 61 38 belonging to the Institutt for Geologi, University of Oslo. The slides are kept in the type collection of Paleontologisk Museum, University of Oslo.

PLATE 1

Fig. 1. *Calamospora nathorstii* (HALLE) KLAUS 1960. 1061/5:49.8—104.0. Assoc. A, B.
Fig. 2. *Sphagnumsporites* sp. 1048/4:50.2—102.4. Assoc. A, B.
Fig. 3. *Biretisporites potoniei* DELCOURT & SPRUMONT 1955. 1005/12:35.2—109.1. Assoc. A, B.
Fig. 4. *Cyathidites australis* COUPER 1953. 1005/4:39.4—119.2. Assoc. A, B, C, D, E, F.
Fig. 5. *Dictyophyllidites mortonii* (COUPER) DETTMANN 1963. 1005/6:34.3—108.7. Assoc. A, B.
Fig. 6. *Retusotriletes mesozoicus* KLAUS 1960. 1005/11:30.5—122.1. Assoc. B.
Fig. 7. *Concavisporis* sp. 1005/11:44.0—108.5. Assoc. B.
Fig. 8. *Dictyophyllidites mortonii* (COUPER) DETTMANN 1963. 1005/11:38.8—112.8. Assoc. A, B.
Fig. 9. *Cyathidites australis* COUPER 1953. 1005/4:28.2—117.6. Assoc. A, B, C, D, E, F.
Fig. 10. *Cyathidites australis* COUPER 1953. Corroded specimen. 1005/11:38.5—117.6. Assoc. A, B, C, D, E, F.
Fig. 11. *Biretisporites* cf. *spectabilis* DETTMANN 1963. 1594/8:41.7—108.7. Assoc. B.
Fig. 12. *Biretisporites* cf. *spectabilis* DETTMANN 1963. 1005/6:42.8—117.7. Assoc. B.
Fig. 13. *Apiculatisporites parvispinosus* LESCHIK 1955. 1005/5:43.8—108.2. Assoc. B.
Fig. 14. *Conbaculatisporites mesozoicus* KLAUS 1960. 1005/6:41.9—111.5. Assoc. B.
Fig. 15. *Conbaculatisporites mesozoicus* KLAUS 1960. 1005/9:37.4—109.0. Assoc. B.
Fig. 16. *Uvaesporites argenteaeformis* (BOLCHOVITINA) SCHULZ 1967. 1061/5:50.2—118.3. Assoc. A, B.
Fig. 17. *Uvaesporites argenteaeformis* (BOLCHOVITINA) SCHULZ 1967. 1005/8:37.4—105.9. Assoc. A, B.
Fig. 18. *Heliosporites reissingerii* (HARRIS) MUIR & VANKONIJNENBURG—VANCITTERT 1970. 1381/6:44.2—111.1. Assoc. A.
Fig. 19. *Marattisporites scabratus* COUPER 1958. 1005/11:37.8—107.1. Assoc. B.
Fig. 20. *Cyathidites australis* COUPER 1958. Corroded specimen. 1005/11:38.5—117.6. Assoc. A, B, C, D, E, F.
Fig. 21. *Unidentified species.* 1065/1:30.9—116.5. Assoc. D.
Fig. 22. *Conbaculatisporites hopensis* BJÆRKE & MANUM 1977. 1005/10:44.7—102.6. Assoc. B.
Figs. 23, 24. *Apiculatisporis globosus* (LESCHIK) PLAYFORD & DETTMANN 1965. 1005/10:31.6—111.0. Assoc. B.

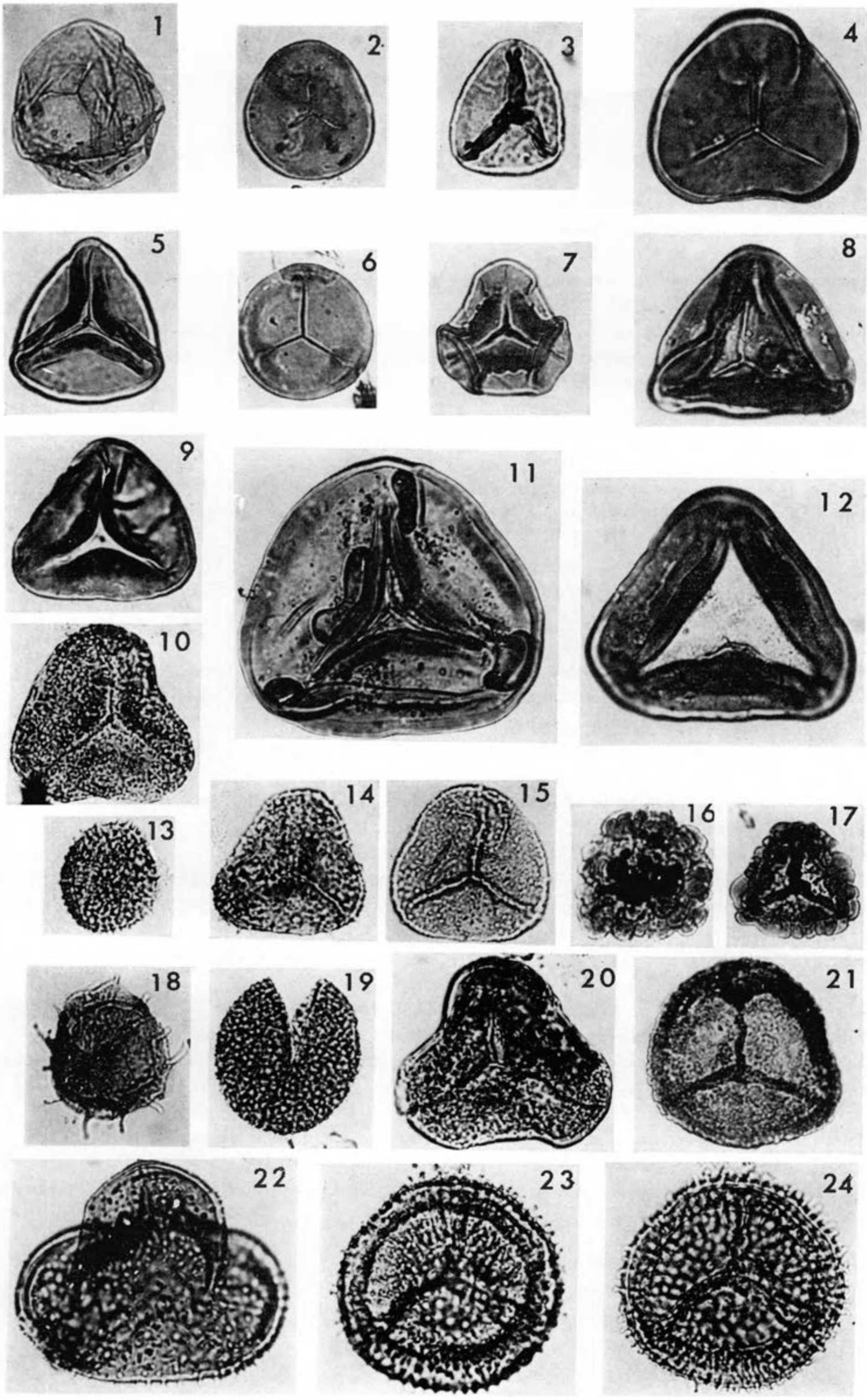
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PLATE 2

Fig. 1. *Lycopodiacidites microrugulatus* (SCHULZ 1967) n. comb. 1590/2 :47.9—106.9. Assoc. A, B.
Fig. 2. *Lycopodiumsporites semimuris* DANZE-CORSIN & LAVEINE 1963. 1594/2 :47.9—106.9. Assoc. A, B, C, D, E.
Fig. 3. *Lycopodiumsporites semimuris* DANZE-CORSIN & LAVEINE 1963. 1005/11 :46.6—110.3. Assoc. A, B, C, D, E.
Fig. 4. *Sphagnumsporites clavus* (BALME 1957) n.comb. 1054/1 :40.4—112.7. Assoc. A.
Fig. 5. *Spagnumsporites psilatus*(ROSS) COUPER 1958. WS 65/1 :46.1—110.0. Assoc. F.
Fig. 6. *Rugulatisporites* sp. 1054/1 :39.7—107.0. Assoc. A.
Fig. 7. *Cavatoretisporites obvius* BJÆRKE & MANUM 1977. 1061/5:54.2—111.3. Assoc. A.
Fig. 8. *Lycopodiumsporites* cf. *austroclavatidites* (COOKSON) POTONIE 1956. 1061/5:52.9—105.7. Assoc. A.
Fig. 9. *Camarozonosporites aulosenensis* SCHULZ 1967. WS 65/1 :30.0—105.0. Assoc. F.
Figs. 10, 11. *Camarozonosporites rudis* (LESCHIK) KLAUS 1960. Fig. 10 proximal focus, Fig. 11 distal focus. 1005/3 :32.3—122.1. Assoc. A, B, C, D.
Fig. 12. *Camarozonosporites laevigatus* SCHULZ 1967. 1005/8:32.4—113.4. Assoc. A, B.
Fig. 13. *Stereisporites perforatus* LESCHIK 1955. 1380/1 :38.4—116.0. Assoc. A, B, C, D.
Fig. 14. *Selagosporis mesozoicus* SCHULZ 1967. 1591/3:30.9—109.0. Assoc. A, B.
Fig. 15. Unidentified species 1005/3 :42.1—118.7. Assoc. B.
Fig. 16. *Zebrasporites laevigatus* SCHULZ 1967. 1005/5:27.2—121.1 Assoc. A, B.
Figs. 17, 18. *Zebrasporites interscriptus* KLAUS 1960. 1005/4 :33.2—107.6. Assoc. A, B, C.
Fig. 19. *Selagosporis mesozoicus* SCHULZ 1967. 1005/5:26.7—114.7. Assoc. A, B.
Fig. 20. *Annulispora bicollateralis* (ROGALSKA) BJÆRKE & MANUM 1977. 1591/3 :45.6—109.7. Assoc. A.
Fig. 21. *Annulispora folliculosa* DEJERSEY 1959. 1593/2 :40.5—101.4. Assoc. A, B.
Fig. 22. *Classopollis* sp. 1005/10 :30.6—122.5. Assoc. B.
Fig. 23. *Classopollis* sp. 1005/6:30.7—116.9. Assoc. B.
Fig. 24. *Polycingulatisporites mooniensis* DEJERSEY & PATEN 1963. 1005/10:25.7—102.0. Assoc. B.
Fig. 25. *Polycingulatisporites mooniensis* DEJERSEY & PATEN 1963. 1005/2 :40.2—102.0. Assoc. B.
Fig. 26. *Annulispora* sp. 1053/4 :42.1—111.0. Assoc. A.
Fig. 27. *Duplexisporites problematicus* PLAYFORD & DETTMANN 1965. 1005/5 :40.8—112.0. Assoc. A, B, C, D.
Fig. 28. *Kyrtomisporis* sp. Fragment of distal face. 1589/5 :43.4—104.1. Assoc. A.
Fig. 29. *Kyrtomisporis speciosus* MÄDLER 1964. 1054/1 :43.0—113.4. Assoc. A, B, C, D, E.
Fig. 30. *Limbosporites lundbladii* NILSSON 1958. Proximal focus. 1005/4 :44.6—121.6 Assoc. B.
Fig. 31. *Duplexisporites problematicus* PLAYFORD & DETTMANN 1965. 1005/5 :32.2—122.5. Assoc. A, B, C, D.
Fig. 32. *Kyrtomisporis speciosus* MÄDLER 1964. 1052/2 :31.1—120.6. Assoc. A, B, C, D, E.
Fig. 33. *Limbosporites lundbladii* NILSSON 1958. Proximal focus. 1005/5:26.3—120.2. Assoc. B.
Fig. 34. *Limbosporites lundbladii* NILSSON 1958. Distal focus. 1005/3:34.8—121.0. Assoc. B.

PLATE 2

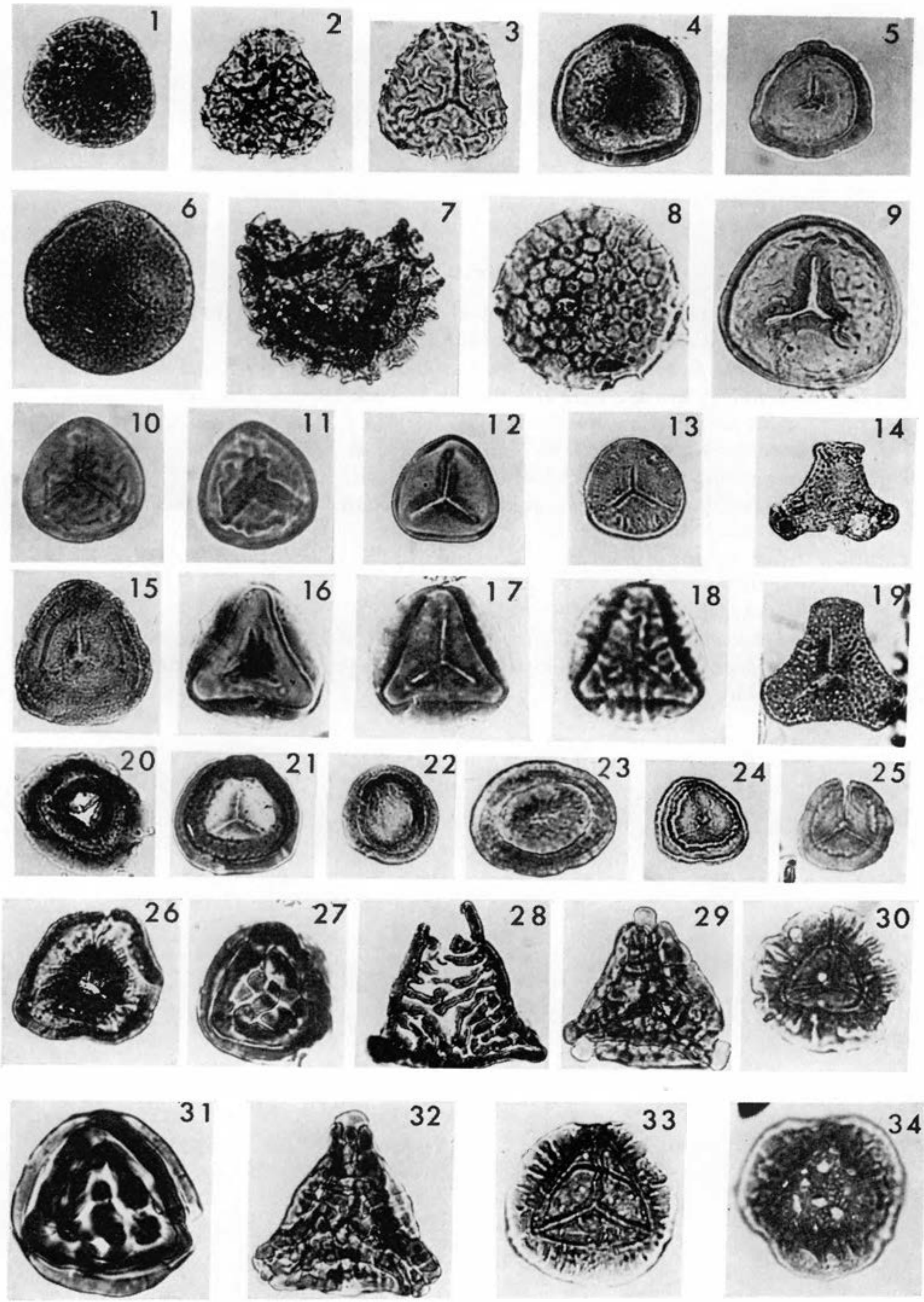
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PLATE 3

Figs. 1, 2. *Annulispora* sp.. Corroded specimen. Assoc. 1061/5:48.0—104.2 Assoc. A.
Fig. 3. Unidentified species. 1061/5:40.8—107,3. Assoc. A.
Fig. 4. *Densosporites fissus* (REINHARDT) SCHULZ 1967. 1005/5:27.3—122.3. Assoc. B.
Fig. 5. Unidentified species. 1589/5:49.0—105.7. Assoc. B.
Fig. 6. *Cingulizonates rhaeticus* SCHULZ 1967. 1054/1:34.4—118.2. Assoc. A, B.
Fig. 7. *Rugulatisporites* sp. 1382/1:38.7—109.7. Assoc. B.
Fig. 8. *Polycingulatisporites* sp. 1589/5:37.2—116.9. Assoc. B.
Fig. 9. *Polycingulatisporites* cf. *densus* (DEJERSEY) PLAYFORD & DETTMANN 1965. 1594/1:50.3—109.8. Assoc. B.
Fig. 10. *Polycingulatisporites crenulatus* PLAYFORD & DETTMANN 1965. 1594/1:42.1—105.9. Assoc. B.
Fig. 11. *Velosporites* sp. 1005/3:42.1—118.7. Assoc. A, B.
Fig. 12. *Lycopodiacidites rugulatus* (COUPER) SCHULZ 1967. 1057/4:25.4—106.0. Assoc. A, B, C.
Figs. 13, 14. *Velosporites* sp. Fig. 13 distal focus; Fig. 14 proximal focus. 1054/1:42.8—104.2. Assoc. A, B.

PLATE 3

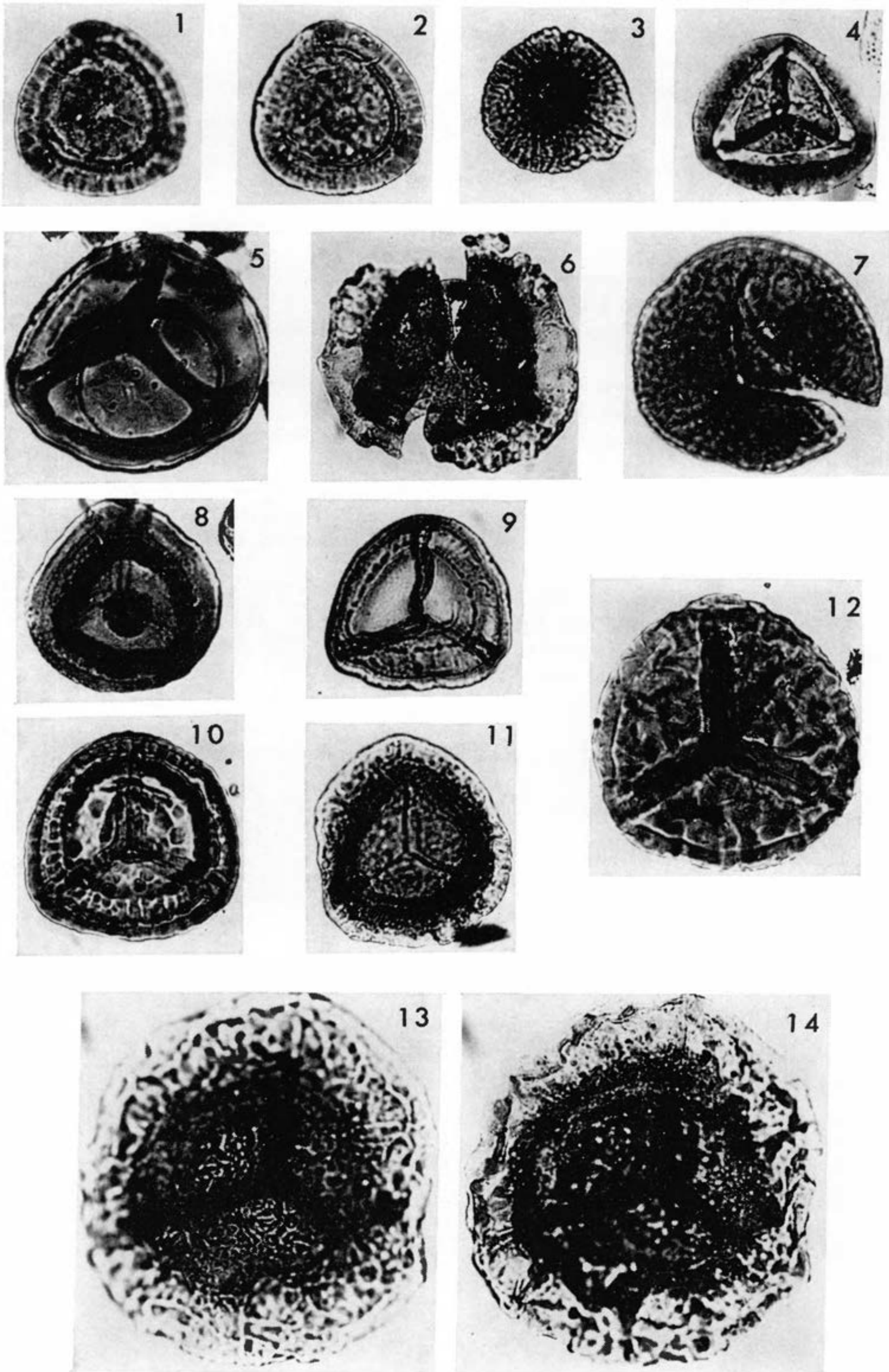

PLATE 4

Fig. 1. *Ginkgocycadophytus granulatus* DEJERSEY 1964. 1005/6:37.5—105.4. Assoc. B.
Fig. 2. *Perotrilites* sp. 1055/3:38.3—107.6. Assoc. A.
Fig. 3. *Aratrisporites fimbriatus* (KLAUS) PLAYFORD & DETTMANN 1965. 1005/3:52.9—109.6. Assoc. B.
Fig. 4. *Aratrisporites laevigatus* BJÆRKE & MANUM 1977. 1005/4:37.7—107.2. Assoc. B.
Fig. 5. *Ginkgocycadophytus* sp. 1591/5:34.4—105.2. Assoc. A.
Fig. 6. *Aratrisporites fimbriatus* (KLAUS) PLAYFORD & DETTMANN 1965. 1005/9:36.8—110.5. Assoc. B.
Fig. 7. *Ricciisporites tuberculatus* LUNDBLAD 1954. 1005/8:28.3—107.2. Assoc. A, B.
Fig. 8. *Verrucatosporites scabratus* BJÆRKE & MANUM 1977. 1382/1:40.6—101.8. Assoc. B.
Fig. 9. *Ovalipollis limbatus* (MALJAVKINA) POCOCK & JANSONIUS 1969. 1005/6:36.2—116.9. Assoc. A, B, C, D.
Fig. 10. *Chasmatosporites apertus* NILSSON 1958. 1005/6:31.5—110.9. Assoc. B, C.
Fig. 11, 12. *Chasmatosporites hians* NILSSON 1958. 1005/4:30.3—115.9. Assoc. A, B, C.
Fig. 13. *Chasmatosporites hians* NILSSON 1958. 1005/3:44.3—102.0. Assoc. A, B, C.
Fig. 14. *Chasmatosporites hians* NILSSON 1958. 1005/3:54.1—103.7. Assoc. A, B, C.
Fig. 15. *Ovalipollis ovalis* (KRUTZSCH) POCOCK & JANSONIUS 1969. 1005/3:41.3—101.9. Assoc. A, B.
Fig. 16. *Ovalipollis limbatus* (MALJAVKINA) POCOCK & JANSONIUS 1969. 1590/2:43.4—117.4. Assoc. A, B, C, D.
Fig. 17. *Striatites* sp. 1005/10:25.6—103.7. Assoc. B.

PLATE 4

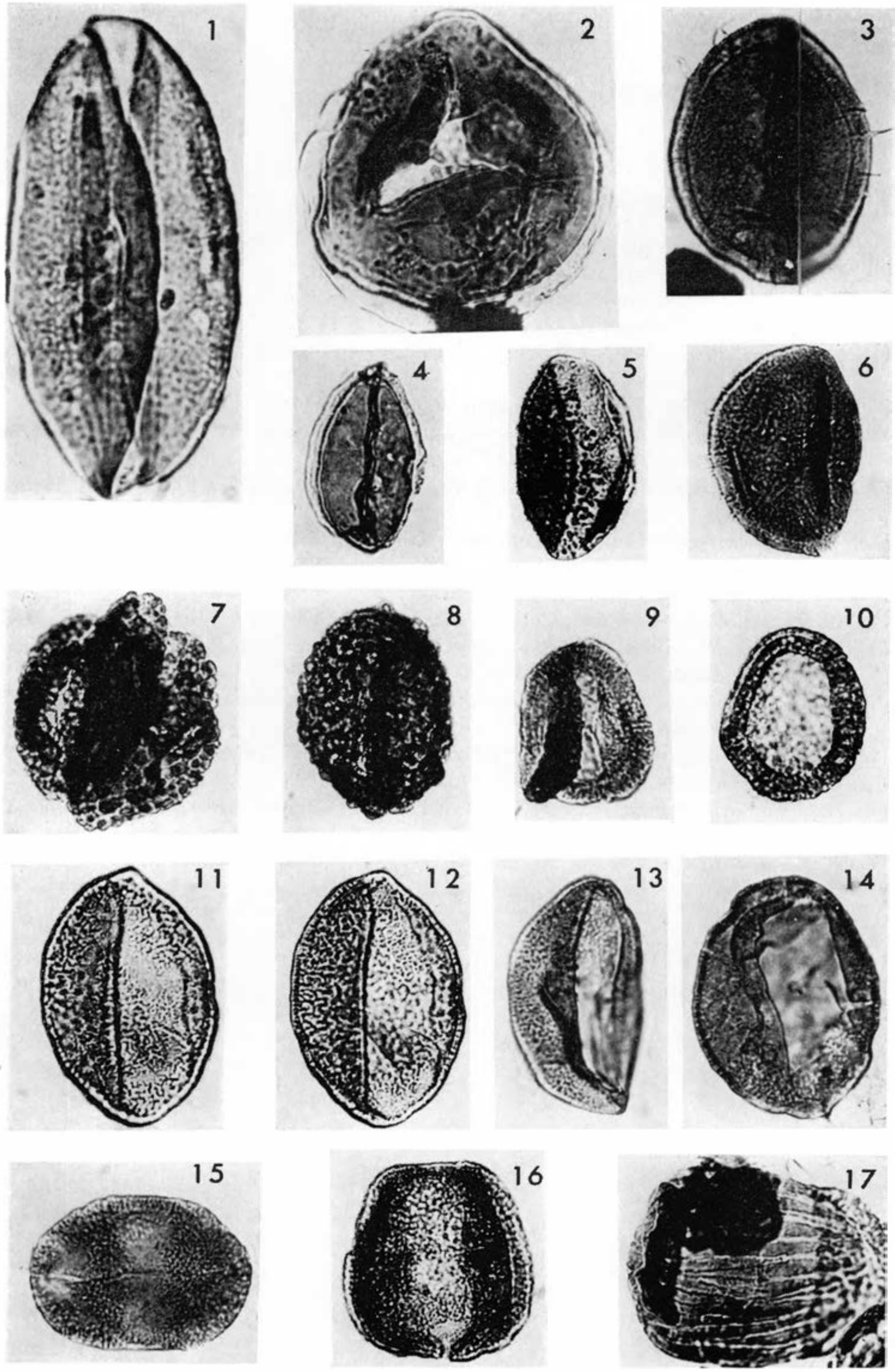

PLATE 5

Fig. 1. *Protodiploxypinus* sp. 1005/6:35.2—102.4. Assoc. B.
Fig. 2. *Protodiploxypinus* sp. 1005/11:40.1—110.4. Assoc. B.
Fig. 3. *Protodiploxypinus minor* BJÆRKE & MANUM 1977. 1005/2:26.8—100.8. Assoc. A, B.
Fig. 4. *Protodiploxypinus minor* BJÆRKE & MANUM 1977. 1379/1:35.7—106.1. Assoc. A, B.
Fig. 5. *Caytonipollenites pallidus* (REISSINGER) COUPER 1958. 1005/11:43.4—112.4. Assoc. A, B, C, D, E.
Fig. 6. *Protodiploxypinus gracilis* SCHEURING 1970. 1005/2:37.5—103.2. Assoc. A, B.
Fig. 7. *Protodiploxypinus ornatus* (PAUTSCH) BJÆRKE & MANUM 1977. 1005/7:31.2—117.3. Assoc. B.
Fig. 8. *Protodiploxypinus ornatus* (PAUTSCH) BJÆRKE & MANUM 1977. 1005/8:42.6—1118.9. Assoc. B.
Fig. 9. *Alisporites microreticulatus* REINHARDT 1964. 1054/1:26.8—121.0. Assoc. A.
Fig. 10. *Platysaccus* sp. 1382/3:24.7—104.3. Assoc. C
Fig. 11. *Podocarpites* sp. 995/1:29.0—102.1. Assoc. E.
Fig. 12. *Cerebropollenites mesozoicus* (COUPER) NILSSON 1958. 995/3:42.0—104.0. Assoc. C, D, E.
Figs. 13, 14. *Cicatricosisporites australiensis* (COOKSON) POTONIÉ 1956. Fig. 13 proximal focus; Fig. 14 distal focus. WS 65/3:44.0—104.3. Assoc. F.
Fig. 15. *Cicatricosisporites perforatus* (BARANOV, NEMKOVA & KONDRATIEV) SINGH 1964. WS 65/2:28.0—106.7. Assoc. F.
Fig. 16. *Neoraistrickia truncata* (COOKSON) POTONIÉ 1956. 1065/7:45.2—119.8. Assoc. C.
Fig. 17. *Chomotriletes* sp. WS 65/2:47.5—119.4. Assoc. F.
Fig. 18. *Cicatricosisporites australiensis* (COOKSON) POTONIÉ 1956. WS 65/4:42.7—121.4. Assoc. F.
Fig. 19. Unidentified sp. 1065/7:31.5—114.2. Assoc. C.
Fig. 20. *Cicatricosisporites cooksonii* BALME 1957. WS 65/3:49.8—116.5. Assoc. F.

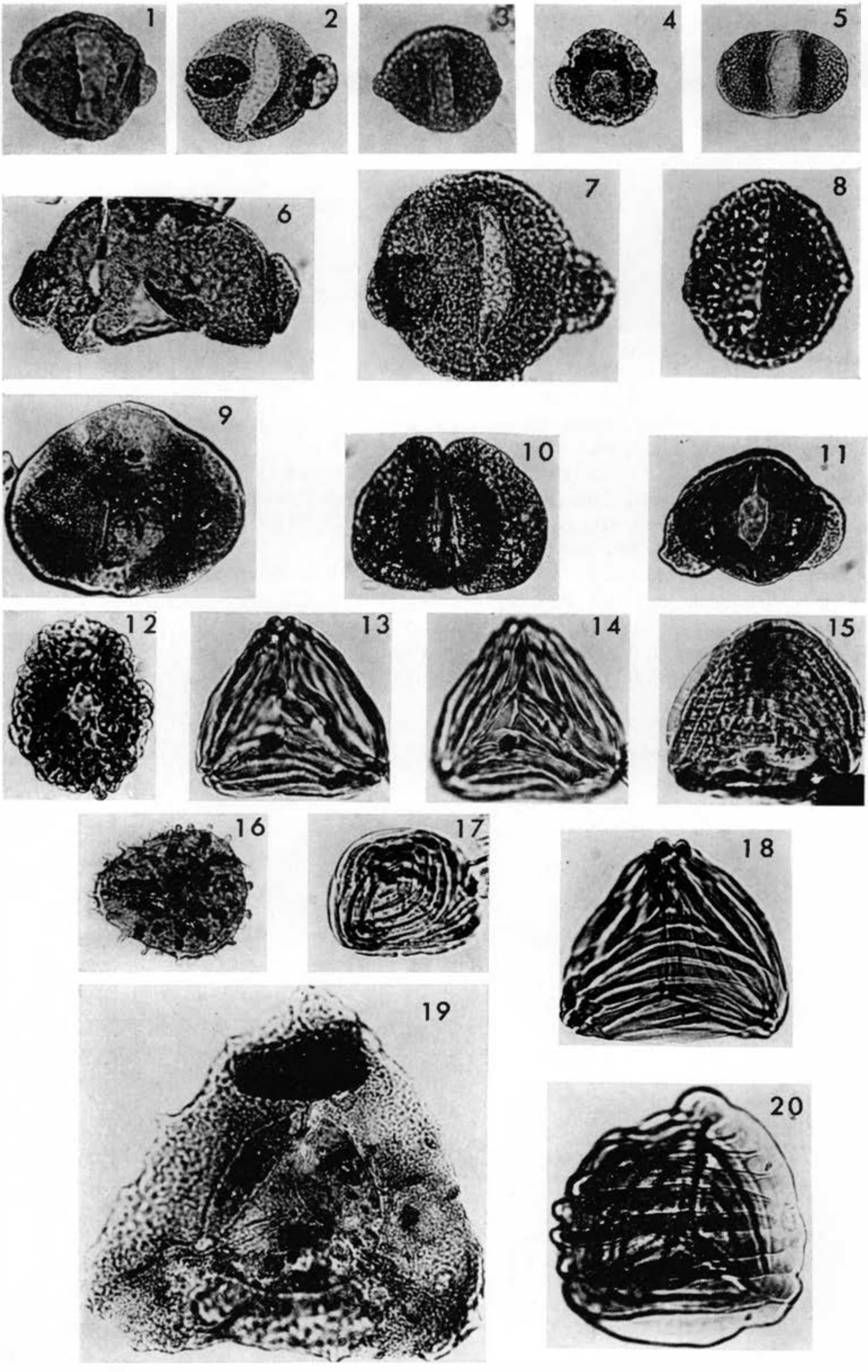
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PLATE 6

Fig. 1. *Corollina torosus* (REISSINGER) CORNET & TRAVERSE 1975. Lateral view × 1000. 1382/1: 40.0–103.1. Assoc. C, D.

Fig. 2. *Corollina torosus* (REISSINGER) CORNET & TRAVERSE 1975. Lateral view × 1000. 1382/1: 39.7–101.3. Assoc. C, D.

Fig. 3. *Corollina torosus* (REISSINGER) CORNET & TRAVERSE 1975. Polar view, proximal focus × 1000. 1382/1:34.1–104.7. Assoc. C, D.

Fig. 4. *Pareodinia evittii* (POCOCK) WIGGINS 1975. 1065/6:29.8–93.6. Assoc. D.

Fig. 5. *Pareodinia evittii* (POCOCK) WIGGINS 1975. 1065/3:35.4–93.2. Assoc. D.

Fig. 6. *Pareodinia evittii* (POCOCK) WIGGINS 1975. 1065/5:37.6–92.7. Assoc. D.

Fig. 7. *Pareodinia* sp. 995/28:43.0–101.9.

Fig. 8. *Pareodinia ceratophora* (DEFLANDRE 1947) GOCHT 1970. 995/1:52.2–95.1. Assoc. D, E.

Fig. 9. *Pareodinia* cf. *evittii* (POCOCK) WIGGINS 1975. 1383/1:36.7–111.3. Assoc. D.

Fig. 10. *Pareodinia* sp. D. 1378/21:50.9–93.7. Assoc. D.

Fig. 11. *Pareodinia* sp. A. 995/2:46.2–100.0. Assoc. D, E.

Fig. 12. *Pareodinia* sp. B. 1065/1:48.1–110.9. Assoc. D, E.

PLATE 6

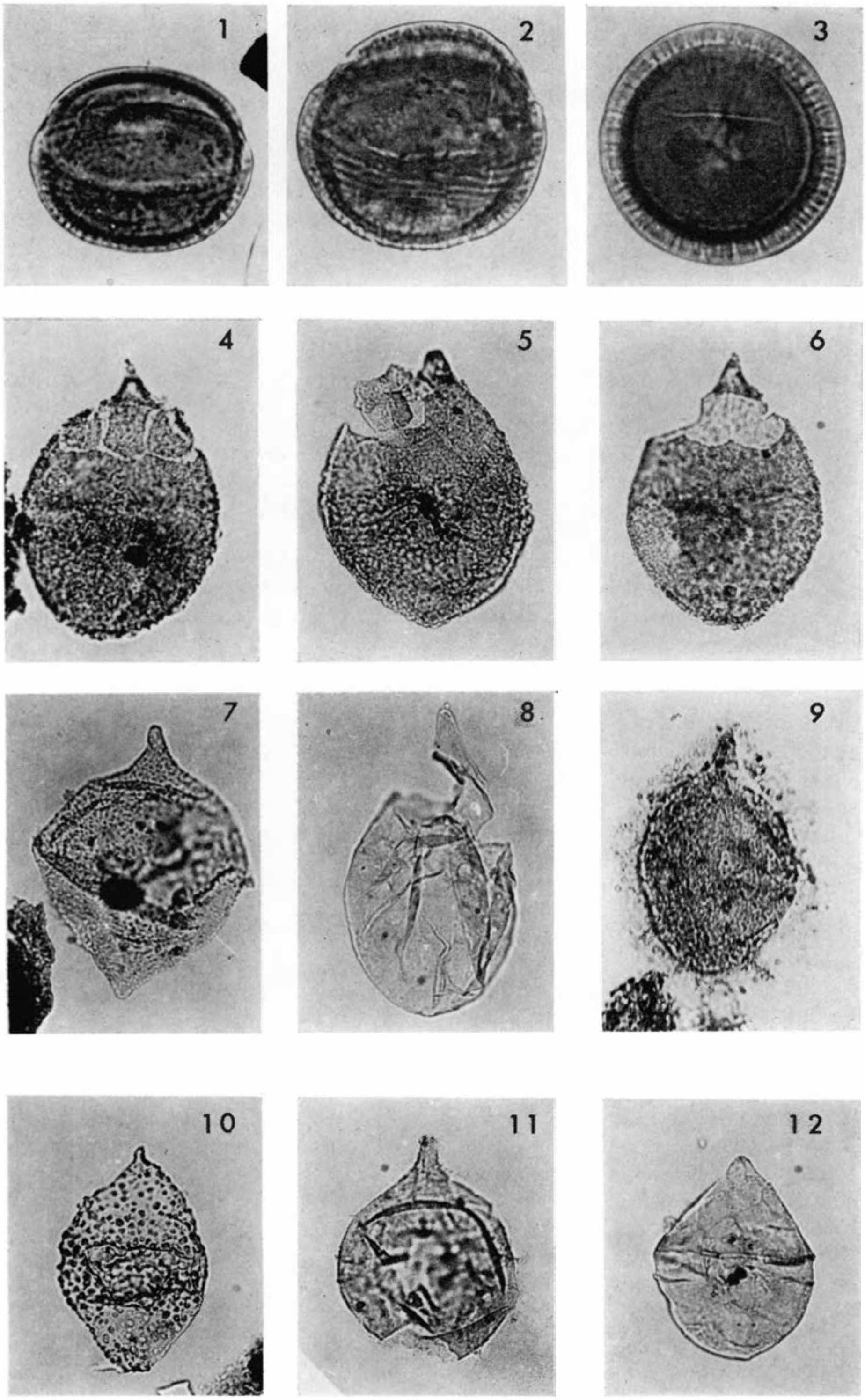


PLATE 7

Figs. 1, 2. *Fromea* sp. A. 1378/21:47.2—92.5. Assoc. D.
Fig. 3. *Chystroeisphaeridia chytroeides* SARJEANT 1962. 1378/9: 36.4—101.8. Assoc. D.
Fig. 4. *Tenua* sp. B. 1378/15:37.8—103.6. Assoc. D.
Fig. 5. *Chytroeisphaeridia chytroeides* SARJEANT 1962. Note free operculum inside test. 1378/20: 32.7—111.9. Assoc. D.
Fig. 6. *Chytroeisphaeridia chytroeides* SARJEANT 1962. 1378/21:39.8—112.8. Assoc. D.
Fig. 7. *Chlamydophorella* sp. 1378/21:30.2—99.3. Assoc. D
Fig. 8. *Tenua verrucosa* SARJEANT 1968. 1065/3:44.8—106.0. Assoc. D, E.
Fig. 9. *Tenua verrucosa* SARJEANT 1968. 1065/3:36.9—103.8. Assoc. D, E.
Fig. 10. *Canningia ringnesii* MANUM & COOKSON 1964. WS 51/5:48.1—111.1.
Fig. 11. *Tenua* sp. A. 995/25:44.0—96.1. Assoc. E.

PLATE 7

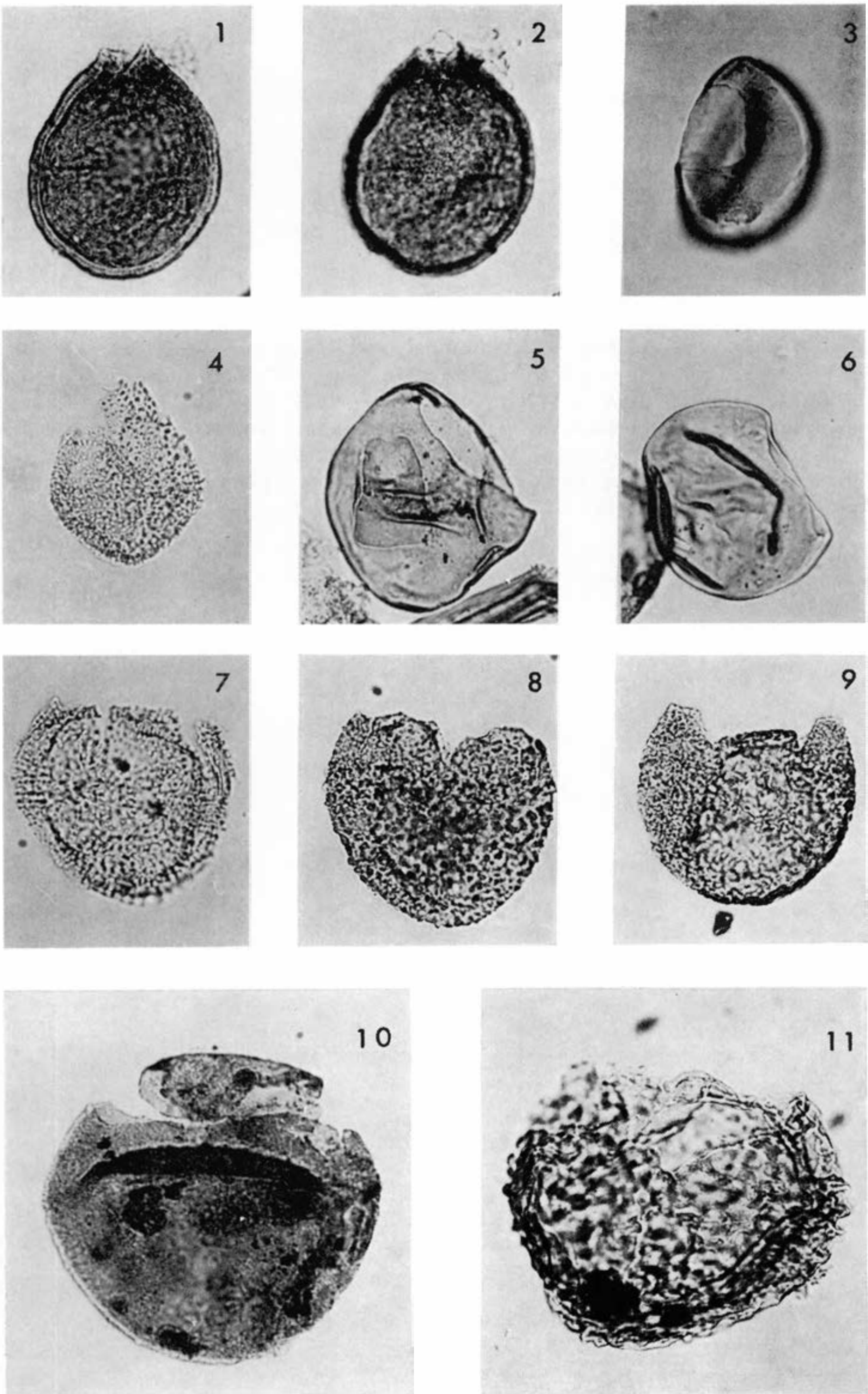


PLATE 8

Fig. 1. *Canningia ringnesii* MANUM & COOKSON 1964. 1065/3:33.4—94.8. Assoc. D.
Fig. 2. *Canningia minor* COOKSON & HUGHES 1964. 1065/1:34.2—110.2. Assoc. D.
Fig. 3. *Tenua hystrix* EISENACK 1958. 995/25:44.6—102.4. Assoc. E.
Figs. 4, 5. *Gonyaulacysta jurassica* var. *longicornis* (DEFLANDRE) GITMEZ 1970. Fig. 4. Dorsal. focus; Fig. 5 ventral focus. 995/27:23.8—103.0. Assoc. E.
Fig. 6. *Gonyaulacysta jurassica* DEFLANDRE 1938. 1065/1:44.5—110.6 Assoc. D, E.
Figs. 7, 8. *Leptodinium* sp. A. 995/26:54.6—113.4. Assoc. E.

PLATE 8

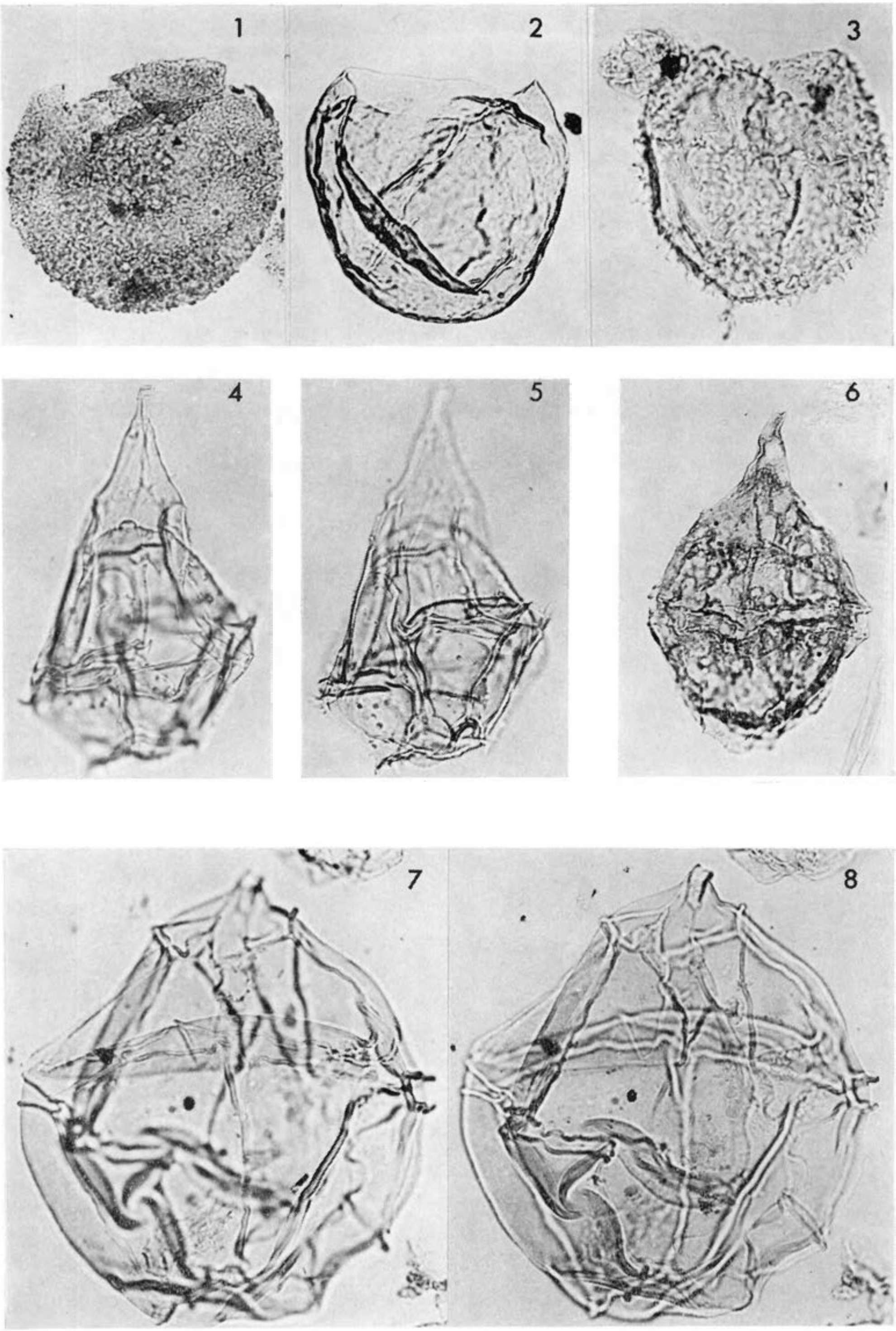


PLATE 9

Fig. 1. *Gonyaulacysta cladophora* DEFLANDRE 1938. 995/29:42.7—97.4. Assoc. D, E.
Fig. 2. *Gonyaulacysta cladophora* DEFLANDRE 1938. 1378/9:26.3—93.2. Assoc. D, E.
Fig. 3. *Gonyaulacysta cladophora* DEFLANDRE 1938. 995/29:45.9—113.9. Assoc. D, E.
Fig. 4. *Adnatosphaeridium caulleryi* (DEFLANDRE) WILLIAMS & DOWNIE 1969. 1378/20:43.5—95.4. Assoc. D.
Fig. 5. *Gonyaulacysta eisenackii* DEFLANDRE 1938. 1378/10:31.7—114.7. Assoc. D.
Fig. 6. Sp. Indet. 995/28:53.9—103.8. Assoc. E.
Fig. 7. *Tasmanites* sp. 1065/1:39.3—95.8. Assoc. D.

PLATE 9

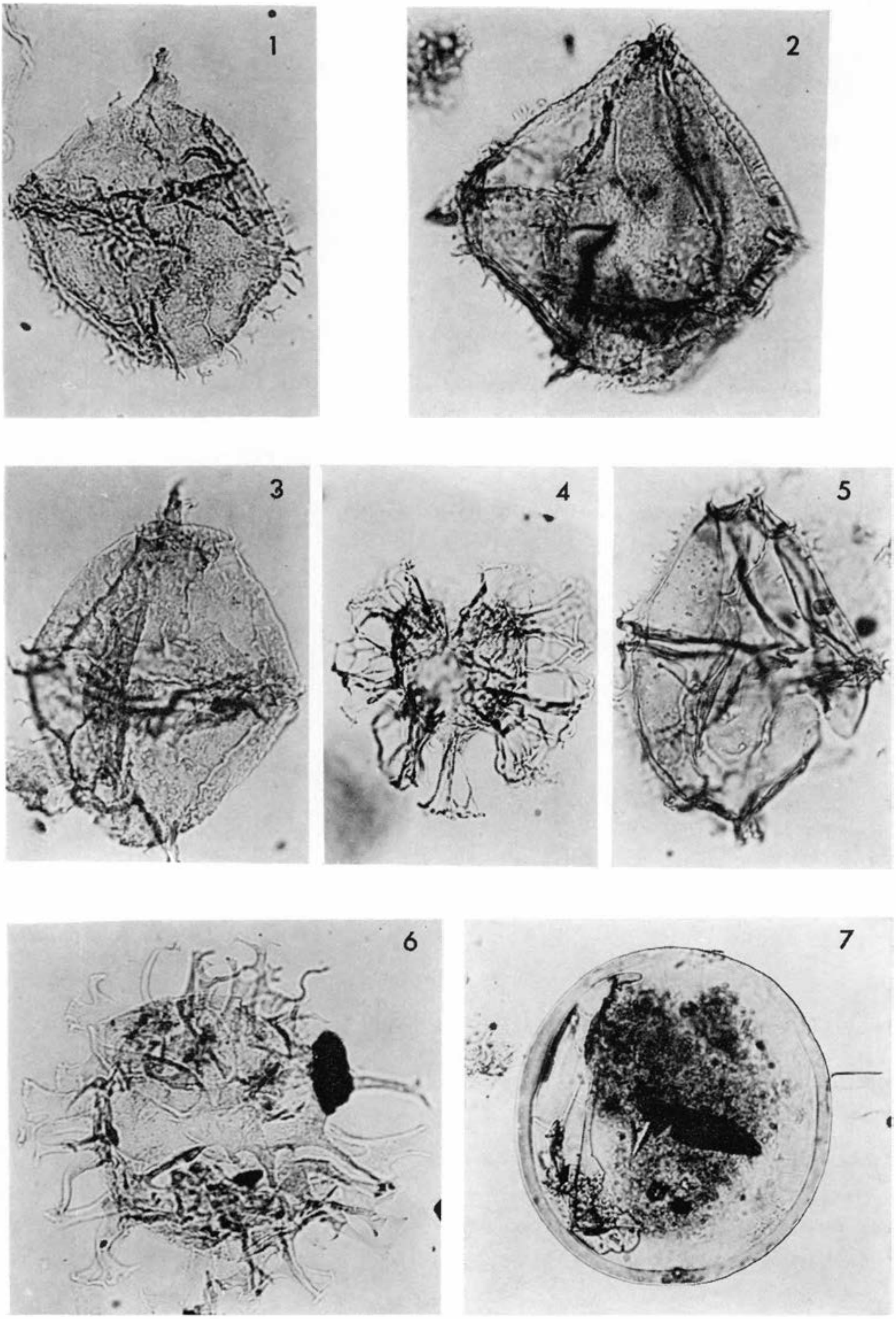


PLATE 10

Figs. 1—3. *Lithodinia* sp. A. Fig. 1 ventral focus; Fig. 2 focus on outline; Fig. 3 dorsal focus. 995/33:30.7—103.7 Assoc. E.

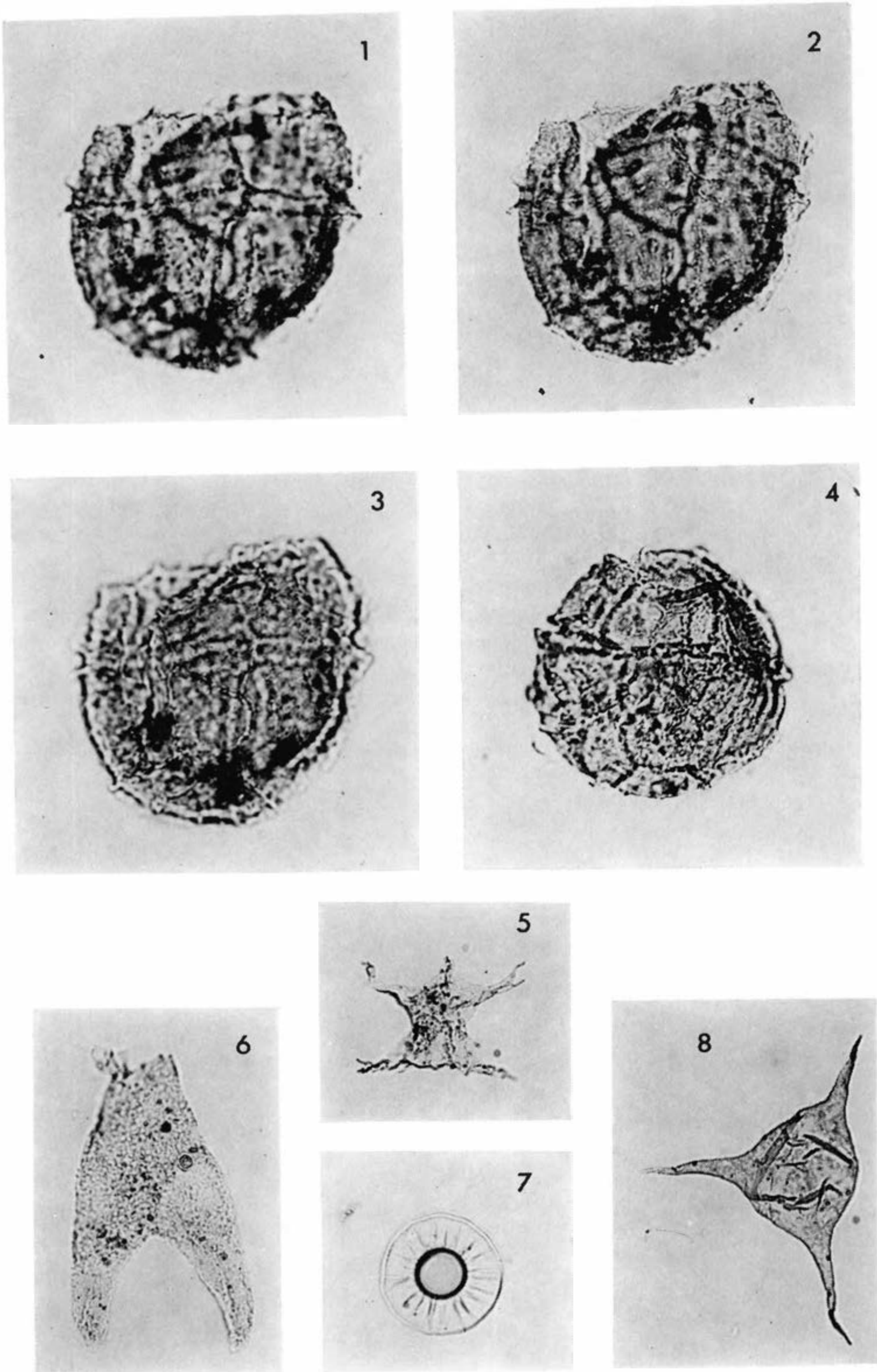
Fig. 4. *Lithodinia* sp. A. Complete specimen. 995/32: 42.4—102.1. Assoc. E.

Fig. 5. Sp. Indet. 1065/1:34.8—109.7. Assoc. D.

Fig. 6. *Nannoceratopsis pellucida* (DEFLANDRE) EVITT 1961. 1065/2: 39.6—112.4. Assoc. D.

Fig. 7. *Pterospermopsis australiensis* DEFLANDRE & COOKSON 1955. 1382/1:30.6—107.9. Assoc. A, C.

Fig. 8. *Veryhachium reductum* DEUNFF 1954. 1061/5: 17.3—99.3. Assoc A, C.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Preservation and abundance of palynomorphs, and observations on thermal alteration in Svalbard

By S. B. MANUM,[1] T. BJÆRKE,[1] T. THRONDSEN[1] and M. EIEN[1]

Contents

Abstract

Variations in sample productivity and palynomorph preservation in Mesozoic and Tertiary sediments in Svalbard are controlled by sedimentary facies.

Observations on palynomorph colour indicate no regional trend in thermal alteration east of the Spitsbergen Trough. Vitrinite reflectance measurements indicate increasing thermal alteration from the NE margin towards the centre of the trough. This is interpreted as a result of increasing depth of burial and possible raised geothermal gradient southwestwards. East of the Spitsbergen Trough there has probably been no significant differences in depth of burial or regional variations in geothermal gradient during the late Mesozoic or Tertiary.

Introduction

Since the beginning of palynological investigations in Svalbard, the erratic productivity of apparently promising lithologies has been a matter of much concern. MANUM's early studies on the Tertiary of Spitsbergen demonstrated that coals generally yielded workable assemblages, whereas silts and sandstones from the same succession were unproductive (MANUM 1962, Table 1). Subsequent attempts to process representative samples from the Mesozoic sequence in the central and western parts of Spitsbergen gave very disappointing results.

Until the mid 1960's, samples studied were mostly from central and western

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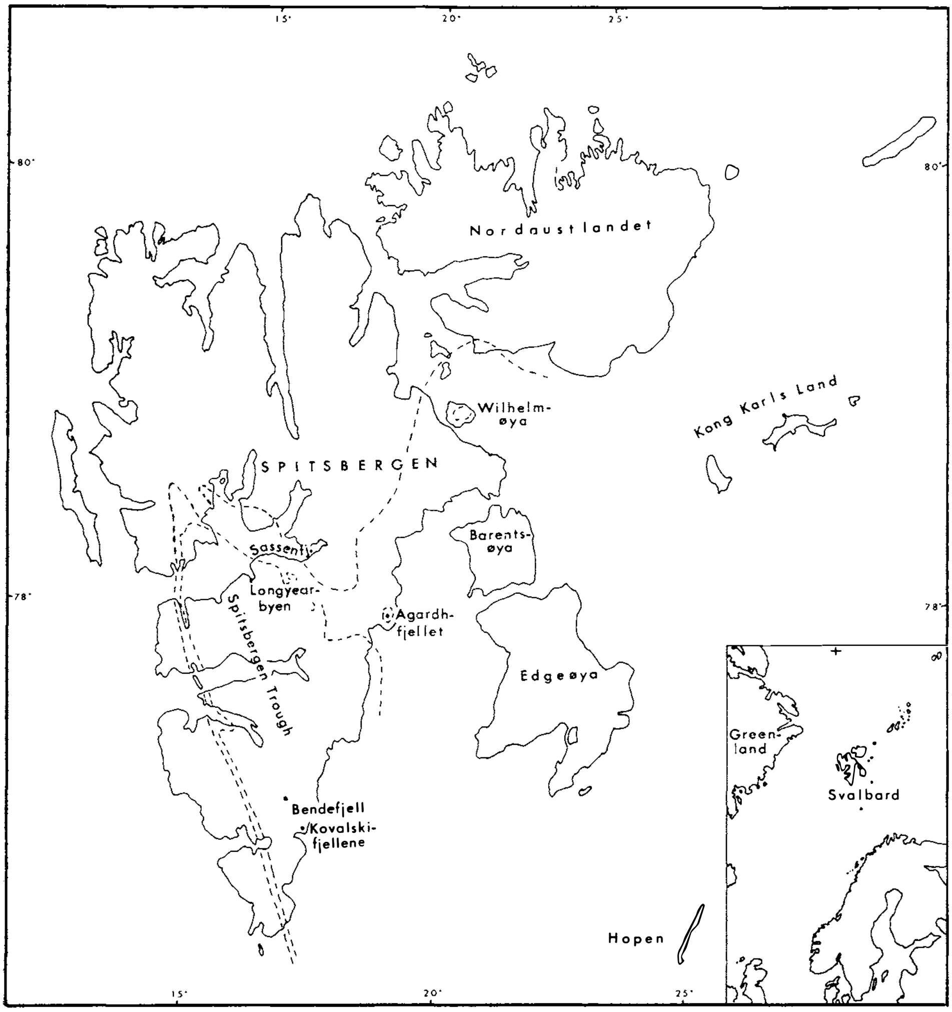

Fig. 1. *Map of Svalbard. Broken lines indicate base of Triassic and Jurassic respectively.*

Spitsbergen. During the last decade, however, improved transport facilities and further exploration have made representative material from eastern areas available for investigation. Workable palynological assemblages have been obtained from the Mesozoic sequence of Hopen (SMITH et al. 1975; BJÆRKE 1975; BJÆRKE and MANUM 1977), Kong Karls Land (SMITH et al. 1976; BJÆRKE 1977 (this vol.)), Wilhelmøya (SMITH 1975; BJÆRKE and DYPVIK 1977 (this vol.)) and Agardhfjellet (BJÆRKE et al. 1976). From a palynological point of view, therefore, the eastern areas seem better than the western areas (Figure 1).

Recently, HUGHES et al. (1976) reviewed available observations on preservation and general abundance of post-Silurian palynomorphs in the entire Svalbard area in an attempt to explain the variations observed. They advocate varying burial history under other sediments as the principal factor controlling palynomorph preservation and abundance on a regional basis, particularly in the Mesozoic sequence which is the most consistently represented from west to east.

In our recent studies, covering a wide range of Mesozoic and Cainozoic sediments in Svalbard, we have continuously met with the problems of poor sample productivity and greatly variable palynomorph preservation. However, our results do not support the hypothesis of HUGHES et al. (1976) that depth of burial (or heat) is the principal controlling factor of the observed variations. Our observations point to diagenetic degradation controlled by sedimentary facies as the more important factor.

Palynomorph preservation and abundance

Preservation of palynomorphs extracted from sediments is a complex subject. Degradation of palynomorph wall substance ('sporopollenin') in sediments involves a number of agencies; some acting more or less simultaneously, others clearly separated in time. As yet, processes involved are far from completely understood, but some general features appear to be clear.

It is important here to distinguish between 1) biological and other oxidation processes acting during the very early stages in the history of a sediment, controlled by sedimentary environment, and 2) processes taking place during the extended history of burial and consolidation when heat is the principal controlling factor. The effect of heat on palynomorphs as seen in preparations where no oxidation has been applied, is a general darkening. Morphological details are little affected unless thermal alteration reaches extreme stages (semi-anthracite to anthracite). However, early diagenetic degradation produces different effects such as gradual fading of morphological features and eventual destruction of entire specimens, or local destruction of wall material caused by microbial activity (HAVINGA 1967; CUSHING 1967; ELSIK 1971).

The principal hypothesis of HUGHES et al. (1976) is that the state of preservation and abundance of palynomorphs are related to the geothermal effect (or depth of burial) on palynomorph degradation in Svalbard. They have compiled observations on preservation from published sources and these are presented in a generalized form on a map (l.c. Figure 1). 'Preservation' is used in a broad sense, qualified by 'good', 'fair' and 'poor'. Such terms may be adequate as general indications of the quality of morphological details used for identification, but they convey no information on the type of observed degradation of the wall substance and so are of little value for interpreting the processes involved. HUGHES et al. (1976) present no observations on palynomorph colour, which would have been directly related to the discussion of their hypothesis. Their observations refer basically to other aspects of preservation than those most intimately related to carbonization or thermal alteration, and they are therefore inappropriate to demonstrate geothermal history of the sediments.

HUGHES et al. (1976, p. 237) stated that their study "did not show up any

Table 1

Sample productivity and palynomorph preservation in sections trough Mesozoic and Tertiary rocks in Svalbard.

MESOZOIC		Localities															
		Hopen				Kong Karls Land				Agardh-fjellet				Wiman-fjellet			
A G E	STRATIGRAPHIC INTERVAL	Interval	Samples	Productivity	Preservation	Interval	Samples	Productivity	Preservation	Interval	Samples	Productivity	Preservation	Interval	Samples	Productivity	Preservation
Aptian/ Albian	Carolinefjellet Formation														50	L	P
Barremian	Helvetiafjellet Formation						3	H	G						20	L	P
Valang./ Hauteriv.	Rurikfjellet Member										100	L H	P G		50	L H	P G
Callov./ Kimmeridg.	Agardhfjellet Member						20	L H	G G		100	L L	F P		50	L	F
Rhaetian/ ?Toarcian	Wilhelmøya Fm./Mbr.		50	H	G F		80	L H	G F		10	B			20	H H	G F
Carnian/ ?Rhaetian	DeGeerdalen Fm./Mbr.		150	L/ H	G/ P										3	L	P

Productivity: H=high, L=low, B=barren   Preservation: G=good, F=fair, P=poor

Table I — *Part 1.*

TERTIARY		Localities					
		Longyearbyen - Nordenskiöldfjellet			Kovalskifjella		
AGE	STRATIGRAPHIC INTERVAL	Interval Samples	Productivity	Preservation	Interval Samples	Productivity	Preservation
Miocene-Oligocene	Aspelintoppen Formation	12	H B	G P			
?	Battfjellet Formation	8	B				
Eocene	Gilsonryggen Formation	13	H B	F P			
	Sarkofagen Formation	3	B				
?	Basilika Formation	8	B		18	L	P
Paleocene	Firkanten Formation	23	H B	G			

Productivity: H=high, L=low, B=barren   Preservation: G=good, F=fair, P=poor

Table I — *Part 2.*

obvious difference in productivity of palynomorphs through the Mesozoic succession within any one area". Our observations, based on approximately 700 samples, show just the opposite. In all sections studied by us, obvious differences in productivity and preservation were noted (Table 1); moreover, these differences cannot be correlated with depth of burial.

On Hopen, most of the samples from the DeGeerdalen Formation (Upper Triassic) were barren or yielded restricted assemblages of little stratigraphic value. However, a few samples from different horizons yielded diverse and well preserved assemblages. From the lower part of the overlying Wilhelmøya Formation (Rhaetian) all samples produced diverse assemblages of fair to good preservation (BJÆRKE and MANUM 1977).

In the Sassenfjorden area, Spitsbergen, diverse palynomorph assemblages of fair to good preservation were recovered from the Wilhelmøya Member (Rhaetian–Lower Jurassic) (BJÆRKE and DYPVIK 1977 (this vol.)), while the Middle Jurassic shales of the Agardhfjellet Member produced poorer and less well preserved assemblages. From the marine shales of the Rurikfjellet Member (Lower Cretaceous) excellently preserved and diverse dinoflagellate assemblages were obtained (BJÆRKE et al. 1976; BJÆRKE, in prep.), but both productivity and preservation become poorer towards the overlying fluvial Festningen sandstone.

The marginal marine deposits of the Carolinefjellet Formation (Aptian–Albian) in Sassendalen have as yet failed to produce workable assemblages.

Observations from Tertiary sediments in the Longyearbyen–Nordenskiöldfjellet area, show that coal samples generally yield workable assemblages, while carbonaceous muds, silts and sandy sediments are usually unproductive (MANUM 1962; THRONDSEN, thesis in prep.).

From these observations on successions within restricted areas we can only conclude that differences in productivity and preservation are controlled by facies.

When stratigraphically equivalent strata are compared on a regional basis, we still find no consistent pattern in preservation or abundance which may be correlated with depth of burial. Thus, we observed no obvious differences in either productivity or preservation between samples from the lower part of the Wilhelmøya Formation (Rhaetian) on Hopen and Kong Karls Land in the east, and samples from Sassenfjorden in the west. Similarly, samples from the upper part of the Wilhelmøya Formation on Kong Karls Land and in Sassenfjorden produced well preserved assemblages in both localities.

Lower Cretaceous dinoflagellates from Agardhfjellet and Sassenfjorden are excellently preserved at both localities, showing no regional variation at this stratigraphic level (BJÆRKE et al. 1976; BJÆRKE, in prep.).

Another example is offered by the Basilika Formation (Lower Tertiary). Samples from this unit in the Longyearbyen area are unproductive, while stratigraphically equivalent samples from Kovalskifjellene produced poorly preserved palynomorphs. Phytoclast (dispersed vitrinite) reflectance measurements, however, indicate higher thermal alteration of these sediments in the southern part of the Spitsbergen Trough. Debris analyses indicate a difference in facies between these two areas, the Basilika Formation at Kovalskifjellene having occupied a more offshore position during the deposition (THRONDSEN, thesis in prep.).

Observations on thermal alteration

A general west to east shallowing of the Mesozoic and Tertiary sedimentary basin in Svalbard is evident (ORVIN 1940; LIVŠIC 1974; KELLOGG 1975). Sediments in the main Spitsbergen Trough in the west appear to have been subject to rather deep burial, estimates run in excess of 2.5 km overburden on present sediments in the central parts (LIVŠIC 1974). The comparatively high rank of Tertiary coals in the trough, being transitional between hard brown coal and sub-bituminous coal, is an indication of the extent of burial. Obviously a west to east gradient in burial depth will show up in a corresponding gradient in the diagenesis of palynomorphs and other dispersed organic matter in the sediments.

However, there is another plausible source for a west–east gradient, namely raised geoisotherms along the early spreading axis of the Greenland Sea, which at the time of opening (Lower Oligocene) appears to have been close to Spitsbergen (TALWANI and ELDHOLM 1977).

In view of the exploration for hydrocarbons in Svalbard and the adjacent Barents Shelf, an understanding of the geothermal history of the sediments is of primary interest. The diagenetic characters of dispersed palynomorphs and plant debris are excellent temperature indicators in the most critical interval for maturation of organic material. Therefore, palynological analyses in Svalbard are now directed towards the problems of thermal history in addition to stratigraphic problems.

No significant difference in sporomorph colour has been observed in samples from the lower part of the Wilhelmøya Formation (Rhaetian) from Hopen, Kong Karls Land, and Sassenfjorden. In all three localities, a slight to moderate alteration is indicated. Lower Cretaceous palynomorphs from Agardhfjellet on the east coast of Spitsbergen and from Sassenfjorden, central Spitsbergen, show no significant difference in colour, a slight to moderate alteration is indicated also at this level.

Studies in progress on vitrinite reflectance in Tertiary coals, indicate a lower thermal alteration in the periphery of the Spitsbergen Trough than in the central parts for sediments of equivalent age (Figure 2). In the northeast end of the trough (Knorringfjellet and Konusen), vitrinite in the lowermost coalbearing horizon has reflectivity between 0.4% and 0.5%, while reflectivity of stratigraphically equivalent coals in the Longyearbyen area is 0.7%. At Kolfjellet, western Spitsbergen, reflectivity of equivalent coals is 0.8%. Towards the SW end of the trough, reflectivity also increases, measurements from the Svea area giving 0.9% and from Sørkappland 1.1% (Figure 2; all measurements are maximum reflectivity in oil). This higher reflectivity in the south is possibly explained as a combined effect of burial depth and a higher geothermal gradient (THRONDSEN, thesis in prep.). In Nordenskiöldfjellet, Longyearbyen, reflectance measurements on the Tertiary give values from 0.7% at the base, decreasing gradually to 0.4% at the top. Sediment thickness

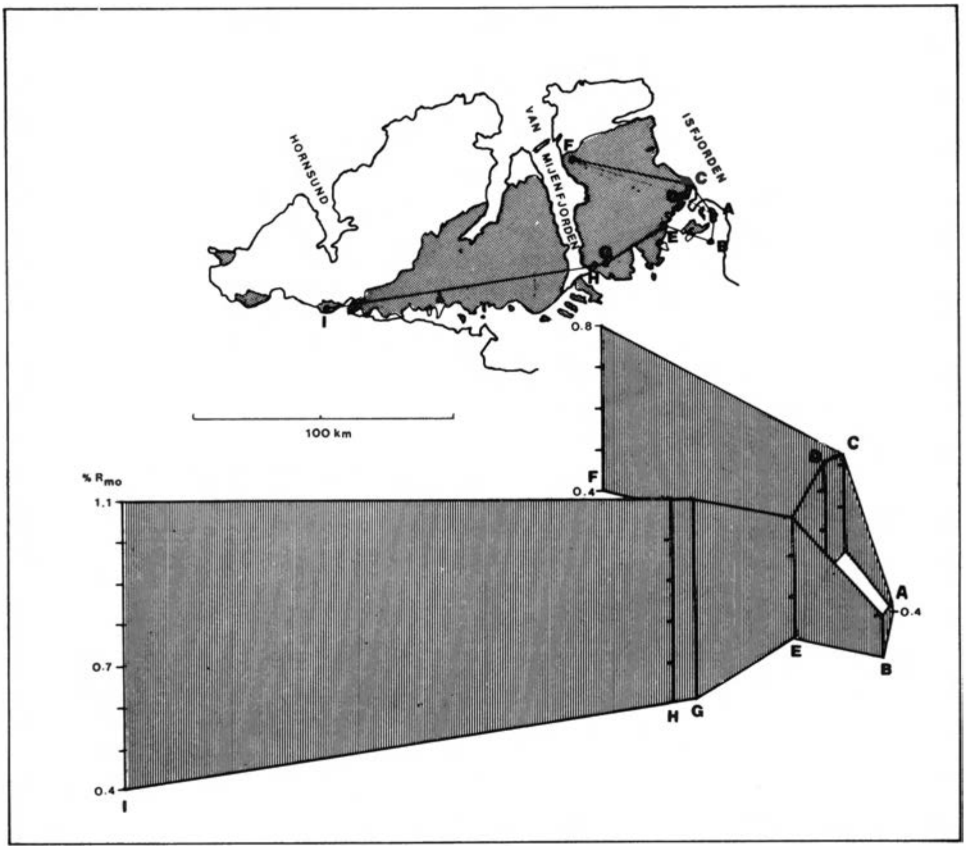

Fig. 2. *Vitrinite reflectance measurements on coals from the Firkanten Formation (Lower Tertiary), Spitsbergen. Localities: A: Konusen, B: Knorringfjell, C: Bjørndalen, D: Longyearbyen, E: Bolterdalen, F: Kolfjellet, G: Ortbreen, H: Svea, I: Hedgehogfjellet.*

between these beds is approximately 900 m, thus, no exceptional geothermal gradient is indicated by these results (THRONDSEN, thesis in prep.).

A few reflectivity measurements on Triassic through Tertiary sediments from one succession in Sassenfjorden, about 700 m thick, show a reflectivity of 0.7% at the base (Upper Triassic), 0.6% in the uppermost Jurassic, 0.6% in the lowermost Cretaceous, and 0.5% in the lowermost Tertiary (EIEN, thesis in prep.).

Conclusion

The fact that most Mesozoic and Tertiary sediments in Svalbard are barren or produce poorly preserved palynological assemblages is regarded as a result of unfavourable sedimentary facies. This is supported by observations on stratigraphically restricted productive units which show no regional trend in productivity and preservation. Thermal influence has no observable effect on preservation and productivity unless extreme temperatures are reached.

Our observations indicate no regional west–east trend in the degree of thermal alteration east of the Spitsbergen Trough. Moving from the eastern margin towards the central part of the basin, thermal alteration increases markedly. Vertical sections, however, indicate no exceptional geothermal gradient in the northeastern part of the trough. The implication of these observations is that Tertiary sediments of significant thickness did not extend east of the present Spitsbergen Trough.

Acknowledgements

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Sedimentological and palynological studies of Upper Triassic — Lower Jurassic sediments in Sassenfjorden, Spitsbergen

By TOR BJÆRKE[1] and HENNING DYPVIK[1]

Contents

Abstract

Two sections through the upper 20 m of the Kapp Toscana Formation have been studied sedimentologically and palynologically. The Upper Triassic shales and sandstones (DeGeerdalen Member) are overlain by a phosphorite conglomerate, a marginal marine sandstone and a 15 m thick sequence of marine shales and siltstones. The shale interval is subdivided into a Rhaetian and an upper Lower Jurassic unit separated by a hiatus. The characteristic Brentskardhaugen Bed (Toarcian or younger) is found above this sequence.

Diverse palynomorph assemblages have been recorded from phosphorite pebbles and shales, allowing dating and correlation. The sediments between the DeGeerdalen Member and the Brentskardhaugen Bed is regarded as a lateral equivalent to parts of the Wilhelmøya Formation and correlated with beds on Wilhelmøya, Hopen and Kong Karls Land. The Rhaetian part was formed during a transgressive phase. The upper shale unit is the oldest Jurassic sediments in the area.

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1. Introduction

Several projects at the Institutt for Geology and Paleontologisk Museum, University of Oslo, are now cooperating to provide detailed information on the sedimentology and biostratigraphy of the Upper Paleozoic, Mesozoic and Tertiary sequence of Svalbard.

The present paper is the result of a detailed sedimentological and palynological investigation of Upper Triassic and Lower Jurassic beds from the area between Diabasodden and DeGeerdalen, Spitsbergen. The recognition of a late Triassic–early Jurassic unit (the Wilhelmøya Formation, WORSLEY 1973) in eastern Spitsbergen and on Hopen, made a reexamination of the Triassic–Jurassic sequence of the western areas desirable, and the results presented here are based on field work carried out in 1976. Responsibility for the petrographical part of the investigation lies with HENNING DYPVIK and for the palynological part with TOR BJÆRKE.

2. Geological setting

a. Structural framework

The sections studied here are situated in the Sassenfjorden area on the present north-eastern margin of the Spitsbergen Trough (Fig. 1). Late Paleozoic, Mesozoic and Tertiary units are represented within this trough and the maximum thickness of the Mesozoic–Tertiary sequence is 3750 m (HARLAND et al. 1974).

In the area south of Sassenfjorden the sequence dips gently (2–4°) southwestwards, with Tertiary beds occurring on the hilltops (Fig. 2). Several dolerite dykes and sills cut through the sedimentary rocks and vertical movements along north–south trending faults, especially in the Flowerdalen area, have caused local thickness variations in the sedimentary sequence (PARKER 1966).

The reader is referred to FLOOD, NAGY, and WINSNES (1971 b) and MAJOR and NAGY (1972) for more detailed information on the geology of the area.

b. Stratigraphical nomenclature

A summary of the stratigraphical scheme discussed in the present paper is given in Fig. 5.

The lithostratigraphical subdivision of the Triassic sequence in Spitsbergen was established by BUCHAN et al. (1965). The Upper Triassic Kapp Toscana Formation, largely consisting of non-marine, plant bearing sandstones, was defined in type section at Kapp Toscana in Van Keulenfjorden. The base of this formation was defined as the base of the hard siltstone horizon occurring above the cliff-forming shales of the Botneheia Formation, a horizon which is traced throughout Svalbard (BUCHAN et al. 1965, p. 24). The top of the Kapp Toscana Formation was defined as the base of the characteristic Brentskard-

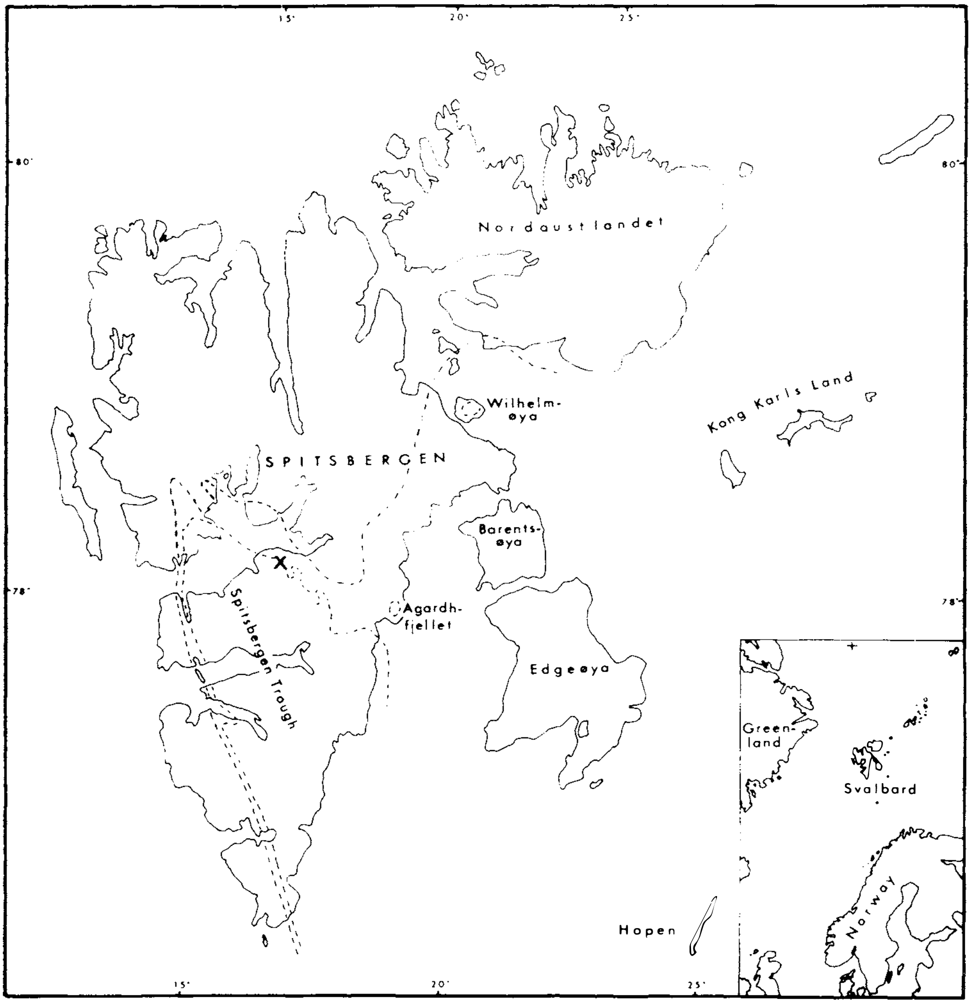


Fig. 1. *Map of Svalbard (1:4 mill.). X marks studied area (see Fig. 2).*

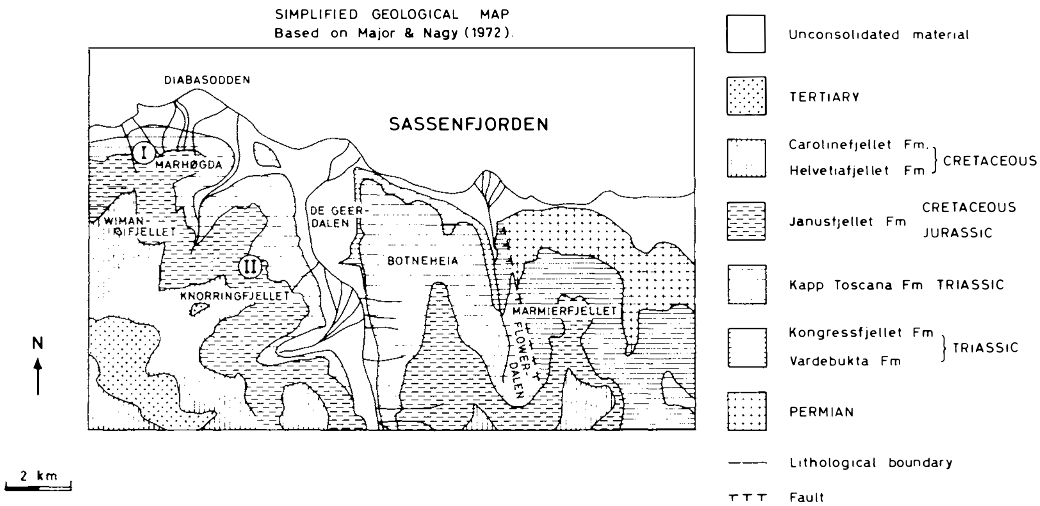


Fig. 2. *Map of the Sassenfjorden area, location of sections indicated (I, II).*

haugen Bed, previously termed the "Lias conglomerate" (Fig. 3). PARKER (1967) re-defined the Kapp Toscana Formation to include the Brentskardhaugen Bed.

The Kapp Toscana Formation includes two members, the lower Tschermakfjellet Member and the upper DeGeerdalen Member, the type localities of which are at Botneheia, five kilometres east of the sections described in the present paper. From sections published by BUCHAN et al. (1965) it is not clear whether they in fact placed the upper boundary of the DeGeerdalen Member at the Brentskardhaugen Bed or at a conglomerate and red weathering sandstone (units B and C of this paper) found 15 m lower in the succession (see p. 137). The definition of the boundary given by BUCHAN et al. (1965) may well correspond to this lower conglomeratic horizon, which may have been mistakenly interpreted as the Brentskardhaugen Bed. This conglomeratic horizon has certainly not been noted by these or other workers.

FLOOD, NAGY, and WINSNES (1971 a) proposed a change in rank of the Kapp Toscana Formation to group and a change of the Tschermakfjellet and DeGeerdalen Members to formation in eastern Svalbard, while the original rank was maintained in the western areas. However, HARLAND et al. (1974) extended the change in rank to western areas, but offered no new information on sections from type localities.

WORSLEY (1973) introduced a new lithostratigraphical unit based on sections from Wilhelmøya and Hellwaldfjellet, the Wilhelmøya Formation, stratigraphically between the DeGeerdalen and the Janusfjellet Formations. SMITH (1975) proposed a decrease in rank to member of this unit and included it in the DeGeerdalen Formation. Results presented here and observations from other localities (EDWARDS 1975, FLOOD et al. 1971 a, WORSLEY 1973) show that the sediments of the Wilhelmøya Formation are distinct from DeGeerdalen sediments and that they are not lateral equivalents. Consequently the nomenclature of WORSLEY (1973) is maintained for the eastern areas. Because of the less distinctive lithological boundaries and because only a part of the Wilhelmøya Formation is represented, we consider it appropriate to maintain the lower rank of these stratigraphical units in the western areas, and accept the status of these units as proposed by BUCHAN et al. (1965) and subsequently adopted by MAJOR and NAGY (1972), and also reduce the rank of the Wilhelmøya Formation to member in the western areas (Fig. 5).

3. Description of sections

a. Methods

In addition to field observations, samples of shales and sandstones were studied both in thin section and by X-ray diffraction analyses (Philips diffractometer). Diffraction analyses were executed on both oriented (suspension slide) and unoriented slides (vaseline) (GIBBS 1965). Sulphur (S) and trace elements were determined on five samples using X-ray fluorescence analyses of pressed undiluted pellets, while organic carbon ($C_{org.}$) was analysed by gravimetric combustion method (Leco Induction Furnace) (Table 1).

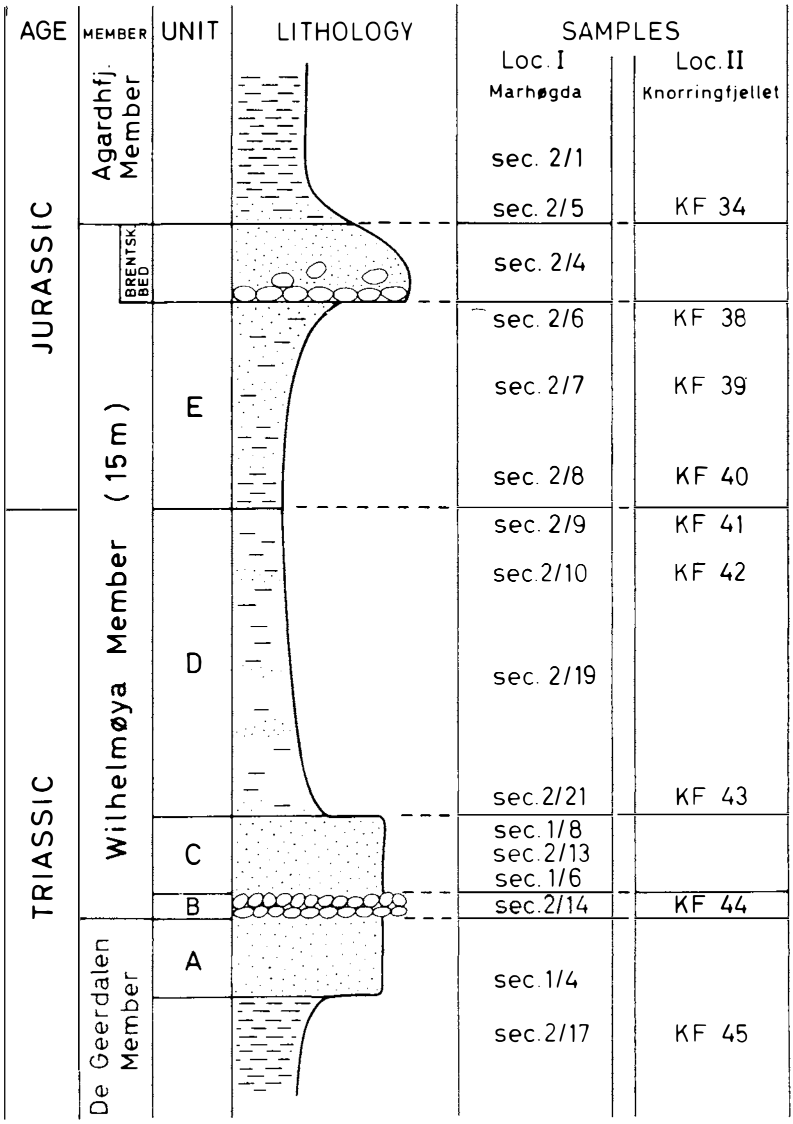


Fig. 3. *Lithological column and position of samples.*

b. Descriptions

Two sections through the upper 20 m of the Kapp Toscana Formation have been investigated (Figs. 2 and 3). The two sections, situated 5 km apart, are closely similar in lithology, thickness and palynological content (Fig. 6).

The shale, silt and sandstone sequence of the DeGeerdalen Member terminates in a 3 m thick, laminated light grey sandstone of fine to very fine sand with planar low angle crossbedding (unit A). In thin section it is seen to be mainly composed of subangular to subrounded fragments of quartz, rock fragments (volcanics) (28 vol.%) and feldspar, with quartz, dolomite and siderite

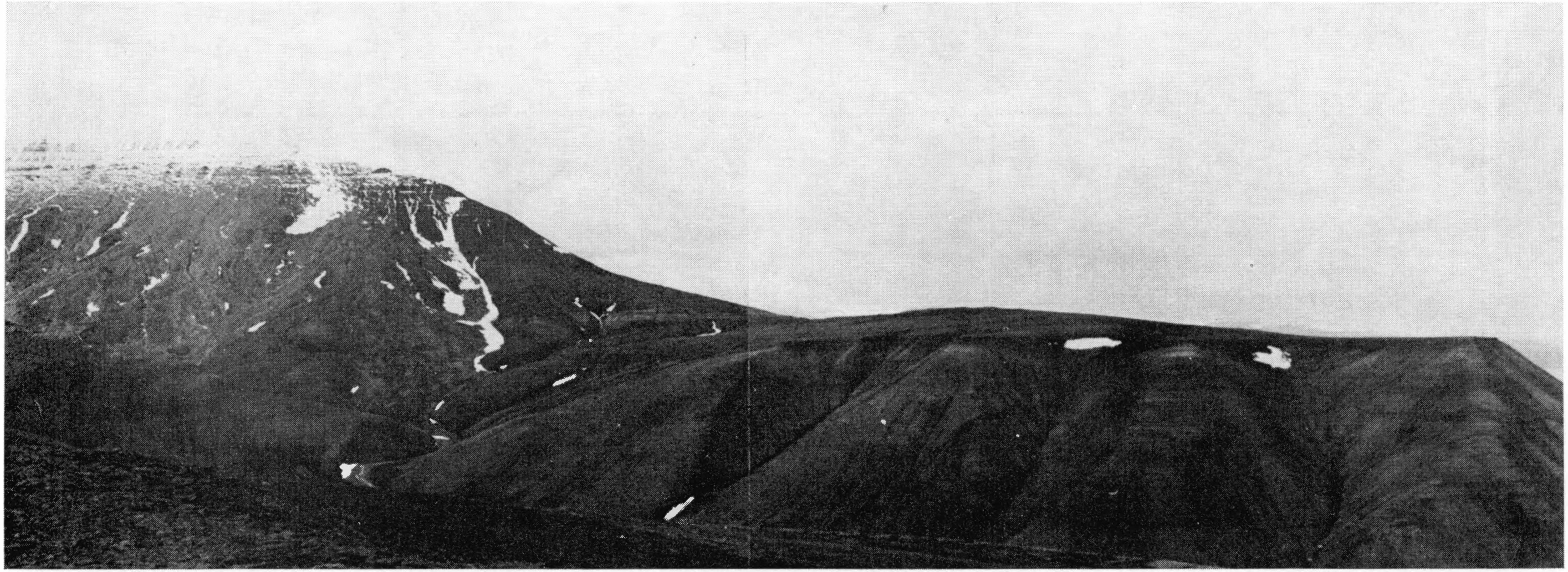


Fig. 4. *Marhøgda, view towards the west. Sandstone unit C forms the plateau, slopes below Upper Triassic DeGeerdalen Formation and above Jurassic-Cretaceous shales of the Janusfjellet Formation.*

cement making up about 15 vol.%. Some chlorite grains and also dispersed grains of glauconite occur. This sandstone (unit A) has a lithology typical for the De Geerdalen Member sandstones as described by FLOOD et al. (1971 a) and EDWARDS (1975).

Unit A is overlain by a phosphorite conglomerate, 10 to 40 cm thick (unit B). Pebbles are mainly composed of phosphorite and dolomite, with a few mud-flakes. Phosphorite of fluor apatite type constitutes 30 to 40% of the rock, and dolomite, quartz, feldspar, iron oxides, glauconite, chamosite and clay minerals make up the bulk of this poorly sorted conglomerate. The pebbles have a maximum diameter of 4 cm and the mean grain size of the matrix is 1–2 mm. Quartz and feldspar dominate in the fraction less than 2 mm. In the fine sand fraction also grains of glauconite and chamosite occur. The 15–32 μ fraction is rich in light mica.

The conglomerate (unit B) is almost everywhere covered by scree composed of blocks from the overlying red weathering sandstone. The conglomerate was, however, observed at all localities where the base of the sandstone was exposed.

The red weathering sandstone, unit C, forms a regional positive topographical feature (Fig. 4). This 2 m thick sandstone which is intensively bioturbated, also contains convolute lamination. Compared with the sandstone of unit A, the sandstone of unit C is sparse in rock fragments and feldspar (5–15 vol.% in thin section). In addition the sandstone (unit C) consists of 25–45 vol.% dolomite and siderite cement, 40–50 vol.% quartz, 5–10 vol.% glauconite and minor amounts of iron oxides. This sandstone is also characterized by subangular grains of about 0.1 to 0.15 mm in diameter. EDWARDS (1975) reported similar lithology for sandstones from the Wilhelmøya Formation.

Table 1.

Results of mineralogical and chemical analyses.

Results of modal thin analyses, volume percent

Sample	*Unit*	*Quartz*	*Rock frag., feldspar*	*Mica*	*Dolomite*	*Glauconite*	*Fe-oxides*
SEC 1–4–76	A	43	28	3	15	1	10
SEC 1–6–76	C	43	11	1	27	9	9
SEC 1–8–76	C	42	6	1	40	4	7
SEC 2–13–76	C	46	6	1	43	4	–

Results of trace element analyses. S, Cr, V, Rb, Sr, Ba, Ni, Co and Zr were determined by XRF while $C_{org.}$ was determined by a combustion methode. Values in ppm for Cr, V, Rb, Sr, Ba, Ni, Co and Zr.

Sample	*Unit*	*%$C_{org.}$*	*%S*	*Cr*	*V*	*Rb*	*Sr*	*Ba*	*Ni*	*Co*	*Zr*
KF 39–76	E	2.96	0.94	191	258	69	126	610	30	11	280
KF 40–76	D	2.94	1.21	160	235	88	211	510	51	9	266
KF 41–76	D	1.35	0.32	255	218	88	125	585	97	17	234
KF 43–76	D	0.56	0.17	318	262	47	41	835	38	4	344
KF 45–76	De Geerd. Mb.	0.81	0.05	136	250	83	54	457	66	22	208

Grain size analyses carried out after dissolution in HCl, show that a well sorted bedload population constitutes more than 90 weight % of the red sandstone, the remainder being a poorly sorted suspension population.

The red weathering sandstone is overlain by a 15 m thick shale interval with thin silt and sandstone horizons. The shale sequence is subdivided into two units (unit D and E) on the basis of palynological observations (see p. 143). The mineralogy shows minor variations through these units; illite, kaolinite, chlorite, smectite, mixedlayered clay minerals, quartz, plagioclase and potash feldspar are the main components. The quartz+feldspar/clay minerals ratio calculated from X-ray diffractograms, indicates grain size variations (DYPVIK 1977). In the shale sequence the ratio shows decreasing grain size upwards, reaching a minimum value in the upper part of unit D, 3 to 4 m below the Brentskardhaugen Bed (Fig. 3). At this particular level a change in the palynological assemblages is also found. The overlying shales just below the Brentskardhaugen Bed (unit E) are again according to the X-ray diffraction analyses, coarser grained. Shales from just above the red sandstone have a lower quartz/feldspar ratio than shales higher up in the sections, indicating increasing maturity upwards.

The amounts of organic carbon and sulphur also increase upwards to about 3 % $C_{org.}$ and 1 % S just below the Brentskardhaugen Bed. Only minor variations in trace elements are recorded, approximating the composition of the average shale of TAYLOR (1965).

The complex Brentskardhaugen Bed is found above the shales. The age of this unit is considered to be Toarcian or Bathonian (PARKER 1967; BIRKENMAJER 1975). This unit is now being studied in the Sassenfjorden area by SVEN BÄCKSTRÖM, University of Oslo.

4. Palynology

Twenty samples have been studied palynologically, producing diverse assemblages of spores, pollen, dinoflagellates and acritarchs. The stratigraphical position of samples is shown in Fig. 3. The palynomorphs are listed in Table 2 and the stratigraphical ranges for selected species are shown in Tables 3 and 4.

In addition to the material from Sassenfjorden, 10 samples were studied from Wilhelmøya and Hellwaldfjellet for comparison. Ranges of selected species from these localities are shown in Table 5 and discussed in Chapter 5 b.

Preparation followed standard techniques using HCl, HF, sonification and heavy-liquid separation ($ZnBr_2$, sp.gr. 2.2). Some residues were oxidized for 5 to 10 minutes in HNO_3.

Residues were sieved through a 20 μ net and mounted as strew preparations.

Two of the three samples investigated from below the lower phosphorite conglomerate, yielded only black organic debris, the third sample produced a monotonous assemblage of smooth, trilete spores and bisaccate pollen with no marine species. The assemblage is closely similar to assemblages

Table 2.

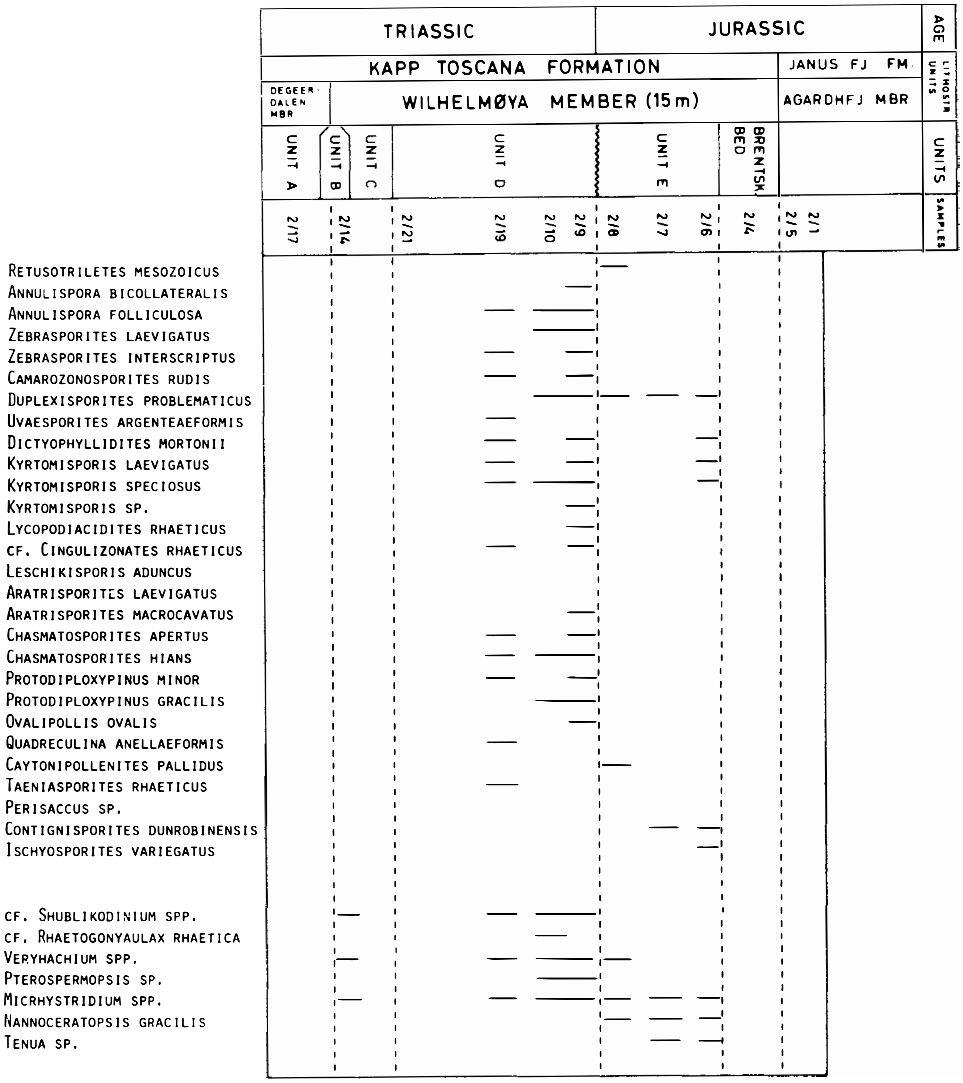
List of palynomorph species.

Cyathidites minor COUPER 1963
Cyathidites australis COUPER 1953
Retusotriletes mesozoicus KLAUS 1960 (Karnian)
Annulispora bicollateralis (ROGALSKA) BJÆRKE & MANUM 1977 (Upper Rhaetian-Liassic)
Annulispora folliculosa (ROGALSKA) DEJERSEY 1959 (Upper Triassic-Liassic)
Polycingulatisporites densatus (DEJERSEY) PLAYFORD & DETTMANN 1965 (Rhaetian-Liassic)
Zebrasporites laevigatus SCHULZ 1967 (Rhaetian)
Zebrasporites intersrciptus KLAUS 1960 (Upper Triassic)
Contignisporites dunrobinensis (COUPER) SCHULZ 1967 (Liassic)
Camarozonosporites laevigatus SCHULZ 1967 (Middle Rhaetian)
Camarozonosporites rudis (LESCHIK) KLAUS 1960
Duplexisporites problematicus (COUPER) PLAYFORD & DETTMANN 1965
Ischyosporites variegatus (COUPER) SCHULZ 1967 (Upper Liassic-Middle Jurassic)
Dictyophyllidites mortonii (DEJERSEY) PLAYFORD & DETTMANN 1965
Kyrtomisporis laevigatus MÄDLER 1964 (Upper Rhaetian–Lower Liassic)
Kyrtomisporis speciosus MÄDLER 1964 (Upper Rhaetian)
Kyrtomisporis sp.
Lycopodiacidites rugulatus (COUPER) SCHULZ 1967 (Middle Rhaetian-Jurassic)
Lycopodiacidites rhaeticus SCHULZ 1967 (Middle Rhaetian)
Velosporites sp.
Cingulizonates rhaeticus (REINHARDT) SCHULZ 1967 (Middle Rhaetian–Lower Liassic)
Uvaesporites argenteaeformis (BOLCHOVITINA) SCHULZ 1967 (Upper Triassic–Lower Cretaceous
Leschikisporis aduncus (LESCHIK) POTONIÉ 1958
Aratrisporites laevigatus BJÆRKE & MANUM 1977
Aratrisporites macrocavatus BJÆRKE & MANUM 1977
Chasmatosporites apertus NILSSON 1958 (Rhaetian-Middle Jurassic)
Chasmatosporites hians NILSSON 1958 (Rhaetian-Middle Jurassic)
Protodiploxypinus gracilis SCHEURING 1970 (Upper Triassic)
Protodiploxypinus minor BJÆRKE & MANUM 1977
Protodiploxypinus ornatus (PAUTZSCH) BJÆRKE & MANUM 1977
Ovapipollis ovalis (KRUTZSCH) POCOCK & JANSONIUS 1969 (Upper Triassic–Lower Liassic)
Qadraeculina anellaeformis MALJAVKINA 1949 (Middle Rhaetian–Lower Cretaceous)
Caytonipollenites pallidus COUPER 1958 (Jurassic–Lower Cretaceous)
Striatoabietites aytugii VISSCHER 1966 (Upper Triassic)
Taeniasporites rhaeticus SCHULZ 1967 (Rhaetian)
Cycadopites nitidus (BALME) DEJERSEY 1962
Perisaccus sp.
Rhaetogonyaulax rhaetica (SARJEANT) LOEBLICH & LOEBLICH 1968 (Upper Triassic)
Shublikodinium spp. WIGGINS 1973 (Karnian)
Pterospermopsis sp.
Cymatiosphaera spp.
Micrhystridium spp.
Veryhachium spp.

observed from the upper part of the Iversenfjellet Member (De Geerdalen Formation) on Hopen and from the De Geerdalen Formation of Edgeøya. However, it is not possible to use these assemblages for dating. SMITH (1975) reported negative results from De Geerdalen sediments of Wilhelmøya and

Table 3.

Stratigraphical range of palynomorph species at loc. I, Marhøgda.

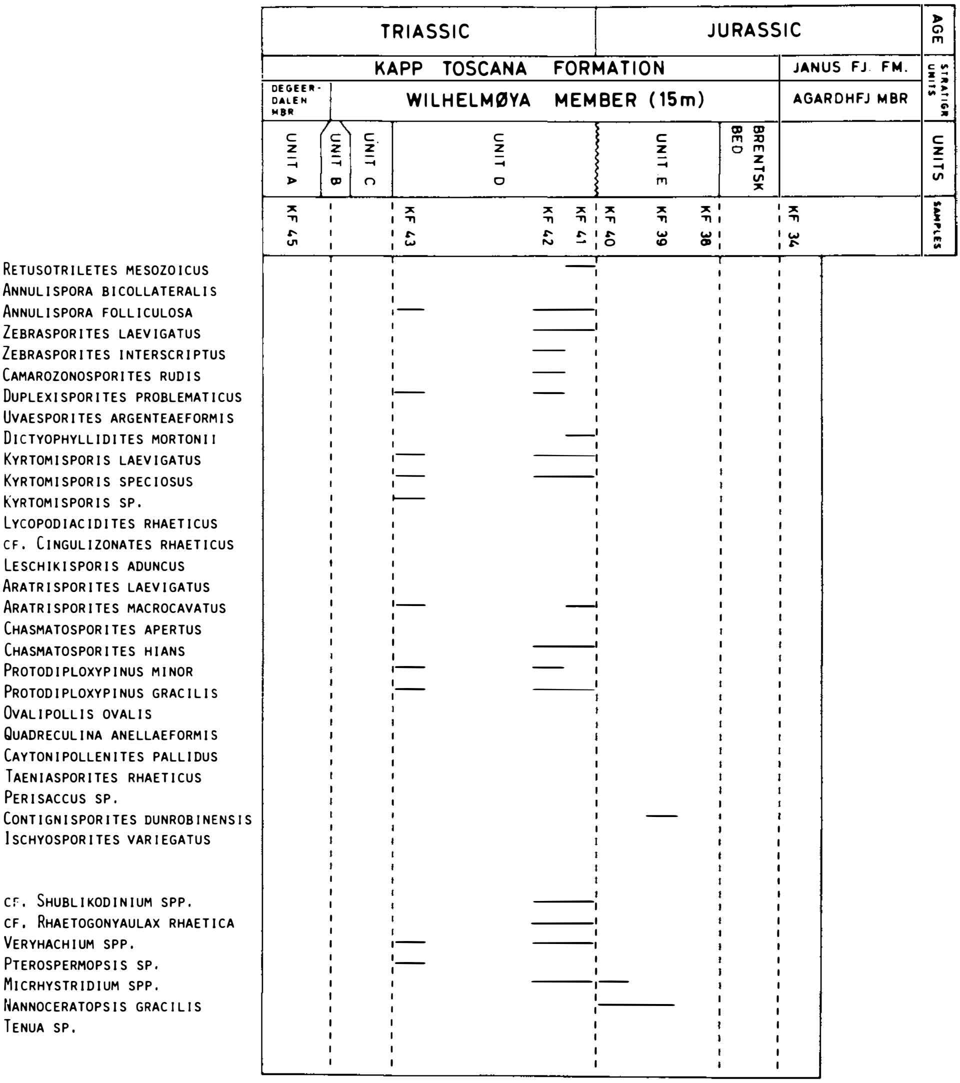


Hellwaldfjellet. Also from Hopen very few samples from this interval yielded workable assemblages (BJÆRKE and MANUM 1977).

Phosphorite pebbles from unit B produced rich assemblages of acritarchs and dinoflagellates. Only a few sporomorphs were observed. The marine species include a variety of *Micrhystridium* spp., *Baltisphaeridium* spp., and *Veryhachium* spp. in association with *Pterospermopsis* sp., *Cymatiosphaera* spp. and two species of dinoflagellates probably belonging to the genus *Shublikodinium*. A similar marine assemblage was recorded from the basal sandstone of the Wilhelmøya

Table 4.

Stratigraphical range of palynomorph species at loc. II, Knorringfjellet.

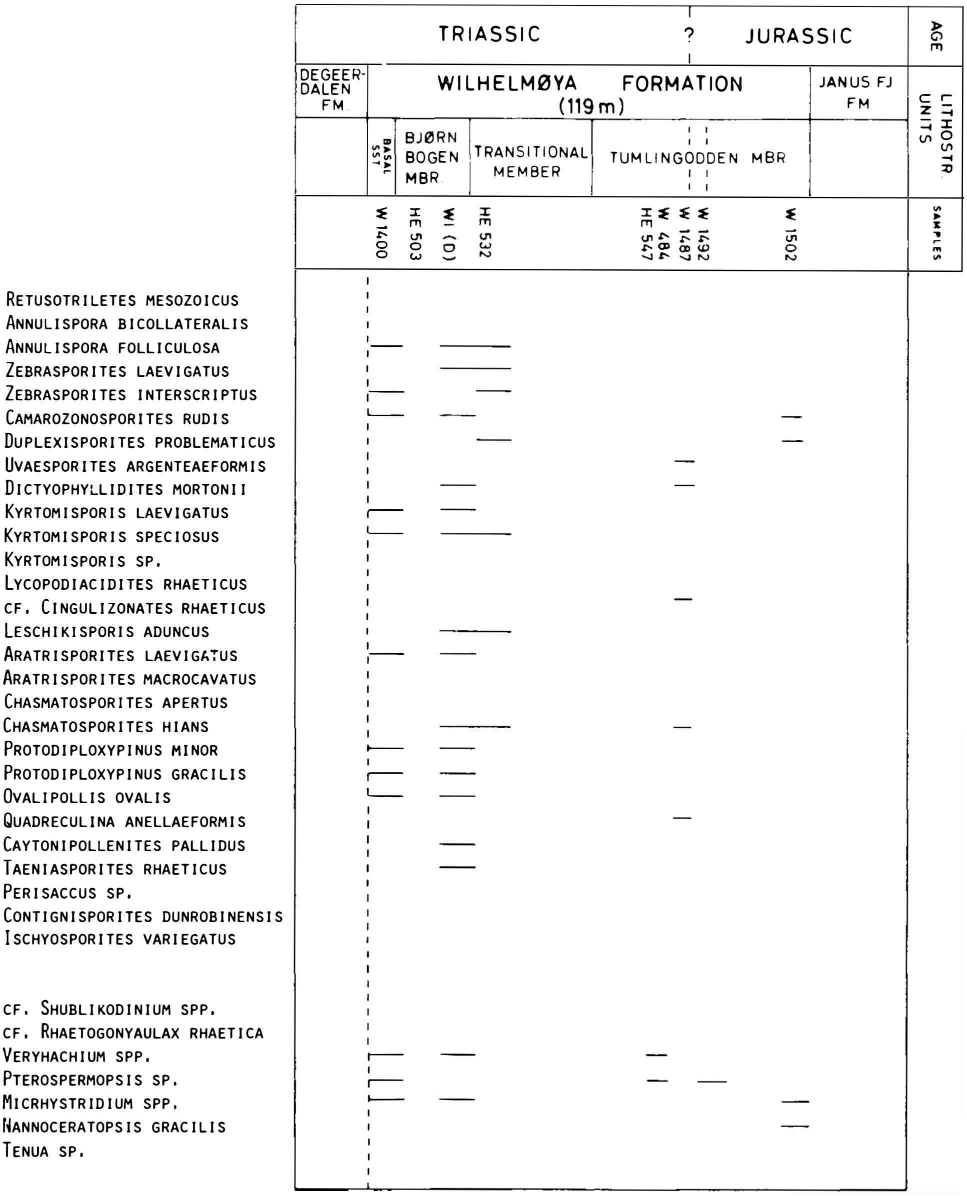


Formation on Hopen, and was there associated with a characteristic Rhaetian spore and pollen assemblage. The age of this assemblage is also probably Rhaetian.

Samples from unit D produced diverse assemblages of spores, pollen, dinoflagellates and acritarchs, indicating a marginal marine environment. The palynomorphs were corroded, but the preservation allowed identification. Characteristic and abundant *Kyrtomisporis speciosus*, *Annulispora folliculosa*, cf. *Rhaetogonyaulax rhaetica*, and *Veryhachium* spp. were observed in association with

Table 5.

Stratigraphical range of palynomorph species on Hellwaldfjellet and Wilhelmøya. Position of samples related to the lithostratigraphy of WORSLEY (*1973*).



Duplexisporites problematicus, Camarozonosporites rudis, C. laevigatus, Zebrasporites laevigatus, Z. interscriptus, Selagosporis mesozoicus, Protodiploxypinus gracılis, P. minor, P. ornatus, Annulispora bicollateralis, Uvaesporites argenteaeformis, Kyrtomisporis laevigatus, Aratrisporites laevigatus, A. macrocavatus, Chasmatosporites hians, *Ovalipollis ovalis*, *Lycopodiacidites rugulatus*, *L. rhaeticus* and *Taeniasporites rhaeticus*. This is a characteristic Rhaetian assemblage. Assemblage composition as well as state of preservation compare closely with material described from the Flatsalen Member, Wilhelmøya Formation, on Hopen (SMITH et al. 1975; BJÆRKE 1975; BJÆRKE and MANUM 1977) and from the Arnesenodden Bed, Wilhelmøya Formation, on Kong Karls Land (BJÆRKE 1977).

About 3 m below the Brentskardhaugen Bed there is a complete change in assemblage, only a few long ranging species extend across this horizon. The dinoflagellate species *Nannoceratopsis gracilis* dominates with species of *Tenua* and *Micrhystridium* also present. *Contignisporites dunrobinensis*, *Ischyosporites variegatus* and smooth trilete spores constitute the terrestrial part of the assemblage. The debris is completely different from that observed in unit D. A minor lithological change at this horizon is indicated by results of X-ray diffraction analyses. *Nannoceratopsis gracilis* has previously been described from Pliensbachian and younger sediments in Denmark and Germany and *C. dunrobinensis* and *I. variegatus* also point to a late Lower or early Middle Jurassic age (ALBERTI 1961; EVITT 1961; EVITT 1962; SCHULZ 1967). The increase in plant debris towards the Brentskardhaugen Bed in this upper shale unit suggests a regressive development.

Samples from just above the Brentskardhaugen Bed produced a poorly preserved dinoflagellate assemblage of Middle Jurassic aspect.

The palynological results from localities 1 and 2 allow a correlation between the two sections. A regional correlation is discussed in Chapter 5b.

5. Discussion

a. Depositional environment

Palynological assemblages from the uppermost shaly part of the De Geerdalen Member (beneath unit A, Fig. 3) indicate a non-marine depositional environment. Mineralogically these shales consist of immature material which is coarser grained than the shales of unit D, and contain no marin indicators. The De Geerdalen shales were probably deposited in a non-marine environment.

The light grey sandstone of unit A was probably deposited in a marginal marine environment. Angular grains in a wellsorted sediment mainly consisting of fine sand and with low angle cross lamination is typical for beach environments (HOYT and WEINER 1963). Absence of marine indicators in the shales below, make a barrier island environment less probable (REINECK and SINGH 1973; SWIFT 1975). After the deposition of this sandstone, there seems to have been a break in clastic sedimentation combined with upwelling of phosphor-rich water on the shallow shelf, resulting in apatite replacement of carbonate and apatite precipitation. After deposition these sediments were reworked by wave and current activity and concentrated in a lag deposit. A marine origin of the conglomerate is demonstrated by the marine flora in the phosphorite pebbles and by the occurrence of glauconite and chamosite grains. In marine

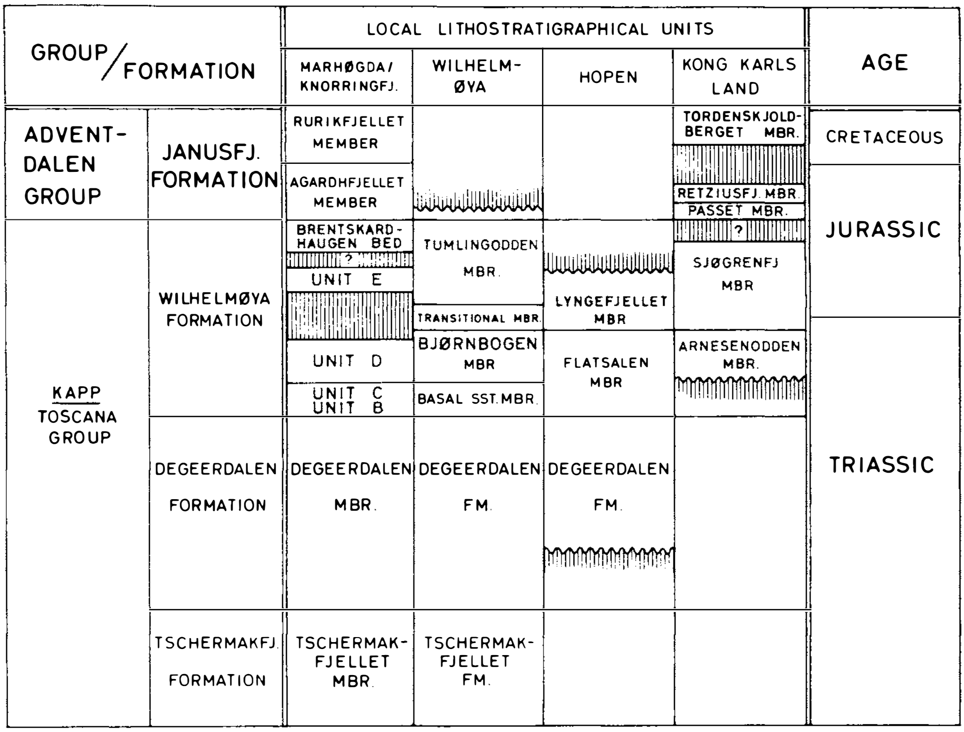


Fig. 5. *Lithostratigraphical units in the Upper Triassic-Jurassic of Svalbard.*

environments with diverging upwelling an association of black shales, dolomites, light sandstones and phosphatic deposits are usually found (McKelvey 1967). Recent phosphorite deposits are formed at 30 to 300 m depth (Bromley 1967; D'Anglejan 1967), while occurrences of glauconite and chamosite indicate deposition between 20 and 100 m depth (Porrenga 1967). It is possible that the phosphatic deposition on the Californian and Mexican Pacific coasts, as described by D'Anglejan (1967) may be a reasonable model for the deposition of this phosphorite layer.

After a break in sedimentation the shallow shelf was transgressed and marine sands were deposited (unit C). The glauconite bearing red weathering sandstone of unit C is strongly bioturbated, which is characteristic for recent offshore sands (Reineck and Singh 1973). The poorly sorted suspension population of the sandstone may be expected in an environment where shelf mud is sedimented on sand already deposited. Convolute lamination structures in the sandstone indicate relatively rapid deposition and liquifaction phenomena. The sandstone of unit C differs in composition from the sandstone of unit A, and the other sandstones of the De Geerdalen Member.

Unit D consists of dark marine shales which become finer grained, richer in organic material and more mature upwards, representing a transgressive phase with offshore mud deposition. The uppermost 3–4 m of these marine shales (unit E) are found to be somewhat coarser and to consist of more continentally

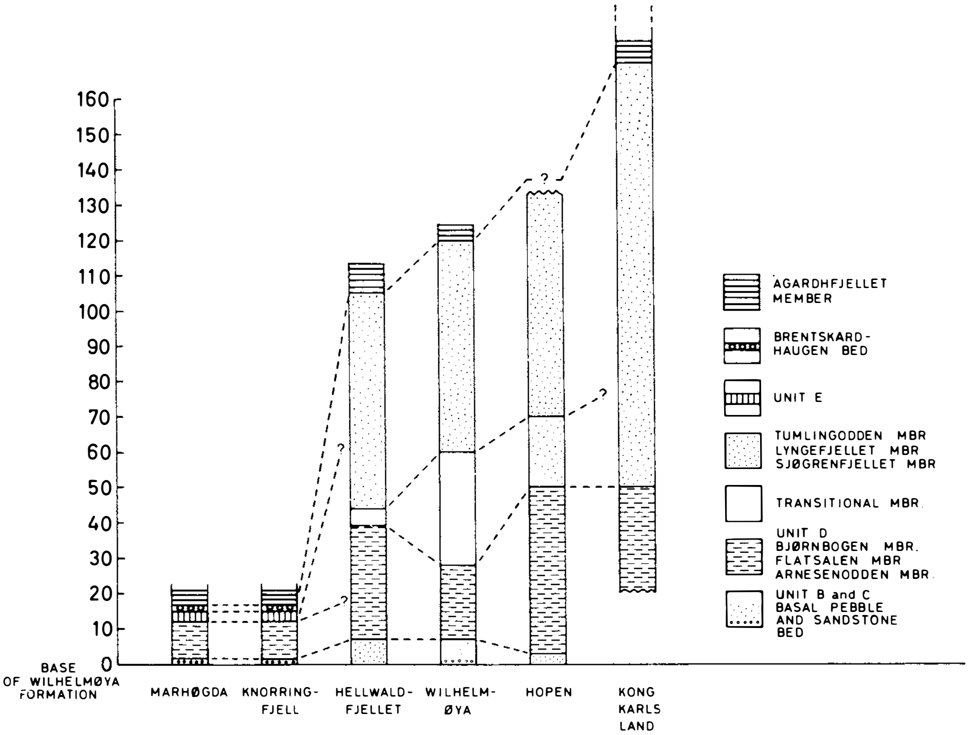


Fig. 6. *Correlation of sections at Marhøgda, Knorringfjellet, Hellwaldfjellet, Wilhelmøya, Kong Karls Land and Hopen.*

derived organic material than the underlying part of the unit. The palynological data indicate a break in sedimentation at the base of unit E. The marginal marine shales of unit E are the first Jurassic beds deposited in the area. Deposition began in a marine environment as shown by the domination of marine dinoflagellates. An increasing supply of terrestrial organic material towards the Brenskardhaugen Bed suggests a regressive development.

b. Age and correlation

The sequence described above is lithologically similar to parts of the Wilhelmøya Formation described from Wilhelmøya (WORSLEY 1973). The palynological results strongly support a correlation of unit B, C, and D with the "basal sandstone" and Bjørnbogen Member of the Wilhelmøya Formation, and of unit E with parts of the Tumlingodden Member, Wilhelmøya Formation (Fig. 6).

Palynological assemblages from unit A offer no evidence regarding their age, but they compare with assemblages from De Geerdalen sediments on Hopen and Edgeøya. The De Geerdalen Formation has previously been dated as "Rhaeto-Liassic" based on plant-macrofossils (BÖHM 1912; NATHORST 1913). The flora recorded from the non-marine sandstones of this unit has been compared with "Rhaeto-Liassic" floras from Scania and east Greenland. Subsequent revisions of the stratigraphy in these areas have made this comparison less valid (see discussion in BUCHAN et al. 1965).

Well preserved palynomorph assemblages from the phosphorite pebbles of unit B compare with the marine component of assemblages reported from the lowermost part of the Wilhelmøya Formation on Hopen (BJÆRKE 1975; BJÆRKE and MANUM 1977). Characteristic Rhaetian sporomorphs constitute the terrestrial component of these assemblages on Hopen. We are therefore inclined to regard the phosphorite conglomerate as correlative with the basal pebble bed of the Wilhelmøya Formation and to be of Rhaetian age.

The diverse assemblages recorded from unit D are closely similar to assemblages described from the Flatsalen Member, Wilhelmøya Formation, on Hopen and the Arnesenodden Bed, Wilhelmøya Formation, on Kong Karls Land (BJÆRKE 1975; BJÆRKE and MANUM 1977; BJÆRKE 1977). The Flatsalen Member on Hopen was lithologically correlated with the Bjørnbogen Member on Wilhelmøya (WORSLEY 1973). The palynological development observed in Sassenfjorden support a correlation of unit D with this lower marine member of the Wilhelmøya Formation, the age of this unit also being Rhaetian. Palynological data from the type locality at Wilhelmøya are still poor, but an assemblage from the lowermost part of the Bjørnbogen Member contain many species in common with unit B and unit D of the sections described here, including *Kyrtomisporis speciosus*, *K. laevigatus*, *Aratrisporites laevigatus*, *Chasmatosporites hians*, *Ovalipollis ovalis*, *Protodiploxypinus gracilis*, *P.* cf. *minor*, *Striatoabietites aytugii*, cf. *Taeniasporites rhaeticus*, *Zebrasporites laevigatus*, *Annulispora folliculosa*, *Duplexisporites problematicus*, *Camarozonosporites rudis*, all characteristic species of unit D and of definitely Rhaetian aspect. In addition to these are a number of acritarch species found within unit B.

From Hellwaldfjellet a similar assemblage is found in the upper part of Bjørnbogen Member, although the marine elements are absent here.

The age of the shales of unit E is definitely Jurassic (see p. 143) and the change in palynomorph assemblage from unit D to unit E marks a hiatus. However, no lithological break was observed in the field and only X-ray diffraction analyses show a change in lithology at this horizon. On Wilhelmøya an assemblage containing the characteristic dinoflagellate *Nannoceratopsis gracilis* has been recorded from the upper part of the Tumlingodden Member, Wilhelmøya Formation. This suggests a correlation between unit E and Tumlingodden Member (Fig. 6).[1]

[1] KLUBOV (1965) reported foraminifera from Wilhelmøya comparing with Pliensbachian faunas from North Siberia. Above the beds dated as Pliensbachian, KLUBOV found phosphorite nodules containing Toarcian ammonites also known from the Brentskardhaugen Bed elsewhere in Svalbard. These faunas are found within KLUBOV's set 28 and 29. However, as pointed out by WORSLEY (1973), the stratigraphical succession as described by KLUBOV, may be based on some misinterpretations. Large-scale landslides on Wilhelmøya have caused repetitions and gaps in the sequences studied by KLUBOV and consequently the exact position of his faunas, compared with WORSLEY's sections, is not known. The beds dated as Pliensbachian by KLUBOV were regarded as part of the Transitional Member by WORSLEY (1973, p. 13).

The palynological evidence given here and the faunas reported by KLUBOV (1965) show that marine sediments of upper Lower Jurassic and/or lower Middle Jurassic age are represented both in Spitsbergen and in Wilhelmøya. In Spitsbergen they overlie Rhaetian beds, while in Wilhelmøya a more complete sequence was deposited. As pointed out by WORSLEY (1973), it is highly probable that several breaks occur in the sequence on Wilhelmøya, and the time intervals represented by this succession is unknown.

c. Stratigraphy

Palynological and lithological data strongly indicate that the sections described here are a lateral equivalent of the Wilhelmøya Formation. The upper boundary of the De Geerdalen Member has to be redefined to agree with the definition of the base of the Wilhelmøya Formation. The Wilhelmøya Formation is suggested reduced in rank to member in central Spitsbergen (Figs. 5 and 6).

The light sandstones of unit A have a lithological affinity with sandstones from the De Geerdalen Member, while the red sandstones of unit C show lithological similarities with the basal sandstone of the Wilhelmøya Formation (see p. 137).

The lower part of the shale interval (unit D) is correlated with the Bjørnbogen Member, while the upper 3 m (unit E) is correlated with the uppermost part of the Tumlingodden Member, Wilhelmøya Formation.

The hiatus occurring between unit D and E (see p. 143) indicate erosion or a period of non-deposition which may locally have removed the Wilhelmøya Member completely. This may be the case at the type section of the De Geerdalen Member, situated about 5 km east of locality 2, at Botneheia (Fig. 2).

Lateral equivalents of the Wilhelmøya Member as described in our sections, also seem to be present in other localities in Spitsbergen. ROZYCKI (1959) described a section through a correlative interval from Passhatten in southern Spitsbergen. He reported a conglomeratic sandstone with bone fragments 7 m below the Brentskardhaugen Bed. A similar development seems to be present in Oscar II Land, where a phosphatic conglomerate occurs 23 m below the Agardhfjellet shales (BUCHAN et al. 1965). Above the conglomerate there is a shale sequence with interbeds of silt- and sandstone. Clay-ironstone concretions are also found. The upper 20 m at Festningen consists of a sequence of conglomerate and sandstone and a 16 m thick shale interval with clay-ironstone

However, KLUBOV reported phosphorite from the base of his set 29. Phosphorite was described by WORSLEY only from the upper part of the Tumlingodden Member and the Pliensbachian beds of KLUBOV may probably belong to the Tumlingodden Member. Set 28 of KLUBOV may correspond to the clay horizon in the middle part of the Tumlingodden Member. The Bajocian and Callovian foraminifera fauna of KLUBOV's set 30, may correspond to the uppermost part of the member. KLUBOV states that set 30 (5.5 m thick) is found above the phosphorites and that they contain poorly preserved belemnites which were observed by WORSLEY from the pebble bed just above the marine clay interval. From the species list, there seems to be an overlap between the upper part of set 29 and the lower part of set 30, which supports the interpretation suggested here.

concretions and finegrained calcareous sandstone. The Brentskardhaugen Bed is missing and seems to be represented only by a yellow weathering marl (HOEL and ORVIN 1937).

In other localities, for instance in Van Keulenfjorden (BUCHAN et al. 1965) and at Kistefjellet (FREBOLD 1930), the Wilhelmøya Member seems to be missing. A variable development must be expected considering the many hiatuses in the sequence and the small thicknesses involved.

6. Conclusion

The sections studied from the Sassenfjorden area are regarded as lateral equivalents of the uppermost part of De Geerdalen Member and parts of the Wilhelmøya Formation (Figs. 5, 6).

Dark non-marine shales of the De Geerdalen Member were transgressed by the marginal marine sand of unit A in Rhaetian times. The sandstone, which has a lithology similar to De Geerdalen Member sandstones was overlain by a phosphorite conglomerate (unit B). This conglomerate, containing a marine dinoflagellate flora similar to assemblages from the Basal Sandstone of the Wilhelmøya Formation on Hopen, was deposited in a period with minor supply of clastic material on a shallow marine shelf with diverging upwelling. After deposition the conglomerate was reworked by wave and current activity and subsequently phosphorite pebbles were concentrated as a lag deposit. Parts of the outwashed material was probably deposited as the overlying red, marine sandstone (unit C), which most likely was formed in offshore environments. Offshore muds were deposited above this sandstone. These marine sediments are considered to be of Rhaetian age and are correlated with the Bjørnbogen Member of the Wilhelmøya Formation. The shales became mineralogically more mature and finer grained upwards. This Rhaetian transgressive phase terminates 3 to 4 m below the Brentskardhaugen Bed. Following a significant break in sedimentation, 3 to 4 m of marine shales (unit E) of late Lower Jurassic Age (Pliensbachian-Toarcian) were deposited in a regressive sequence before the deposition of the Brentskardhaugen Bed.

Further stratigraphical, paleontological and sedimentological investigations within this interval are required to establish a paleogeographical model for the formation of the Wilhelmøya Member and to obtain a regional understanding of its relationship to underlying and overlying formations.

7. Acknowledgements

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Erratic clasts in the Lower Tertiary deposits of Svalbard — evidence of transport by winter ice

By ARNE DALLAND[1]

Contents

Abstract

Different types of occurrence of erratic clasts are described from the Lower Tertiary sedimentary rocks in the Nordenskiöld Land area of Svalbard. In the upper part of the Sarkofagen Formation (Eocene) three main types of occurrence can be recognized: 1) Clasts that are randomly scattered throughout most of the formation; 2) Clasts concentrated on erosion surfaces, probably created by storm waves in shallow marine areas; and 3) Clast concentrations in thin horizons not related to erosion surfaces. The latter type sometimes form excellent marker horizons that can be traced for long distances. In all three types of occurrence the size of the clasts may vary from coarse-grained sand to cobbles and blocks. The material appears to have been rafted into the basin of deposition. Different mechanisms of rafting are discussed, and it is concluded that there is much evidence in favour of transportation by winter ice.

Introduction

The sedimentary rocks of the Tertiary Central Basin of Svalbard consists mainly of alternating shale and sandstone units with a cumulative thickness in excess of 2000 meters. On a large scale the succession of strata may be looked upon as consisting of four large, coarsening-upward sequences, dominated by shales and mudstones in their lower parts and by fine- to medium-grained sandstones in their upper parts.

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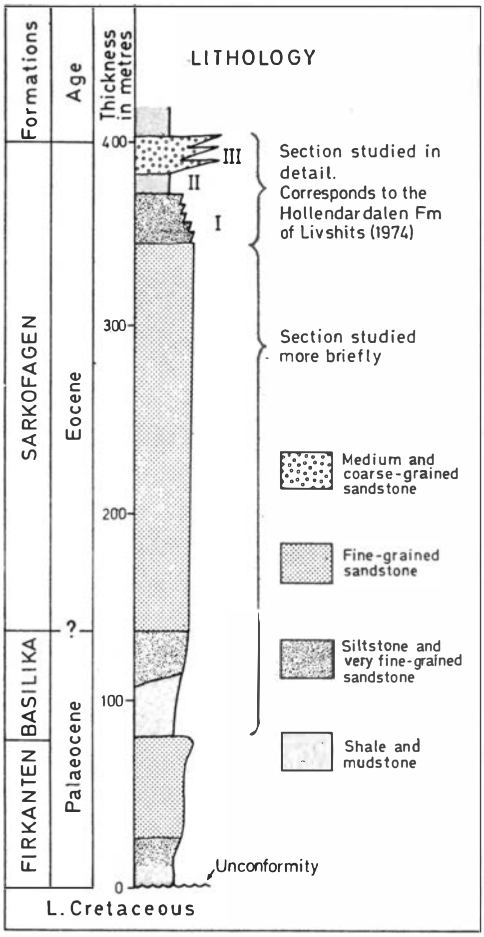


Fig. 1. *A simplified profile through lower part of the Tertiary succession in the Longyearbyen area, Svalbard.*

Most of the Tertiary sediments were probably deposited in marine or marginal marine environments, but non-marine deposits are also important, especially in the uppermost part and close to the base of the succession, where a number of coal seams occur. As to the age of the sequence, different opinions exist. Most of the workers that have been studying the area in recent years (LIVSHITS 1965, 1974; ATKINSON 1963; KELLOGG 1975; VONDERBANK 1970; HARLAND et al. 1976) agree on a Palaeocene age for the basal part of the sequence, but estimates of the age of the upper part vary from Palaeocene to Oligocene or Miocene.

The Tertiary sequence, particularly in its lower part, contains abundant erratic clasts, ranging in size from coarse-grained sand and up to cobbles and blocks. Most of the fragments are well-rounded and occur rather randomly scattered in nearly every bed in some of the formations. The size and the distribution of the fragments are in most cases quite independent of the average grain size of the host beds. In some horizons pebbles occur in a more concentrated manner than usual, and individual paraconglomerate beds, often only a few centimeters thick, can be traced over wide areas.

This rather striking occurrence of scattered large fragments in otherwise relatively fine-grained sediments in the Tertiary deposits of Svalbard has been noticed previously by several workers, e.g. NATHORST (1910); ATKINSON (1963); LIVSHITS (1965, 1974); VONDERBANK (1970); BIRKENMAJER and NAREBSKI (1963) argued in favour of driftwood or kelp as the transporting agent, while KELLOGG (1975) mentioned the possibility of rafting by shore ice.

The following discussion on the origin and mode of transport of the fragments is based mainly on sedimentological studies of the Basilika (Palaeocene) and the Sarkofagen (?Eocene) formations in northern Nordenskiöld Land (Fig. 1).

(The formation names used here are those of MAJOR and NAGY (1972). LIVSHITS (1967, 1974) has suggested another lithostratigraphical scheme for the Tertiary sequence.) The upper part of the Sarkofagen Fm, corresponding approximately to the Hollendardalen Fm of LIVSHITS, has been particularly studied in great detail at a number of localities across the area (Fig. 2).

The host sequence

The upper part of the Sarkofagen Formation can be divided into three lithological units:

(I) A lower unit of glauconite-bearing, fine-grained sandstones and siltstones;

(II) A middle mudstone-shale unit; and

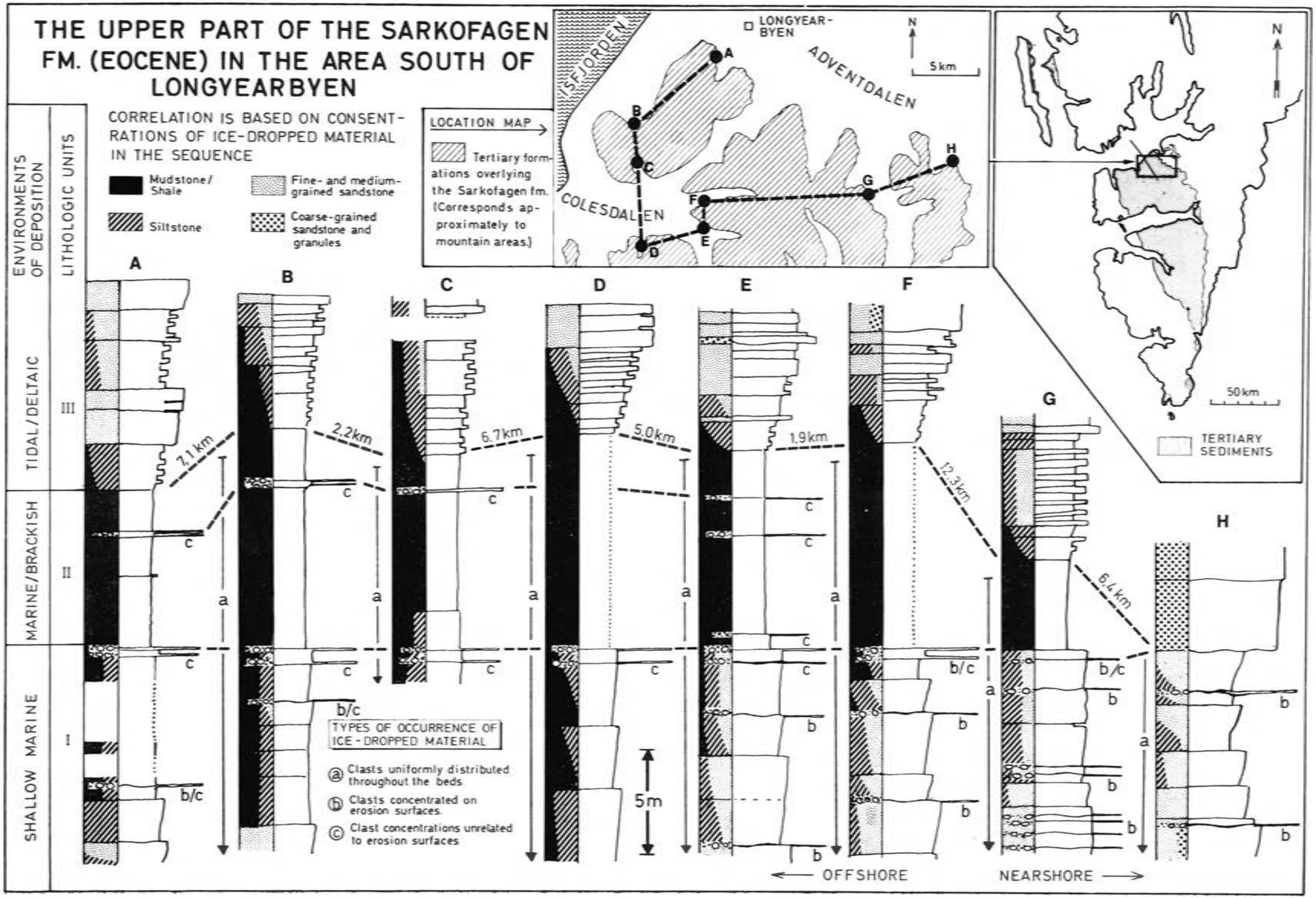
(III) An upper unit that is characterized by coarsening-upwards cycles with thin lenticular and wavy beds of alternating mudstone, siltstone, and very fine-grained sandstone at the base, mainly sandstone beds containing current ripples and low-angle cross-lamination in the middle, and a top part that usually contains beds of medium-grained sandstone. The top part is commonly cross-bedded, or it may have an uneven or irregular lamination often associated with in situ rootlets and thin coal streaks.

Parts of some of the logged profiles are presented in Fig. 2 in a much simplified form. The lower part of unit (I) and the upper part of unit (III) are omitted in the figure. Unit (I) is interpreted as a shallow marine deposit, unit (II) was probably deposited in a marine- or brackish-water environment, and the top unit (III) is thought to represent small prograding delta lobes, much influenced by tidal currents in their lower parts. The sedimentary structures and the depositional environments of the three units will be discussed in detail elsewhere (DALLAND 1977, in preparation). Here, only those features directly relevant to the occurrence of the erratic clasts will be discussed.

The erratic clasts

The size of the clasts varies from coarse sand to blocks of more than 150 kg. In most of the sequence large cobbles and blocks are relatively scarce, and fragments of granule and pebble size appear to dominate. The volume of erratic sand grains is often difficult to estimate, especially in sandstone beds, where the difference in size between the sand grains of the matrix and the erratic sand grains is small. In some beds however, the erratic sand fraction may be volumetrically dominant relative to the coarser-grained erratic fragments.

Throughout the Basilika and Sarkofagen Formations, more than 95% of the erratic material consists of chert and quartz/quartzite fragments, usually very


THE UPPER PART OF THE SARKOFAGEN FM. (EOCENE) IN THE AREA SOUTH OF LONGYEARBYEN
CORRELATION IS BASED ON CONSENTRATIONS OF ICE-DROPPED MATERIAL IN THE SEQUENCE
Mudstone/ Shale
Siltstone
Fine- and medium-grained sandstone
Coarse-grained sandstone and granules
LOCATION MAP
Tertiary formations overlying the Sarkofagen fm. (Corresponds approximately to mountain areas.)
ISFJORDEN
LONGYEARBYEN
ADVENTDALEN
COLESDALEN
N
5km
50km
TERTIARY SEDIMENTS
ENVIRONMENTS OF DEPOSITION
LITHOLOGIC UNITS
TIDAL/DELTAIC
MARINE/BRACKISH
SHALLOW MARINE
III
II
I
A
B
C
D
E
F
G
H
7,1 km
2,2km
6,7km
5,0km
1,9km
12,3km
6,4km
a
b
c
b/c
5m
TYPES OF OCCURRENCE OF ICE-DROPPED MATERIAL
ⓐ Clasts uniformly distributed throughout the beds.
ⓑ Clasts concentrated on erosion surfaces.
ⓒ Clast concentrations unrelated to erosion surfaces
OFFSHORE
NEARSHORE

well rounded. Commonly, but not always, quartz grains dominate in the coarse sand and granule fraction, whereas most of the larger fragments consist of black chert. The chert fragments sometimes contain brachiopods, bryozoans or corals, indicating a Permian age for those erratic clasts. The quartzite fragments may be derived from metamorphic rocks in the 'Hecla Hoek' sequence or from other sources containing metamorphosed sediments. The roundness of many of the chert and quartz pebbles strongly suggests that they may have gone through more than one cycle of erosion and deposition.

Fig. 2 is designed mainly to show how some of the thin paraconglomerate beds can be traced within the area of study. The erratic clasts are largely restricted to the marine parts of the sequence (units (I) and (II) of Fig. 2). Only occasionally are pebbles found in the deltaic deposits (unit (III)) and occurrences here seem to be restricted to the other parts of the delta influenced by tidal currents.

In addition to the chert and quartzite pebbles, fragments of gneisses and granitic rocks, greenschists, sandstones, and non-metamorphosed volcanic rocks have been observed, and especially at one level in the Sarkofagen Fm, just below unit (I) of Fig. 2, grey to white angular fragments are abundant. These fragments are derived from a silicified carbonate rock, and some of them contain abundant, but badly preserved fossils. Bryozoans and shell fragments, probably of brachiopods, have been identified, and like the chert pebbles the most likely source for the white, angular fragments may be found in the Permian sequence, where silicified carbonate beds are common. As the fragments appear to have about the same composition regardless of whether they are found in tight mudstones or in sandstones, the silicification must have taken place before they became embedded in the Tertiary sequence. X-ray diffraction patterns show that they contain more than 90% quartz and only a few per cent calcite. The silicification must have made the rock more resistant to solution and abrasion during transport than it otherwise would have been, but still the fragments are considerably softer than the chert and quartzite pebbles, and they could probably not have remained in a high-energy environment for a very long time without being rounded or abraded to finer-grained material. This implies derivation from a near-by source, or some special transport mechanisms, like rafting or density currents have to be considered. As will be discussed below, density current deposits seem unlikely in most of the sequence. Rafting was probably important, and can explain the erratic type of occurrences, but in a few beds the white fragments occur in non-erratic situations. For instance, in the upper part of the Sarkofagen Fm, close to the north-eastern limit of the Tertiary outcrops, the fragments are found in coarse-grained fluvial deposits. According to LIVSHITS (1974), the white fragments are absent

←

Fig. 2. *Simplified sedimentary logs through the upper part of the Sarkofagen Fm., northern Nordenskiöld Land, showing the distribution of erratic clasts. The lower part of Unit I and the upper part of Unit II are not shown in the figure.*

in the western parts of the Tertiary Basin, and in the upper part of the Sarkofagen Fm in the area between Longyearbyen and Svea the fragments occur in increasing abundance toward the NE, indicating exposure of (?) Permian rocks not too far beyond the present-day north-east boundary of the Tertiary Basin at the time of deposition. Some fragments appear to have been weathered before the deposition took place.

Types of erratic clast occurrences

There are three main types of occurrence of erratic clasts as shown in Fig. 3.

Type (a) is the most common and consists of rather uniformly scattered clasts. This type can be found throughout the marine part of the sequence. The erratic material of type (a) never makes up more than about 2–3% of the total volume in any bed.

In type (b) the clasts are concentrated on hummocky erosion surfaces. These surfaces are found only in the marine sand/siltstone beds and are typically undulating in a rather irregular manner. They consist of shallow pits or hollows, small "hummocks", and intervening low ridges of variable size and shape. The crest of the ridges are commonly sharp. The most prominant character of the surfaces is perhaps the irregularity. There seems to be a total lack of linear or directional features, and the main erosive agent may have been storm waves that caused enough turbulence to bring silt and very fine-grained sand into suspension so that the material could be transported by relatively weak currents. The distance between neighbouring pits may vary from 30 to 80 centimeters, and the amplitude of the surfaces is usually less than 15 centimeters. The clasts are found in the hollows and occur as patches of quartz/chert conglomerate. The patches may coalesce to form a nearly continuous sheet of varying thickness (from 1 to 10 centimeters) covering all but the highest points of the surface. More commonly, however, only a small fraction of the erosion surfaces contain conglomerate, and in some instances the occurrence of erratic clasts are restricted to a few pebbles in the deepest hollows of the erosion surface and are difficult to detect unless the outcrops are large. When well-developed, the erratic clasts of type (b) have a self-supporting framework.

Type (c) is found in the finer-grained part of the sequence (Fig. 2) and is essentially similar to type (a), but with much greater pebble con-

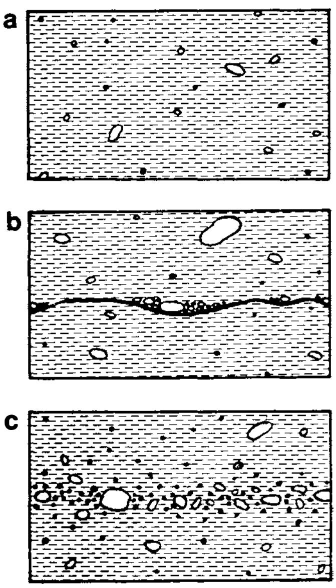


Fig. 3. *The main types of distribution of erratic clasts within the Basilika and Sarkofagen Formations, northern Nordenskiöld Land. Vertical sections, scale approx. 25 by 45 centimeters.*

centrations. The erratic clasts of type (c) occur in horizontal bands, usually between 2 and 10 centimeters thick. The boundaries are most commonly gradational, but especially the lower boundary may be relatively sharp.

The mean size and the composition of the clasts and the clast/matrix ratio may vary much between different horizons, but seems to be relatively constant within one single band, and this can sometimes be used as a means of correlation. As shown in Fig. 1, the type (c) pebble concentrations are excellent marker beds, and can be correlated over much of the investigated area. Especially a "twin" horizon at the top of unit (I) is easy to correlate, and also in the upper part of unit (II) there is a thin bed that can be found in most of the profiles. The latter is unusual in that it is partly re-worked and the erratic material contains more coarse-grained sand than the other type (c) beds, and there is only some few per cent of the normal matrix present. In part due to the re-working, the erratic material in this bed has a self-supporting frame-work, while in other beds of the (c) type the coarse sand and pebble clasts are supported by mud and silt and are more typical para-conglomerates or diamictites, usually with less than 30% of coarse clastics.

As indicated in Fig. 2, the mud/shale unit is sometimes badly exposed, so the existence of the thin upper conglomerate layer cannot be proved in every section, but it probably occurs over most of the area.

Gradations exist between type (a) and type (c) beds, but only horizons with distinctly higher concentrations of erratic clasts than normal in the sequence are assigned to type (c). In the upper part of unit (I), close to the eastern shoreline of the Sarkofagen basin, gradations occur between type (c) and type (b).

The proximity to the basin margin at this time is shown by the wedging out of all three units toward north-east, and by a general coarsening of the beds in the same direction. (Since only parts of units (I) and (III) are shown in Fig. 2, the wedging out can be seen only for the middle unit (II).) In unit (I) the proximity to the shoreline is also reflected by increasing numbers of erosion surfaces eastward and correspondingly more type (b) conglomerates are developed in the eastern profiles.

The high glauconite content and the abundance of trace fossils of different types indicate a marine origin for unit (I). It is probably a shallow-water deposit, and the hummocky surfaces are thought to have been eroded mainly by storm waves. There are no indications of subaerial exposure of this unit. The conglomerate material in the hollows of the erosion surfaces is thought to be derived mainly from the erratic clasts (type (a)) in the underlying beds. In most cases only a few cm of erosion would be needed to account for the conglomerate accumulations, and at least the larger clasts were probably concentrated in situ without having been transported very much. The types of clasts and the grain size distribution in the type (b) conglomerates seem to correspond very well to the erratic clasts found in the beds below.

Although the erratic clasts as shown in Fig. 3 occur in different ways, the type of material is essentially the same: well-rounded coarse sand, granules, pebbles and cobbles of chert and quartz. It is most likely that all of it originated from the same type of source, probably a high-energy environment where coarse-grained material was accumulating. Beaches would perhaps be the most likely source, but also rivers could produce similar deposits, and in both cases the material could have been reworked from older, already mature sediments.

The amount of erratic material in units (I) and (II) increases toward the east, and it is supposed that most of it was carried out into the basin from an eastern shoreline. To the east and south-east of the studied area, the upper part of the Sarkofagen Formation contains beds of very coarse-grained sand and gravel with numerous well-rounded pebbles of chert and quartz. These deposits have not yet been studied in detail, and so the environments of deposition are uncertain, but the source for the erratic material must be sought in these or in similar deposits within the same area, perhaps also in areas a little further east and north where there are no Tertiary deposits left to-day. As mentioned, a likely source for the white, angular fragments is silicified carbonate beds in the Permian sequence. Extensive outcrops of Permian rocks occur to-day to the NE, around the inner part of the Isfjord area, and in this general area Permian outcrops may have existed already in Lower Tertiary time. This is also consistent with the extrapolated isopach curves for the combined Basilika and Sarkofagen Fms (KELLOGG 1975, Fig. 7), where the zero thickness line is drawn through this area.

The erratic material found in the profiles A to F (Fig. 2) to the west must have been transported a distance of at least 20 kilometers from the shoreline. The mean percentage of erratic material in the 250-meter thick Sarkofagen Fm is roughly estimated to be between 1 % and 0.1 % of the total rock volume. This implies a large volume of erratic material, and similar material is found also in the thick shale formations (Basilika and Gilsonryggen Formations) below and above.

General mechanism of emplacement

Within the area where the Basilika and the Sarkofagen Formations have been studied there are no signs of turbidity current deposits or large-scale submarine slumping activity that could have brought the larger clasts out into the basin. The most spherical of them could, of course, have rolled on a well-consolidated and smooth sea bottom without the help of abnormally strong currents, but some of the larger clasts found have a flattened prismatic form, with only slightly rounded corners, and the transport of such blocks would have required currents of immense competance. As a result of cohesion between the small particles, mud and clay sea bottoms can often be swept by relative strong currents without being eroded, whereas beds of fine-grained sand will be eroded by much weaker currents. A large part of the sequence in which the pebbles occur consists of very fine-grained to fine-grained sandstone. The current strength needed to move many of the larger clasts, especially those of low sphericity, would be so high that it is difficult to see how the fine-grained

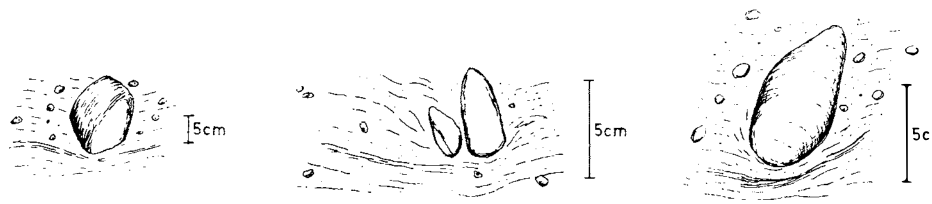


Fig. 4. *Erratic clasts in mudstone/siltstone matrix. The pebbles are commonly found in unstable positions, indicating that they have been dropped from the surface waters of the Early Tertiary depositional basin. Drawings are made from photographs. Vertical sections.*

sand beds could have escaped erosion, and large clasts occur at every level in the marine sandstone beds. This leads us to the same conclusion as BIRKENMAJER and NAREBSKI (1963): the material was dropped from above and not transported along the bottom oi the basin.

In many cases it is furthermore possible to demonstrate this kind of deposition as very many of the blocks rest in unstable positions in relation to the original sea bottom (Fig. 4). The orientation of these pebbles and blocks is abnormal in relation to transportation and deposition by normal currents, but is easily explained if the blocks were dropped and thus had a vertical velocity strong enough to penetrate a few centimeters into the fine-grained sediments as they hit the bottom. Occasionally bomb- or rod-shaped pebbles can be seen standing with their long axes nearly vertical and the heavy "nose" pointing downward (Fig. 4). Because of intense bioturbation and lack of lamination in the sediment it is rarely possible to measure the degree of penetration of the blocks into the bottom. Unstable positions of pebbles and blocks are most typically found in the mud- and siltstone beds, and are not so prominent in beds of sandstone. This may be because a sandy bottom was less easily penetrated by falling blocks.

Discussion of possible transport mechanisms

The agent of transport must have had a considerable capacity to pick up and raft sand, gravel, pebbles and blocks. As the exact composition of the source beds is unknown, it is impossible to comment on the extent of selective picking-up of clasts, but the range of grain sizes found does not suggest much selectivity. The agent was probably capable of transporting finer-grained material too, if present in the source area, but such material would be very difficult to recognize from the normal sediments in the area of deposition.

It is well-known that certain sea animals and birds may carry sand grains and pebbles off shore (EMERY 1955), but this will be extremely small amounts compared to the total sediment volume, and transport agents other than kelp, driftwood or ice do not seem necessary to discuss here. As the erratic clasts were brought out into a marine- or brackish-water basin, it is natural first to look at kelp. Certain modern types of large brown kelp are known to be capable of transporting pebbles and even cobbles for long distances (EMERY and TSCHUDY 1941; SCHUMWAY 1953; MENARD 1953). Already NATHORST (1910) suggested that the erratic clasts in the Tertiary rocks of Svalbard might have been transported by marine algae, and BIRKENMAJER and NAREBSKI (1963) accepted kelp as a possible transport agent for the smaller erratic pebbles in the sequence. There are, however, some serious objections to kelp as the main transport agent:

1) Kelp is very selective in relation to the size of the material that can be transported. Most kelp is attached to pebbles or to larger rocks and would have very little capacity to carry the smaller grain sizes that make up much of the erratic material in the investigated area, and the larger fragments of several kilogrammes would probably be too heavy to raft in this way.

2) The ability of kelp as a medium of transport seems to be too limited to account for the huge volume of erratic material in the Lower Tertiary rocks in Svalbard, even if the rate of "normal" deposition was moderate to slow. To the author's knowledge there are no wide-spread recent offshore deposits where kelp-rafted material occur in concentrations that are approximately equal to the concentrations of erratic material in the Sarkofagen Formation, and there is no reason to believe that the transport capacity of kelp was significantly higher in Eocene times than it is to-day.

3) Stones from the shallow marine areas where brown kelp is found are usually tightly covered by calcareous epifauna, such as bryozoans and worm tubes. If such stones were dropped and penetrated a little into a muddy sea bottom, there should be a fair chance that traces of the epifauna would be preserved, at least on the lower side of the stones that were immediately covered. No traces of fossil epifauna have been observed, but of course this may be due to diagenetic solution of carbonate.

The second possible rafting agent is driftwood. BIRKENMAJER and NAREBSKI (1963) concluded that driftwood or floating islands of tangled growth might have carried the larger clasts into the area of deposition, referring especially to large blocks of dolerite found in the Lower Tertiary sequence of Sørkapp Land in the thick shale formation (Gilsonryggen Fm) on top of the Sarkofagen Fm. Small bits and pieces of coalified wood are found occasionally throughout the Sarkofagen Fm, and especially the upper deltaic unit (unit III of Fig. 1) contains very much plant material, ranging from imprints of leaves and small pieces of wood to larger coalified tree trunks. EMERY (1955) has shown that driftwood may be the main rafting agent of larger rock fragments in far offshore regions of the tropics, but in areas closer to the shore and at high latitudes other transport mechanisms dominate. In times of warmer and more uniform climate than today the areas of predominant driftwood rafting may have been larger. But looking at the Eocene upper Sarkofagen sequence, there are some serious objections to driftwood as the main transport agent:

1) Most driftwood will be rafted out into the sea during flood stages in rivers, and probably only a small portion will be a result of marine erosion of

coastlines. This means that if driftwood was responsible for the clast rafting in the upper part of the Sarkofagen Formation, one should expect to find the highest concentrations of erratic clasts in sediments deposited at the mouth of rivers or just seaward of deltas. But at the outer part of the deltaic cycles of unit (III) (Fig. 2) there is very little erratic material, and since this part of the cycles was dominated by tidal currents, the few larger erratic fragments found, could as well have been rafted from nearby shorelines and into the tidal channels.

2) In the marine part of the Sarkofagen Formation there seems to be no correlation between the amount of erratic material and the amount of fossilized wood fragments in the beds, and in the deltaic part of the sequence the correlation seems to be inverse.

3) As in the case of the brown kelp, it is highly doubtful if the capacity of driftwood to raft clasts would be large enough to account for the concentrations of erratic clasts found in the investigated sequence. Driftwood would be less selective than kelp with respect to the size of the fragments that could be picked up, but most of the material, especially the silt, sand, and gravel fractions would easily be washed away and could not be rafted very far, unless it was kept in place by extremely tight root systems.

Then, to the last of the three possible mechanisms of rafting – winter ice. KELLOGG (1975) stated that shore ice or, possibly, floating plants brought the pebbles out into the finer grained environments of deposition, and that the rafted material undoubtedly was formed at a shoreline north or east of the depositional area. He did not, however, present evidence in favour of one or the other of the two transport agents mentioned. The present author believes that there is much evidence in favour of ice rafting of the clasts, some of which is listed below:

1) Unlike driftwood or kelp, shore ice will be able to pick up and raft all the grain sizes normally found on the shorefaces, and this explains very well the wide range in grain sizes and the high degree of roundness of most of the clasts.

2) Wherever sea ice can be formed along a coastline it will be able to raft clastic material, and normally in far greater quantities than any other rafting agent. This may be true even if the ice is thin and the sea is frozen for only short periods, and only in extra cold winters.

3) Ice-rafted clasts are found in marine sediments as old as 50 m.y. (early Eocene) in the sub-Antarctic area, and icecaps are supposed to have existed on the Antarctic continent already at this time.

4) In Eocene time the Svalbard area was situated at high latitude (about 71–72° north) and there was no solar radiation for several months during the winter time.

5) The climate was probably more continental than today, with relatively warm summers and cold winters.

6) The Tertiary basin may have been land-locked on most sides.

7) The fresh-water influx into the basin may have been large, causing relatively low salinities in the sea water.

8) Transport by winter ice occurs today at relatively low latitudes, given conditions similar to those mentioned in points 5, 6 and 7.

9) No glaciers or ice-bergs are necessary to account for ice rafting of clasts.

10) There is no contradiction between ice rafting and relatively luxuriant vegetation and coal formation at the same time within the same general area.

11) Ice rafting may explain certain occurrences of isolated patches of sand and gravel in the fine-grained parts of the Sarkofagen Fm.

Some of the points above have to be commented upon. As to the first two points: Transport by winter ice can be observed to take place today in many areas, for example in most of the fjords of Norway, but surprisingly little is published about this mechanism of clast rafting. During cold winters, ice is transporting clastic material from the shores of the Kattegat area of Denmark and Sweden, and by the influence of the Baltic Current and southerly winds some of it reaches the shorelines of the eastern part of Norway. This phenomenon has been studied by JOHANSEN (1960) through a number of years. The rafted material includes flint derived from Upper Cretaceous carbonate rocks (mainly from the eastern shorelines of Denmark), and winter ice rafting of flint pebbles was of some importance for the stone age inhabitants of eastern Norway as a supply of material useful for making stone implements. Results from pebble counts on beaches formed at different times during the Holocene in the Oslofjord area show that an impressive amount of ice-rafted flint pebbles have accumulated. Most of the counts have given percentages of flint pebbles between 0.5 and 2 of the total pebble material, and the percentage was in some beaches as high as 6. Some of this material was certainly rafted by ice-bergs during the later stages of the Weichselian glaciation, but in many instances the flint pebbles must have been transported by winter ice during post-glacial time. Flint and other types of rock material can be observed incorporated in the winter-ice of the Kattegat and Skagerak area today, and they can also be found in post-glacial marine clays in the area. The concentration of flint is higher on beaches formed during relatively cold stages of the Holocene. Furthermore, most of the Oslofjord region where many of the pebble counts are made, lay beneath the glacier when the late Weichselian ice-front across Denmark and Sweden had a position most ideal for ice-berg transportation of flint northwards to the Norwegian coast (JOHANSEN 1960).

Recently, FOLLESØ (1977 pers. comm.) has observed winter ice transport of clastic material in the Porsangerfjorden area of Finnmark, Northern Norway. The winter ice in the Finnmark fjords appears to have enormous capacity to transport clasts, sometimes blocks of huge sizes, out into nearby sea areas where the "normal" sedimentation consists of silt and clay.

The high concentration of winter-ice rafted flint found in the beaches of south-eastern Norway suggests that no extreme arctic climate is necessary to account for the amount of ice-rafted material within the Lower Tertiary succession of Svalbard.

The erratic clasts found in Early Tertiary core material from the sub-Antarctic area were probably rafted by icebergs (MARGOLIS and KENNETT 1970), and they suggest the presence of an Eocene Antarctic ice-cap.

This does not necessarily imply glaciation in the Arctic region at the same time, at least not in low-lying areas, but it shows that a steep climatic gradient existed in the southern Hemisphere. The climatic gradient between the equatorial and the polar regions must have been fairly steep also in the northern Hemisphere, and winter ice may have been relatively common in Eocene land-locked marine basins of the Arctic.

Palaeomagnetic data indicate a latitude of about 71°–72°N for the Svalbard area in Eocene time (HARLAND 1975; HAILWOOD 1977). This was before the movement started along the Spitsbergen fracture zone, and the position of the area was a little north of Greenland. The Norwegian–Greenland sea was still a narrow sea-way and did probably not affect the climate of the Svalbard area very much, so there could well have been a continental type of climate in the area around the Tertiary basin. When later in the Tertiary the Norwegian–Greenland Sea became wider and the warm North Atlantic Current crossed the Iceland – Faeroe Ridge, the climate of the Svalbard area probably became more coastal, with less difference between the winter and the summer temperatures. It is therefore quite possible that the local effect of the changes caused higher winter temperatures in the area for some time, for example during Oligocene and Miocene times, despite the general cooling of the Earth during the Tertiary period.

LIVSHITS (1974, Fig. 4) presented palaegeographic maps that show the main Tertiary Basin of Svalbard to be nearly totally land-locked at Eocene time. This means that the sea could easily have been diluted by fresh-water influx. The marine fauna described from the area does not seem to contain a high diversity of species, and many of the bivalves found are described as estuarine forms. This may in part be a result of low salinities of the sea.

Winter ice occurs today on the sea as far south as to the southern shores of the Baltic Sea, the Hudson Bay, and the Bay of St. Lawrence. All these areas lie far from any glaciers that terminate into the sea, and in the case of the Baltic Sea, the area is situated some 2000 kilometers south of the southern limit of pack-ice and ice-berg drift in the Barents Sea. BIRKENMAJER and NAREBSKI (1963) rejected ice as a possible transport mechanism of the erratic clasts of the Svalbard Tertiary sequence, because there is no evidence of Tertiary glaciation in Svalbard, and because the pebbles found were devoid of glacial striations. Obviously, those arguments are not valid if rafting by winter ice is taken into consideration, and in a small, land-locked basin, with low salinities in the sea, this may be a very efficient means of transportation.

The vegetation in the most southern of the areas where winter ice is found today (e.g. the southern shores of the Baltic Sea) is relatively rich, and no doubt coal can be formed under similar climatic conditions. The pollen assemblage from the Palaeocene Firkanten Fm of Svalbard hardly contains any pollen from warm-climate, broad-leaved plants (KELLOGG 1975).

In a few instances isolated, flattened patches of sand and gravel with relatively sharp boundaries of variable shape are found in mud- and siltstones of the Sarkofagen Fm. The size of the patches varies, but most of them are less than 50 cm across. These occurrences bear no relation to erosion surfaces. They may have been formed when smaller pieces broke loose from ice-flows. If the pieces were sufficiently loaded by sand and gravel, they could have sunk to the bottom in shallow areas of the sea before they began to melt, and the erratic material could thus have been concentrated in small patches on the muddy sea bottom.

The other pebble concentrations that are more common and are not related to erosion surfaces (type c of Fig. 3), can be traced as marker beds for long distances. The type c beds may have been formed during periods of lower winter temperatures than usual. The duration of such periods of climatic fluctuations may have been from tens and up to many thousands of years. Periods of increased fresh-water influx into the basin would, of course, have the same effect, and so would a slower rate of normal mud deposition. In some cases the "type c" pebble concentrations may be a combined result of two or of all three of the factors mentioned.

The white, angular fragments of silicified carbonate rocks can not have remained in a beach environment for very long, and it is possible that these clasts were picked up by the ice directly from cliff faces of Permian rocks that stood into the sea, at least during high tide.

Cretaceous erratic clasts of Svalbard

Erratic fragments of chert and quartzite are found also in the shaly Innkjegla Member in the Cretaceous sequence of Svalbard (NAGY 1970). The author has had the opportunity to look at the clasts in the Kvalvågen area, and here the occurrences look very similar to those of the Basilika Fm in the Tertiary sequence. In the Kvalvågen area clasts of at least 50 kilogrammes have been observed, and the similar mode of occurrence may suggest the same transport mechanism as for the Tertiary erratic clasts.

A fairly marked climatic zonation is evident throughout Lower Cretaceous time, and boreal regions, with distinct colder-climate faunal assemblages, can be recognized both on the Northern and Southern Hemispheres (CASEY and RAWSON 1973). It is interesting to note that the Innkjegla Member is supposed to be of Upper Aptian/Lower Albian age (PARKER 1967; NAGY 1970), a time in the Cretaceous known to have been the beginning of a cool period described as "transgression arctique" by H. and G. TERMIER (1952). According to SCHWARZBACH (1963), this cool period reached its maximum in the Cenomanian of the Upper Cretaceous. In the Normandy area of France, JUIGNET et al. (1973) have found much evidence for a cooling of the climate during Upper Aptian time, and in this area a strong boreal influence can be observed in the marine faunal assemblages. The Aptian/Albian occurrence of erratic clasts in the Innkjegla Member also coincides with the northernmost position of Svalbard within the Lower Cretaceous. HARLAND et. al. (1976, Fig. 3) show the Aptian position of Svalbard to be close to 70° north, that is nearly as far north as during Eocene time.

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Olenellid fauna from the base of Lower Cambrian sequence in south Spitsbergen

By KRZYSZTOF BIRKENMAJER[1] and STANISŁAW ORŁOWSKI[2]

Contents

Abstract

A new trilobite fauna determined from the lowest lithostratigraphic unit (Blåstertoppen Dolomite Formation) of the Cambrian in south Spitsbergen indicates the presence of the late Lower Cambrian *Bonnia-Olenellus* Zone already close to the base of the sequence. The succeeding Vardepiggen Formation and Slaklidalen Limestone Formation belong also to this zone. The hiatus at the base of the Cambrian in south Spitsbergen comprises the early (*Fallotaspis* Zone) and middle (*Nevadella* Zone) Lower Cambrian time span, and an undetermined portion of the latest Precambrian. Three lithostratigraphic units of member rank are distinguished within the Blåstertoppen Dolomite Formation.

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A. Geological part

By K. Birkenmajer

INTRODUCTION

During the summer investigations in Sørkapp Land, south Spitsbergen, in 1970, sponsored by Norsk Polarinstitutt (Oslo), a new trilobite fauna was collected by the author from limestone concretions and intercalations which

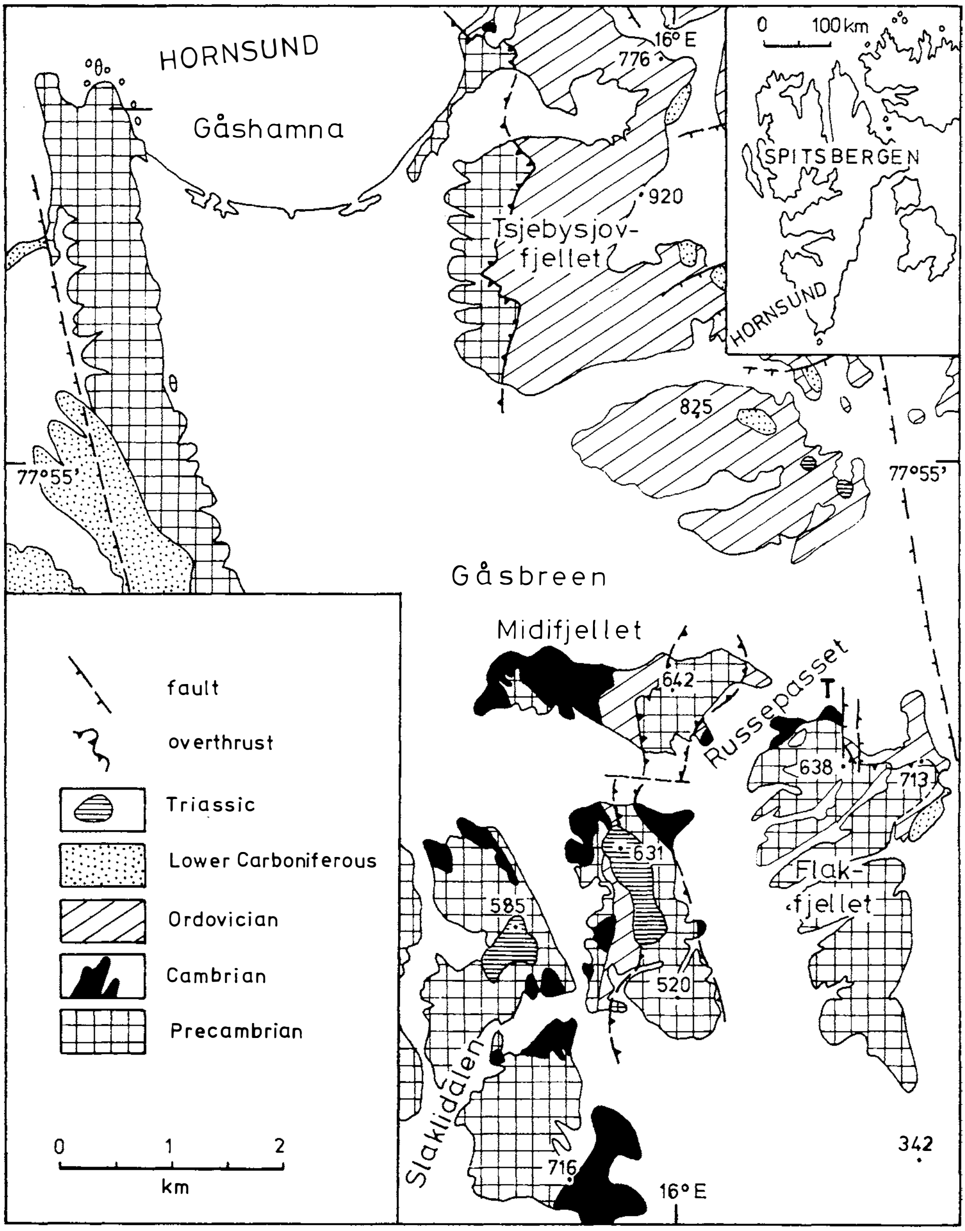

Fig. 1. *Position of the Flakfjellet locality with olenellid fauna (T) in Sørkapp Land and in Spitsbergen.*

occur in a black shale horizon within predominantly carbonate rocks of the Blåstertoppen Dolomite Formation (BIRKENMAJER 1971), the oldest unit of the Cambrian succession of the area (Fig. 1). The fauna determined by S. ORŁOWSKI (this paper) indicates the presence of *Bonnia-Olenellus* Zone (late Lower Cambrian) very close to the bottom of the Cambrian succession. This suggests the presence of an important hiatus at the base of the Cambrian in south Spitsbergen as the result of Jarlsbergian diastrophism (boundary of Precambrian and Cambrian) and succeeding uplift and erosion prior to the Cambrian transgression.

The trilobite-bearing Blåstertoppen Dolomite Formation, as well as the succeeding Cambrian and Ordovician strata, form part of the complex fold structure of the west coast of Spitsbergen, the result of Caledonian orogeny.

BLÅSTERTOPPEN DOLOMITE FORMATION

The Blåstertoppen Dolomite Formation was first recognised in Wedel Jarlsberg Land (BIRKENMAJER 1959, 1960: Blåstertoppen Dolomite) where it occurs as an arenaceous dolomite overlying the late Precambrian Gåshamna Phyllite Formation and underlying the Lower Cambrian black shale with olenellids, the Vardepiggen Formation (BIRKENMAJER 1960, 1975).

In Sørkapp Land, the Blåstertoppen Dolomite Formation is exposed in the vicinity of Gåsbreen. Its best section is at Flakfjellet (Figs. 2, 3). Here, the Blåstertoppen Dolomite Formation is about 95 m thick and may be subdivided into three members: the Gåsbreen Member; the Flakfjellet Member; and the Russepasset Member (BIRKENMAJER 1971).

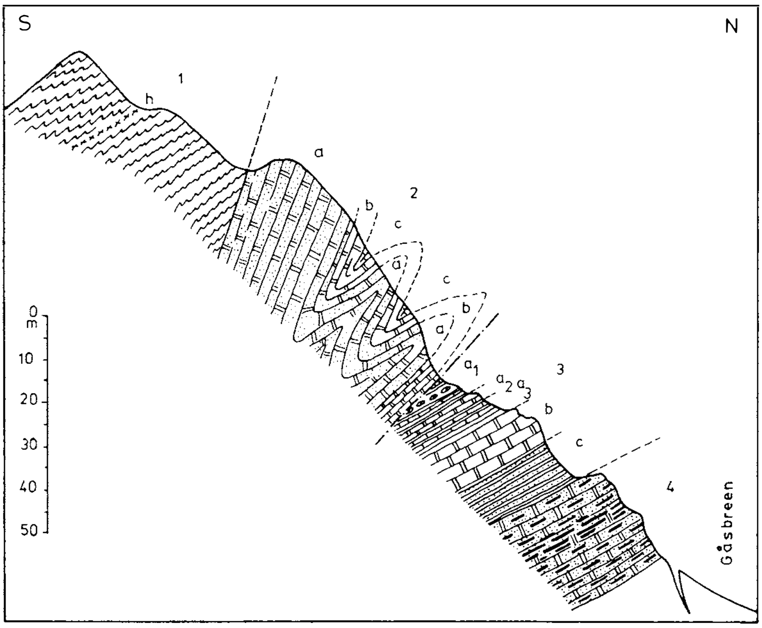

Fig. 2. *Flakfjellet section, scale approximate. For explanations see the text and Fig. 3.*

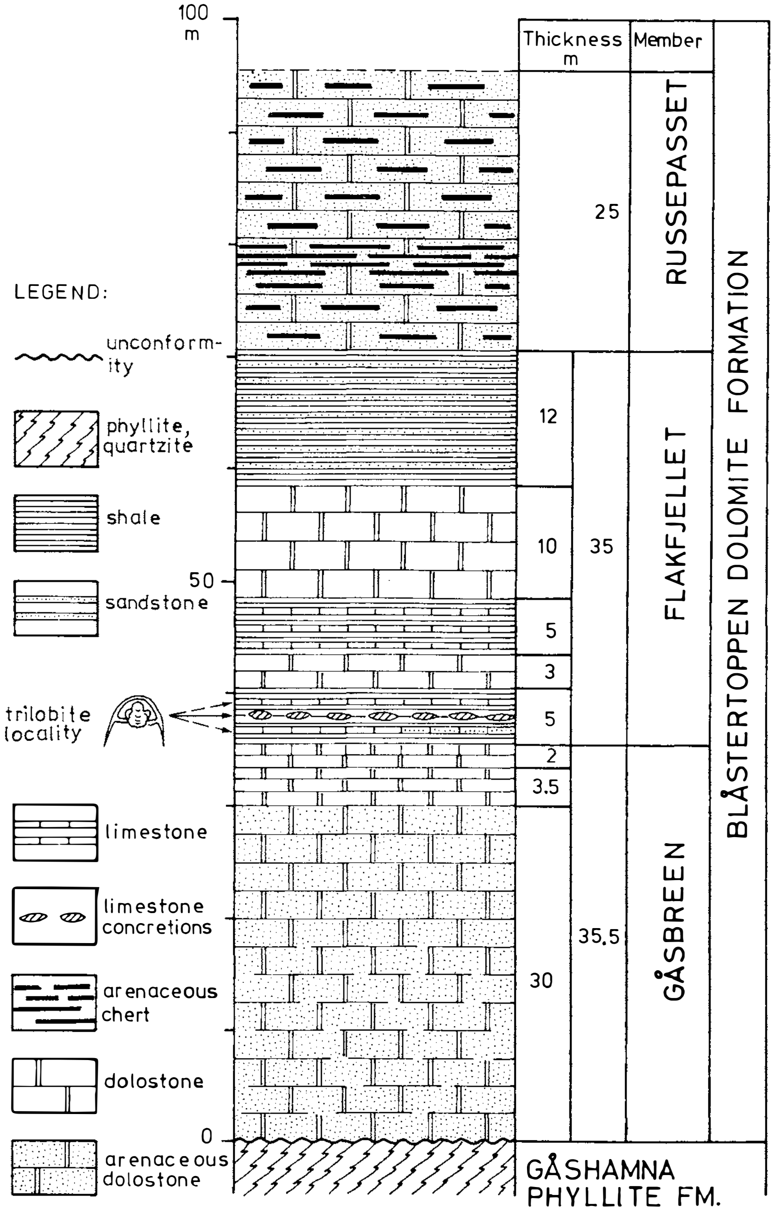

Fig. 3. *Stratigraphical column of the Blåstertoppen Dolomite Formation at Flakfjellet.*

Flakfjellet section
(Figs. 2, 3)

The Flakfjellet section is exposed at the NE tip of Flakfjellet, just above Gåsbreen (Fig. 1). The whole sequence is here tectonically overturned (Fig. 2), but the beds are relatively slightly deformed, save for the Gåsbreen Member and the Precambrian Gåshamna Phyllite Formation.

Stratigraphy and lithology	Thickness in metres
4. Blåstertoppen Dolomite Fm.: Russepasset Mb.	
b. Dolostone, arenaceous, black or blue, yellow weathered, in layers 2–3 m thick, alternating with bands of white to bluish pseudo-cherts 0.1–1 m thick. The pseudo-cherts are recrystallized quartz-sand intercalations. Some smaller lenticular intercalations of black pseudo-chert (1–10 cm thick) show transition to dolomitic sandstone.	
a. Dolostone, strongly arenaceous, yellow, with very numerous pseudo-chert and quartzitic sandstone intercalations 0.1–1 m thick, alternating with dolostone bands 2–10 cm thick. Sometimes the psammite intercalations join each other to form bands up to 5–7 m thick. Well rounded quartz grains about 1 mm in diameter are visible at the stratigraphic top of some siliceous layers, their middle and stratigraphically lower parts being often transformed into quartzite. Thickness of a+b (incomplete)	c. 25
3. Blåstertoppen Dolomite Fm.: Flakfjellet Mb.	
(total thickness 35 m)	
c. Shale, black, with thin black or brownish-black sandstone intercalations....	c. 12
b. Dolostone, brecciated, grey or yellow, sometimes veined with bluish quartz	c. 10
a_3. Shale, black, with black limestone intercalations 1–10 cm thick. Thickness c. 5 m.	
a_2. Dolostone, laminated, black or grey, veined with white or yellow quartz. In stratigraphically lower part of the horizon, there occur thin bands of black limestone. Thickness c. 3 m.	
a_1. Shale, often calcareous, black, with intercalations (5–10 cm thick) and lenticular concretions (5–10 cm thick and 10–50 cm in diameter) of grey to black limestone. The limestone intercalations are often silty, especially near the stratigraphical bottom of the Member, where they often transist into grey, calcareous, fine-grained sandstone or siltstone (1–5 cm, sometimes up to 25–30 cm thick), and often show tectonically reversed current and convolute lamination. Trilobite remains (olenellids), mostly cephala, usually well preserved, occur both in the limestone concretions and intercalations, but they are more frequent and better preserved in the concretions. Thickness of a_1 c. 5 m. Total thickness of a_1–a_3....	c. 13
(Thrust fault)	
2. Blåstertoppen Dolomite Fm.: Gåsbreen Mb.	
(total thickness c. 35 m)	
c. Dolomitic limestone, grey	2
b. Dolostone, yellow	3.5
a. Dolostone, arenaceous, yellow	c. 30
1. Gåshamna Phyllite Formation	
Phyllite, quartz-phyllite and quartzite, black, blue, grey, green, with a reddened zone of haematite mineralization in the middle. Incomplete thickness..........	c. 50

Gåsbreen Member

Name. – After Gåsbreen glacier in Sørkapp Land, south Spitsbergen (Fig. 1), the major glacier in the vicinity of the type section at Flakfjellet (BIRKENMAJER 1971).

Type section. – Flakfjellet, Sørkapp Land (Figs. 2, 3).

Thickness. – About 35 m in the type section.

Lithology. – Yellow arenaceous dolostone which passes upward into pure dolostone and dolomitic limestone.

Boundaries. – Lower boundary – angular unconformity against the late Precambrian Gåshamna Phyllite Formation. Upper boundary is marked by a change in lithology: from dolostone and dolomitic limestone (Gåsbreen Mb.) to black shale (Flakfjellet Mb.).

Age. – No fossils have been found in the Member. The unit is conformably overlain by the Flakfjellet Member which yielded late Lower Cambrian olenellids (see below). It rests unconformably (angular unconformity) upon folded and eroded late Precambrian Gåshamna Phyllite Formation from which it is separated by a hiatus. As the trilobites of the *Bonnia-Olenellus* Zone occur barely 1–4 m above the top of the Gåsbreen Member, its late Lower Cambrian age is most probable.

Distribution. – The Member was distinguished in the Flakfjellet section in Sørkapp Land.

Equivalents. – None.

Flakfjellet Member

Name. – After Flakfjellet in Sørkapp Land, south Spitsbergen (Fig. 1) – see BIRKENMAJER (1971).

Type section. – Flakfjellet, Sørkapp Land (Figs. 2, 3).

Thickness. – 35 m in the type section.

Lithology. – The Member begins with black shale with thin grey limestone intercalations and concretions, the latter containing olenellid fauna. Above follow thin horizons of dolostone, shale with limestone intercalations, dolostone, and finally shale with sandstone intercalations.

Boundaries. – Lower boundary is placed at the change of lithologies: from dolostone and dolomitic limestone (Gåsbreen Mb.) to black shale (Flakfjellet Mb.). Upper boundary is placed at the change of lithologies: from black shale with thin sandstone intercalations (Flakfjellet Mb.) to arenaceous dolostone with pseudo-cherts (Russepasset Mb.).

Fauna and age. – Olenellid fauna: *Olenellus svalbardensis* KIELAN and *O. sculptilis* n. sp. ORLOWSKI occur in limestone intercalations and concretions within black shale of the lower part of the Member. This fauna indicates the *Bonnia-Olenellus* Zone, late Lower Cambrian of the Pacific Province.

Distribution. – The Member was recognized in the Flakfjellet section in Sørkapp Land.

Equivalents. – None.

Russepasset Member

Name. – After Russepasset in Sørkapp Land, south Spitsbergen (Fig. 1) which is a major pass in the vicinity of the type section at Flakfjellet (BIRKENMAJER 1971).

Type section. – Flakfjellet, Sørkapp Land (Figs. 2, 3).

Thickness – 25 m (incomplete) in the type section.

Lithology. – Black or blue, yellow weathered arenaceous dolostone with arenaceous pseudo-chert intercalations.

Boundaries. – Lower boundary is placed at the change of lithologies: from black shale with sandstone intercalations (Flakfjellet Mb.) to arenaceous dolostone with pseudo-cherts (Russepasset Mb.). This boundary is slightly disturbed by a thrust fault at type locality. Upper boundary not exposed in the type section. In other sections (Sørkapp Land and Wedel Jarlsberg Land) the succeeding Vardepiggen Formation starts with black or greenish shale usually with sedimentary breccia at the base.

Age. – No fossils were found from the Member. The unit is conformable, but with slight distortion of the beds at the contact with the Flakfjellet Member (minor thrust-fault). The latter yielded olenellids of the *Bonnia-Olenellus* Zone. The succeeding Vardepiggen Formation still belongs to this Zone (see below). Thus a late Lower Cambrian age of the Russepasset Member is obvious.

Distribution. – The Member was recognized in the Flakfjellet section in Sørkapp Land. In the case of absence of olenellid-bearing shales with limestone intercalations and concretions (Flakfjellet Mb.) in the middle of the Blåstertoppen Dolomite Formation (as is the case in Wedel Jarlsberg Land), it may be difficult to distinguish the Russepasset Member from the Gåsbreen Member.

Equivalents. – None.

DISCUSSION

Relation of the Cambrian to the Precambrian

The hiatus at the base of the Blåstertoppen Dolomite Formation (Gåsbreen Mb.) in Sørkapp Land is the result of Jarlsbergian diastrophism which produced folding and dynamic and regional metamorphism of the whole Precambrian succession (Hecla Hoek) in south Spitsbergen, and was followed by uplift and erosion (BIRKENMAJER 1975). This hiatus separates the Gåshamna Phyllite Formation (late Precambrian = Varangian resp. Vendian) from almost unmetamorphosed Cambrian sediments. Fragments of the Gåshamna phyllite were found as secondary deposit in sedimentary breccia intercalations in the Blåstertoppen Dolomite Formation of Wedel Jarlsberg Land (BIRKENMAJER 1960). Isotopic determinations from 529 to 636 Ma of the rocks older than the Cambrian, from south, northwest and northeast Svalbard (see GAYER et al. 1966; GEE and HJELLE 1966; HARLAND et al. 1966; HARLAND 1969, 1972; GEE 1972), though probably showing some overprinting by Caledonian metamorphosis, could indicate the age of the Jarlsbergian diastrophism as around 600 Ma, i.e. close to the boundary of Cambrian and Precambrian (BIRKENMAJER 1975).

At Flakfjellet, the olenellid trilobites of the *Bonnia-Olenellus* Zone appear already 36–40 m above the base of the Cambrian succession in limestone concretions and intercalations of a black shale horizon which separates carbonate (predominantly arenaceous dolostone) members of the Blåstertoppen Dolomite

Formation. It seems probable that the base of the Formation (Gåsbreen Mb.) already belongs to the *Bonnia-Olenellus* Zone (Table 1). If so, the Lower Cambrian transgression in south Spitsbergen would begin at the close of Lower Cambrian, and the sedimentary hiatus at the base of the Cambrian would comprise the early Lower Cambrian (*Fallotaspis* Zone) and the middle Lower Cambrian (*Nevadella* Zone).

Table 1

Stratigraphy of the Cambrian succession at Hornsund, south Spitsbergen

LITHOSTRATIGRAPHY						CHRONOSTRATIGRAPHY		
Supergroup	Group	Formation	m	Member	m	Zone	Series	System
HORNSUND	SØRKAPP LAND						CAN-AD-IAN	ORDO-VIC-IAN
		WIEDERFJELLET QTZ.	300					
	SOFIEKAMMEN	NØRDSTETINDEN	150				U.?	CAMBRIAN
		GNÅLBERGET MARBLE	250-300				M.?	
		SLAKLIDALEN LST.	10-120			*Bonnia-Olenellus*	LOWER	
		VARDEPIGGEN	130-215					
		BLÅSTERTOPPEN DOL.	100-150	RUSSEPASSET	25+			
				FLAKFJELLET	35			
				GÅSBREEN	35			
						Nevadella		
		Jarlsbergian diastrophism				*Fallotaspis*		
	SOFIEBOGEN	GÅSHAMNA PHYLLITE					LATE PRECAMBRIAN (VENDIAN)	

Age of the Lower Cambrian succession

The above data indicate the late Lower Cambrian age (*Bonnia-Olenellus* Zone) of the Blåstertoppen Formation which begins the Lower Cambrian succession in south Spitsbergen. The succeeding Vardepiggen Formation (130–215 m thick) consists predominantly of black and greenish shale with sedimentary breccia and limestone intercalations (BIRKENMAJER 1975; *Olenellus* shale, lower part of the Slakli "series" of BIRKENMAJER 1960). Olenellid trilobites, *Olenellus svalbardensis* KIELAN and *Nevadella* sp., were determined from the shale by KIELAN (1960; see also BIRKENMAJER 1960). The first species is identical with that found in the Flakfjellet Member and indicates that the Vardepiggen Formation still belongs to the *Bonnia-Olenellus* Zone. The attribution of the other olenellid to *Nevadella* sp. by KIELAN (1960) was questioned by COWIE (1974, p. 127) and by ORLOWSKI (this paper). This is an "olenellid indet.".

From the Slaklidalen Limestone Formation (10–120 m thick) which consists of grey limestone (BIRKENMAJER 1975; Slakli limestone, upper part of the Slakli "series", BIRKENMAJER 1960; Slakli "series" (*partim*), MAJOR and WINSNES 1955) and succeeds the Vardepiggen Formation, comes a diversified fauna with trilobites *Olenellus* cf. *thompsoni* HALL, *O.* sp. I and II, *Serrodiscus bellimarginatus* (SHALER et FOERSTE), *S.* cf. *speciosus* (FORD), *Calodiscus lobatus* (HALL), *C.* sp. ind., *Pagetia* sp., as well as *Hyolithellus* cf. *micans* BILLINGS, *H.* sp., *Platyceras primaevum* BILLINGS and *Obolella* cf. *atlantica* WALCOTT (MAJOR and WINSNES 1955; COWIE 1974). The fossils were determined mainly from scree and moraine blocks at Midifjellet and from limestone in situ at Wiederfjellet and eastern Gåshamna in Sørkapp Land. According to COWIE (1974, p. 127, 128) "This is a Pacific Province fauna with some affinities with the Atlantic Province shown by the presence of species of *Serrodiscus* and *Calodiscus*. The trilobites, including eodiscids and olenellids, indicate the upper part of the Lower Cambrian (? *Bonnia-Olenellus* Zone of FRITZ 1972) but the fauna probably does not indicate the youngest part of the Lower Cambrian times".

B. Palaeontological part

By S. ORŁOWSKI

PRESERVATION OF OLENELLID FAUNA

The olenellid fauna from the Flakfjellet Member (Blåstertoppen Dolomite Formation) occurs in dark lenticular limestone intercalations and concretions which are moderately hard, with numerous, small joints and scarce slickensides. No complete trilobite carapaces were found, the most common are cephala and their parts, and parts of pleurae. This mode of occurrence of trilobite fragments suggests a shallow-marine environment where the trilobite carapaces were subject to disintegration and often fragmentation.

Large cephala belonging to *Olenellus svalbardensis* KIELAN are flattened more than smaller cephala of *Olenellus sculptilis* n. sp. These large cephala were especially subject to tectonic deformation which is visible as cracks and often small displacements of carapace fragments, as well as distortion of original length and width of the carapace fragments. However, the preservation of the specimens is good, and often both the carapace and its delicate ornamentation are preserved.

The cephala of *Olenellus sculptilis* are also tectonically deformed, but to a less extent. Their strong convexity is still well visible, with well marked glabella and cephalic border, their state of preservation is often very good.

The lack of complete specimens and the presence of tectonic deformation in many carapace fragments, caused difficulties in determining a part of the collection. Out of about 100 specimens collected by K. BIRKENMAJER, only some 20 were specifically determinable.

The elaborated material is housed in Paleontologisk Museum, Oslo, as Collection PMO A 35887–35999.

SYSTEMATIC DESCRIPTION OF OLENELLIDS

Family: Olenellidae VODGES, 1893
Subfamily: Olenellinae VODGES, 1893
Genus: *Olenellus* BILLINGS, 1861

Olenellus svalbardensis KIELAN, 1960
(Pl. I, Figs. 1–7)

1960 *Olenellus svalbardensis* n. sp.; KIELAN, pp. 84–88; Pl. I, Figs. 1–3; Pl. II, Figs. 1–5; Pl. III, Figs. 1–5; Pl. IV, Figs. 1, 2.
1974 *Olenellus* cf. *svalbardensis* KIELAN, POULSEN, pp. 82–83; Pl. I, Figs. 1–3.

Material. – One almost entire cephalon, five partly preserved cephala, some extraocular cheeks and many fragments.

Description. – Cephalon large, semicircular in outline, slightly convex, about twice as wide as long. Cephalic border narrow, slightly convex, turning posteriorly into long genal spines, almost as long as the cephalon. Genal spines convex, narrow (tr). Posterior margin slightly bent posteriorly, its lateral part is slightly directed anteriorly.

Glabella broad (tr), convex to variable degree, reaches about one-third of width of cephalon across palpebral lobes, increasing slightly in width (tr) toward the frontal lobe; largest width across the frontal lobe. Occipital lobe long (sag) with small node near the posterior margin, and small triangular areas near dorsal furrows. Occipital furrow well marked on sides. Four pairs of glabellar furrows; S1 and S2 not joined across glabella, S3 joined across glabella.

Palpebral lobe curved, reaching from the frontal lobe of glabella to the level of occipital furrow. Palpebral area narrow (tr), extraocular cheek about three times as wide as palpebral area. Extraocular cheeks covered with ridges which radiate from the eyes to the cephalic border.

Preglabellar field very short (sag) in the front of glabella.

Remarks. – This species was described by KIELAN (1960) from black shales of the Slakli "series" (now: Vardepiggen Formation, BIRKENMAJER 1975) of Vardepiggen, Wedel Jarlsberg Land (south Spitsbergen). All specimens are extremely flattened, the majority are strongly weathered.

The specimens described in this paper were found in dark limestone concretions and intercalations within black shales of the Flakfjellet Member (Blåstertoppen Dolomite Formation) at its type locality (Figs. 2, 3) in Sørkapp Land, south Spitsbergen. They are much larger and more convex than those collected from the shales at Vardepiggen. The specimens are very similar to those described by KIELAN (1960) but their preservation is much better. their proportions are much larger, the glabella is slightly longer and broader (tr), the glabellar furrows are shallower – this feature is connected with the presence of dorsal carapace.

Dimensions. – The largest cephalon is about 35 mm long and 65 mm broad along posterior margin, and about 60 mm across palpebral lobes; the length of genal spine is about 30 mm.

Type horizon and locality. – *Olenellus svalbardensis* occurs in black shales of the Vardepiggen Formation (previously lower part of the Slakli "series") at Vardepiggen, and in dark limestone concretions and lenses within black shale of the Blåstertoppen Dolomite Formation at Flakfjellet in the Hornsund area, south Spitsbergen. POULSEN (1974) described *Olenellus* cf. *svalbardensis* from the Lower Cambrian Schley Fjord (Shale) Formation of North Greenland.

Olenellus sculptilis n. sp. ORŁOWSKI
(Pl. II, Figs. 1–4)

Holotype. – Cephalon No. A 35832 from Flakfjellet, south Spitsbergen, presented in Pl. II, Figs. 1a–c.

Type horizon. – Lower Cambrian, Flakfjellet Member of the Blåstertoppen Dolomite Formation.

Type locality. – Flakfjellet, Sørkapp Land, south Spitsbergen (Figs. 1–3).

Derivation of name. – From Latin word *sculptilis* – covered with ornamentation.

Material. – Two almost completely preserved cephala, three partly preserved cephala, some fragments.

Diagnosis. – An *Olenellus* species with very convex, parallel-sided and long glabella, with narrow and convex cephalic border, and with characteristic ornamentation on the glabella, cheeks, cephalic border and genal spines.

Description. – Cephalon small, semicircular in outline, convex, about twice as broad as long. Cephalic border narrow but very convex, inner cephalic margin very sharp, with almost the same width in the front and lateral parts, turning posteriorly into genal spines. Posterior margin slightly bent posteriorly, its lateral part slightly directed anteriorly.

Glabella convex, parallel-sided, rounded anteriorly, reaching almost to cephalic border, occupying about one-third of cephalon across palpebral lobes. Three pairs of glabellar furrows directed laterally-backward, two pairs separated, only S3 joined across glabella. Occipital furrow distinct only on sides, not joined across glabella. Occipital lobe with small node near the posterior margin and with small triangular area on its sides.

Palpebral lobes near the glabella, reaching posteriorly to the level of occipital furrows. Palpebral area much narrower than extraocular cheek.

Glabella, cheeks, cephalic border and genal spines are covered with very strong and distinct ornamentation of irregular ridges. Middle part of glabella covered with shorter, transversal ridges; lateral parts of glabella and the rest of cephalon covered with longer ridges situated parallel to the outer rim of cephalon and curving along with it. Genal spines covered with longitudinal ridges.

Thorax and pygidium unknown.

Discussion. – *Olenellus sculptilis* n. sp. differs from *Olenellus thompsoni* (HALL) in more convex glabella, shorter (tr) extraocular cheek, much convex cephalic border and in characteristic ornamentation on cephalon. The new species differs from *O. svalbardensis* KIELAN in smaller size, more convex glabella, more convex cephalic border and other pattern of ornamentation on extraocular cheeks.

From *O. praenuntius* COWIE (COWIE 1968)* the new species differs in broader and longer glabella, more convex cephalic border and another ornamentation pattern; from *O. truemani* WALCOTT (see FRITZ 1972) it differs in broader glabella, longer palpebral lobes and another ornamentation pattern; from *O. paraoculus* FRITZ (FRITZ 1972) it differs in broader and more convex glabella, the shape of anterior lobe of glabella, another situation of palpebral lobes, other type of margin and ornamentation.

The new species is similar to *O. lapworthi* PEACH (LAKE 1936) in the shape of glabella, but differs in longer palpebral lobes, more distinct cephalic border and in ornamentation.

Dimensions. – The cephalon is about 18 mm long and 32 mm broad.

STRATIGRAPHICAL REMARKS

The Lower Cambrian stratigraphy in the area of occurrence of the genus *Olenellus* and related genera, was the matter of debate for many decades. WALCOTT (1910) distinguished four trilobite zones in the Lower Cambrian, the highest one characterized by the presence of *Olenellus*. LOCHMAN (1956) extended the occurrence of *Olenellus* within the Lower Cambrian and distinguished the lower *Olenellus* subzone and the upper *Olenellus* subzone. She has also correlated the Lower Cambrian trilobite zones of the Pacific Province with those of the Atlantic Province and with HUPÉ's zones of Morocco.

The last biostratigraphic scheme of the Lower Cambrian given by FRITZ (1972) distinguishes three trilobite zones: (1) *Fallotaspis* Zone, (2) *Nevadella* Zone and (3) *Bonnia-Olenellus* Zone. This scheme is based on the occurrence of trilobites in Lower Cambrian geological sections of western North America: type Sekwi District of Mackenzie; Northern Cariboo Mountains, British Columbia; White-Inyo Mountains, SE California. A correlation was made by FRITZ with the sections in Comley, Shropshire, England; Anti-Atlas Mountains, Morocco; the Siberian Platform.

Based on FRITZ's (1972) stratigraphical standard, the trilobite fauna with *Olenellus svalbardensis* KIELAN and *O. sculptilis* n. sp. from the Flakfjellet Member of the Blåstertoppen Dolomite Formation (Sørkapp Land, south Spitsbergen) belongs to the *Bonnia-Olenellus* Zone, upper part of the Lower Cambrian. This zone is comparable with the *Protolenus* Zone of the Atlantic Province (BERGSTRÖM 1973; ORŁOWSKI 1974).

The presence of *Nevadella* Zone in south Spitsbergen has been questioned by

* FRITZ (1972) recognized the differences between *O. praenuntius* and *O. truemani* as being within the range of specific variation and included this species to *O. truemani*.

COWIE (1974) who expressed an opinion that *Nevadella* sp. determined by KIELAN (1960) from black shales of Vardepiggen (now: Vardepiggen Formation, BIRKENMAJER 1975) is an "olenellid indet.". COWIE's view is also shared by the present author after re-examining the original specimens from BIRKENMAJER's collection of Vardepiggen.

Acknowledgements

IWO BIRKENMAJER, SVEIN GULBRANDSEN and ØYVIND GULDAHL helped K. BIRKENMAJER while collecting trilobites at Flakfjellet in 1970. Their assistance is here acknowledged with pleasure.

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PLATES

PLATE I

Olenellus svalbardensis KIELAN from the Flakfjellet Member (Blåstertoppen Dolomite Formation), Flakfjellet, south Spitsbergen. All photos natural size, except for Fig. 2 – × 1.5, taken by B. DROZD. All specimens are in Paleontologisk Museum, Sarsgate 1, Oslo, Norway.

1. Partly preserved cephalon (No. PMO A 35828).
2. Part of cephalon, latex cast (No. PMO A 35918).
3. Part of crushed cephalon (No. PMO A 35951).
4. Glabella and palpebral lobes (No. PMO A 35830).
5. Extraocular cheek (No. PMO A 35833).
6. Cephalon (No. PMO A 35829).
7. Part of cephalon (No. PMO A 36363).

PLATE I

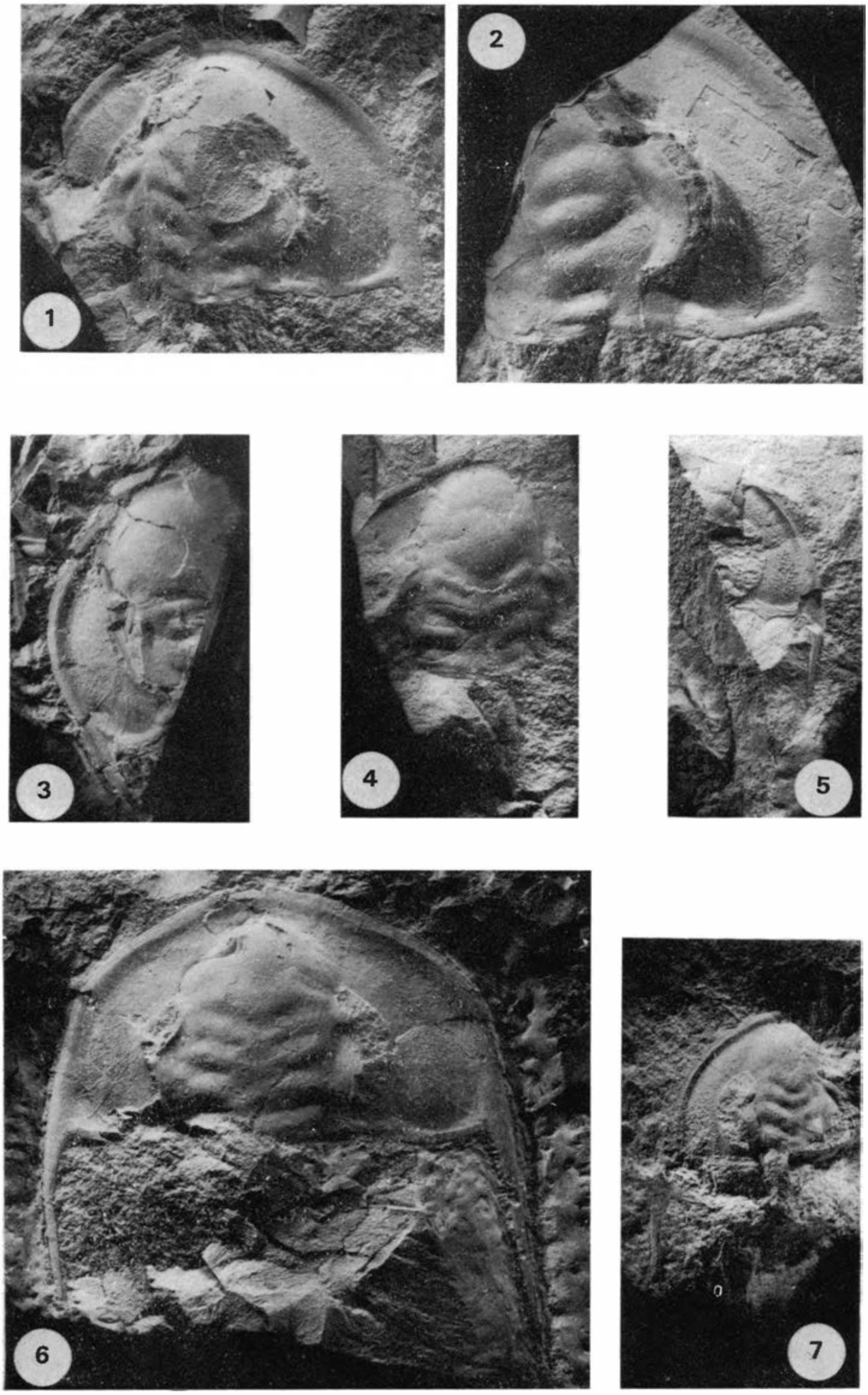
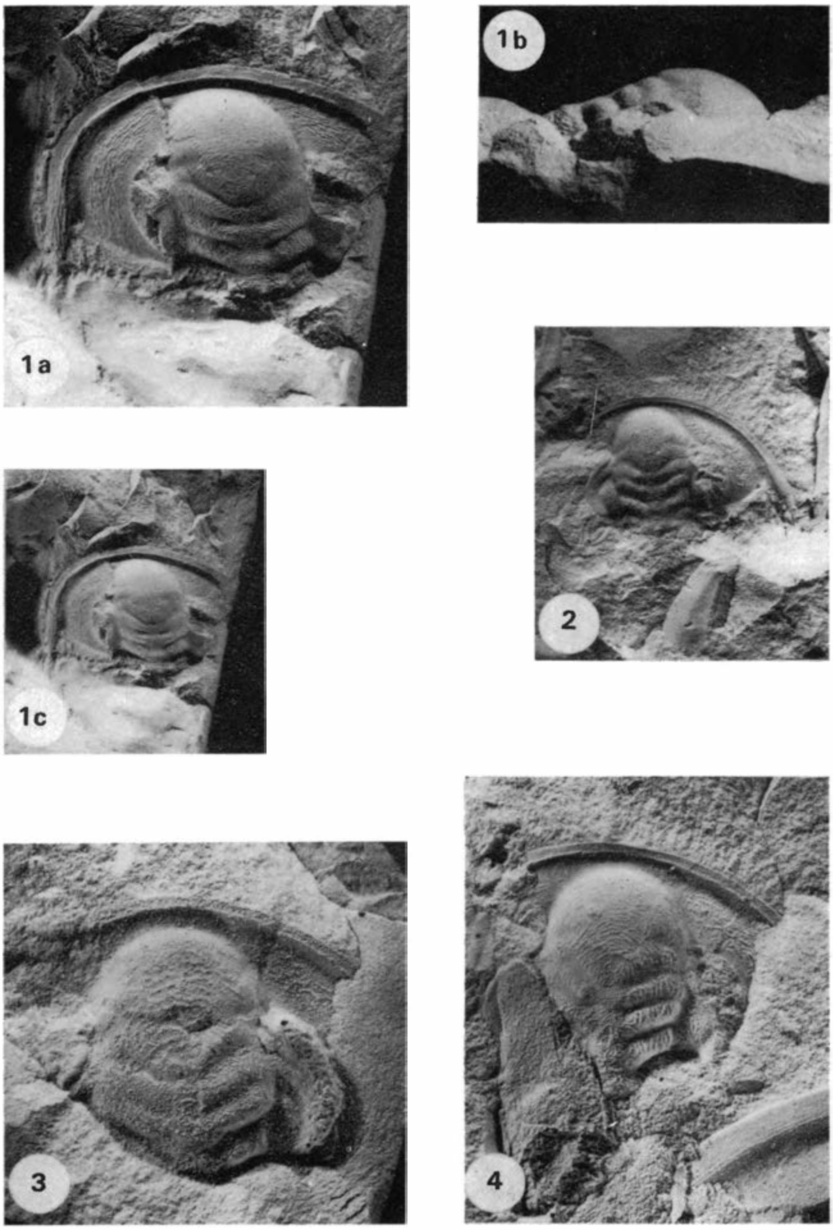


PLATE II

Olenellus sculptilis n. sp. ORŁOWSKI from the Flakfjellet Member (Blåstertoppen Dolomite Formation), Flakfjellet, south Spitsbergen. All photos ×2, except for 1c and 2 – natural size, taken by B. DROZD. All specimens are in Paleontologisk Museum, Sarsgate 1, Oslo, Norway.

1a–c. Cephalon: a, c – dorsal view; b – side view (No. PMO A 35832), holotype.
2. Partly preserved cephalon (No. PMO A 35919).
3. Latex cast of cephalon (No. PMO A 35835).
4. Latex cast of cephalon (No. PMO A 35920).

PLATE II



Trace fossil evidence for predation on trilobites from Lower Cambrian of south Spitsbergen

By Krzysztof Birkenmajer[1]

Contents

Abstract

Trace fossils in form of vertical to sub-vertical burrows filled with fine fragments of trilobite exoskeleton occur in the Lower Cambrian shale unit at Midifjellet, south Spitsbergen. The burrows, interpreted as trace-fossil evidence for predation on trilobites, were probably dwelling burrows of sea anemones. These burrows are good indicators of bottom and top in strongly tectonically disturbed Cambrian strata of the Caledonian fold belt of Spitsbergen.

Introduction

During the summer investigations in Sørkapp Land, south Spitsbergen, in 1970, sponsored by Norsk Polarinstitutt, a horizon rich in trace-fossils (burrows) was found in the Lower Cambrian shales at Midifjellet (Figs. 1, 2). The burrows, attributed to the ichnogenus *Dolopichnus* Alpert et Moore, occur in the Vardepiggen Formation (Birkenmajer 1975) which belongs to the *Bonnia-Olenellus* Zone of late Lower Cambrian (Birkenmajer and Orlowski in print).

Description of trace fossils

Morphology

Large, vertical or sub-vertical burrows, 5–25 cm high and usually 1–5 cm in diameter, filled throughout with fragmented trilobite exoskeletons up to 1–2

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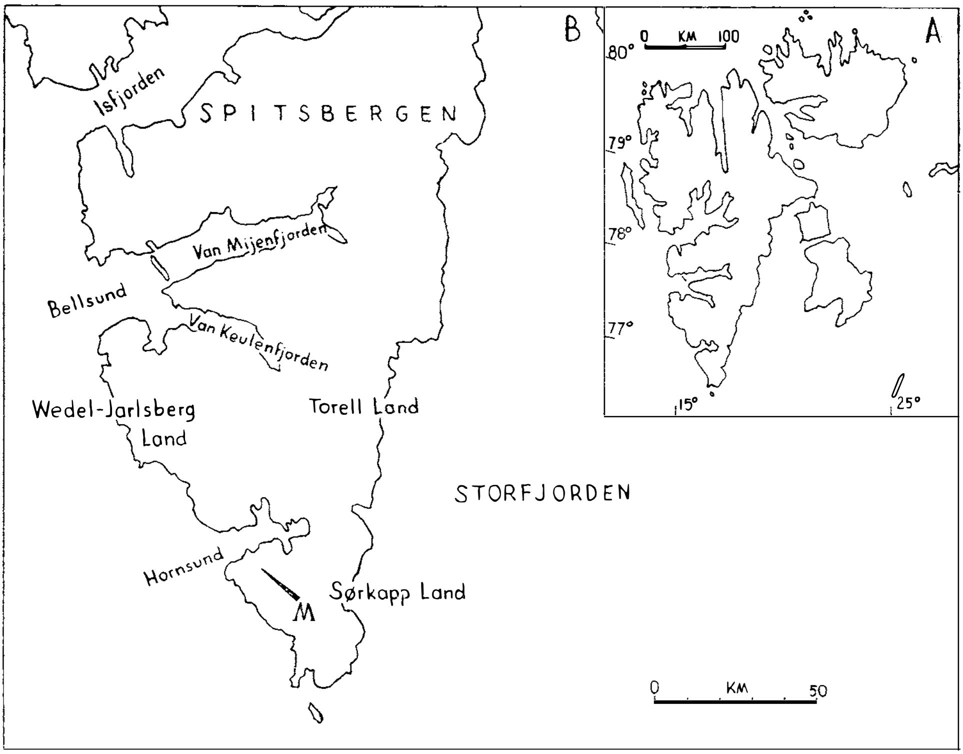


Fig. 1. *Key maps to show the position of Midifjellet (M) in south Spitsbergen (B) and in Svalbard (A).*

mm long, sometimes also with fragments of other shelly fossils, occur usually in green to blackish, slightly phyllitic shale (Figs. 4, 5A, B), but often penetrate through calcareous siltstone intercalations which are from 1 mm to 10 cm thick (Figs. 3, 4). The trilobite detritus occurs also in the shale just above the burrows (Figs. 3, 4). The trilobite fragments in the burrows are subparallel to the bedding.

The burrows may be subdivided into three types according to their shape in vertical cross-section (Fig. 6).

A. Single burrows are cylindrical or conical (funnel-shaped) in cross-section, usually with wide entrance and narrowing downward, often pointed apex. Some of the burrows are bulbous near the apex, the smaller ones often twisted and with narrow entrance; the latter may be partly the effect of section oblique to the axis of the burrow. The burrows are from several to nearly 20 cm high, with entrance of up to 5 cm in diameter, usually wider than the burrow.

B. Multiple burrows form clusters (colonies) of parallel burrows, often merging, up to 25 cm high. The downward-oriented apex is either pointed, rounded, or bulbous. Cleavage may develop between individual burrows in clusters (Fig. 4, lower part).

C. Complex burrows form clusters (colonies) resembling *B*, but are less regular,

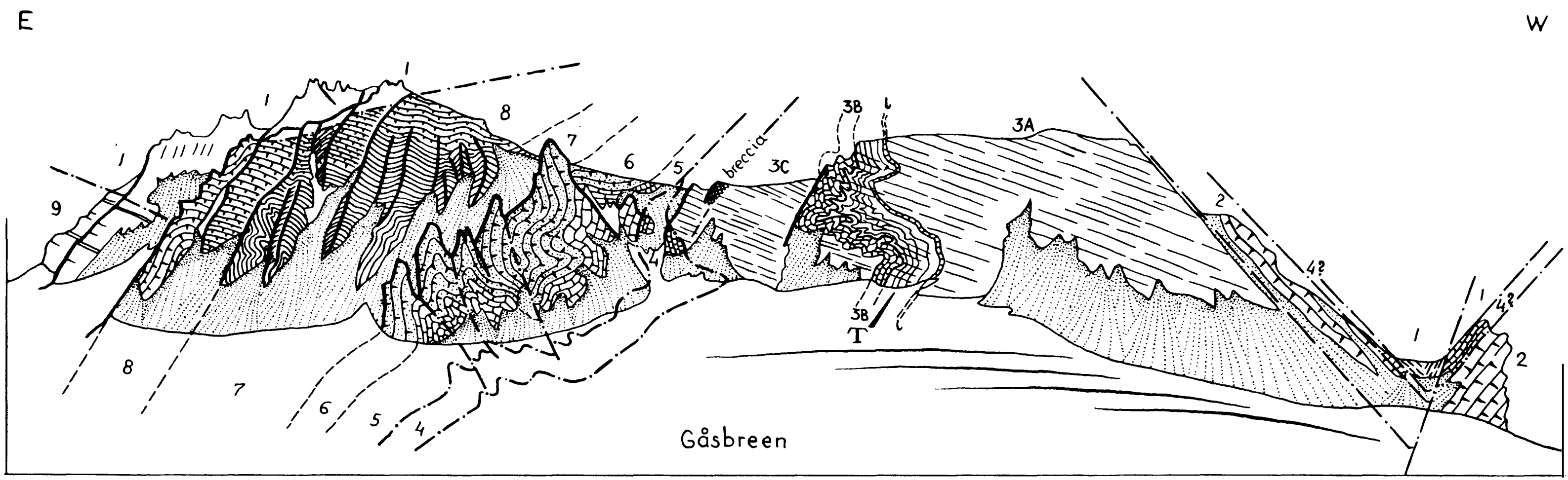


Fig. 2. *Perspective view of Midifjellet from the north with position of trace fossils (T)* Dolopichnus *sp. Precambrian: 1 – Gåshamna Phyllite Formation. Lower Cambrian: 2 – Blåstertoppen Dolomite Formation; 3A–C – Vardepiggen Formation (A, C – shale, B – limestone, 1 – silty limestone); 4 – Slaklidalen Limestone Formation. Middle-Upper Cambrian (?): 5 – Nørdstetinden Formation. Lower Ordovician (Canadian): 6, 7 – Wiederfjellet Quartzite Formation; 8 – Luciapynten Dolomite Formation; 9 – Nigerbreen Limestone Formation and Hornsundtind Limestone Formation. Main tectonic contacts are marked by dashes and dots. Cleavage marked in shaly complexes.*

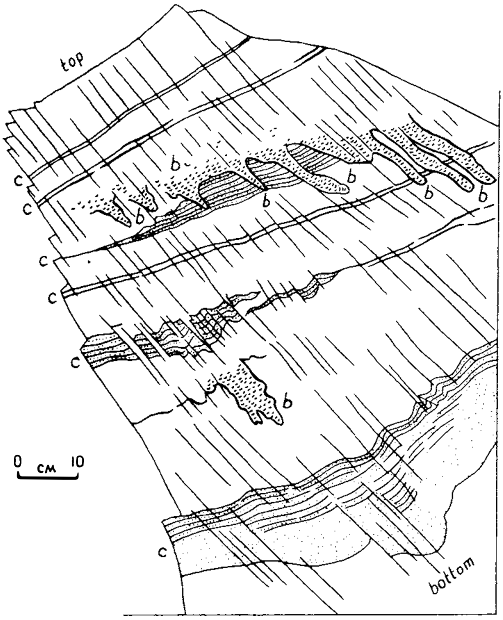
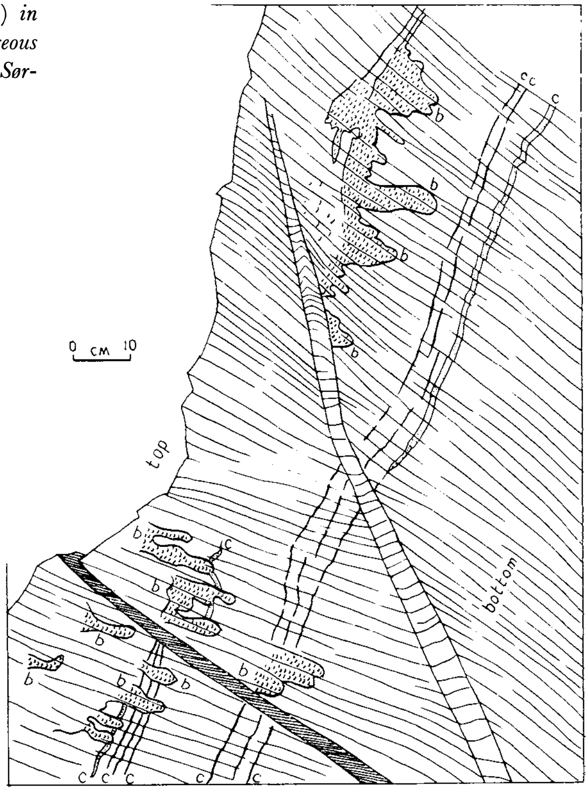


Fig. 3. *Burrows* Dolopichnus *sp.* (*b*) *in cleaved Lower Cambrian shale with calcareous siltstone intercalations* (*c*). *Midifjellet, Sørkapp Land.*

Fig. 4. *Burrows* Dolopichnus *sp.* (*b*) *in cleaved Lower Cambrian shale with calcareous siltstone intercalations* (*c*). *Midifjellet, Sørkapp Land.*



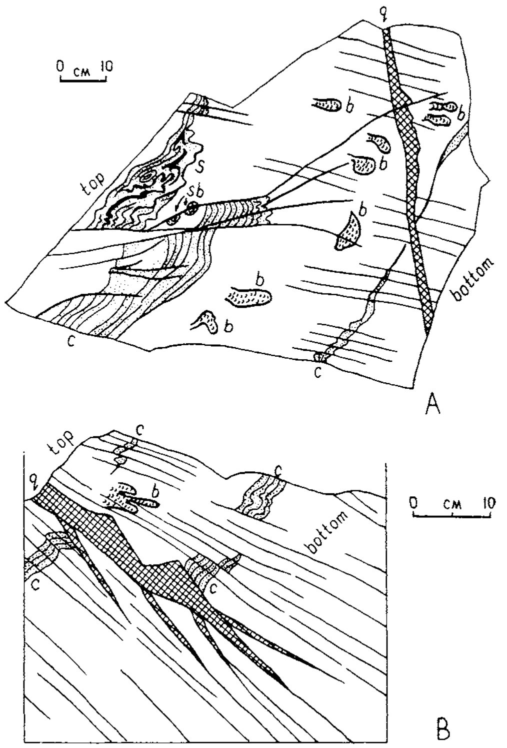


Fig. 5. *Burrows* Dolopichnus *sp.* (*b*) *in cleaved Lower Cambrian shale with calcareous siltstone intercalations* (*c*) *and veined with quartz-ankerite* (*q*). *s – slumped layers; sb – slump balls. Midifjellet, Sørkapp Land.*

with vertical, sub-vertical, and horizontal branches. They seem to be partly deformed by synsedimentary initial slumping (see Fig. 4, upper part).

Due to strong cleavage of the shales it was not possible to examine the burrows in cross-section or on bedding planes. The burrows are good indicators of bottom and top in strongly tectonically disturbed Cambrian strata of the Caledonian fold belt of Spitsbergen.

Discussion

The general character and sizes of the burrows, especially of type *A*: cylindrical or conical (funnel-shaped), vertical to sub-vertical burrows filled with trilobite detritus, resemble those of the ichnogenus *Dolopichnus* ALPERT et MOORE (type species *D. gulosus* ALPERT et MOORE) from Lower Cambrian mictritic quartz arenite of the Poleta Formation in Esmeralda County, Nevada, interpreted as dwelling burrows of sea anemones (ALPERT and MOORE 1975). No central, vertical, internal cylindrical core (cast of coelenterion) was found in the burrows from Spitsbergen, contrary to those from Nevada. However, some short burrows of *Dolopichnus gulosus* ALPERT et MOORE lack a central cylinder and contain trilobite fragments throughout, as in the specimens from Spitsbergen.

The burrows from Lower Cambrian of south Spitsbergen show a variety of shapes (Figs. 3–6) much larger than those given for *Dolopichnus gulosus*. They

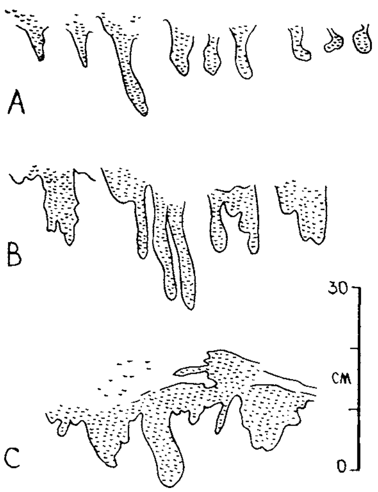


Fig. 6. *Main morphologic types within burrows* Dolopichnus *sp. from Lower Cambrian shale at Midifjellet, Sørkapp Land.*

may represent various stages of development of sea anemone dwelling burrows: from smaller, rather simple single burrows (Fig. 6A) to larger, more irregular multiple burrows (clusters resp. colonies: Fig. 6B), sometimes with deformation produced by initial slumping (complex burrows: Fig. 6C).

The diagnostic features of *Dolopichnus gulosus* ALPERT et MOORE include not only their shape and size in vertical cross-section, but also the characteristic shape and structure of the lower termination (apex) and upper ending (entrance) of the burrows. As no observations were possible in sections parallel to the bedding planes in the Spitsbergen forms, their ichnospecific attribution is left open.

Other related burrows such as *Bergaueria* PRANTL (Cambrian – Ordovician), *Conostichus* LESQUEREUX (Carboniferous), *Kulindrichnus* HALLAM (Jurassic), *Cylindrichnus* TOOTS (Cretaceous – Tertiary) and *Anemonichnus* CHAMBERLAIN et CLARK (Carboniferous – Permian), generally attributed to sea anemones (HALLAM 1960; HÄNTZSCHEL 1962; CHAMBERLAIN 1971; ALPERT 1973; CHAMBERLAIN and CLARK 1973; ALPERT and MOORE 1975) differ from our burrows in shape, ornamentation, and internal structure. The ichnogenus *Dolopichnus* which is chosen as the name for our burrows, includes i.a. *Cyclozoon* WURM (*partim*) and *Laevicyclus* QUENSTEDT (*partim*) – ALPERT and MOORE (1975).

The common prey of living sea anemones are crustaceans. Anemones will ingest live or dead individuals, and even molted exoskeletons. The early Cambrian anemones probably caught live trilobites small enough to ingest (ALPERT and MOORE 1975) which seems also to be the case with our examples from Spitsbergen.

Olenellid trilobites often occur in shales of the Vardepiggen Formation (BIRKENMAJER 1960a, b; KIELAN 1960) where they are represented almost exclusively by the genus *Olenellus* (see COWIE 1974; BIRKENMAJER and ORLOWSKI 1977), and the fragments in the burrows are probably of the genus *Olenellus*. The tests of olenellid trilobites are very thin and could have been easily broken by muscular action of the sea anemones (see ALPERT and MOORE 1975).

Sedimentary environment

The sedimentary environment of the Lower Cambrian shale containing *Dolopichnus* burrows in south Spitsbergen was that of non-carbonate clayey bottom of a shallow shelf. Frequent calcareous siltstone intercalations from 1 mm to 10 cm thick are usually well laminated parallel to the bedding plane, sometimes ripple-bedded. Though often disturbed by cleavage and small faults, the thicker siltstone intercalations often show lenticular shapes (Fig. 3) and traces of subaqueous slumping and slump balls (Fig. 5A). A part of the deformation in siltstones may be due to load casting (Fig. 3, bottom). The calcareous silt was probably deposited on clayey bottom from clouds of suspension and was subsequently resettled by oscillations of the water body to form lenticular smaller or larger ripples, often subject to load-casting and slumping.

The burrows often start from thin siltstone laminae (Fig. 3, middle part; Fig. 4, lower and upper parts), which represented a temporary arenaceous bottom. Some longest single and multiple burrows penetrate through one or several siltstone laminae or lenses (Fig. 3, upper part). The latter case could have been an indication that the sea anemones migrated upward the sediment to keep pace with episodes of relatively rapid accumulation of silt and clay.

ALPERT (1973) and ALPERT and MOORE (1975, p. 228) concluded that the burrow-dwelling sea anemones of the early Palaeozoic, contrary to the late Palaeozoic and younger anemones, were apparently unable to migrate upward to keep pace with rapid sedimentation. A sudden burial of the anemones by a thick layer of sand may have caused their death, and can explain the preservation of coelenteron and burrows of *Dolopichnus gulosus*. In our case from south Spitsbergen, the burial by calcareous silt was negligible and probably did not cause the death of sea anemones. The burrows are never filled with silt, and an upward migration of the anemones after each short episode of burial, either by silt or by clay, would explain the near-horizontal preferred orientation of trilobite fragments due to settling of the digested fragments in abandoned, lower parts of the dwelling burrows, and the lack of central tube in the burrows corresponding to coelenteron.

Acknowledgements

During the field work in south Spitsbergen, the author was assisted by Iwo BIRKENMAJER, SVEIN GULBRANDSEN, and ØYVIND GULDAHL. Their help is much appreciated.

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Hovgaard Fracture Zone

By Olav Eldholm[1] and Annik M. Myhre[1]

Contents

Abstract

A detailed survey has revealed that the Hovgaard Fracture Zone is not a single linear ridge, but is composed of two en echelon basement ridges separated by a sediment-filled trough. The trend of the fracture zone indicates that it was formed in conjunction with an extinct plate boundary in the Greenland Sea. The North American–Eurasian plate boundary between the Greenland Sea and the Arctic Ocean appears to be a structurally complex region which is bounded to the south by the Hovgaard Fracture Zone.

Introduction

In the early planning stage of leg 38 of the Deep Sea Drilling Project, a site in the vicinity of the Hovgaard Fracture Zone in the Greenland Sea was suggested. The main objective was to study the biostratigraphy of the sediments above the general level of the basin sediments. From analysis of V2704 seismic profiler data a drill-site was proposed at an elevated portion of the frature zone at 78°27′N, 2°04′E. A site survey was carried out onboard R/V "Vema" in 1973 (leg 3010). During this survey it became evident that the suggested location was not an ideal drill-site and also that the fracture zone was more complex than earlier indicated. Due to both scientific and logistic reasons the proposed site was assigned a low priority and was not drilled.

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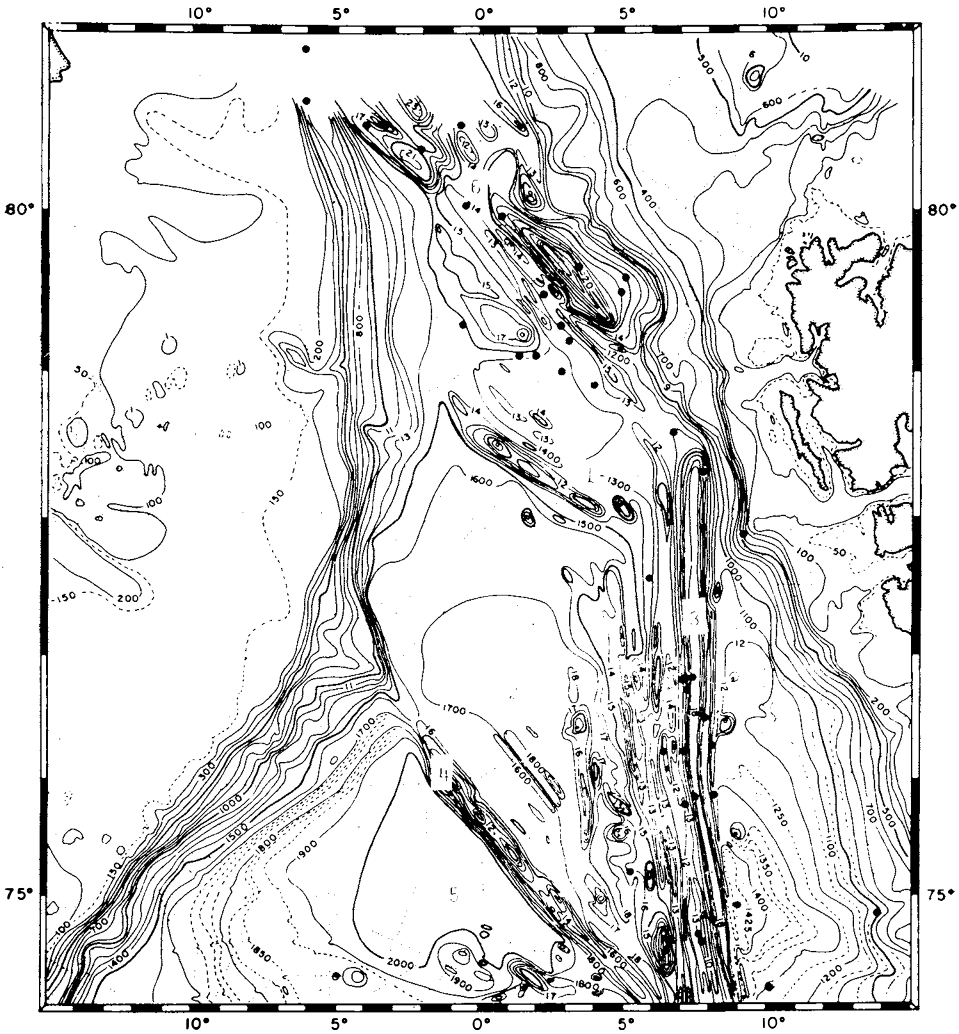

Fig. 1. *Bathymetric map of the Greenland Sea from* Johnson *and* Eckhoff (1966). *Contours in uncorrected fathoms. Black circles indicate earthquake epicenters* (Sykes 1965).

1: Hovgaard Fracture Zone.
2: Boreas Basin.
3: Knipovich Ridge.
4: Greenland Fracture Zone.
5: Greenland Basin.
6: Spitsbergen Fracture Zone.

In this note we present the data obtained during the site survey together with earlier Lamont-Doherty marine geophysical data as maps and sections. The data are particularly interesting in view of the plate tectonic evolution of the Greenland Sea and we have made an attempt to analyze the features in terms of an oceanic fracture zone created by the process of sea-floor spreading.

The Hovgaard Fracture Zone was first mapped and defined by Johnson and

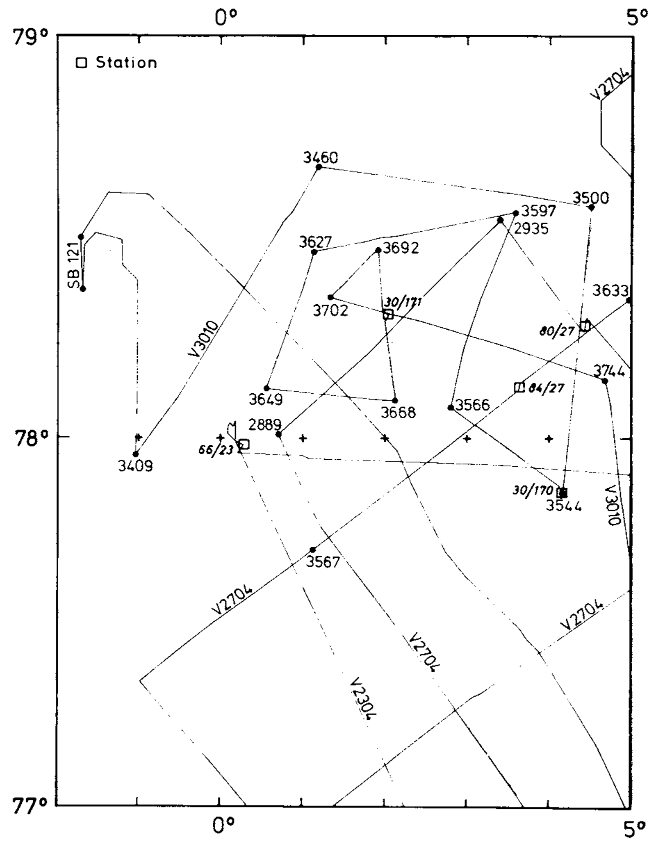

Fig. 2. *Track chart showing the R/V VEMA tracks in the survey area. V*3010 *refers to cruise* 30 *leg* 10. *Numbers next to filled circles indicate distance in nautical miles along the track. Station refers to ship's station. At most stations bottom samples were collected by piston coring together with heat flow measurements, bottom photography and measurements of the amount of particulate matter in the water column. With the exception of heat flow these data are not discussed here.*

ECKHOFF (1966) and named after an island on the east coast of Greenland. JOHNSON and ECKHOFF (1966) mapped the fracture zone as a linear topographic ridge striking about 300° (Fig. 1). They recognized that the strike of the ridge was slightly different from those of the Spitsbergen and Greenland fracture zones (320°). The ridge was about 95 miles in length and rose from a sea-floor level of about 1500 fathoms to a crest shallower than 1200 fathoms. A minimum depth of 760 fathoms was recorded at 78°30′N, 0°30′E. Neither its junction with the Greenland continental margin nor with the Knipovich Ridge was considered established by JOHNSON and ECKHOFF (1966). They also indicated that the fracture zone was mapped from limited data and that the navigation was not always considered fully reliable.

Fig. 2 shows the R/V "Vema" tracks during cruises 23, 27 and 30. Satellite navigation was employed throughout. Satellite fixes were received frequently due to the high latitude, and we have at least two good fixes on each track

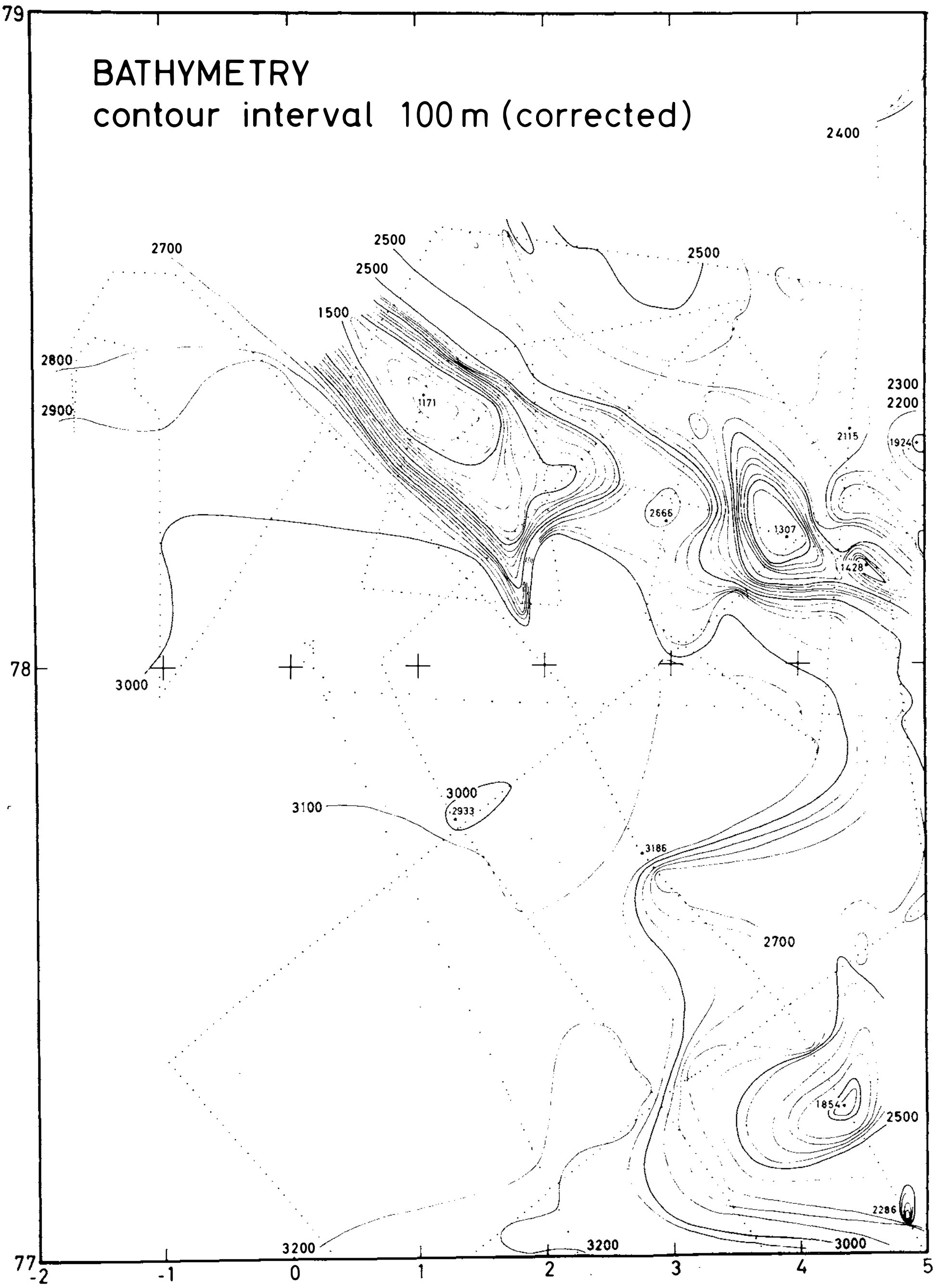

Fig. 3. *Bathymetry map. Sounding control shown by dotted lines.*

segment of the V3010 site survey. The navigation is considered reliable, which is confirmed by the close correspondence of both gravity and topography values at intersecting tracks in areas where there are sharp gradients in the bathymetry and in the gravity field.

Bathymetry

Fig. 3 shows the bathymetry in corrected meters, contoured at 100 m intervals. The Hovgaard Fracture Zone as defined by JOHNSON and ECKHOFF (1966) is the area of high relief just north of 78°N. However, there is no single linear topographic ridge evident in this map. The present data show that the fracture zone consists of at least two segments offset and separated by a trough.

The smooth Boreas Basin lies at a depth of approximately 3200 m at about 77°N, and there is a slight rise in the sea-floor topography towards the Hovgaard Fracture Zone. The Boreas Basin terminates at the south-western escarpment of the Hovgaard Fracture Zone. At the base of this escarpment there is an abrupt and pronounced change in the bathymetric gradient (Fig. 3). The ridge segments are characterized by steep walls on both the northeastern and southwestern side with minimum depths of 1171 m and 1307 m on the western and eastern ridge segments, respectively. To the north there is a small basin with an average depth of about 2500 m (Figs. 1, 3). We note the distinct level difference of 500–600 m on either sides of the fracture zone. In the easternmost part of the surveyed area there are local peaks and troughs which reflect the proximity to the Knipovich Ridge province. The continuation of the fracture zone to the northwest is not certain because ice conditions prevented surveying. However, the data of JOHNSON and ECKHOFF (1966) and the "Vema" 30 tracks may be interpreted in terms of decreasing relief.

In some of the available bathymetric charts a pronounced local depression is mapped to the southwest of the fracture zone (LEROY 1948; EGGVIN 1963). A depth of 4846 m at about 78°26'N, 2°18'W was mapped by EGGVIN (1963). This is approximately 1800 m deeper than the general level of the Boreas Basin in this area. Our westernmost line runs only about 13 km east of this position. Our observations, therefore, do not lend support to an increase in depth of this magnitude, and we believe the reported depression is in error.

Gravity

The free-air gravity anomaly map (Fig. 4) reflects the same major features as the bathymetric map. The area of high topographic relief is represented by elongate anomalies of more than 100 mgal. The maximum anomaly is 173 mgal over the eastern ridge segment, whereas the maximum value over the western ridge is 131 mgal. These prominent anomalies are surrounded by minima which may partly be edge effects. A similar general pattern is observed in the vicinity of the Greenland Fracture Zone (TALWANI and ELDHOLM 1977). The 42 mgal difference in maximum values between the two ridge segments does

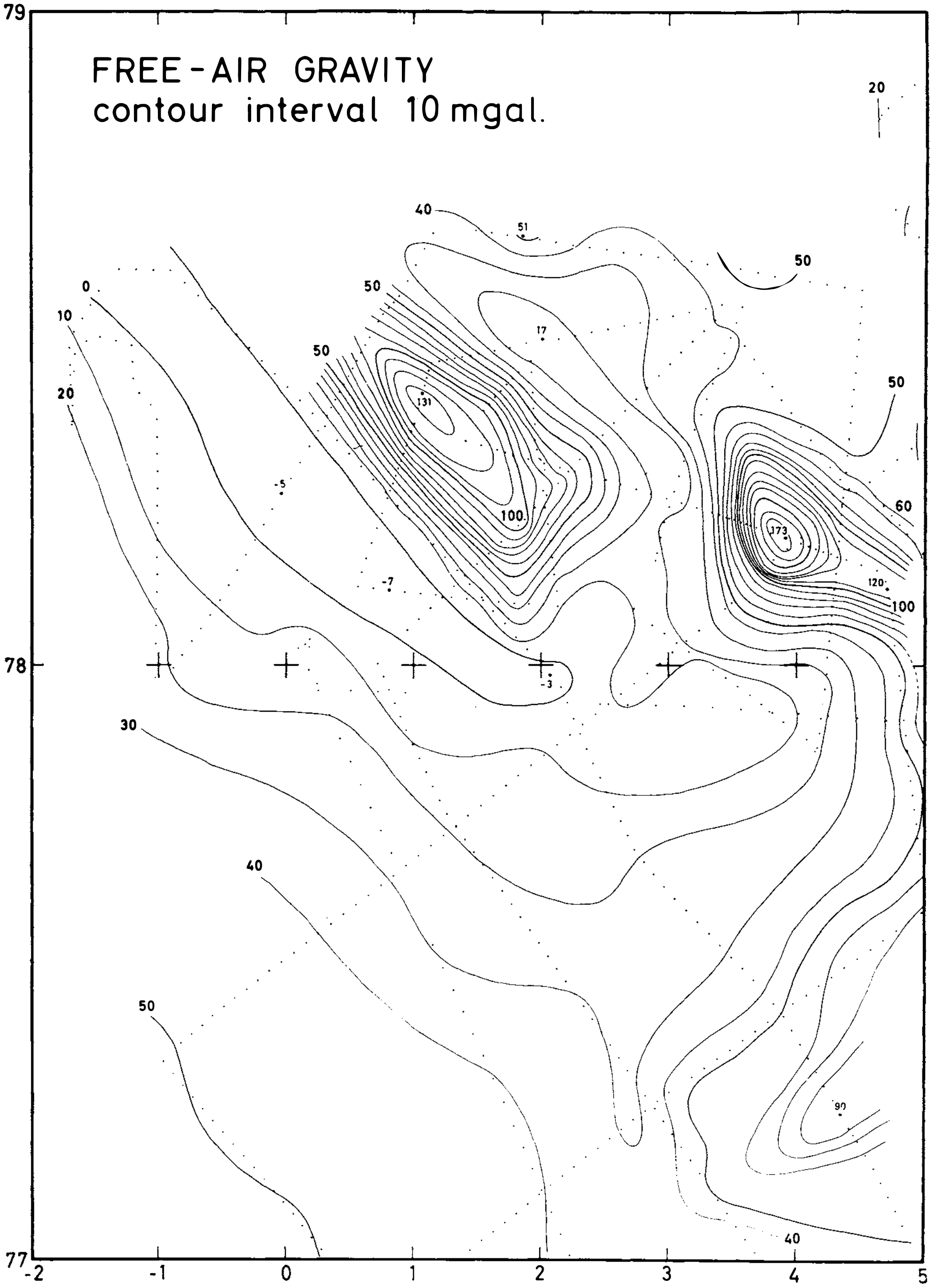

Fig. 4. *Free-air gravity anomaly map. Points of measurement shown by dotted lines.*

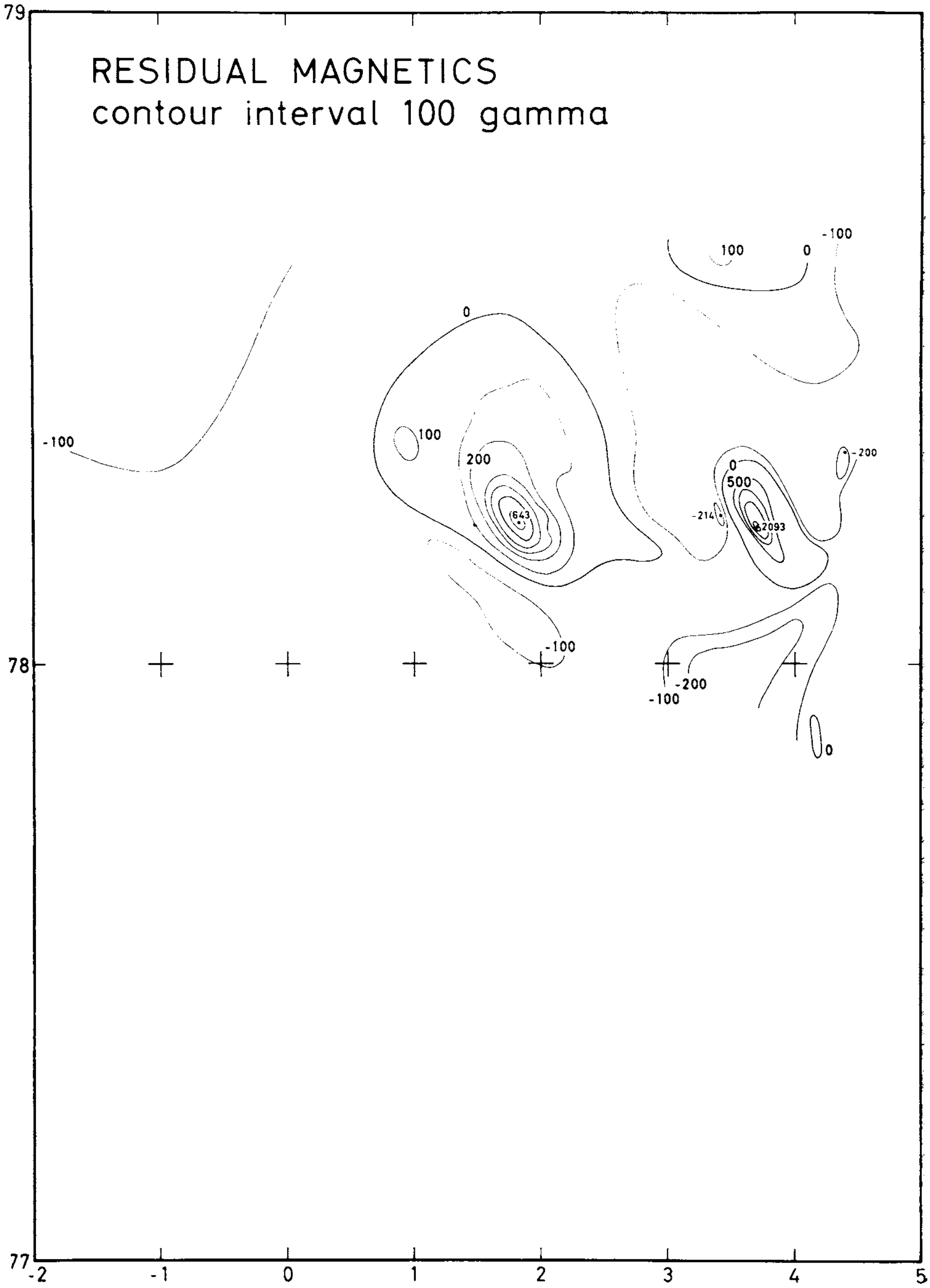

Fig. 5. *Magnetic residual anomaly map. Reliable contouring was not possible in the Boreas Basin.*

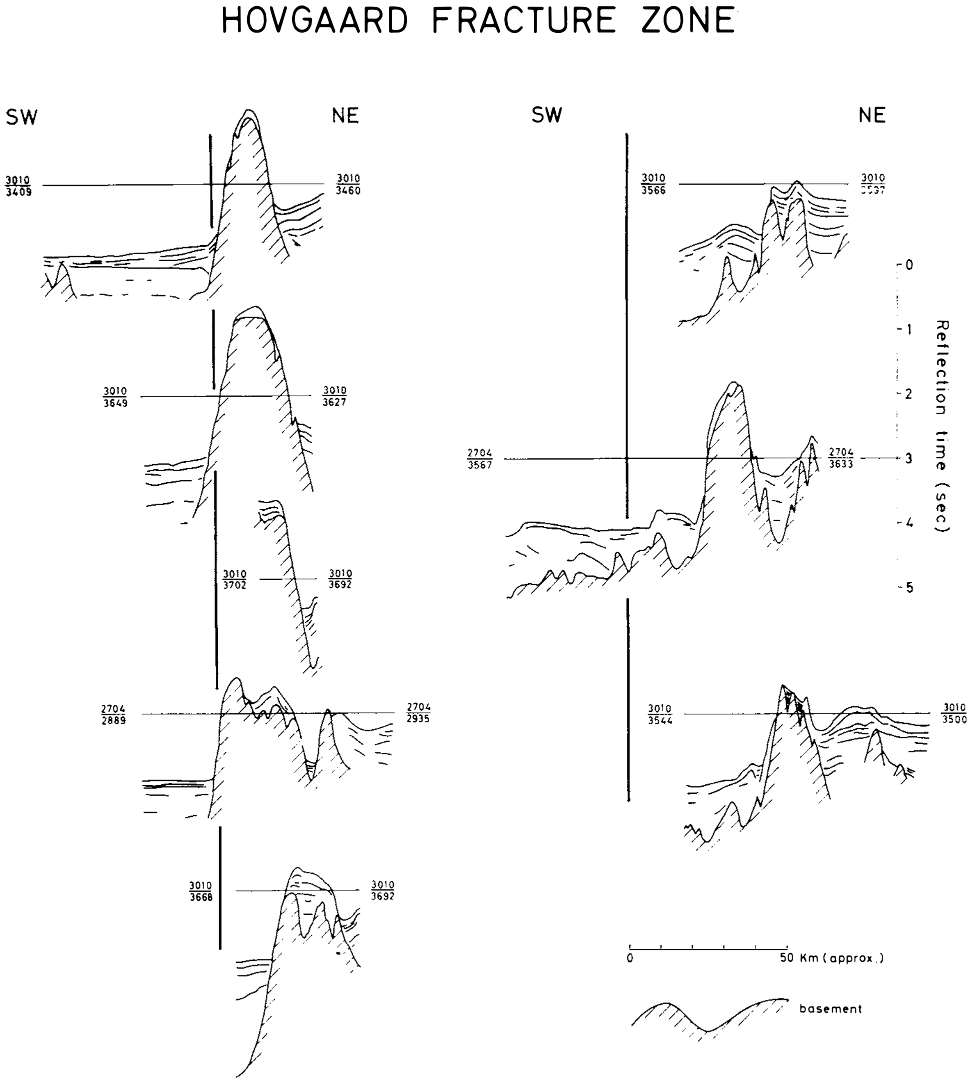

Fig. 6. *Line drawings of seismic profiler records crossing Hovgaard Fracture Zone. The sections are aligned along a line (solid black) defined by the base of the southern wall of the western basement ridge. Locations of sections shown in Fig.* 2.

not appear to be any simple topographic effect because the eastern segment is even deeper than the western segment (Fig. 3). It may be attributed to an important difference in the densities of the underlying rocks, although we cannot rule out contributions due to undetected topography slightly off the ship's tracks.

The regional level of the free-air anomalies in the Boreas Basin is about 50 mgal (TALWANI and GRØNLIE 1976) gently decreasing towards the fracture zone. The decrease of the free-air anomalies in the northernmost part of the Boreas Basin appears to be partly associated with an increasing depth to oceanic basement. On the northern side of the fracture zone a regional level of about 50 mgal is present a short distance away from the fracture zone. The free-air gravity field shows also a regional increase towards the Knipovich Ridge.

Magnetics

The magnetic residual anomalies (Fig. 5) are generally of low amplitude. This observation together with the absence of diurnal correction and evidence of magnetic disturbances which occur quite frequently at high latitudes, has precluded contouring the residual anomalies except in areas where quite prominent magnetic anomalies have been recorded. Prominent positive anomalies are associated with both segments of the fracture zone. The positive anomaly over the eastern segment is quite spectacular. It appears, though, that these anomalies are not representative of the overall ridge structure, but represent magnetic bodies within the ridges. There is no obvious systematic relationship between the free-air and magnetic maxima.

In the Boreas Basin there appears to be a weak, approximately north–south trend in the anomalies. However, we do not have enough data to confidently make a lineation map. If these anomalies are of the sea-floor spreading type they have a much lower amplitude than sea-floor spreading anomalies identified elsewhere in the Norwegian–Greenland Sea.

Seismic data

The regional distribution and the character of the sediments have been discussed by ELDHOLM and WINDISCH (1974). We have continuous seismic profiler records along all the tracks in Fig. 2. Most of the profiles crossing the Hovgaard Fracture Zone have been presented as line drawings in Fig. 6. Fig. 7 shows a profile along the central part of the ridge segments. We have also constructed an isopach map showing the thickness of sediments above acoustic basement (Fig. 8). From the profiles and the isopach map it is obvious that the topographic highs in the bathymetry reflect basement peaks and ridges and that the two main ridges are separated by a prominent sediment-filled basement trough (Figs. 7, 8). Both walls of the basement highs are generally barren of sediments, but in most profiles sediments are deposited on top of the central parts of the basement ridges smoothing local relief. Here the stratification in the sediments appears to reflect the basement topography. The sediments in the basin south of the western ridge segment are horizontally stratified with indications of younger turbidites above more acoustically homogeneous material. On the northern side of the fracture zone and south of the eastern segment the stratification is associated with current deposition. In particular, we note that there are more than 1.5 sec of sediments just to the south of the western basement ridge and that the sediments are thicker south of the western ridge than off the eastern ridge segment. On some tracks oceanic basement has not been identified

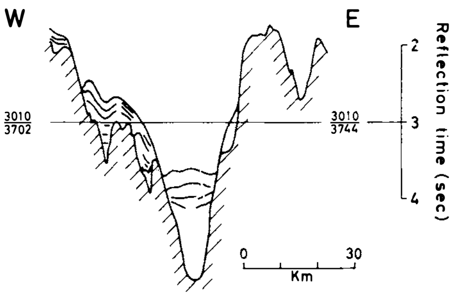

Fig. 7. *Line drawing of seismic profiler records along the central part of the Hovgaard Fracture Zone. Location shown in Fig. 2.*

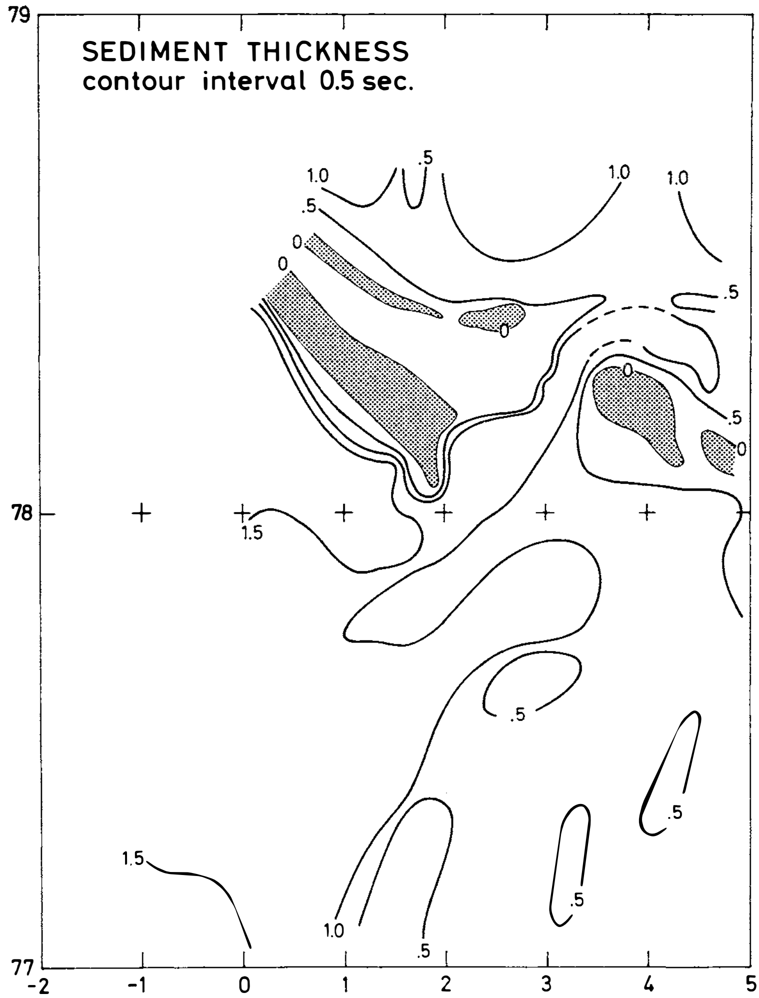

Fig. 8. *Isopach map of sediments above acoustic basement in two-way reflection travel time. If the sediment velocity is* 2.0 *km/sec,* 1.0 *second is equal to a sediment thickness of* 1.0 *km. Shading shows areas of outcropping basement at the sea floor.*

just south of the ridges. In the Boreas Basin there is increasing sediment thickness westward, and a sonobuoy (buoy 121, Fig. 2) shows a total sediment thickness of 2.8 km above a 5.35 km/sec refractor.

Discussion and summary

The "Vema" survey has added new detailed information about the Hovgaard Fracture Zone and the northernmost part of the Boreas Basin. Our data show that the Hovgaard Fracture Zone (JOHNSON and ECKHOFF 1966) consists of two northwest trending basement ridges that are offset by a deep sediment-filled trough. Elongated basement ridges are in many cases associated with oceanic fracture zones which may be considered as indicators of the relative direction of motion between plates. Although the central part of these ridges are mapped precisely, their continuation towards the Greenland continental margin and the Knipovich Ridge are not known in detail. The basement ridges are bounded by steep walls on both sides forming a central plateau which is, in places, almost flat-topped due to a cover of sediments that locally have smoothed the basement relief.

The basement ridges mark the northern boundary of the Boreas Basin. The change in the average level of the sea floor of about 500–600 m on either side of the fracture zone may indicate that the ridges separate areas that have undergone different structural development. The sediment cover is relatively thick on both sides of the fracture zone (Fig. 8). It also appears that there is more sediment accumulated on oceanic basement in the Boreas Basin than what is observed on oceanic basement of comparable age elsewhere in the Norwegian–Greenland Sea (ELDHOLM and WINDISCH 1974). Primarily, we attribute this to the proximity of the continents during the entire history of development of the Greenland Sea (TALWANI and ELDHOLM 1977).

Fig. 9 shows the most important features of our geophysical data. In addition to the data presented earlier we have also included three heat flow stations reported by LANGSETH and ZIELINSKI (1974). Two of the stations are located in the Boreas Basin just south of the fracture zone, whereas one station is located in the sediments on top of the western basement ridge. The heat flow values are in the range of 1.94–2.36 HFU. The minimum value is measured on top of the basement high. According to LANGSETH and ZIELINSKI (1974) these values are within the normal range on young oceanic crust in the North Atlantic and the Norwegian–Greenland Sea. We consider the difference between the station on top of the ridge and those in the adjacent basin too small to be significant.

The marine geophysical data in the Greenland Sea have not yet been conclusively interpreted within the framework of plate tectonics, and we have no direct information about the detailed evolution of the Greenland Sea based on sea-floor spreading anomalies. Poles of plate rotation describing the relative motion between Europe and Greenland has been calculated by TALWANI and ELDHOLM (1977) from magnetic anomalies and fracture zones in the North Atlantic and the Norwegian Sea.

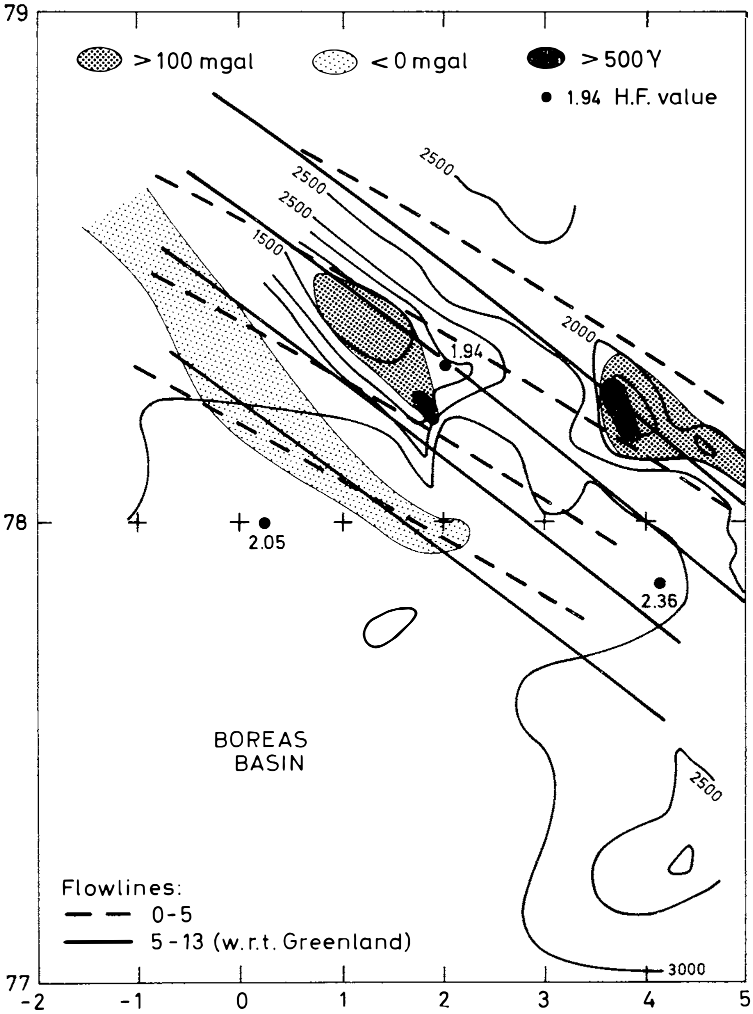

Fig. 9. *Sketch map showing major features from bathymetry, gravity and magnetics. Flow-lines are constructed from the poles of rotation given by* Talwani *and* Eldholm (1977).

To better understand the nature of the basement ridges constituting the Hovgaard Fracture Zone, we have constructed theoretical flow-lines describing the plate motion in the Greenland Sea. We have used the finite difference poles of rotation for the time periods between present and anomaly 5, and between anomaly 5 and anomaly 13. These time periods represent the Cenozoic crustal extension in the Greenland Sea (Talwani and Eldholm 1977). The resulting flow-lines keeping Greenland as a fixed plate are plotted in Fig. 9 for the time period between anomalies 5–13 (10–38 mybp.). We have also made the corresponding flow-lines for the finite difference pole with respect to Eurasia, but the difference between the azimuths of the flow-lines were negligible. The comparison of the flow-lines with the geophysical data (Fig. 9) indicates to us that the two basement ridges may well be associated with the structural evolution of the Greenland Sea and may indeed be parts of fracture zones. It is possible that the western and most prominent basement ridge represents the early stage of the rifting in the period between anomalies 5 and 13. No present seismic activity is associated with the basement ridges (HUSEBYE et al. 1975; AUSTEGARD 1976). The study by TALWANI and ELDHOLM (1977) has indicated a complicated history of opening in the Greenland Sea and that the present day Knipovich Ridge spreading center may be a recent feature. Furthermore, we note that the Knipovich rift valley extends north of the Hovgaard Fracture Zone (Fig. 1). Thus it is natural to assume that the basement ridges represent a fracture zone associated with an earlier location of the plate boundary in the Greenland Sea. Though there is a small basin between the Hovgaard and Spitsbergen fracture zones (Fig. 1) the topography is clearly more irregular than in the Boreas Basin. It is likely, therefore, that the area between the Hovgaard and Spitsbergen fracture zones is structurally more complex than the remainder of the Greenland Sea. At present, the Spitsbergen Fracture Zone appears to be composed of a system of transform faults and short ridge segments in an en-echelon fashion. We suggest that this region of complex plate boundary may have extended further southward prior to the spreading from the Knipovich Ridge. Thus, the Hovgaard Fracture Zone demarcates the southern boundary of a region that structurally is the manifestation of a complex and composite major regional offset of the ridge axis from the Greenland Sea to the Arctic Ocean.

Acknowledgements

We thank the officers, crew and scientific staff on board R/V "Vema" whose efforts provided the data in this study, and Dr. L. JOHNSON for permission to use Fig. 1.

G. GRØNLIE and Y. KRISTOFFERSEN reviewed the paper.

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Radiocarbon datings and the extension of the Weichselian ice-sheet in Svalbard

By OTTO SALVIGSEN

Contents

Abstract

Some earlier published radiocarbon datings from Svalbard older than 10,000 years B.P. are reviewed, and the results of a total of sixteen datings from Amsterdamøya, Danskøya, Prins Karls Forland, and Bellsund are presented. Ten of them have finite ages of between about 28,500 and 44,000 years, the rest having ages of between about 9400 and 12,600 years. The datings and other observations indicate that considerable areas on the western coast of Svalbard have been ice-free in an interstadial and that e.g. Prins Karls Forland has not been covered by ice later. At Amsterdamøya and Danskøya moraines from one and probably two stadials have been dated. In the western part of Svalbard the maximum extension of glacier ice has clearly taken place prior to 40,000 years B.P.

Acknowledgement

The ^{14}C datings were performed under the direction of Dr. REIDAR NYDAL and Mr. STEINAR GULLIKSEN, and I am very grateful for their information on the dating procedure. I should also like to thank my assistant, Mr. PÅL PRESTRUD, for his efficient help in the field work, and various staff members at Norsk Polarinstitutt for their valuable assistance to make the manuscript ready for publication.

Introduction

The results of the first ^{14}C datings of material from Svalbard were published about 1960 (FEYLING-HANSSEN and OLSSON 1960; BLAKE 1961). Since then a great number of datings have been made, resulting in land-uplift curves for the last 9,000–10,000 years. Such curves from different parts of Svalbard can for instance be seen in papers by HOPPE 1971 and BOULTON and RHODES 1974. Several aspects concerning isostasy and eustasy from this period could be discussed, but are not commented on in this paper.

Because our present information about Weichselian stratigraphy and chronology in Svalbard is so limited, a lot of different opinions prevail among investigators. Several ^{14}C datings obtained by the author during field work in 1975 at Amsterdamøya, Danskøya, and Prins Karls Forland give new information about the last ice age in Svalbard and will be presented here. First some earlier datings of old material shall be reviewed.

Previous datings

On high marine levels in the Lady Franklinfjorden area, Nordaustlandet, BLAKE (1961) found shells providing dates exceeding 35,000 years B.P., and likewise on high levels in Kong Karls Land, shells older than 38,000 years were also found (KNAPE 1971). In both cases the shells were found in patterned ground below the upper marine limit, but the finders thought that they could have been moved by glacier ice.

At Blomstrandhalvøya, Kongsfjorden, shells dated to about 40,000 years B.P. have been found, but not in situ (MOIGN 1974).

From Billefjorden, Isfjorden, datings of wood fragments as well as shells in situ have come out with ages older than 33,000 years (LAVRUŠIN 1969). BOULTON and RHODES (1974) have datings of shells from marine deposits in Billefjorden older than respectively 42,000, 45,000, and 56,000 years.

Driftwood has been found at the base of a marine terrace at Brøggerhalvøya, Kongsfjorden, and has been dated to 25,450±200 years B.P. (LAVRUŠIN 1969).

Shells found by FEYLING-HANSSEN (1965) on the high terraces in Billefjorden were dated to 21,300±500 years B.P. Due to contamination, the result was considered as a minimum age by FEYLING-HANSSEN.

Near Aavatsmarkbreen, Forlandssundet, G. S. BOULTON (SHOTTON et al. 1974) collected shells from various heights ranging in age between 10,000 and 15,000 years. General comments suggest that discorrelation between date and beach height may be due to hard water effect or some isotopic replacement.

Present datings

The dating results of samples collected by the author in 1974 and 1975 are shown in Table 1. The age determinations are based on a ^{14}C half-life of 5,570 years. For whalebones, isotopic fractionation is corrected for by normaliz-

Fig. 1. *Location map.*

ing to $\delta\,^{13}C$ = —25‰ PDB, and for shells it is normalized to $\delta\,^{13}C$ = 0‰ PDB. For shells from the Svalbard area, the apparent age is about 510 years (MANGERUD and GULLIKSEN 1975), and consequently 100 years could be substracted from the ages of shells given in the list. The number of years to be subtracted is more uncertain in the case of the whalebone, but 400 years have been used earlier for the Svalbard area (HOPPE et al. 1969; OLSSON et al. 1974). These problems, however, are of little significance for the interpretation of the dating results. From visual criteria the dated shell material seemed to be suitable for ^{14}C dating. It had good surface texture, and in some samples periostracum was also preserved. Before dating the outer fraction (20% of the weight) was removed. Figs. 2, 3, 7, and 8 give a general view of the areas where the shell samples were collected.

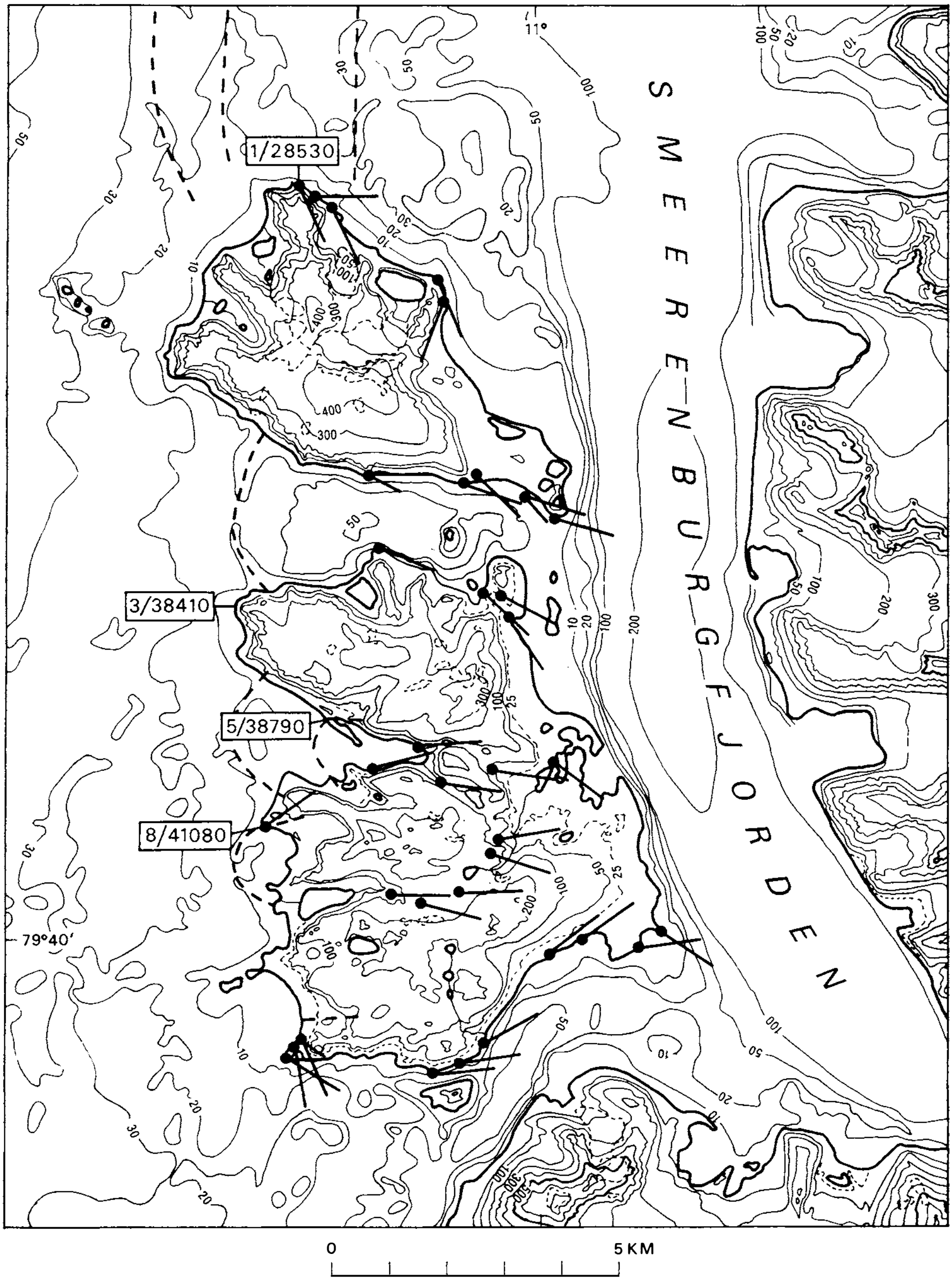

Fig. 2. *Topographic map of Amsterdamøya and Danskøya. Dotted lines indicate moraine ridges. Locality numbers and ages of samples are given in frames. The directions of glacial striae are shown by ball-headed lines; when crossing striae occur, the oldest direction has the shortest line.*

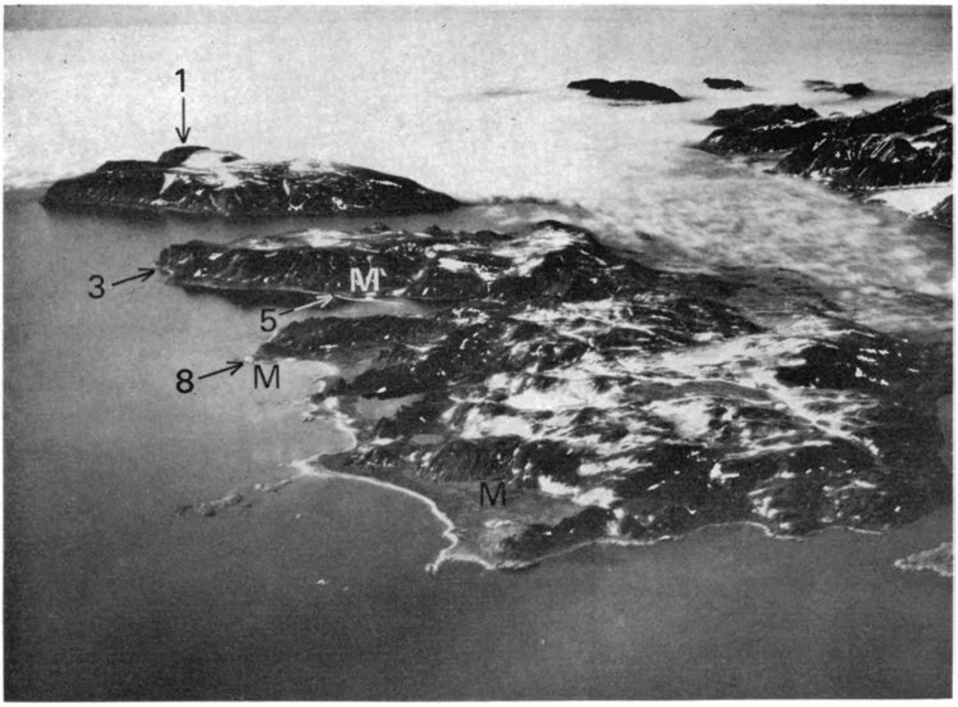

Fig. 3. *Oblique photo of Amsterdamøya and Danskøya with locality numbers and moraine ridges marked off.*

Comments to datings

Amsterdamøya and Danskøya

The datings carried out on material from Amsterdamøya and Danskøya is of great interest as they give the first age determination of the submarine moraines in the north-western corner of Svalbard (Liestøl 1972). From Amsterdamøya and northwards it is a complex system of submarine ridges formed by glacier streams from Smeerenburgfjorden.

At the northernmost point of Amsterdamøya, Hakuytodden, sea bottom material has been deposited on land by such a glacier stream. One shell sample (1/T-2091) has been dated to about 28,500 years B.P. The shells and shell fragments were picked out from a small pocket of sand between big, well rounded stones, all of it most probably having the same age. This dating indicates that a glacier stream in Smeerenburgfjorden advanced and reached Hakluytodden later than 28,500 years B.P.

Three samples from Danskøya have ages about 10,000 years older than the above mentioned sample from Amsterdamøya. Two of them (5/T-2093 and 8/T-2094) were found in moraine ridges on land meeting the sea in steep cliffs formed by abrasion (Fig. 4). It should be emphasized here that the islands have had no uplift in relation to sea level since the ice cover disappeared (Boulton and Rhodes 1974), and on slopes of naked rocks, perched boulders can be seen in several places near the present surf limit. The third sample (3/T-2092) was

Fig. 4. *The sea-facing end of the moraine ridge in Kobbefjorden (Locality No. 5). The shells were found near the person in the middle upper part of the picture.*

also found in material which had probably been pushed up from the sea bottom.

If the ages are reliable, the datings from Danskøya give maximum ages for the moraines where they were found. However, ages of about 40,000 years are usually regarded as minimum ages, and it is possible, therefore, that the moraines are older than the actual finite ages.

It seems most probable that the deposits dated on Amsterdamøya and Danskøya represent two different ages and stadials. If they should be given names, they should get them from these two islands. None of these stadials represents the maximum extension of the ice cover. The high areas of the islands are covered by autochtone blockfields (Fig. 5), but scattered erratics were found almost up to the highest top of about 500 m a.s.l. The datings confirm the impression that these areas have been ice free for a very long time.

The directions of glacial striae observed on the islands are shown in Fig. 2. Numerous roche moutonnées were seen in the eastern part of Danskøya. Broadly speaking, the islands consist of migmatites, and in high areas striated surfaces are weathered and badly preserved. Near the sea level, however, the surfaces are often polished and well preserved mainly because they have recently been uncovered (Fig. 6). Most of the striae have a westerly direction, and where crossing striae occur, the youngest are best adjusted to the topographic conditions. Beautiful stoss-and-lee topography also appears in several places, giving an impression of intense ice erosion.

Fig. 5. *Autochtone blockfield in the northern part of Amsterdamøya about* 300 *m a.s.l. The blocks are of different sizes and very sharp-edged. Observe the standing person in the middle of the photo.*

Prins Karls Forland

Raised beaches are very distinct up to about 30 m a.s.l. in the southern part of Prins Karls Forland and up to over 20 m a.s.l. in the northern part. In both areas vaguer marine features exist up to levels about 20 m higher than just

Fig. 6. *Crescentic gouge on the stoss side of a striated and polished rock surface near the sea level in the northern part of Amsterdamøya. Ice movement from left to right.*

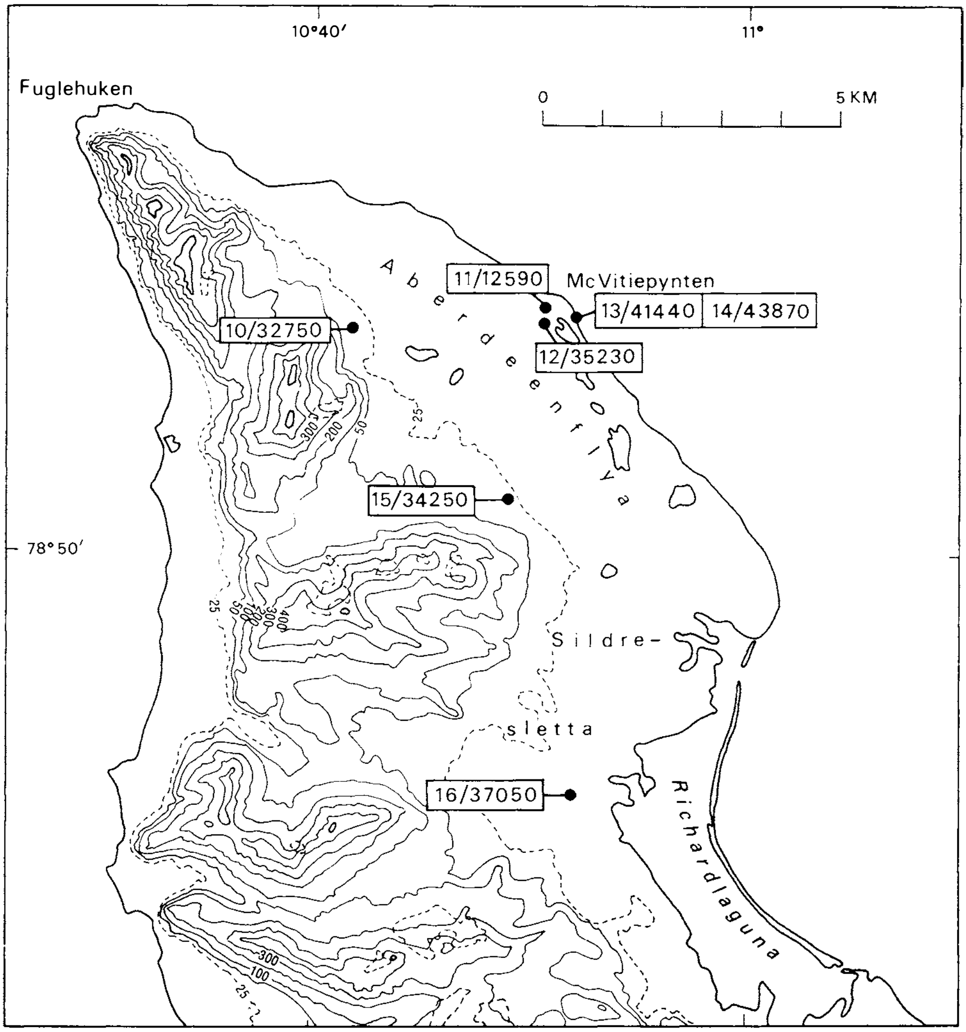

Fig. 7. *Topographic map of the northern part of Prins Karls Forland. Locality numbers and ages of samples in frames.*

mentioned. The same pattern can be seen in the middle part of the island, but no material suitable for dating was found there.

The datings from Prins Karls Forland give little information about the rate of the last uplift of the island. In the southern area one level about 10 m a.s.l. has been dated (24/T-2232 and 20/T-2235). In this case the shells have lived near the tide zone and give the same age as the whalebone, when the apparent age of the latter has been subtracted.

An attempt was also made to date a level about 28 m a.s.l. in the same area, but without success (18/T-2233). This whalebone was covered by a thick layer of moss and was badly preserved. It has probably been contaminated and the age determination has therefore given a too young result.

Fig. 8. *Oblique photo of the northern part of Prins Karls Forland with locality numbers marked off.*

One dating (11/T-2096) give an interesting age of about 12,600 years, which is probably reliable and not caused by a mixing of shells of different ages. The shells have, however, lived at an unknown waterdepth and do not date the level where they were found.

The datings giving finite ages of more than 30,000 years B.P. were all carried out on shells found in the northeastern part of Prins Karls Forland (Figs. 7 and 8). Two of them date a great deposit of glacio-marine sediments where they were found in situ (Figs. 9 and 10). These sediments meet the sea in a steep, wave-cut cliff stretching more than five kilometres southwards from Mc-Vitiepynten, in some places reaching almost 20 m a.s.l. Shells were found in a few places in the middle part of the section. Sample 13/T-2100A was taken from a thin shellrich layer and 14/T-2101 consisted of shells found scattered in the sand about 0.5 m higher up (Fig. 9). The real age of the latter should therefore be younger than that of the former. The upper part of this deposit has been built up and washed by the sea in Late- and Post-glacial time, and the top layer is composed of well rounded stones and gravel. This top layer is usually

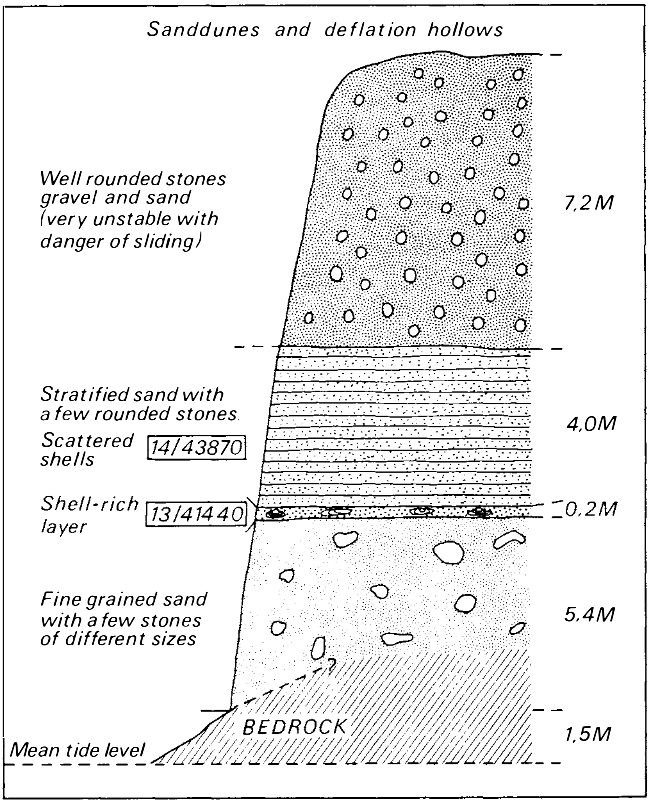

Fig. 9. *Section of sediments in the cliff south of McVitiepynten with locality numbers and ages of samples in frames.*

much thinner than shown in Fig. 9 which presents a section from the place where the dated shells were collected. In other places, the cliff shows a different composition, but the lowest lying layer is usually found. 16/T-2099 also consisted of shells found where they had once lived. In a river cut shells were found quite near to, and also within, cracks in the underlying bedrock slate.

Three samples of shells (10/T-2095, 12/T-2097, and 15/T-2098) were all found on or near the surface in areas of patterned ground (Fig. 11). If these features on levels between 30 and 40 m a.s.l. appear in old raised beaches or in till with shells cannot be determined with certainty. However, it seems most likely that no ice from an ice-center in the east has reached Prins Karls Forland later than about 40,000 years B.P. The great amount of old sediments from McVitiepynten and southwards would have been in a very exposed position for later ice erosion. It is difficult to believe, therefore, that these sediments should have survived if glacier ice had overridden the area.

The sediments at McVitiepynten have been deposited there more than 40,000 years ago quite near to an ice margin in Forlandssundet. Later there has also been a relatively high sea level (SHEPARD 1963; MILLIMAN and EMERY 1969),

Fig. 10. *View towards the north of the sediments south of McVitiepynten. This section was similar to that on Fig. 9, but no shells were found here.*

Fig. 11. *Patterned ground with shell fragments in the southern part of Prins Karls Forland, about 20 m a.s.l. In the background a well developed talus terrace.*

Table 1

Field Sample No.	Laboratory dating No.	Dated material	^{14}C-years before 1950 $\pm 1\sigma \pm 2\sigma$	$\delta^{13}C$‰	Sample weight (g)	Sample elevation (m)	Locality
—74.1	T–1829	Whale jaw	9400 ± 120	—18.8	27	10	Calypsostranda, Bellsund
2	T–1830	*Mya truncata* *Hiatella arctica*	10310 ± 200	+ 1.3	30	29	,, ,,
—75.1	T–2091	,, ,,	28530 $^{+430}_{-410}$ $^{+890}_{-800}$	+ 0.5	28	6–8	Hakluytodden, Amsterdamøya
3	T–2092	*Mya truncata*	38410 $^{+1410}_{-1190}$ $^{+3110}_{-2230}$	+ 0.7	25	6–7	Kapp De Geer, Danskøya
5	T–2093	*Mya truncata* *Hiatella arctica*	38790 $^{+940}_{-840}$ $^{+2010}_{-1600}$	+ 0.6	28	3–4	Kobbefjorden, ,,
8	T–2094	*Hiatella arctica*	41080 $^{+2670}_{-2000}$ $^{+6690}_{-3600}$	+ 1.1	24	3–4	Luftskipsodden, ,,
10	T–2095	*Hiatella arctica*	32750 $^{+450}_{-430}$ $^{+930}_{-830}$	+ 1.4	28.4	30	Aberdeenflya, Prins Karls Forland
11	T–2096	*Mya truncata* *Hiatella arctica*	12590 ± 70	+ 0.9	26.1	9	,, ,,

12	T–2097	*Hiatella arctica*	35230 +470+970 −440−860	+ 1.0	28	12	,, ,,
15	T–2098	*Hiatella arctica* *Mya truncata*	34250 +440+910 −420−820	+ 0.9	28	36	,, ,,
16	T–2099	*Hiatella arctica* *Mya truncata*	37050 +910+1950 −830−1580	+ 1.2	28	20	Sildresletta, Prins Karls Forland
13	T–2100A	*Mya truncata* *Hiatella arctica*	41440 +1570+3530 −1310−2440	+ 0.3	28	5.5	McVitiepynten, ,, ,,
14	T–2101	*Mya truncata*	43870 +4310+14270 −2790−4860	+ 0.3	23.5	6	,, .. ,,
24	T–2232	*Mya truncata*	9300 ± 120	+ 0.2	56	10	Austflyodden, ,, ,,
20	T–2235	whale jaw	9880 ± 140	−19.2	23	10	,, ,, ,,
18	T–2233	whale bone	10000 ± 130	−16.1	38	28	Persisvatna, ,, ,,
6*	T–2390	*Mya truncata* *Hiatella arctica*	40680 +1820+4090 −1490−2720		32	4	Luftskipodden, Danskøya
22*	T–2391	*Hiatella arctica*	10880 ± 100	+ 1.0	32	21	Vestflya, Prins Karls Forland
30*	T–2392	*Mya truncata*	37340 +910+1880 −820−1540	+ 1.2	32	10	Aberdeenflya, ,, ,,

* received after submission of article and therefore not commented upon in the text.

and from the period 30,000 to 40,000 years B.P. shells have been found up to about 40 m a.s.l. In the last glacial period of the Weichselian the sea level has dropped until the melting of ice again has caused a new rise. Even if no ice sheet reached Prins Karls Forland, the isostatic rebound has given the island a rapid emergence in the socalled Late-glacial period.

Discussion

^{14}C ages older than about 30,000 years are often considered dubious and minimum ages. In an attempt to check some of these ages, Th/U datings are planned carried out at the Radiological Dating Laboratory, Norges Tekniske Høgskole, Trondheim (NYDAL 1975). In the future further investigations are required in the areas briefly dealt with in this paper. The datings presented here seem to correspond with a preliminary chronological correlation scheme for the glaciation of Svalbard presented by TROICKIJ et al. (1975). However, other things in their scheme should be questioned until more information is available. GROSVAL'D et al. (1974) have presented stages of deglaciation of the Barents Sea area. About 10,000 years ago there must have been considerably less glacier ice on the western coast of Svalbard (and probably elsewhere in the Barents Sea area) than shown in their Fig. 6.

At present most conclusions should be tentative, and it is difficult to make comparisons to areas outside Svalbard. Nevertheless some examples of datings from other areas should be mentioned briefly.

It has been documented that outer East-Greenland has been partially ice free during at least the last part of the Weichselian (FUNDER and HJORT 1973), and WEIDICK (1976) has presented datings from northern Greenland that substantiate the concept of a reduced Inland Ice in Late Weichselian time.

From Arctic Canada a lot of datings have given results older than 30,000 years B.P. (BLAKE 1976).

From Central Europe several descriptions of interstadial sediments have been made, e.g. ZAGWIJN 1974 and FELBER and HUSEN 1975, and also from Norway apart from Svalbard, Weichselian findings have been dated (MANGERUD 1972). R. DAHL (1972) has discussed the distribution of ice in different periods of the Weichselian and the last datings from Svalbard do not contradict the hypothesis that the last ice sheet was no "super ice sheet".

Conclusions

1. It is evident that the whole area of Svalbard has been covered by an extensive ice sheet at least once, but the exact period of time cannot be determined with certainty.

2. The datings from the period 25,000 to 40,000 years B.P. probably belong to a complex interstadial period with large ice free areas.

3. In the Late Weichselian the ice margin has reached Amsterdamøya and Danskøya, but not Prins Karls Forland. There has probably been ice free areas

in other parts of Svalbard too, and the extension of the ice sheet during the last stadial (maximum 18,000–20,000 years ago) might have been modest compared with the extension in one or several earlier periods.

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Blomsterskardbreen, Folgefonni, mass balance and recent fluctuations

By ARVE M. TVEDE and OLAV LIESTØL

Contents

Abstract

The maximum extension in post-glacial time for Norwegian glaciers is supposed to have occurred in the eighteenth century. Observations at Blomsterskardbreen show a maximum as late as 1940.

Introduction. Hydrology and climate

The Blomsterskardbreen glacier is an outlet from the southernmost of the three icecaps included in the name Folgefonni. The highest point is 1640 m a.s.l. and the terminus reaches down to 820 m. Blomsterskardbreen today is draining a total of 45.7 km² from the south-facing rim of this icecap, making it the largest glacier unit in the Folgefonni area and the third largest in Scandinavia, according to the hydrological classification system used by ØSTREM and ZIEGLER (1969) and ØSTREM, HAAKENSEN, and MELANDER (1973). The glacier can be said, strictly speaking, to consist of two hydrologic units, a western branch draining to the river Blådalselva, and an eastern branch draining to the river Londalselva (see Figs. 1 and 2). However, morphologically it is very difficult to distinguish between these two parts, and as the water draining to Londalselva was diverted to Blådalselva in 1970, through a tunnel from the lake Blomsterskardvatn, the two branches can today be considered as one glacier unit.

The lake Blomsterskardvatn has an elevation of 1030 m, and a maximum length and width of 1.1 km and 0.4 km, respectively. On recent topographic maps this lake seems to be glacier-dammed and consequently Blomsterskardvatn was considered the source for several devastating floods in Londalselva (sometimes called Sandvikelva), as described by LIESTØL (1956, pp. 138–139). However, later investigations revealed that Blomsterskardvatn was not truly glacier-dammed; more or less permanent drainage possibilities seem to have existed (up to 1970) near the edge of the glacier, leading to the spillway 0.4 km NE of the north end of Blomsterskardvatn (see Figs. 5 and 6). The floods in Londalselva evidently had their causes from the sudden emptying of another lake, Sauavatn, at the head of the valley, 6 km NE of Blomsterskardvatn. Since 1953, frequent air photos show Sauavatn, dammed by the glacier Sauabreen, to be filled one year and nearly empty the next. The last report of any sudden flood at the mouth of Londalselva was reported in 1962. However, the sudden emptying of Sauavatn is still active and evidently quite frequent. As the valley has been uninhabited during the last 10–15 years, the floods following these outbursts have not been reported or recorded.

The southern parts of Folgefonni receive some of the highest amounts of precipitation registered in Norway, surpassed only by the Ålfotbreen glacier area south of Nordfjord. Precipitation stations located along Åkrafjorden, 10–20 km south of Blomsterskardbreen, record an annual average of 2200–2800 mm. A discharge station in Blådalselva has registered an average annual runoff volume, from a drainage area of 151.5 km^2 (including Blomsterskardbreen), equivalent to a mean annual precipitation amount of 4600 mm. Combining the precipitation records, runoff records and results from mass balance measurements mentioned later in this paper, we have calculated the mean annual amount of precipitation to be between 5000 mm and 5500 mm on the higher parts of Blomsterskardbreen. Further north along Folgefonni, the precipitation amount drops gradually, but seems to stabilize between 3500 mm and 4000 mm on the northern half of the icecap.

No direct registration of the air temperature is available for Blomsterskardbreen, but regularly operating weather stations are located along Åkrafjorden. From 1965 to 1968 a weather station was operating, in the summer months, at Holmaskjeri, 1560 m a.s.l. and located 15 km north of Blomsterskardbreen. Using the measured lapse rate between these stations and the standard normal air temperature values from Indre Matre, we have calculated the mean air temperature for June, July, and August, at the average equilibrium line (1370 m a.s.l.), to be 3.6°C. The temperature normally stays above 0°C from 20 May to 25 September; thus the average ablation season lasts 127 days at Blomsterskardbreen.

Mass balance measurements

Regular mass balance measurements at Blomsterskardbreen started in April 1970 and continued throughout 1971. During these two years, 10 ablation stakes were located along a profile from the highest point down to 1070 m a.s.l. (see Fig. 1). The distribution pattern of the snow accumulation was mapped by means of a network of snow soundings, covering most of the glacier area. The

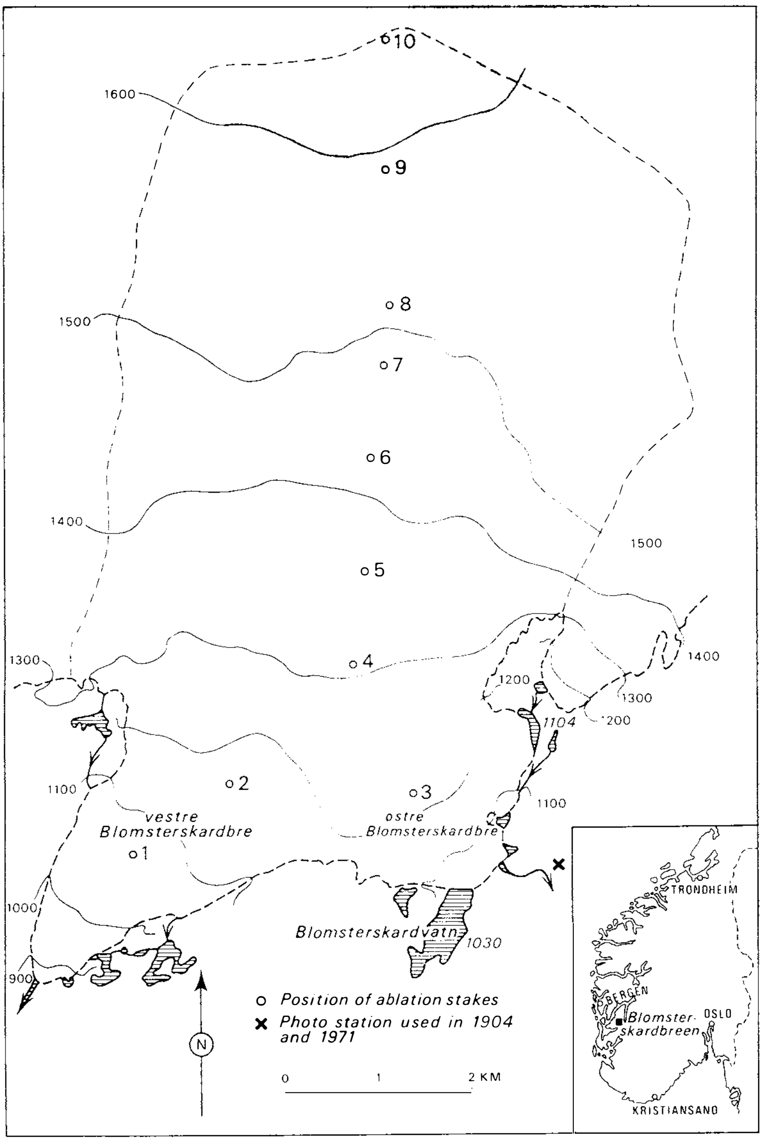

Fig. 1. *Location map showing some of the names used in the text and the position of the ablation stakes used on Blomsterskardbreen. Lakes have been presented as dotted surfaces. The glacier outline is taken from a map surveyed in* 1959.

homogeneous orientation and the smooth surface of the glacier generate only small local variations in snowdepth within each elevation band, as measured in late April. Consequently, the measurements of mass balance can be carried out using only a limited number of ablation stakes, compared with most other glaciers. Since 1972 only the net balance at the stakes 4, 5 and 6 (see Fig. 1) has been measured once a year, normally in late September. The net balance result for the whole glacier is calculated by assuming that the form and the

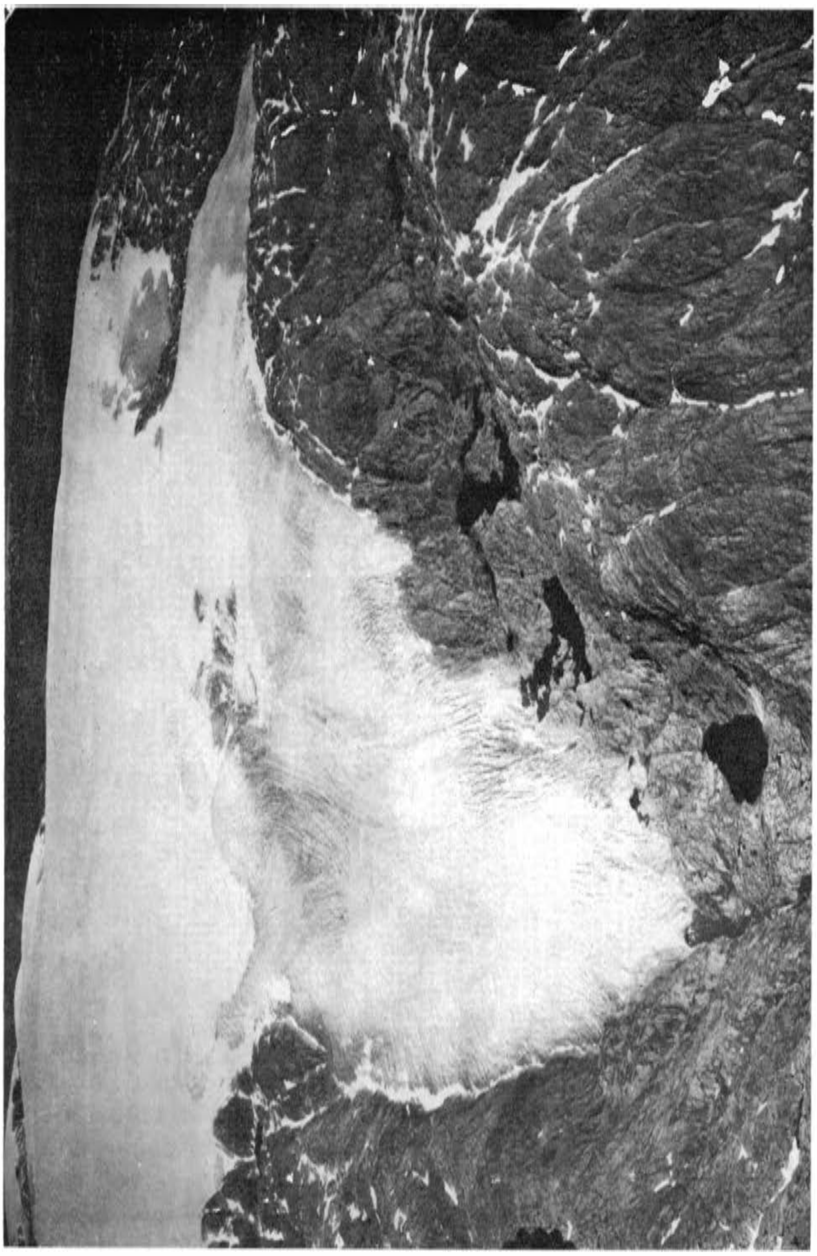

Fig. 2. Oblique aerial photo from 1955 of Folgefonni and the outlet glacier Blomsterskardbreen seen from south-west. Vestre Blomsterskardbre in the foreground and Østre Blomsterskardbre to the right.

Photo: Norsk Polarinstitutt (N 55 1685)

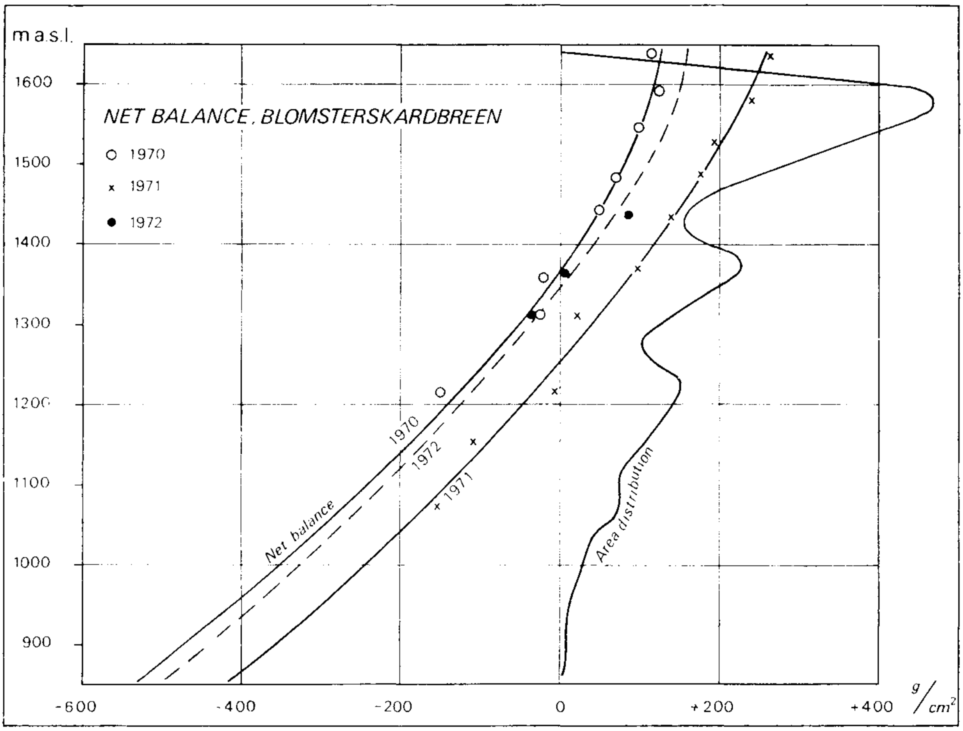

Fig. 3. *Net balance curves for the years 1970, 1971 and 1973 of Blomsterskardbreen.*

slope of the net balance curve are repeated from one year to another. To fix the position of each year's net balance curve, the measured values at the stakes are plotted into the diagram and the curve is fitted in between the points (see Fig. 3). A more thorough analysis of this technique is given by TVEDE (1974, pp. 15–18).

During a visit to Blomsterskardbreen on 24 September 1976 none of the stakes visible in 1975 could be found. The net balance results for 1975–76 then had to be calculated by using a different approach. Luckily the glacier was included in a vertical air photographic survey on 21 September 1976. On this day the glacier was covered with fresh snow above the 1370 m-level, but the "old" snowline was not covered on the photos by this fresh snow. Due to the late date of photography, the "old" snowline must closely coincide with the equilibrium line for 1976. At an average, this snowline could be detected at 1210 m a.s.l.

In order to transfer this information to the net balance values, an approach demonstrated by LIESTØL (1967, p. 46) was used. The corresponding values for specific net balance and the elevation of the equilibrium line for the period 1970–75, were plotted into a diagram (Fig. 4). These two quantities seem to be very closely related and to have a linear relationship. Similar curves were presented by ØSTREM (1975, pp. 411–412) for several glaciers in Scandinavia

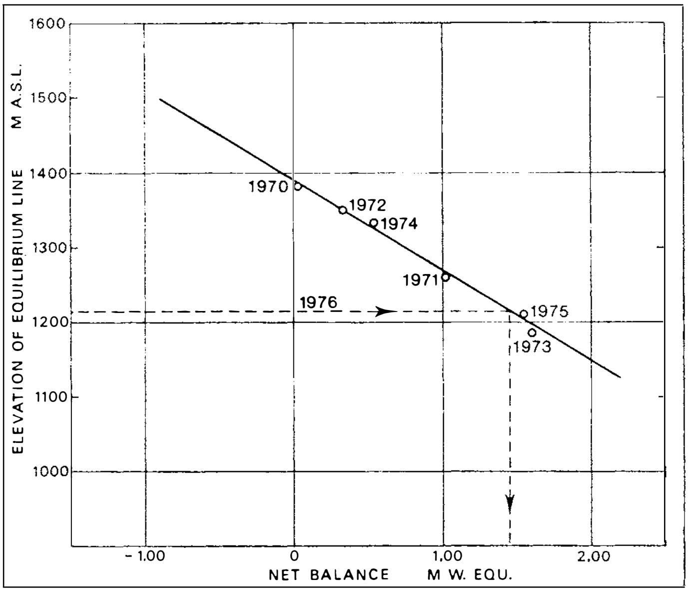

Fig. 4. *The heights of the equilibrium line as observed at Blomsterskardbreen for the years 1970–75 are plotted against the measured net balances for the same years. The most likely correlation line is drawn.*

and Canada. So, by using the value 1210 m as the elevation of the equilibrium line in Fig. 4, the specific net balance for 1976 can be estimated as +1.4 m of water.

In the period 1970–76, six out of the seven years have had positive net balance values, and one year (1970) had a neutral result. Since September 1969 Blomsterskardbreen has, at an average, thickened by a total of 6.3 m of water, or 0.9 m/year. Comparing net balance values from this glacier to similar values from Ålfotbreen where detailed mass balance measurements have been performed since 1963, a close relationship is found. Since 1969 Ålfotbreen has increased by an average of 0.82 m/year. Also for the individual years the net balance results are very similar at Ålfotbreen and at Blomsterskardbreen. This close relationship supports the validity of the simplified way of measuring net balances at Blomsterskardbreen. A similar increase in glacier mass has, as the one documented for these extreme maritime glaciers, during the last years also been measured at Nigardsbreen and Hardangerjøkulen. However, at the more continental glaciers in Jotunheimen, negative mass balance results have been dominating in the same period (see TVEDE (1974)).

Recent fluctuations

The Folgefonni glacier was, according to HOEL and NORVIK (1962, p. 8), mentioned in literature as early as 1613 under the name "Fuglesand". Being located near the sea and therefore easily accessible, Folgefonni received considerable attention from various "explorers" and pioneer tourists throughout the 18th and 19th centuries. However, most of the interest was centered on Bondhusbreen and Buarbreen, two outlets reaching down into populated valleys, approximately 15 km N and NE of Blomsterskardbreen. Consequently, a considerable amount of information exists about the fluctuations at these parts of Folgefonni through descriptions, sketches, and later on, photos, provided by various sources.

In contrast to the Buarbreen–Bondhusbreen area, the information about fluctuations at Blomsterskardbreen is very scarce. The glacier is not visible from the populated valleys, and the access routes are arduous; thus only few visitors did reach the glacier proper. The oldest description is given by Sexe (1864, p. 7). From the information given in his text it is not possible to determine accurately the position of the glacier terminus, and Sexe evidently did not realize the real dimensions of Blomsterskardbreen. He does, however, mention a large flood in the upper part of Blådalselva that occurred around 1820. The drainage from Vestre Blomsterskardbre ceased to flow for a period of time, and then quite suddenly a huge water volume was released, evidently from underneath the glacier (op. cit. p. 18).

The first exact information, usable to determine any former position of the glacier terminus, is given by Rekstad (1905, p. 15). He photographed Blomsterskardvatn and the lower part of Østre Blomsterskardbre from a rock knob approximately 600 m E of the glacier (see Figs. 1 and 5). The date of his visit is stated as 1 August 1904. A similar photo was taken from exactly the same position by one of the authors on 13 August 1971. The two photos are presented together as Figs. 5 and 6. A comparison of the photos leads to the surprising conclusion that Østre Blomsterskardbre has advanced approximately 200–250 m between 1904 and 1971 and does today cover a much larger part of Blomsterskardvatn than was the case in 1904. To the knowledge of the authors this is the only glacier in Scandinavia where a net advance has been documented within the last 70 years.

Rekstad also took a photo of Vestre Blomsterskardbre at the same time, but from a considerably longer distance. A comparison with the topographic map from 1959 indicates a net advance at this glacier as well, from 1904 to the present.

When did this advance take place? A fairly accurate topographic map, probably surveyed around 1920, presents Blomsterskardvatn as having approximately the same size and configuration as on Rekstad's photo. In connection with a flood in Londalselva in July 1938, a sketch was taken of Blomsterskardvatn showing the lake to be divided by the glacier, but evidently not covered by glacier-ice to the same extent as is the case today. The first vertical air photos covering the glacier were taken in 1953. Similar photos taken in 1959 and 1976, only reveal insignificant changes (less than 50 m) at Blomsterskardbreen during the last 23 years. The advance consequently seems to have occurred between 1920 and 1940, probably mainly in the 1930's. An analysis of the climatic conditions in this part of Norway has demonstrated that a strong increase in the glacier mass must have taken place between 1915 and

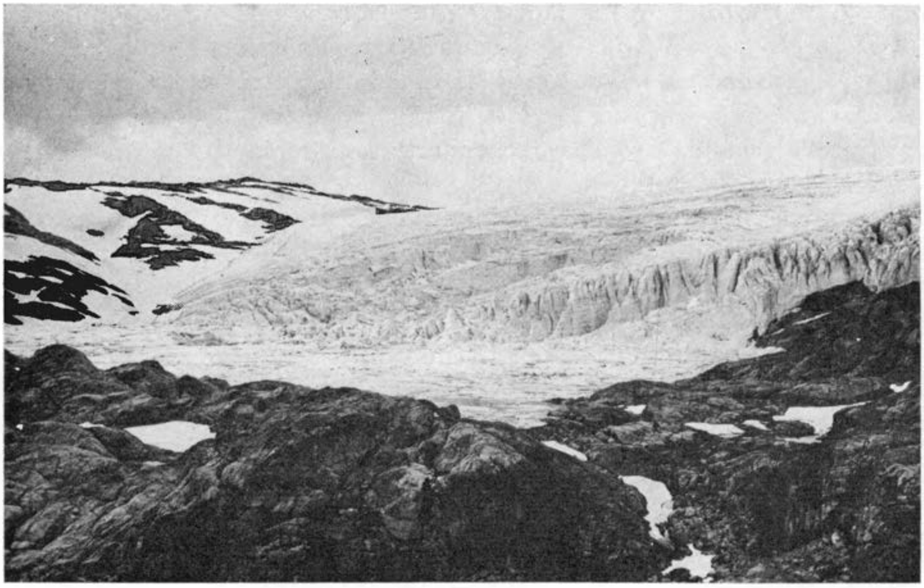

Fig. 5. *Østre Blomsterskardbre photographed by* J. REKSTAD *on 1 August 1904. The lake Blomsterskardvatn in front of the glacier, is mostly covered with winter ice.*

Fig. 6. *Østre Blomsterskardbre photographed on 13 August 1971 from the same spot as used by* REKSTAD *in 1904 (see above). The two photos cover exactly the same area. The glacier had advanced 200–250 m from 1904 to 1971 and has covered most of Blomsterskardvatn visible on Fig. 5.*

1925. Due to increased fall and winter precipitation, the net balance conditions did not turn markedly negative later, despite much warmer summer temperatures between 1930 and 1960.

At both Buarbreen and Bondhusbreen a strong frontal advance was measured between 1920 and 1930, but, in contrast to Blomsterskardbreen, these glaciers had reached their maximum historical extent somewhat earlier, around 1880–1890. As Blomsterskardbreen is much longer and less steep than both Buarbreen and Bondhusbreen, a significant longer response time would be expected. It is reasonable to believe that the reaching of a maximum advanced position as late as around 1940, is the response to the strong positive net balances experienced around 1920. A more detailed analysis of the recent fluctuations at the other parts of Folgefonni will be given by TVEDE and LIESTØL (in prep.), together with some calculations of former mass balance conditions.

The historical fluctuations documented at Folgefonni, in general, and at Blomsterskardbreen, in particular, do deviate considerably from what is known to have happened in other Scandinavian glacier regions. A certain caution, therefore, seems required when generalizing about recent regional glacier fluctuations, and about the response of glaciers to climatic changes.

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A Model of Energy Balance in Arctic Mammals

By NILS A. ØRITSLAND

Contents

Introduction

Evaluations of single animal energy balance is an integral part of sound estimates of energetics at the population level and of interest both in wildlife management and basic ecological analysis. Thus efforts have been made to model, for example, the relationship between caribou (*Rangifer tarandus*) population density and its food supply (RUSTEN 1976; WALTERS et al. 1975). The seal herds' consumption of fish is recognized as a potential management problem (LAVIGNE et al. 1976) and food supply is in general considered to be of major importance for reproductory success (GOSSOW 1976). In basic ecological analysis of eruptions of ungulate populations a close relationship between population density and body fat content is hypothesized (CAUGHLEY 1970). The present model on individual mammal energy balance is part of ongoing investigations of Svalbard reindeer (*Rangifer tarandus platyrhyncus* (Vrolik)), polar bears (*Ursus maritimus*) and seals (*Pinnipedia*)[1] and is a step in a physiological approach to analysis of population energetics.

[1] The Norwegian MAB (Man And the Biosphere) programme, Norsk Polarinstitutt. The polar bear research programme conducted through the College of Biological Science, University of Guelph, Ontario; School of Forestry, University of Montana; and Institute of Zoophysiology, University of Oslo, in cooperation with the Canadian Wildlife Service, Manitoba Dept. of Transportation and Renewable Resources and U.S. Fish and Wildlife Service. The Seal research programme directed by K. RONALD, Dean., College of Biological Science, University of Guelph.

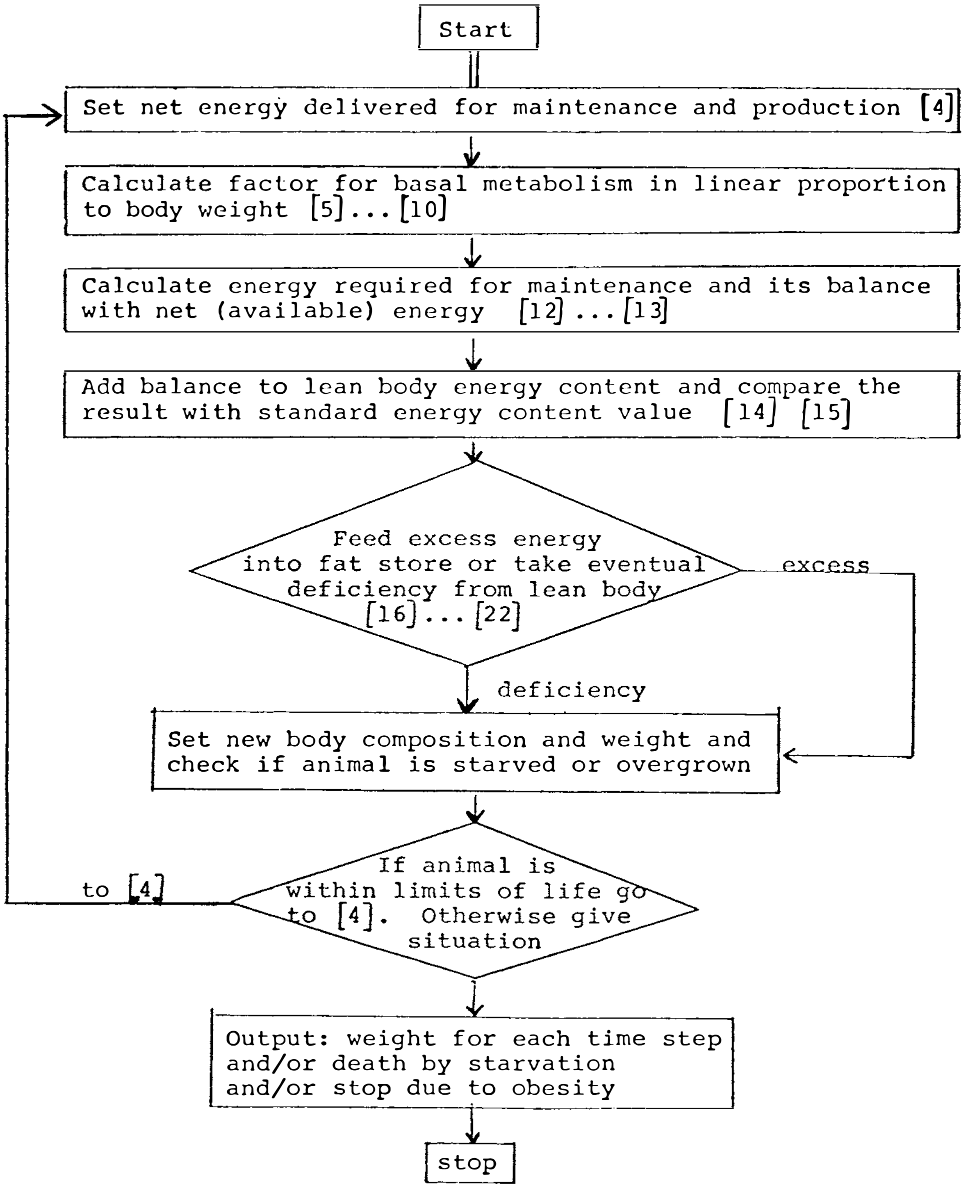

Fig. 1. *Flow chart of model and programme design. Programme line numbers are enclosed in brackets. The detailed APL-programme is listed below.*

Methods

Priority is given to maintenance of the lean body mass while energy flows are balanced against fat mass. Basal metabolism is set to decrease linearly with body weight to a value of 0.6 times normal corresponding to 0.7 times standard body weight (KLEIBER 1961). Maintenance energy requirements are considered as the sum of three levels of activity: basal, lying and walking.

Provided that maintenance energy already has been covered, eventual excess energy from the digestive processes is used for growth of lean body mass up to a standard value. Further excess energy is used towards building up fat stores to an upper limit.

Simulations are performed over one day time steps and terminated (animal dead) if body weight and basal metabolism reach the limiting value of 0.6 times standard, or if the animal grows impossibly fat according to an arbitrary limit, for example 30 percent, set by the user. The general structure of the model is given in Fig. 1. In the present form the model is activated at the energy level of net energy being delivered from the digestive processes while growth efficiencies are not discussed.

TRANSFER FUNCTIONS AND VARIABLES

Basal metabolism (*MB*)

Basal metabolism is set according to KLEIBER and reduced linearly with body weight for the starving animal (KLEIBER 1961).

$$MB = 70 \times W^{0,75} \times MBF \qquad \text{kcal/day}$$

where

W = body weight — kg

$$MBF = -0.33 + \frac{1.33 \times W}{WS}$$

$(0.6 < MBF \leq 1)$

WS = standard body weight — kg

Maintenance energy (*MA*)

Activity metabolism is, for a given body weight, normally considered to be linearly related to walking speed starting with a value of about 1.7 times basal for the animal standing still (TAYLOR et al. 1970). For the starving animal the above relationship may be invalid (KEYS et al. 1950) and in lack of conclusive evidence from litterature, the activity metabolism is here calculated as the sum of increments of basal metabolism.

$$MA = MB \times T \times (T1 + AF1 \times T2 + AF2 \times T3)$$

where

MB = basal metabolism — kcal/day

T = time step — day

T1 = fraction of day (T) spent at basal metabolic level

T2 = fraction of T spent at activity level 1

T3 = fraction of T spent at activity level 2

AF1 = multiplication factor (activity level 1). AF1 is here set to 1.2 to cover the calorigenic effect (SDA) of food (KLEIBER 1961).

AF2 = Multiplication factor (activity level 2). AF2 is here set to 2 corresponding to a slowly walking animal.

Caloric equivalents and body energy content

The caloric value (FEQ) of fat is set to 9.5 kcal/g while the value (EQ) of the lean body mass (wet weight) according to GORECKI (1975) ranges from 1.4 to 2.2 kcal/g. A value EQ = 2 kcal/g is used in the present work. The energy content of the lean body is

LE	= LB × EQ	kcal
where		
LB	= lean body weight	kg
and similarly		
FAE	= FA × FEQ	
where		
FA	= fat weight	kg

PROGRAMME LISTINGS

The model is implemented in APL as shown below. Before initiating the actual energy balance programme (GR) the animal is standardized by the programme DYR.

```
      ∇DYR[⎕]∇
    ∇ DYR
[1]   'STANDARD WEIGHT IS:            ';WS
[2]   'PER CENT FAT IS:               ';FPR
[3]   'GIVE STANDARD WEIGHT'
[4]   WS←⎕
[5]   'DO YOU WANT TO CHANGE FAT PRCNT?'
[6]   S←⎕
[7]   →(S=1)/LA
[8]   FA←FPR×WS
[9]   FAES←FA×9500
[10]  LB←LBPR×WS
[11]  LES←EQ×LB
[12]  →17
[13] LA:'GIVE NEW FAT PRCNT, (0<FPR≤1)' '
[14]  FPR←⎕
[15]  LBPR←1-FPR
[16]  →8
[17]  'BODY COMPOSITION:'
[18]  'STANDARD WEIGHT (WS)          :';WS
[19]  'PER CENT FAT                  :';FPR
[20]  'FAT MASS                      :';FA
[21]  'LEAN BODY MASS                :';LB
    ∇
```

```
      ∇GR[⎕]∇
    ∇ GR
[1]   I←⍳1
[2]   W←FA+LB
[3]   WN←W
[4]  L6:NE←NFL×T[I]
[5]   MBF←¯0.33+(1.33×W)÷WS
[6]   →((MBF<0.6),(MBF>1),((0.6≤MBF)∧(1≥MBF)))/(L1,L2,BME)
[7]  L1:MBF←0.6
[8]   →BME
[9]  L2:MBF←1
[10]  →BME
[11] BME:MB←70×(W*0.75)×MBF
[12]  MA←(MB×T1×T[I])+(MB×AF1×T2×T[I])+(MB×AF2×T3×T[I])
[13]  B←NE-MA
[14]  LE←B+LB×EQ
[15]  LEB←LE-LES
[16]  →(LEB>0)/L3
[17]  FAE←(FA×9500)+LEB
[18]  →(FAE≥0)/L4
[19]  LE←(LB×EQ)+FAE
[20]  LB←LE÷EQ
[21]  FA←0
[22]  →V
[23] L4:LB←LES÷EQ
[24]  FA←FAE÷9500
[25]  →V
[26] L3:FA←FA+LEB÷9500
[27]  →(FA≥(FAES÷9500))/L8
```

```
[28]  LB←LES÷EQ
[29] V:W←LB+FA
[30]  WN←WN,W
[31]  I←I+1
[32]  →(I>ρT)/L7
[33]  →((MBF≤0.6)∧(W≤(0.6×WS)))/L5
[34]  →L6
[35] L7:'SIMULATION FINISHED,GROWTH IS:'
[36]  ⌈WN
[37]  →0
[38] L5:'ANIMAL STARVED TO DEATH, WEIGHT LOSS IS:'
[39]  ⌈WN
[40]  'SURVIVAL      = ';((ρWN)-1);' DAYS'
[41]  'WEIGHT AT DEATH IS  ';WN[(ρWN)-1];' KG'
[42]  →0
[43] L8:'ANIMAL IMPOSSIBLY FAT, SIMUL.STOPPED:'
[44]  ⌈WN
    ∇
```

Results

In the present form the programme will output a vector where each element is the body weight corresponding to the actual time steps used for the simulation. One day steps are consequently used throughout the present discussion. Also, in the case of death, the terminal body weight and number of days before death is printed out.

Using a 40 kg animal with 20% fat as standard it appeared that the model is sensitive to changes in time spent at the various activities and the level of activity. Thus survival increased from the standard 57 to 64 days if the time spent walking (grazing — searching for food) was reduced from 60 to 40 per cent of the day. Increasing the energy cost of walking from 2 to 2.5 times basal metabolism reduced survival from the standard 57 to 49 days.

Initial body fat content appears to have a profound effect (Fig. 2), and the model predicts body weights during starvation, survival time and weight at death in an agreeable fashion for a wide range of mammals, from rats (Fig. 2) to reindeer. Thus assuming an initial fat content of 18.5 per cent, a body weight of 14 kg is predicted for the dog Oscar that in reality weighed 15 kg after 47 days of starvation (Kleiber 1961). Also assuming an initial fat content of 8.5 per cent for the Succi-experiments discussed by Keys et al. (1950) and Kleiber (1961) the predicted body weight resulting from 26 days of starvation is 52 kg in comparison to 51 kg recorded for the real life situation. Finally, applying the model to Svalbard reindeer gives reasonable results: A normal good sized male weighs in late summer 110 kg with a fat content of about 23% (Reimers pers. comm.). In late winter, male reindeer found dead from starvation weighs about 55 kg (Reimers op. cit.) as predicted by the model. Similar agreement between real life and simulations appears for female reindeer.

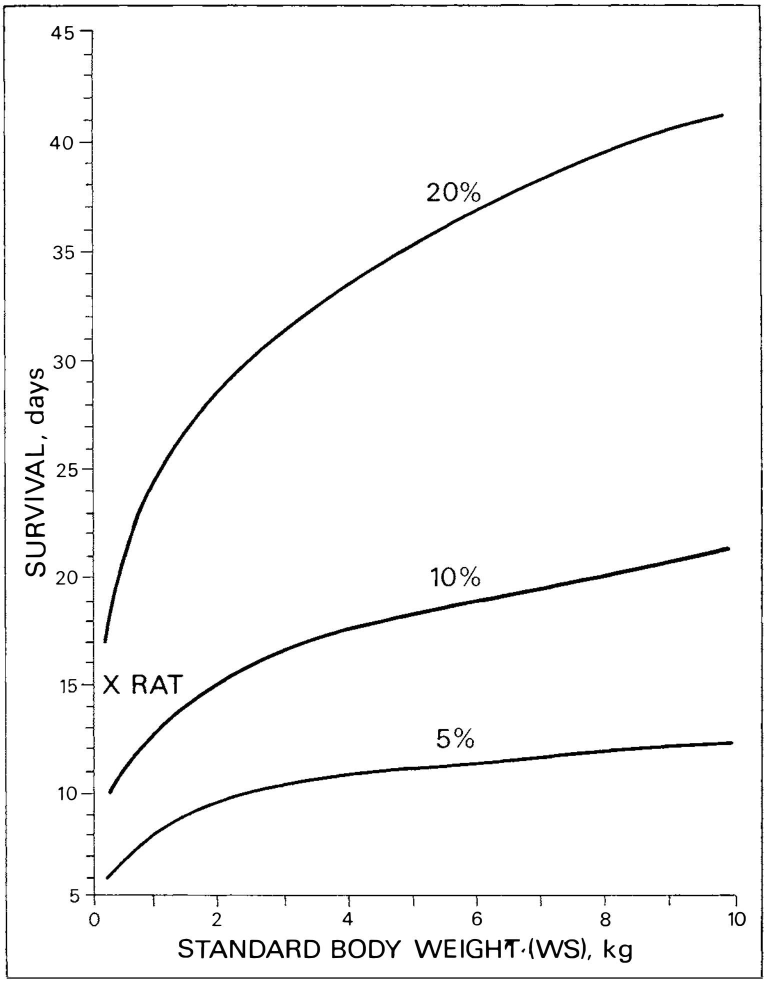

Fig. 2. *Survival after onset of fasting for varying initial standard body weight and body composition* (*% fat*). *In vivo experiments are indicated with X* (Rats, KLEIBER 1961).

Discussion

The present model is designed especially to investigate the results of considering the body as two energy compartments. In this context it may be an oversimplification to give top priority to stabilization of the lean body mass i.e. that maintenance energy is taken primarily from the body fat. GRANDE (1961), however, pointed out how the caloric value of body weight loss during prolonged starvation approaches that of fat. An eventual modification of the energy to weight loss relationship can be included into the present model by differentially activating the energy drain from the two body energy compartments according to body weight or metabolizable energy.

The consequences of giving top priority to stablization of the lean body mass is further demonstrated in Fig. 3. As body weight falls to the level of complete

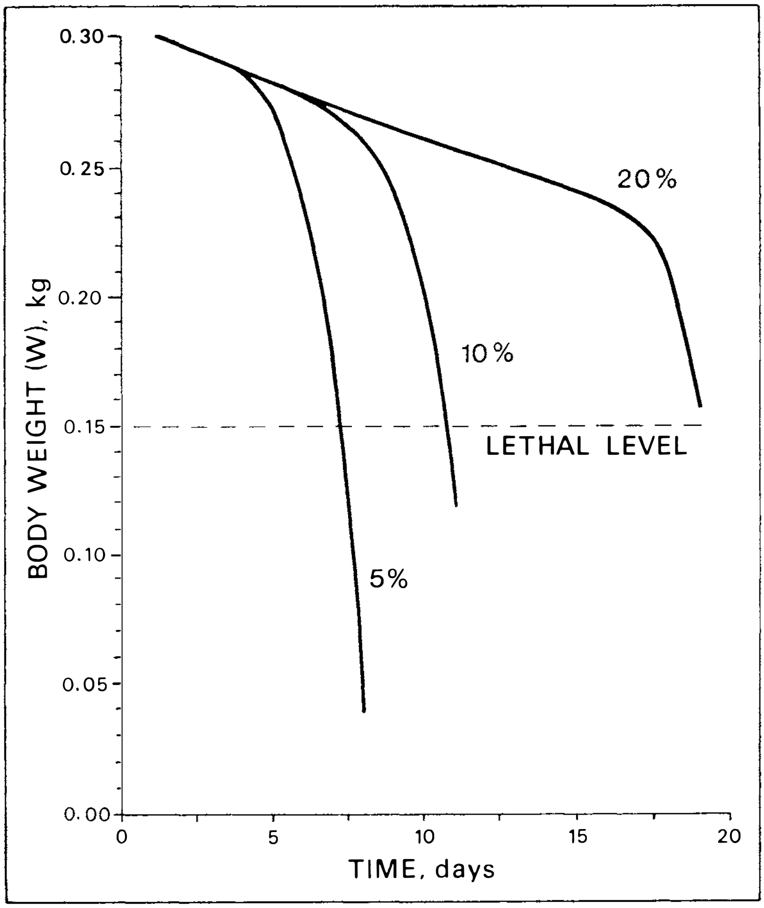

Fig. 3. *Simulations of starvation of an animal with initial body weight 0.3 kg and varying initial body fat content (5, 10 and 20 per cent). The abrupt falls in body weight is due to that energy loss is shifted from fat to lean body while activity levels remain constant.*

fat depletion the rate of weight loss increases steeply towards the lethal level. Obviously the above effect can be dampened by both a modification of energy equivalents as indicated above and by reducing the activity factors in proportion to total body weight loss.

Reduction in activity during prolonged starvation is common (KEYS et al. 1950) and is believed to be present in the Svalbard reindeer. In the ecological perspective, however, reduced activity also implies a reduction of food intake and thus an increased probability of death. On the other hand if conscious or unconscious "judgement" of the energy balance situation is present in, for example, the Svalbard reindeer survival could be greatly improved by the animal minimizing its activity in late spring, thus saving energy for the rapidly increasing grazing activity that follows the melting of snow and ice.

The capability of Svalbard reindeer to build up fat stores during the grazing season has been noted earlier (ØRITSLAND 1970; KROG et al. 1976). Preliminary applications of the present model to body weight and composition data (REIMERS pers. comm.) now being collected systematically through the MAB-project indicates for 1976/77 a starvation survival ability of 20 to 50 days in March, 15 days in May, and 80 to 125 days in September.

Acknowledgements

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Counts and population estimates of Svalbard reindeer *(Rangifer tarandus platyrhynchus)* in Nordaustlandet, Svalbard, in 1974 and 1976

Подсчеты свальбардских оленей (*Rangifer tarandus platyrhynchus*) и расчеты величины их популяции на Северо-Восточной Земле в 1974 и 1976 гг.

By Thor Larsen

Contents

Abstract

Reindeer (*Rangifer tarandus platyrhynchus*) were counted along the north coast of Nordaustlandet, Svalbard, between 13 March and 26 April 1976. Other counts are from the southern parts of Nordaustlandet during the summers of 1974 and 1976. The census suggests a total population of 250 to 300 reindeer in Nordaustlandet in the period 1974 to 1976, with an average density of about 0.1 animal per square kilometre of suitable winter habitat along the north coast. An aerial survey revealed that fixed wing aircraft cannot be used in quantitative population estimates of reindeer in Svalbard when the population density is that low. Data indicate a higher calf mortality in Nordenskiöld Land than in Nordaustlandet during the winter of 1975/76, probably due to over-icing of the vegetation in the west during critical periods.

Аннотация

Северные олени (*Rangifer tarandus platyrhynchus*) были подсчитаны по северному берегу Северо-Восточной Земли Свальбарда между 13-м марта и 26-м апреля 1976 г. Остальные приведенные здесь подсчеты были произведены в южных частях этого же острова во время летних месяцев 1974 и 1976 гг. Перепись указывает цифру в 250—300 голов этого вида на Северо-Восточной Земле в период с 1974 по 1976 г., что представляет собой среднюю плотность распространения данного ливотного примерно в 0,1 на квадратный километр подходящей для зимнего пребывания оленей земли по северному берегу. Воздушный обзор обнаружил, что авиацию с прикрепленными крыльями нельзя использовать для количественных расчетов популяции северных оленей на

Свальбарде при такой низкой плотности ее. Полученные данные указывают на высшую смертность оленят на Земле Норденшельда, чем на Северо-Восточной Земле зимой 1975-1976 г., по всей вероятности происшедшую по причине покрытия льдом растительности на западе во время критических периодов.

Introduction

Systematic counts and population estimates of the Svalbard reindeer (*Rangifer tarandus platyrhynchus*) have not been made before in Nordaustlandet, Svalbard. Previous estimates vary vetween 300 (GLEN 1937) and 600 to 700 animals (DEGE 1954). LØNØ (1959) estimated the reindeer population in Nordaustlandet to be approximately 300 to 400 animals in the late fifties. According to NORDERHAUG (1969) no reindeer were observed in the southern parts of Nordaustlandet until after 1966. This paper presents quantitative reindeer counts which were performed on the north coast of Nordaustlandet in the spring of 1976 in connection with simultaneous investigations of polar bears (*Ursus maritimus*). Information about the reindeer population in southern parts of Nordaustlandet is available from the summer of 1974 (LARSEN 1975) and the summer of 1976 (O. SALVIGSEN pers. comm.).

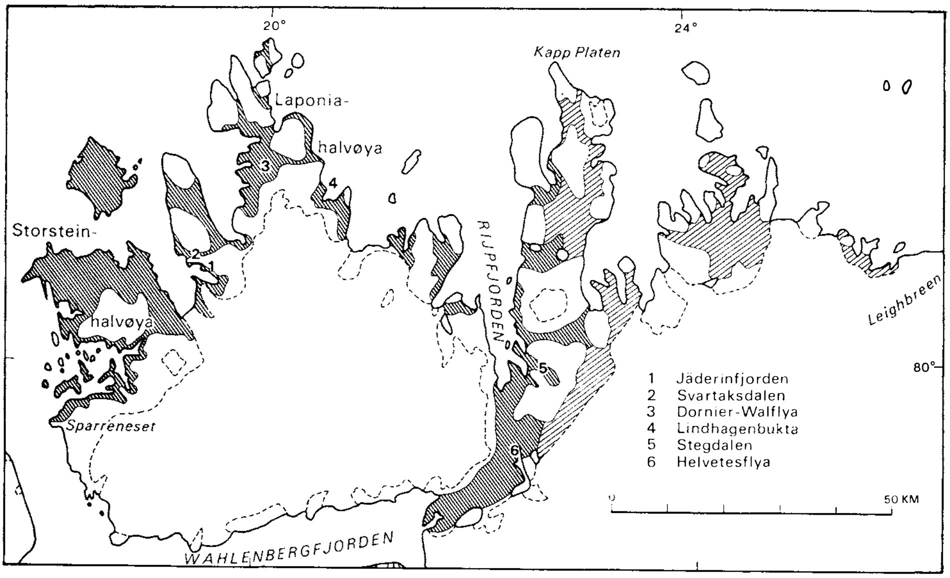

Fig. 1. *Map showing reindeer winter habitat on the north coast of Nordaustlandet.*

: Observed
: Estimated

Карта, показывающая область зимнего пребывания северных оленей по северному берегу Северо-Восточной Земли.

: Отмеченная
: Рассчитанная

Methods

The study area between Sparreneset and Kapp Platen was surveyed repeatedly between 13 March and 26 April 1976. Independent observations and counts were made by the author and his assistant, CLAUS SANDE. Observations were made by means of 7 × 50 binoculars and 20 to 60 power spotting scopes. The spotting scopes were mounted on tripods by means of adaptors permitting continuous horizontal and vertical scanning and readings. Thus the scopes could be switched back in fixed positions to any object which might need to be checked again or by the other observer. Attempts were made to distinguish between adults and year-old calves in registrations, and notes were made on whether the reindeer had antlers or not. When no observations of animals were made, registrations were made of tracks, digging craters, and faeces in an attempt to obtain more information on which areas were preferred by the reindeer at that time of the year.

Late in April, two independent aerial surveys were made for polar bear and reindeer observations with a Cessna 185 with skis. The cruising speed was 130 to 150 km per hour at an altitude of between 70 and 150 metres. Observations were made by the author, CLAUS SANDE, and the pilot. Both sides of the aircraft were covered. Some areas where the number of reindeer were known from previous ground surveys were particularly carefully investigated in an effort to compare reliability and efficiency of the two census methods.

Results

Observations were usually made under good weather conditions. Quantitative polar bear den counts which was the main objective of the study, require very good light conditions, preferrably sunshine with little overcast. Such conditions were also optimal for observations of reindeer and reindeer tracks. We found it relatively easy to distinguish between reindeer and polar bear tracks, even on long distances. Consequently, reindeer counts were assumed to be quantitatively reliable. This was confirmed by repeated counts in some areas and simultaneous counts by both observers independently. Such counts varied very little, and often not at all.

A total of 82 reindeer were counted from the ground between Sparreneset in the west and Kapp Platen in the east (Fig. 1). Of these, 46 were adults and 15 one-year-old calves, while in 21 cases, the age could not be determined with certainty because of the observation distance. The data give an estimated calf percentage of 24.6. It was rarely possible to determine the sex on adults even on short distances. Such observations are too few to be used in a conclusive statement on sex distribution in the population, either in small areas or in the total observation region.

The first aerial survey, made on 25 April, was hampered by poor weather and turbulence which made observations difficult. But another air survey was made the following day under very good weather and light conditions. A total of four reindeer were seen in the area mentioned above. The beaches at Jäderinfjorden, and Svartaksdalen, were particularly carefully surveyed since ground observations had shown that there were six and five reindeer in these areas, respectively. But from the aircraft, only one animal was observed in each of these areas.

Ground observations revealed that the reindeer preferred areas protected from wind and bad weather. Most animals were observed in valleys, along riverbanks, on shores at the foot of mountains, or at the head of certain fjords. They were rarely found on wide and open plains, and not at all high up in the hill- and mountainsides, even if such areas often seemed to have a better food supply than many other areas preferred by the animals. For example, there was only one reindeer on the relatively big peninsula Storsteinhalvøya. Reindeer were not observed in the wide and open valley Helvetesflya between Rijpfjorden and Wahlenbergfjorden, and there were no tracks or faeces to indicate that they had been there prior to our observation period. But in the small valley Stegdalen in Rijpfjorden, as many as 18 reindeer were observed on 28 March. The population density was also relatively high on the limited habitats in Jäderinfjorden and in Svartaksdalen.

Observations of tracks, digging craters, and faeces could not be used to adjust the quantitative count in one way or another. Generally there was good agreement between the relative abundance of such signs and the number of animals in a given area. Tracks, digging craters, and faeces could also give some information about local movements and habitat use within a given area. We found that reindeer usually stayed in one area for several weeks, and only made short, local wanderings. The animals were not widely scattered, but rather lumped in small aggregations of two to six animals per group. There were few migrations from one area to another across fjords or icecaps.

Discussion

During the field period on Nordaustlandet in the spring of 1976, close to all available reindeer winter habitats between Sparreneset and Kapp Platen were surveyed once or several times. It is reasonable to suggest that the number of animals observed from the ground is very close to what really was present in the study area, because of the good agreement between repeated and independent counts in certain areas. Some few animals may have been overlooked in the southern part of Dornier-Walflya or on the plains around Lindhagebukta. But on the basis of other counts and estimates of population densities a maximum of ten animals only may have been overlooked in these areas. On the basis of the ground surveys, the total reindeer habitat in the study area at that time of the year was estimated to approximately 895 square km between Sparreneset and Kapp Platen, by the use of a planimeter on maps at scale 1:500 000. The total reindeer habitat between Kapp Platen and Leighbreen is estimated to 530 square km, based on knowledge about habitat preferences in the areas further west. The average population density in the study area was calculated to be almost 0.1 animal per square km of winter habitat. If we assume the same average densities in the area east of Kapp Platen, there were probably about 49 reindeer in that region. Thus a total of at least 131 reindeer lived on the north coast of Nordaustlandet in the spring of 1976. If this figure is adjusted for animals which may have been overlooked as mentioned above, the total population amounts to almost 150 animals.

In the summer of 1974, T. WINSNES counted 76 reindeer in Palanderdalen and 12 in Zeipelfjella south of Wahlenbergfjorden (LARSEN 1975). In the summer of 1976, O. SALVIGSEN counted 28 reindeer on Svartknausflya in the south over a period of six weeks (O. SALVIGSEN pers. comm.).

The total summer and winter observations and estimates of reindeer in Nordaustlandet in 1974 and 1976 add up to a total population of 247 animals. As censuses have been made in different years and different seasons, the possibility of double counts due to migration between areas cannot be ruled out. But mountains, glaciers and the big Wahlenbergfjorden represent physical barriers not easily crossed by reindeer. It is reasonable to assume that the reindeer in southern Nordaustlandet are separated from the animals in the north by these barriers, and that there is little probability, therefore, of such double counts. But some reindeer in the south may have been overlooked during the summer surveys and counts. Furthermore, there are other potential reindeer habitat areas where counts have not been made, as at Torellneset, the north coast of Wahlenbergfjorden, and south of Sparreneset. These areas are relatively small, however, and cannot sustain any large herds of reindeer. The expeditions from Norsk Polarinstitutt did not observe reindeer on Storøya and on Sjuøyana in 1974 and 1976. Considering all aspects and possible errors, the total reindeer population in Nordaustlandet in 1974–1976 was probably somewhere between 250 and 300 animals, therefore.

The discrepancy between the air and ground counts is important in terms of developing census techniques for reindeer in Svalbard. Observer experience and prior knowledge from ground counts should have minimized differences in this comparative survey. Still, only a fraction of the numbers actually present could be seen from the air. Generally, air observations are affected by factors as speed, altitude, weather, and light conditions. During these surveys it was evident that the lack of snow in many areas, and big stones, boulders, and other terrain features affected the observations. Reindeer running over open plains could be spotted rather easily, while animals standing still were often seen only by accident. Although light and weather conditions appeared to be favourable for air censusing, the cruising speed was probably too high for efficient observations, attributing to the poor success of this method. For the reasons above, reindeer counts from the air during winter is probably of little value in Svalbard as a quantitative census technique, at least in areas where population densities are as low as in Nordaustlandet. Air surveys can, however, be an efficient method to map habitat use, seasonal distribution, and relative abundances.

The calf percentages registered in Nordaustlandet are high. At the north coast it was 24.6 in the spring of 1976, while O. SALVIGSEN observed 39.3 %

calves further south, on Svartknausflya, in the summer of 1976. The samples from Nordaustlandet are small and may be biased, but are still noticeably higher than the 19% which were observed in Nordenskiöld Land in the summer of 1975 (ALENDAL 1975). In Nordenskiöld Land it was down to about 4% the following spring, when the counts were made on Nordaustlandet (K. KASTNES pers. comm.). Spitsbergen and Nordenskiöld Land had several periods with mild weather and subsequent freezing of the vegetation in the winter of 1975/76. We could not find any evidence of such over-icing in Nordaustlandet in the spring of 1976. A higher calf mortality has possibly occurred in Nordenskiöld Land than in Nordaustlandet that winter, due to over-icing of the vegetation in critical periods, and perhaps also combined with higher population densities in the west, and therefore more competition for food.

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Survivorship in the Svalbard reindeer *(Rangifer tarandus platyrhynchus* Vrolik*)* on Edgeøya, Svalbard

By Steven de Bie[1]

Contents

Abstract

Age and sex have been determined on 244 Svalbard reindeer on the basis of skull and/or jaw material, collected from winter range on Edgeøya (Svalbard) by the Netherlands' Spitsbergen Expedition 1968–1969. Of 131 animals, sex could be determined by measuring skull or jaw. Ages were mainly estimated by counting cemental annuli in the first molar. Life tables indicated an apparent potential longevity of about eleven years for males and about sixteen years for females. The mean life expectation after the third year was respectively 2.08 and 3.22 years. Hypotheses are presented to explain the difference in mortality and duration of life between males and females.

Acknowledgements

Mr. P. Oosterveld of the Netherlands' Foundation for Arctic Biological Research (formerly the Foundation Netherlands' Spitzbergen Expedition) placed the skull- and jaw collection at my disposal. With a grant from this Foundation I stayed nearly two months at the Norwegian State Game Research Institute (Ås) to learn techniques and to assemble a reference collection. I thank Mr. E. Reimers and Mr. R. Sørumgård of this institute for their hospitality and indispensable assistance in the project. I wish to express my gratitude to Mr. P. Oosterveld for suggesting the topic, Dr. J. Reddingius for the valuable discussion about several aspects of this study, and Dr. R. H.

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DRENT under whose supervision the project was carried out as a part of my study in biology at the University of Groningen. I thank Mr. D. VISSER for his assistance in photography and for preparing the figures.

Introduction

On the island Edgeøya, situated in the southeast of the Svalbard archipelago (lat. 79°N; long. 20°E), the population size of the Svalbard reindeer (*Rangifer tarandus platyrhynchus* Vrolik) has increased gradually in the last decades (NORDERHAUG 1969, 1970; HJELJORD 1975). This development in this extreme environment, without any disturbance by men and in the absence of natural predators, warrants a further study.

During the winter/summer season 1968–1969, the Netherlands' Spitzbergen Expedition started a broad study of the Svalbard reindeer in the north-west part of Edgeøya. OOSTERVELD (1975) reports the results and gives a general description of the area. This expedition also searched the whole area under investigation for skeletal remains, especially skulls and jaws. In this study, age and sex of this material is presented.

MORRIS (1972) reviews the methods which have been developed to determine the age of mammals. MCEWAN (1963), REIMERS and NORDBY (1968) and MILLER (1974a, 1974b) have studied the age determination in the genus *Rangifer* and found the number of cemental layers in teeth to be a good indicator of age. In this study mainly this method has been employed to age determine the collected skull- and jaw material.

Material and methods

The skull and jaw material has been collected in the Kapp Lee area on Edgeøya (Fig. 1). About 30 km² was searched as thoroughly as possible during the period May–September 1969. The location of each specimen was plotted on a map.

Because demolition processes progress slowly in Arctic regions, these skulls and jaws must have accumulated over many years, certainly from 1925 onwards when the reindeer population became protected.

The collection has the following composition:

57	skulls+mandibles
83	loose skulls or upper jaws
104	loose mandibles
244	specimens totally.

Four methods have been used to determine the sex of these Nos.:

1. *Measuring the length of the mandibles* (*see Fig. 2*).

Criteria: $\leqslant 22.5$ cm → ♀
>23.5 cm → ♂

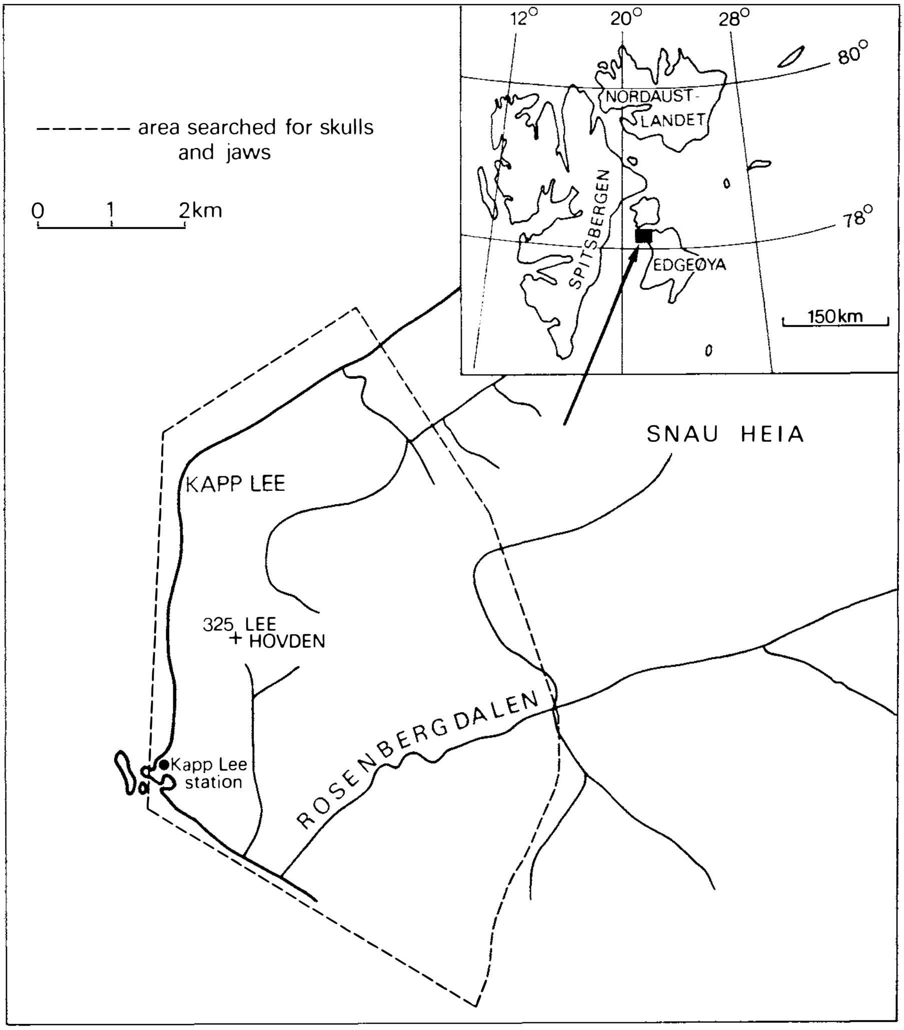

Fig. 1. *Map of the Kapp Lee area, NW Edgeøya.*

These criteria have been based on a reference collection of mandibles of Svalbard reindeer with known sex at the Norwegian State Game Research Institute (Ås). With mandibles, ⩽23.5 and >22.5 cm, sex determination is difficult; sometimes a detailed comparison with mandibles of known sex has been decisive in such cases.

2. *Measuring the height of the mandible, immediately behind the third molar (see Fig. 2).*

Criteria: <3.40 cm → ♀
>3.60 cm → ♂

These criteria have been determined by measuring mandibles of known sex using Method 1 (Fig. 3).

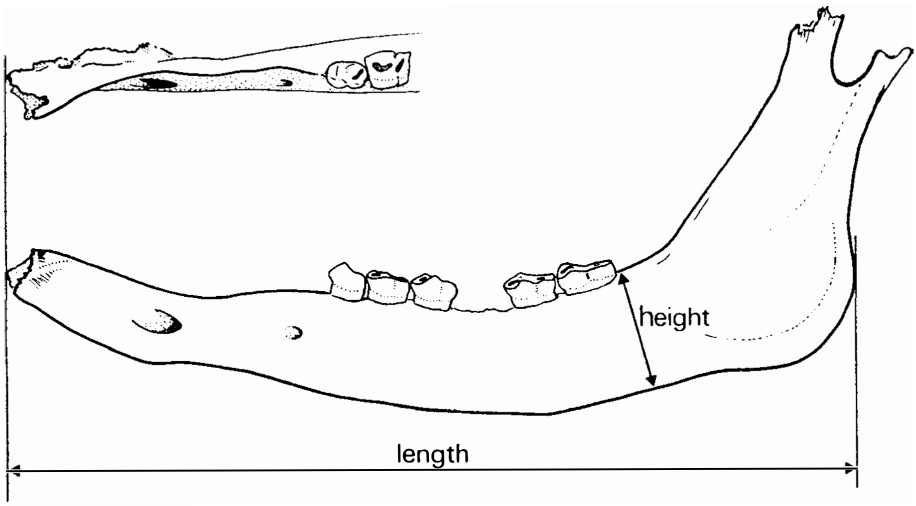

Fig. 2. *Mandible of the Svalbard reindeer.*

3. *Measuring parts of the skull which show no overlap between males and females of the Svalbard reindeer.*

   BANFIELD (1961) mentions:

   a. the basal length
   b. the least outside width of the post nares openings.

   The measurements are taken as described by BANFIELD (1961).

4. *The antlers.*

Mostly one criterion sufficed for the sex-determination; only in dubious cases were other methods used.

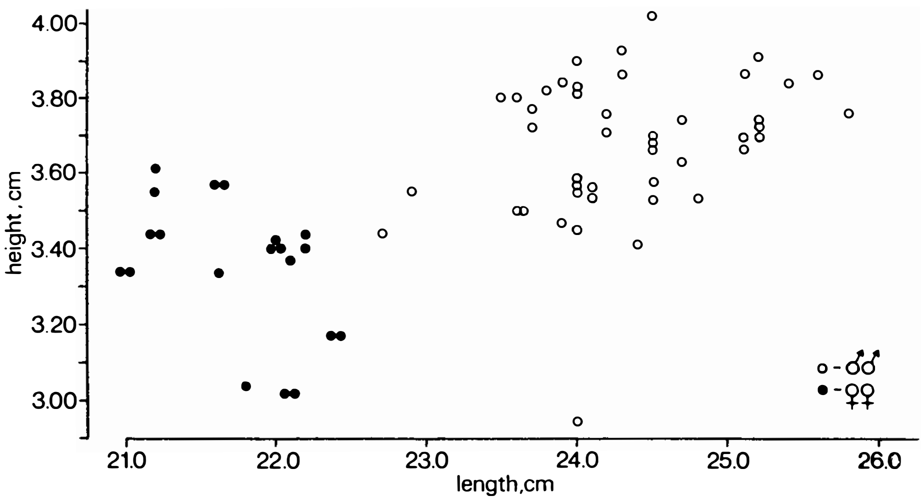

Fig. 3. *Relation between length and height of mandibles for males and females.*

Table 1.

Eruption patterns for mandibular molariform teeth.

age in years	molariform tooth row P2[1]	P3	P4	M1[2]	M2	M3
0–1	m[3]	m	m	p[4]	–[5]	–
c. 1	m	m	m	p	–/e[6]	–
1–2	m/e	m/e	m/e	p	e/p	e
2–3	e/p	e/p	e/p	p	p	p
3–4	p	p	p	p	p	p

[1]) P = premolar
[2]) M = molar
[2]) m = milk tooth
[4]) p = permanent tooth
[5]) – = absent tooth
[6]) e = erupting tooth

Ages were determined in four different ways:

1. The ages of 33 animals were determined by using the eruption pattern of the molariform teeth. This criterion was based on information given by the Norwegian State Game Research Institute (Ås) (Table 1). The eruption pattern is useful until 2½ years of age, at which age the replacement of the milk teeth is complete.

2. The age of 130 specimens (which always included at least one mandible) was determined by counting the winter rest lines (annuli) in the cementum of the first molar of the mandible. This method includes the following procedure. The first molar (called m-1 in this paper) was extracted from the mandible and decalcified in a 5 percent by volume solution of 67 percent commercial nitric acid for 60–72 hours. The tooth was removed from the solution when the root was flexible (soft) under light pressure and then washed in tap water for 24 hours. Longitudinal frozen sections at 60–80 microns were prepared from the buccal side of the m-1, using a freezing microtome with the knife kept uncooled (Fig. 4). Sections were stained in Mayer's acid haemalum (without chloralhydrate) at ±45°C for 35 minutes and washed in tap water for ½–1 hour. Three to four sections were mounted in heated glycerol/gelatine (45°C) on a slide, two or three slides were used for a tooth. For several hours the slides were dried at room temperature. Sections were scanned under a microscope at a magnification of 40× and 100×.

   Each slide was read at random at least three times with several days between each reading. Difficult cases were read once or twice more.

   Before handling the 130 molars in this way, it was verified that the number of annuli in the cementum at the outside of the m-1 corresponded to the number of cementum annuli in the first incisor. This was necessary because most of the mandibles did not contain incisors which were the teeth

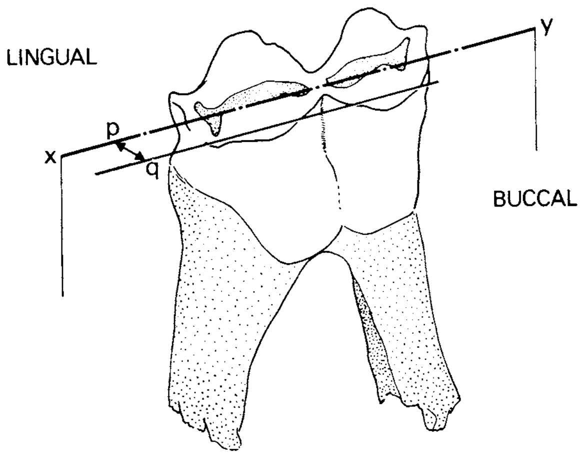

Fig. 4. *The first molar of the mandible of the Svalbard reindeer. x–y: indicates the section plane, p–q: indicates the part of the molar, used for preparing sections.*

on which REIMERS and NORDBY (1968) based their method. In a reference collection from the Norwegian State Game Research Institute (Ås), consisting of eight known age domestic reindeer from nothern Norway, and 14 mandibles of unknown age from Svalbard, the number of cemental annuli in the incisor (i-1) and m-1 was the same. This was also found in the Barren ground caribou (*Rangifer tarandus groenlandicus*) by MILLER (1974a). Number of layers in the teeth also corresponded with age in the known age specimen.

3. The ages of six mandibles and 75 skulls or upper jaws were determined by comparing the state of wear of the molariform teeth with that of corresponding material age determined from annuli in the teeth.

Results

It was possible to determine the sex of 54% (131 Nos.) of the total collection: 105 males and 26 females. The sex of the other 113 Nos. could not be determined because either the jaw- or skull material was incomplete or the material belonged to animals younger than three years. In younger animals, mandibles and skulls are still growing and measurements have a considerable overlap. Table 2 shows the average measurements of complete skulls and mandibles for males and females (in most Nos. the precise measurement could not be determined because of abrasion). The table also includes the measurements of the Svalbard reindeer given by BANFIELD (1961).

Microscopic examination of the m-1 sections revealed that the cementum consists of a regular pattern of broad light purple and narrow dark purple stained layers (Fig. 8). REIMERS and NORBY (1968) and MILLER (1974a) report that the light coloured cementum is deposited in the summer and the dark cementium in the winter; the latter is the socalled winter rest line. Therefore, one light and one dark stained layer represent one year. It was found that longitudinal sections of the m-1 gave the best readability of the annuli. The largest amount of cementum is deposited between the roots of the molar but here the

Table 2.

Mandible and skull measurements of Svalbard reindeer according to this study (A) and BANFIELD *(1961) (B).*

sex		mandible length (cm)				skull							
						basal length (cm)				post nares width (cm)			
		n	mean	range	SD[1]	n	mean	range	SD	n	mean	range	SD
♂	A	22	24,4	22,7–25,6	0,75	4	29,9	29,4–30,7	0,58	40	3,52	3,24–3,86	0,15
♂	B	—[2]	—	—	—	15	28,8	27,1–31,3	1,45	9	3,37	3,10–3,85	0,23
♀	A	8	21,8	21,2–22,2	0,42	—	—	—	—	5	3,11	3,07–3,19	0,046
♀	B	—	—	—	—	13	25,4	24,1–26,6	0,37	5	2,94	2,88–3,03	0,0022

[1]) SD = standard deviation
[2]) no data available

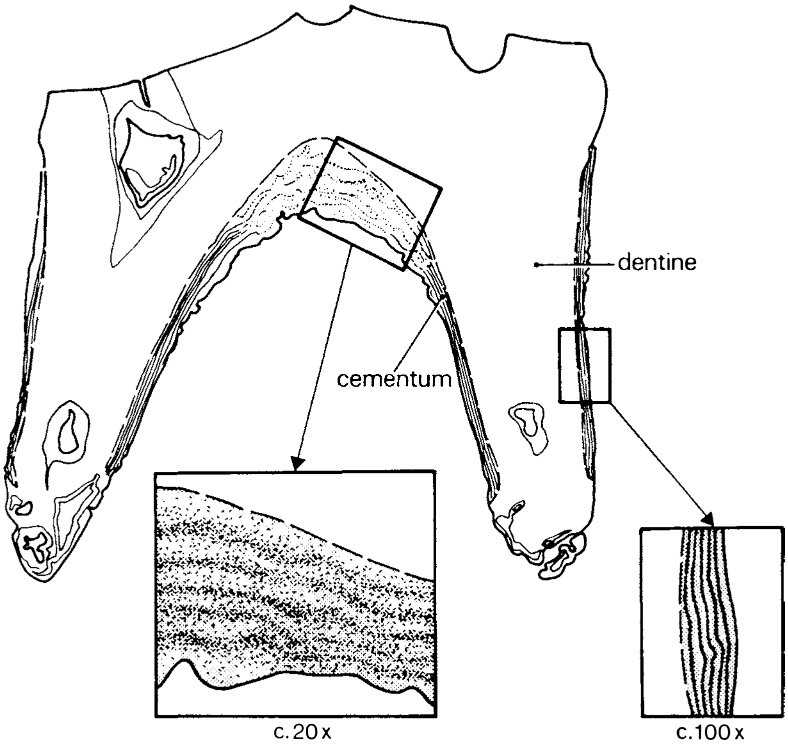

Fig. 5. *Difference in readability between annuli in the cementum between the roots and annuli near the root tip (after photograph).*

annuli are often too indistinct and irregular for a good age determination. Although the cemental layers are closer together, in most cases they are much clearer and easier to count at both sides of the root (Fig. 5).

Mostly the first and second winter rest lines form one dark stained layer. Sometimes this was a difficult point in the age determination.

Frequently it was difficult to determine the presence or not of a winter rest line in the interphase between the cementum and the cementum forming tissue. Consequently an error of ± 1 year has to be taken into account.

Table 3 shows that there is a very good relation between age and number of annuli in the cementum of the m-1 in the reference collection. Therefore, this method was employed wherever possible.

The degree of wear of the molariform teeth, especially in the mandible, is a good indication of the age. The accuracy is not as good as in counting the annuli in the m-1. Mainly there is an underestimation of the age. Wear development in molariform teeth in the mandible is shown by photographs in Fig. 6. In older ages the teeth of the males show a faster wear than those of the females.

Table 4 shows the age distribution of males, females, and for the total collection. From the data in Table 4, life tables and survivor curves for males

Table 3.

Comparison of age and number of annuli in the first molar in the reference collection. Svalbard specimens aged by counting the cemental annuli in the first incisor, Norway specimens of known age animals marked as calves.

	collection number	age in years	number of annuli in first molar
SVALBARD	56	8¾	8
	160	9½	9
	217	3½	3
	A1/75	2¾	2
	A13/74	3¾	3
	A6/74	4¾	5?
	A7/74	5¾	5
	A4/74	6¾	6
	A8/74	7¾	7
	A14/73	8¾	8
	A20/73	9¾	9
	A32/74	10½	10
	A16/73	11	11
	A22/74	16	16
NORWAY	H1/75	2½	2
	H2/75	1½	1
	H3/75	2½	2
	H4/75	5½	5
	H5/75	9½	9
	H6/75	2½	2
	H7/75	11	11?
	H8/75	11	11?

and females of the Svalbard reindeer have been constructed (Tables 5 and 6, Fig. 7). In Fig. 7 the survival axis (vertically) is graduated on a logarithmic scale. In this way mortality is reflected in the slope of the curve regardless of absolute numbers.

From the survivor curve of the males, it appears that the mortality increases with age. In females several periods may be distinguished in which mortality is rather constant: 4–8 years, 8–12 years and 12–15 years. Females live longer than males: respectively maximum 16 years and maximum 11 years. The mean expectation of life after the third year agrees with that: females 3.22 years and males 2.08 years.

Fig. 6a. (1)

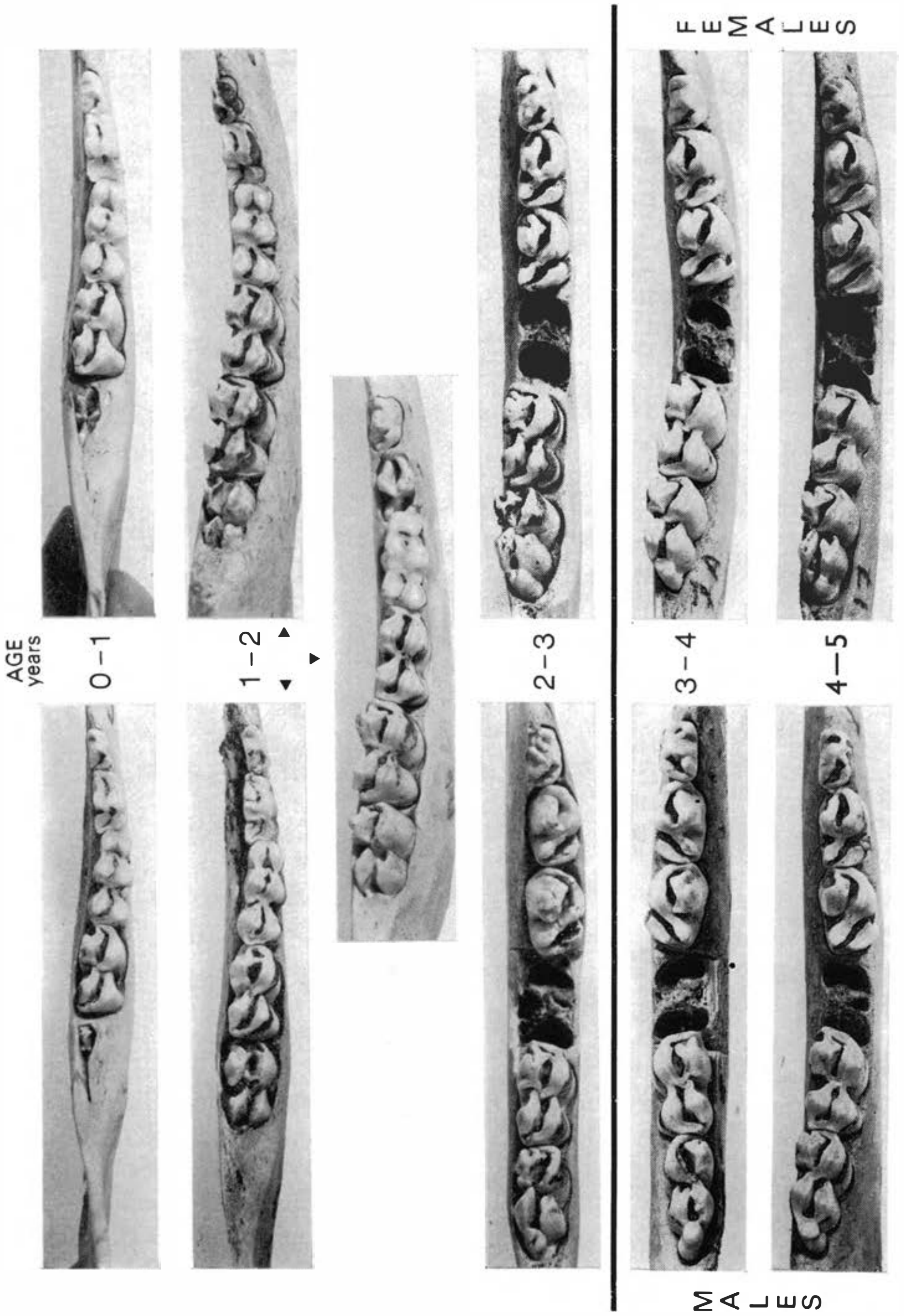

Fig. 6a. (2)

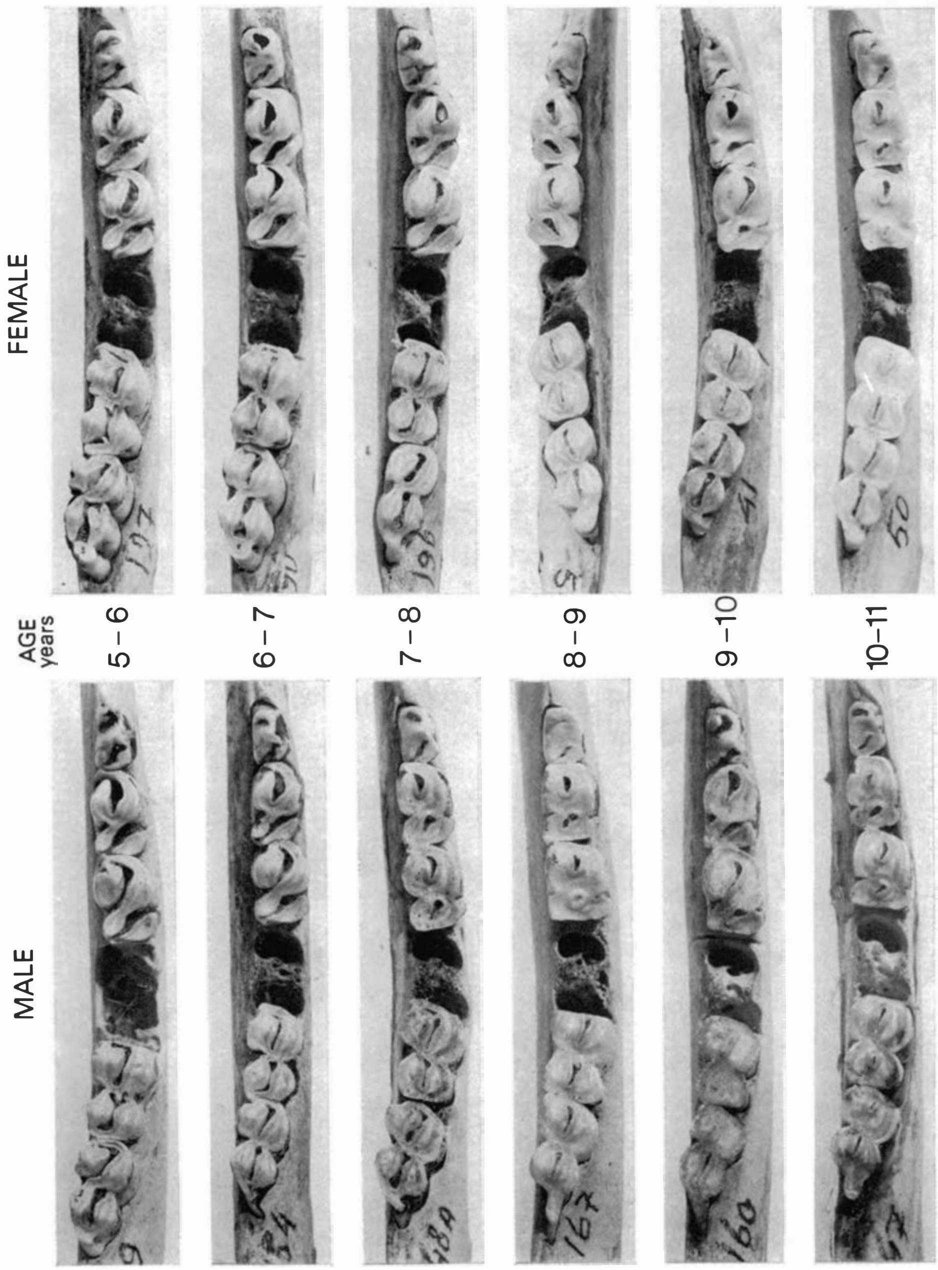

Fig. 6a. (3)

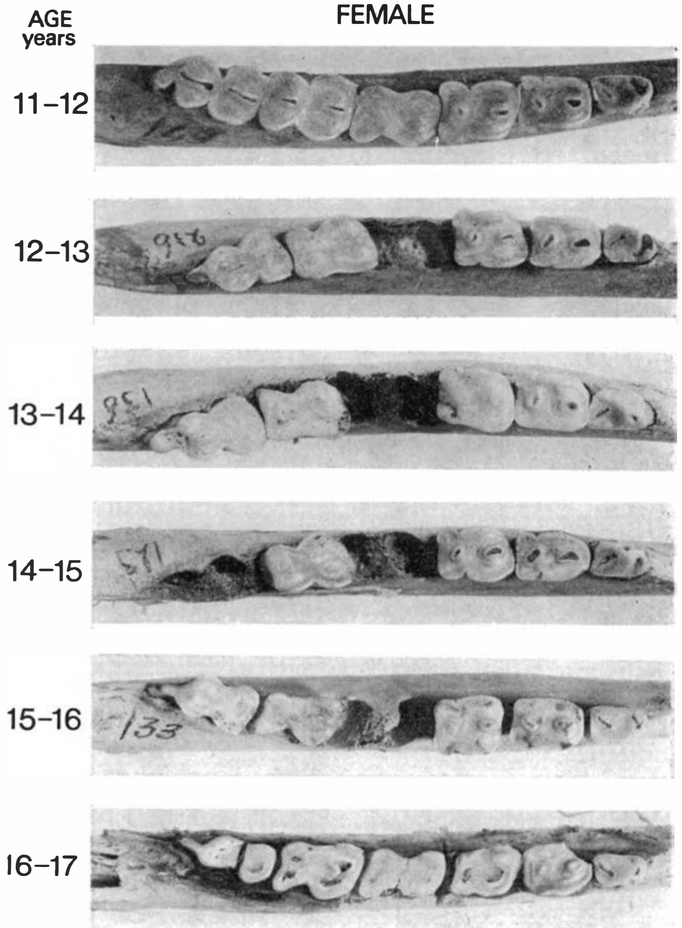

Fig. 6a. *Course of wear of molariform teeth in the lower jaw.*

Discussion

The ranges of the post nares width for males and females of my study are larger than those given by BANFIELD (1961) (Table 2). One specimen, sexed as a female, is a male according to his data. This can be a matter of individual variation, especially since BANFIELD has measured a rather small number of skulls. The problem can only fully be resolved on the basis of more material of known sex reindeer.

In the collection, 87.5% of the male skulls (n=64) were without antlers: these animals died after shedding their antlers. OOSTERVELD (1975) observed that males shed their antlers in winter (December–April) and male knobs are noticeable from April. So we may conclude that these 57 animals died in the

Fig. 6b. (1)

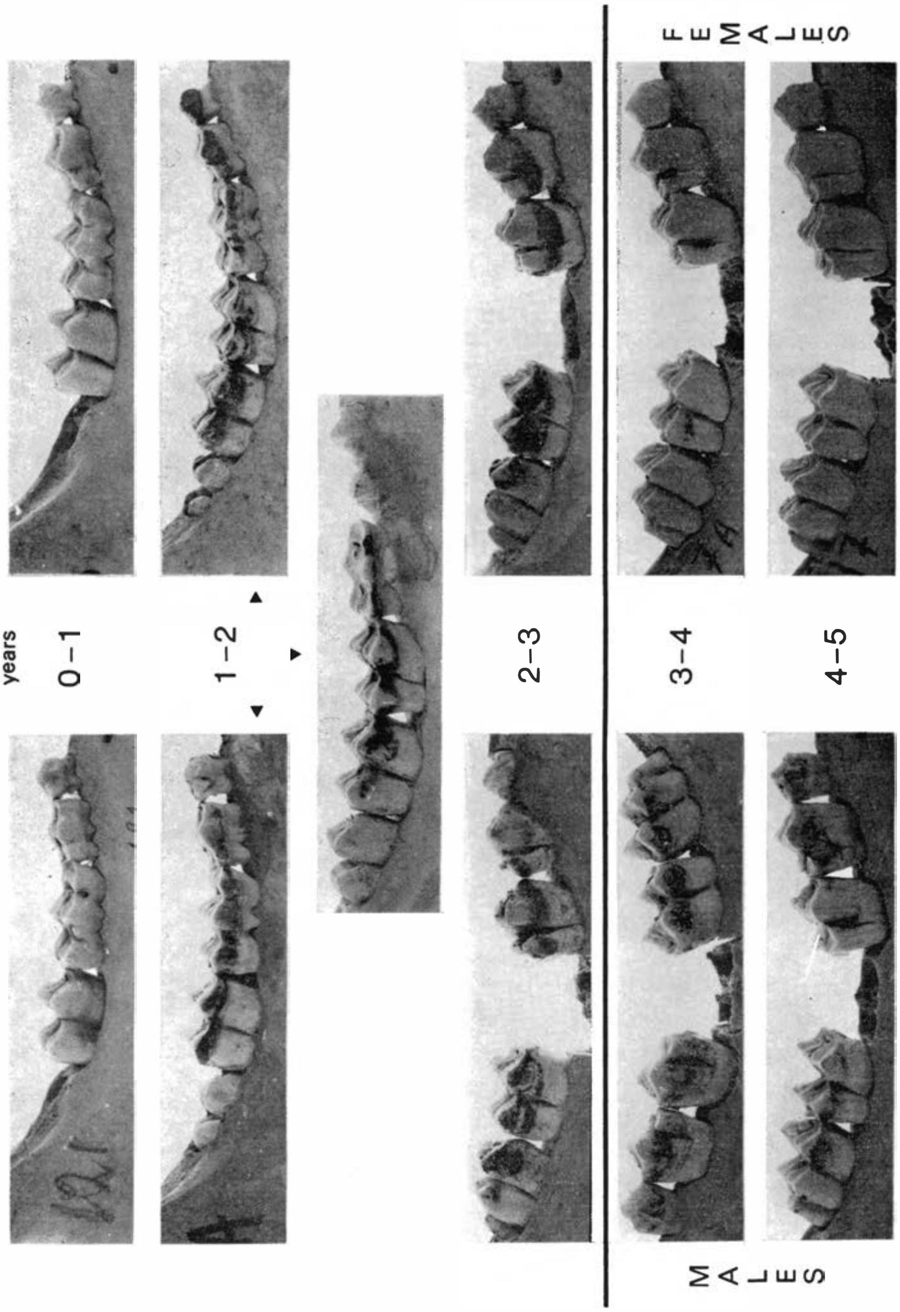

Fig. 6b. (2)

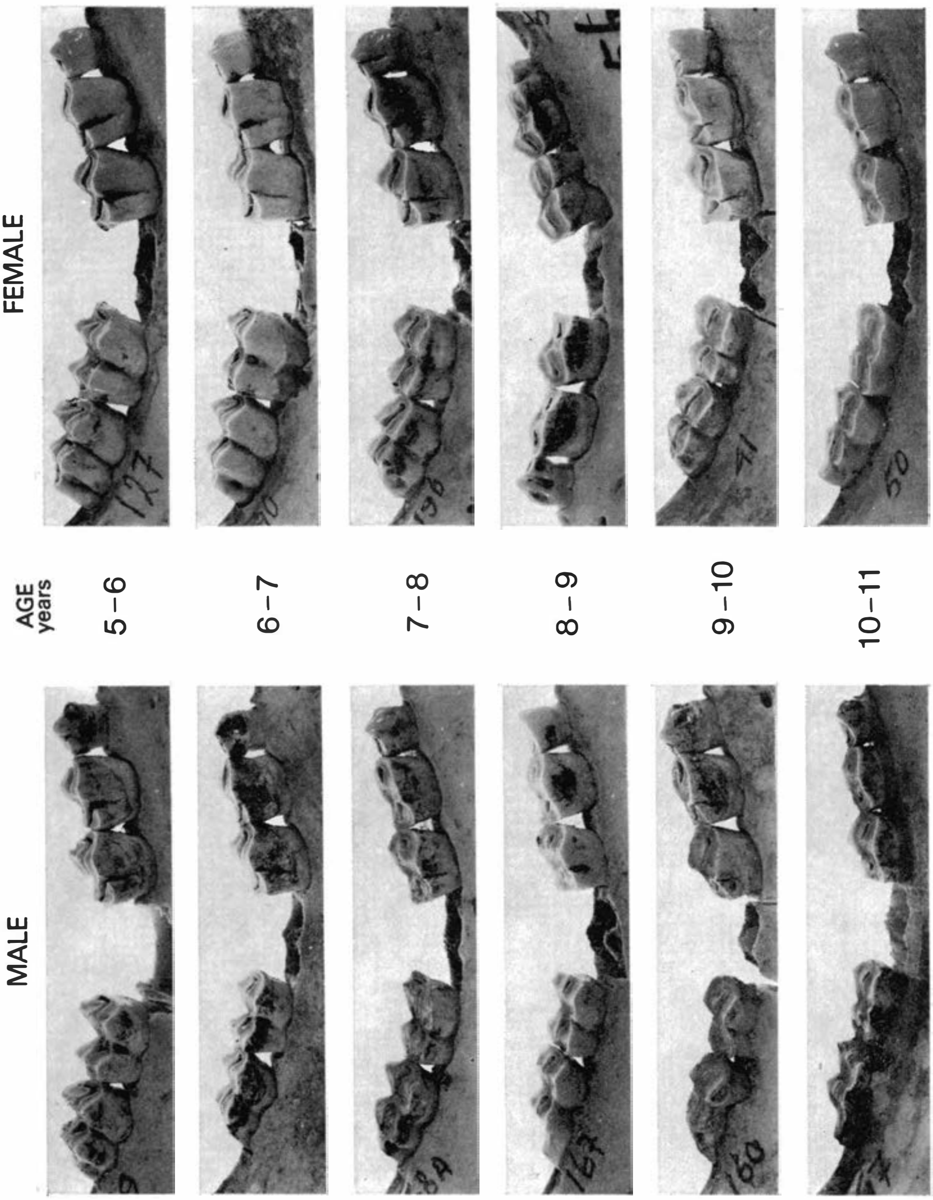

Fig. 6b. (3)

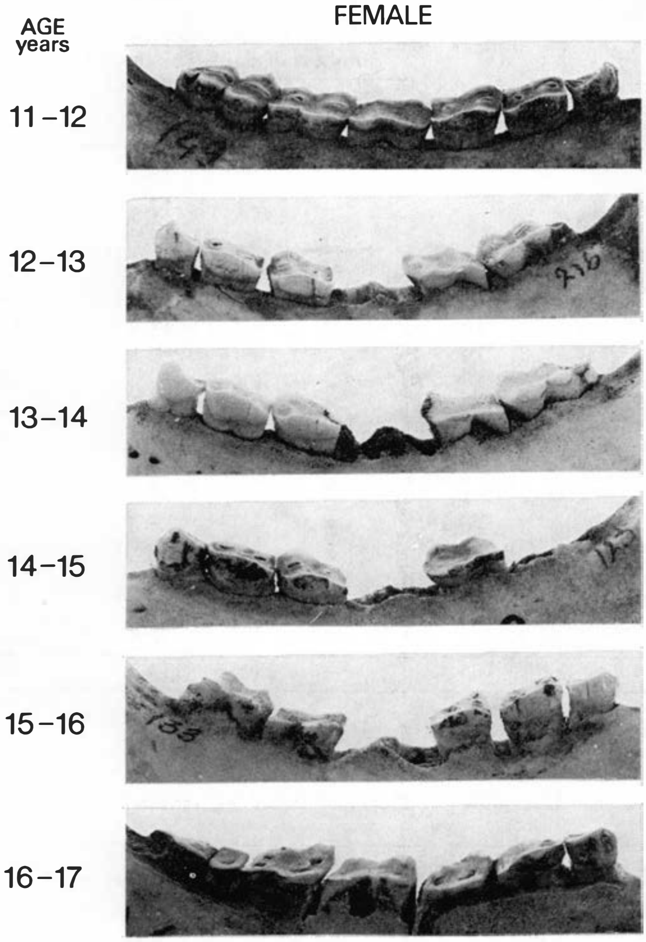

Fig. 6b. *Course of wear of molariform teeth in the lower jaw, buccal view.*

period December–April. This is confirmed by the dark winter rest line as the last deposited cementum in most of the m-1's of the mandibles (Fig. 8). This high percentage of males without antlers shows that the searched area at Kapp Lee is used by reindeer as a winter grazing area. This is confirmed by observations (Oosterveld 1975). It was impossible to determine the season of death for females in the same way. Pregnant females shed their antlers after calving (Oosterveld 1975) (the end of May/beginning of June). It is unknown when barren females shed their antlers.

In this study longitudinal sectioning as indicated in Fig. 4 was found to be the best method for counting the number of annuli in the m-1. Like Miller (1974a), I found that annuli are easier to count near the root tips.

Because of the good relationship between age and number of annuli in the

Table 4.

Age distribution of 244 skulls and jaws of Svalbard reindeer.

	numbers of skulls/jaws found			
age in years	♂	♀	unknown sex	Total
0–1	–	–	14	14
1–2	–	–	17	17
2–3	–	–	14	14
3–4	6	4	9	19
4–5	9	1	11	21
5–6	14	2	14	30
6–7	16	2	9	27
7–8	16	2	8	26
8–9	17	3	5	25
9–10	16	2	5	23
10–11	10	2	3	15
11–12	1	2	3	6
12–13	–	2	–	2
13–14	–	1	–	1
14–15	–	1	–	1
15–16	–	1	–	1
16–17	–	1	1	2
Total	105	26	113	244

Table 5.

Life table for males of Svalbard reindeer.

x	d_x	kd_x	kl_x	$1000q_x$	kL_x	kT_x	e_x*)
3–4	6	57	1000	57	972	4390	4.39
4–5	9	86	943	91	900	3418	3.6
5–6	14	133	857	155	790	2518	2.9
6–7	16	152	724	210	648	1728	2.4
7–8	16	152	572	266	496	1080	1.9
8–9	17	162	420	386	339	584	1.4
9–10	16	152	258	589	182	245	1.0
10–11	10	95	106	896	58	63	0.6
11–12	1	10	10	1000	5	5	0.5

mean expectation of life after 3rd year: 2.08 yr.

* x = age in years
d = number of deaths
l = number surviving from one age class to the next
q_x = mortality rate
L = number of animals alive between age x and age x + 1
T = total number of animals x age units beyond age x
e = expectation of life ($e_x = T_x/l_x$)
k = constant determining the size of the hypothetical cohort, here 1000.

Table 6.

Life table for females of Svalbard reindeer.

x	d_x	kd_x	kl_x	$1000q_x$	kL_x	kT_x	e_x*
3–4	4	154	1000	154	923	5875	5.86
4–5	1	39	846	46	827	4952	5.9
5–6	2	77	807	96	768	4125	5.1
6–7	2	77	730	105	692	3357	4.6
7–8	2	77	653	116	614	2665	4.1
8–9	3	115	576	200	519	2051	3.6
9–10	2	77	461	167	422	1532	3.3
10–11	2	77	384	201	346	1110	2.9
11–12	2	77	307	251	268	764	2.5
12–13	2	77	230	335	192	496	2.2
13–14	1	39	153	261	133	304	2.0
14–15	1	38	114	333	95	171	1.5
15–16	1	38	76	500	57	76	1.0
16–17	1	38	38	1000	19	19	0.5

mean expectation of life after 3rd year: 3.22 yr.

* notation as for table 5.

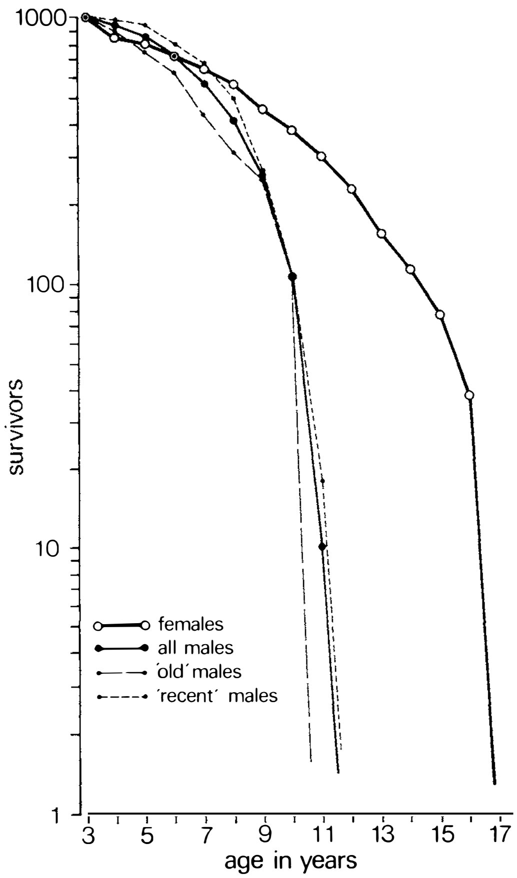

Fig. 7. *Survivor curves for the Svalbard reindeer.*

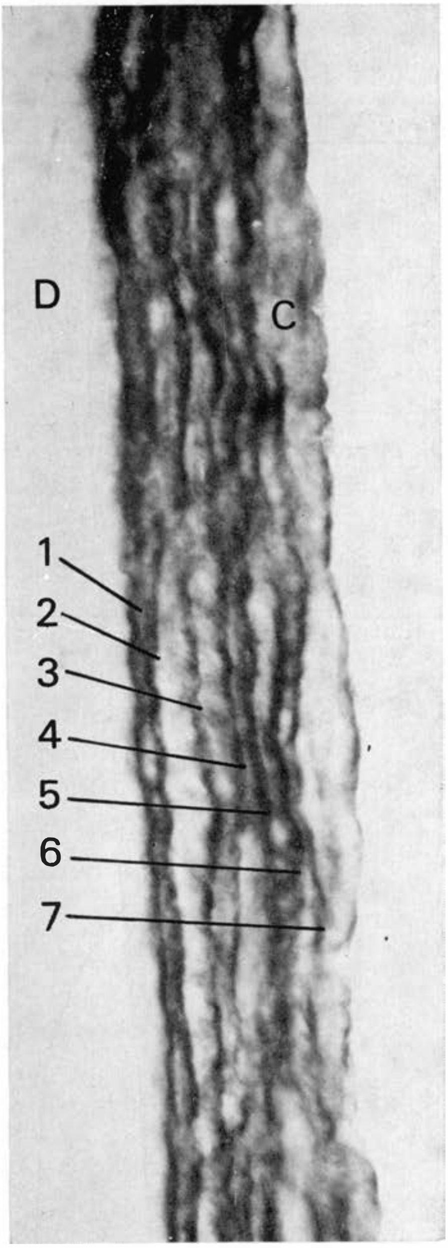

Fig. 8. *Longitudinal section through the first molar of a 7¾-year-old reindeer. Note the dark rest line as the last deposited cementum, indicating the 8th winter of life. D: dentine; C: cementum; 1–7: annuli.*

cementum of the m-1 (Table 3), counting these annuli was considered very reliable for determining the age of Svalbard reindeer. MILLER (1974a) reports the same for the Barren ground caribou. I agree with REIMERS and NORDBY (1968) that the incisor is more readily interpretable, as the annuli are more widely spread and homogeneous, and should be used in preference to the m-1 whenever available.

Prerequisite of this study was an unbiased sample of skulls and jaws from the reindeer population at north-west Edgeøya. This assumption can be considered valid because the area was searched as well as possible by the Netherlands' Spitzbergen Expedition. 54% of the specimens could be sexed. This part consisted of 80% males and 20% females. From composition counts (NORDERHAUG 1970; OOSTERVELD 1975) it appeared that these percentages are not according to reality. Therefore, the collection was not an unbiased sample with regard to the sex ratio, and only seperate time–specific life tables and survivorcurves for males and females are meaningful (Tables 5, 6 and Fig. 7). To be of use, this kind of tables and curves should meet two requirements: 1. The population must be stable over a longer period, and 2. the age–specific mortality must be constant from year to year (CAUGHLEY 1966). It is impossible to find out if the first requirement is met because there is a lack of sufficient counts on population size, and the period in which these skulls and jaws accumulated, is unknown. Whether or not the second requirement holds, cannot be determined. Possibly, the age–specific mortality has not been constant, as appears from the difference between the survivor curves of 'old' and 'recent' males (Fig. 7). For that purpose skulls and jaws of all males were divided in an 'old' and a 'recent' group (Table 7). As characteristics of 'old' were taken: small cracks in bone and teeth, a grey appearance of the bone and sometimes covered with lichens; the remainders of fibres and tendons, the absence of small bone cracks, and a white and fatty appearance were used as criteria for 'recent'. With a X^2-test it appeared that the age distribution of both groups differed significantly ($P<0.05$). However, this significance is doubtful by subjectivity of the criteria.

The cohort to which a dead individual belonged, cannot be determined because the time (year) of death is unknown. Therefore, life tables constructed from skull and jaw remains data are composed of synthetic rather than real,

Table 7.

Classification of males in «old» and «recent», based on the disintegration of the skulls and jaws.

age in years	number of ♂ skulls/jaws 'recent'	'old'	total
3–4	1	5	6
4–5	2	7	9
5–6	8	6	14
6–7	7	9	16
7–8	10	6	16
8–9	14	3	17
9–10	9	7	16
10–11	5	5	10
11–12	1	0	1
	Total 57	48	105

cohorts (SPINAGE 1972). MURPHY and WHITTEN (1976) studied population numbers, age–sex composition and the male age structure of Dall sheep (*Ovis dalli*) in Alaska in 1972. Their results demonstrated that the age structure had not been stationary over the past several years. Differences in numbers in each age-class were due to variation in initial sizes and mortality rates of the cohorts. Because their data showed that this variation in initial size and age–specific survivorship between actual cohorts can be considerable, they conclude that the predictive value of a life table, based on skull and jaw remains, is necessarily limited. It can represent no more than a generalization of the age structure of a population over an indefinite time span (SPINAGE 1972; MURPHY and WHITTEN 1976). This also applies to the life tables of males and females of the Svalbard reindeer. As the study of MURPHY and WHITTEN (1976) shows, data as the initial size and mortality rate of the actual cohorts comprising the population, will give more valid information about the population dynamics. Further research is necessary to collect these data for the Svalbard reindeer.

Nevertheless, the presented life tables provide useful data. There is a difference in mortality rate and therefore in maximum life span between males and females of Svalbard reindeer: females live five years longer (Tables 5 and 6, Fig. 7). This phenomenon is known for a number of herbivores. On the St. Kilda Islands the Soay sheep (*Ovis sp*) lives in circumstances comparable to the Svalbard reindeer: no predation, no interspecific food competition and little evidence of extensive mortality due to disease or parasites (GRUBB 1974). Rams have a shorter life span than ewes, due to a higher mortality in late winter (GRUBB and JEWELL 1974). At that time food intake of the rams and ewes is insufficient for their metabolism, but in rams the reserves are mainly used up in rutting time when they show a very clear reduction in time spent on grazing; there appears to be no opportunity to recover condition in the immediate post-rut period (GRUBB 1974; GRUBB and JEWELL 1974). Early spring is therefore a critical period and rams are less fit to survive this period than ewes, especially in case of a delayed spring. LOWE (1969) found that the highest natural mortality in Red deer (*Cervus elaphus* L.) on the isle of Rhum occurs in late winter, due to malnutrition. Stags are most susceptible to it, probably on account of their inability to recover the condition they lost during the rut in September/October. ESPMARK (1964a, 1964b) ascertained that the dominant male of semi-domesticated reindeer (*Rangifer tarandus ssp*) stops grazing during the rut and that its weight was 23% lower at the end of the winter than before the rut; weights of inferior bulls were 3–12% lower and females kept their weights in the same period. In Newfoundland caribou (*Rangifer tarandus caribou var. terraenovae*), BERGERUD (1971) found that adult males died at higher rates than females. Neither legal hunting nor predation could account for this difference. Although many factors contribute to this greater mortality, the most important factor appears to be a high mortality of males during the rut (BERGERUD 1971). The Svalbard reindeer is not subject to predation or hunting which could explain the difference in mortality rate between males and females. Therefore, a loss of condition in males due to a reduction in time spent on grazing during the rut, resulting in a lower fitness in late winter, could be an important factor contributing to the greater mortality of males. The higher number of skulls of males without antlers (87.5 %) can support this theory. Duration and severity of the winter, together with vegetation growth and food availability in the preceding summer will affect this mortality. Death from fighting during the rut as in Newfoundland caribou (BERGERUD 1971), could also contribute to the higher mortality rate of males.

In mountain sheep (*Ovis dalli* and *Ovis canadensis*), GEIST (1971) found indications that rams are sexually mature at younger ages in a population with low density as a result of their good condition. Consequently they can earlier obtain a dominant position and they die at a younger age. A high population density is correlated with a slower growth, a later sexual maturity and a higher survival in the first years. So the population density influences the survival of the rams by dominance relations. GEIST (op. cit.) supposes that this relation exists in reindeer too. Perhaps the better survival of 'recent' males (from a larger population) than of 'old' males of Svalbard reindeer on Edgeøya is an indication for it (Fig. 7).

In the Newoundland caribou, the sex ratio of adults was in favour of females and it appeared that the mortality of adults was the dominant factor responsible for it since there was no evidence of mortality in recruits that might alter their 50:50 ratio to the adult figure (BERGERUD 1971). From counts (NORDERHAUG 1970; OOSTERVELD 1975) the sex ratio of adult Svalbard reindeer on Edgeøya appeared to be slightly in favour of males. The survivor curves (Fig. 7) seem to point to a surplus of adult females. This difference in adult sex ratio could be the consequence of a too small number of specimens on which the survivor curve of females is based, or of a higher mortality of females than males before the third year. Perhaps the counts are also inaccurate with regard to the adult sex ratio. Adult sex ratio in relation to calf and adult mortality is a critical parameter for the evaluation of the present model. An attempt should be made to follow the survival of a specific cohort of Svalbard reindeer before a detailed comparison with mortality schedules in other wild herbivores is warranted.

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Undersøkelser av praktærfuglen *(Somateria spectabilis)* på Svalbard

(Studies of the King Eider (*Somateria spectabilis*) in Svalbard)

AV MAGNAR NORDERHAUG[1]

Innhold

Abstract

Data collected on the King Eider (*Somateria spectabilis*) on Norsk Polarinstitutt's ornithological expeditions in Svalbard (mainly 1965–1970) are summarized. Fig. 2 outlines the present breeding distribution, while Figs. 3 and 4 give data on productivity and egglaying/hatching. The average breeding period for four clutches was 23 days. Comparison is made of egg sizes and weights for the Common Eider and the King Eider in Figs. 5–7 and Table 1. Brief remarks are given on behaviour on the breeding site and population size.

Finally, the life cycle of the King Eider is discussed (Fig. 9), and information given on existing moulting areas in Svalbard (Fig. 10).

Innledning

Selv om praktærfuglen (*Somateria spectabilis*) kan regnes som en karakterfugl for Svalbard, finnes den bare spredt og forholdsvis sparsomt på øygruppen. Sin vesentlige utbredelse har den i de vestre fjorder og kyststrøk på Spitsbergen, men også herfra er kjennskapet til praktærfuglen sparsomt.

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Fig. 1. *Praktærfugl-hann på hekkeplassen. Spitsbergen, juni 1977.*
Male King Eider in breeding area. Spitsbergen, June 1977.

Photo: M. NORDERHAUG

Hoveddelen av vår viten om praktærfuglen på Svalbard frem til ca. 1960 er sammenfattet av LØVENSKIOLD (1964). Senere har ulike informasjoner kommet til. I sammenheng med Norsk Polarinstitutts biologiske virksomhet på Svalbard (særlig 1965–1970) har en del ornitologiske undersøkelser berørt også praktærfuglen. Materialet fra disse undersøkelsene er i det følgende stilt sammen med øvrige, tilgjengelige data. I forbindelse med dette arbeidet vil jeg rette en særlig takk til cand. real. K. HAGELUND for verdifull bistand under Norsk Polarinstitutts ærfuglundersøkelser.

Utbredelse og biotoputvalg

Selv om praktærfuglen kan sees spredt over det meste av Svalbard i sommerhalvåret, er hekkefunn gjort innenfor forholdsvis begrensede områder. Fig. 2 gir en grovoversikt over artens hekkeområde på Svalbard ut fra tilgjengelige informasjoner (publiserte og upubliserte) frem til 1977. I tillegg kommer et ikke nærmere lokalisert hekkefunn fra Hinlopenstretet.

I motsetning til ærfuglen (*Somateria mollissima*) hekker praktærfuglen for det

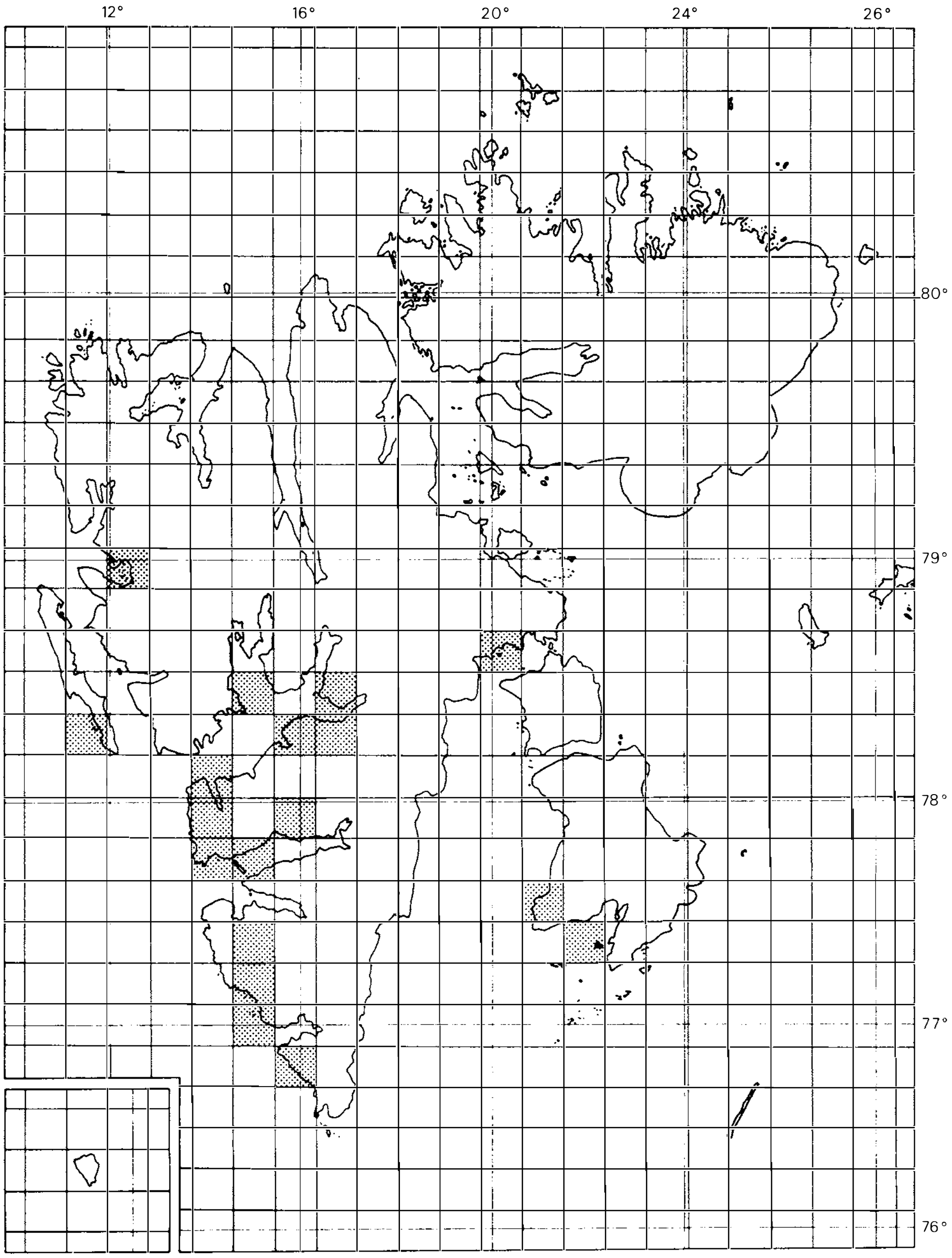

Fig. 2. *Hekkeområder for praktærfugl på Svalbard.*
King Eider breeding areas in Svalbard.

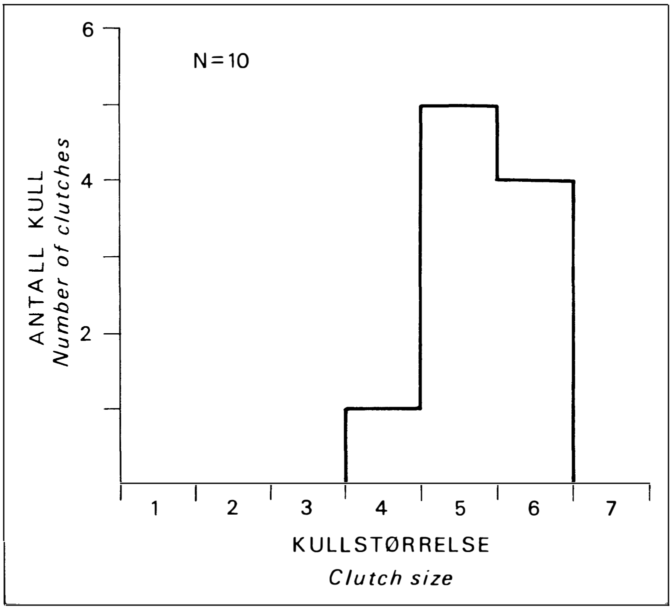

Fig. 3. *Registrert kullstørrelse (egg) for praktærfugl på Svalbard, 1969–1971.*
King Eider clutch size (eggs) observations in Svalbard, 1969–1971.

meste enkeltvis og tildels langt fra kysten. Tørre, vidstrakte flyer og slettepartier, gjerne med innslag av ferskvannsdammer, ser ut til å utgjøre de viktigste hekkeområdene. Et reirfunn fra Chamberlindalen i 1967, i en høyde av 120 m over havet (NORDERHAUG 1969), bør nevnes. Arten hekker imidlertid også nær kysten og kan da etablere seg i ærfuglkolonier. På slike steder kan forøvrig praktærfugl-hanner sees i par med vanlige ærfugl-hunner. Ett tilfelle av bastardering er kjent fra Svalbard i 1969 (K. HAGELUND pers. comm.).

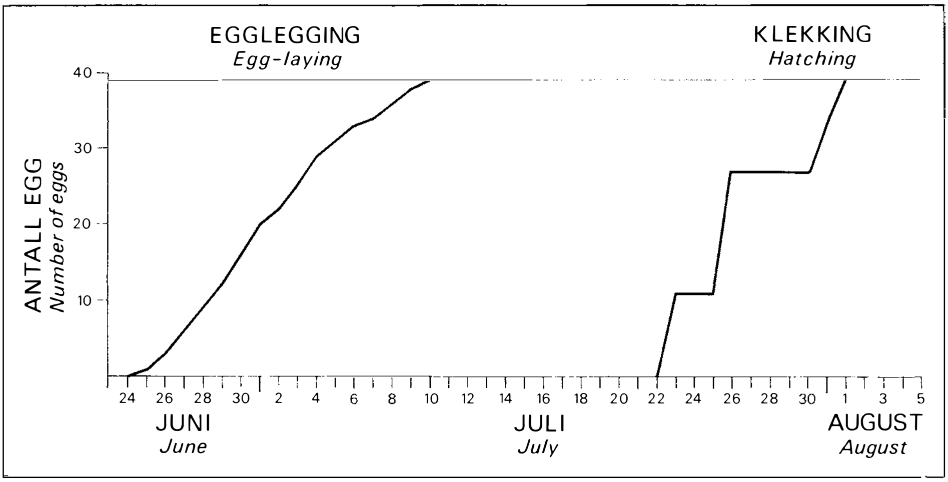

Fig. 4. *Eggleggings- og klekkingsforløp for syv praktærfuglkull, Svalbard 1969.*
Egg-laying and hatching processes for seven King Eider clutches in Svalbard in 1969.

Kullstørrelse

For årene 1969–1971 er det registrert kullstørrelse for ti eggkull fra Svalbard (Fig. 3). Gjennomsnittlig kullstørrelse var 5,3. Registrert kullstørrelse for 17 ungekull fra Svalbard (publiserte og upubliserte data) var 4,0.

Hekkeforløp

I fire undersøkte reir (1969) var rugetiden henholdsvis 23, 23, 23 og 24 døgn. Rugingen ble påbegynt når nest siste egg var lagt. I samtlige fire tilfeller hadde ungen forlatt reiret det 25de døgnet etter at rugingen var påbegynt.

På grunnlag av en gjennomsnittlig rugetid på 23 døgn ble hekkeforløpet beregnet for syv par i 1969 (med en total eggproduksjon på 39 egg, der enten eggleggingsforløpet eller klekkingsforløpet var kjent). Resultatet fremgår av Fig. 4.

Eggdimensjoner. En sammenligning mellom praktærfugl og ærfugl

Hos praktærfuglen er eggenes lengde, bredde og vekt markert mindre enn hos ærfugl. Dimensjonsdata for egg av de to artene fremgår av Figs. 5–7. Materialet bygger på upubliserte informasjoner fra Svalbard i 1960-årene og frem til 1971.

Tabell 1 gir en sammenstilling av materialets størrelse og variasjon for de to artene.

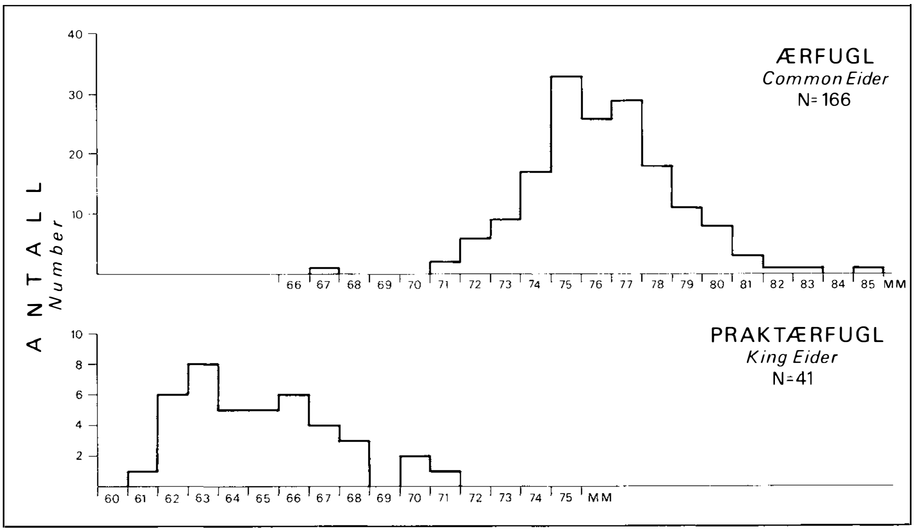

Fig. 5. *Variasjon i egglengde hos ærfugl og praktærfugl på Svalbard.*
Egg length variations for Common Eider and King Eider in Svalbard.

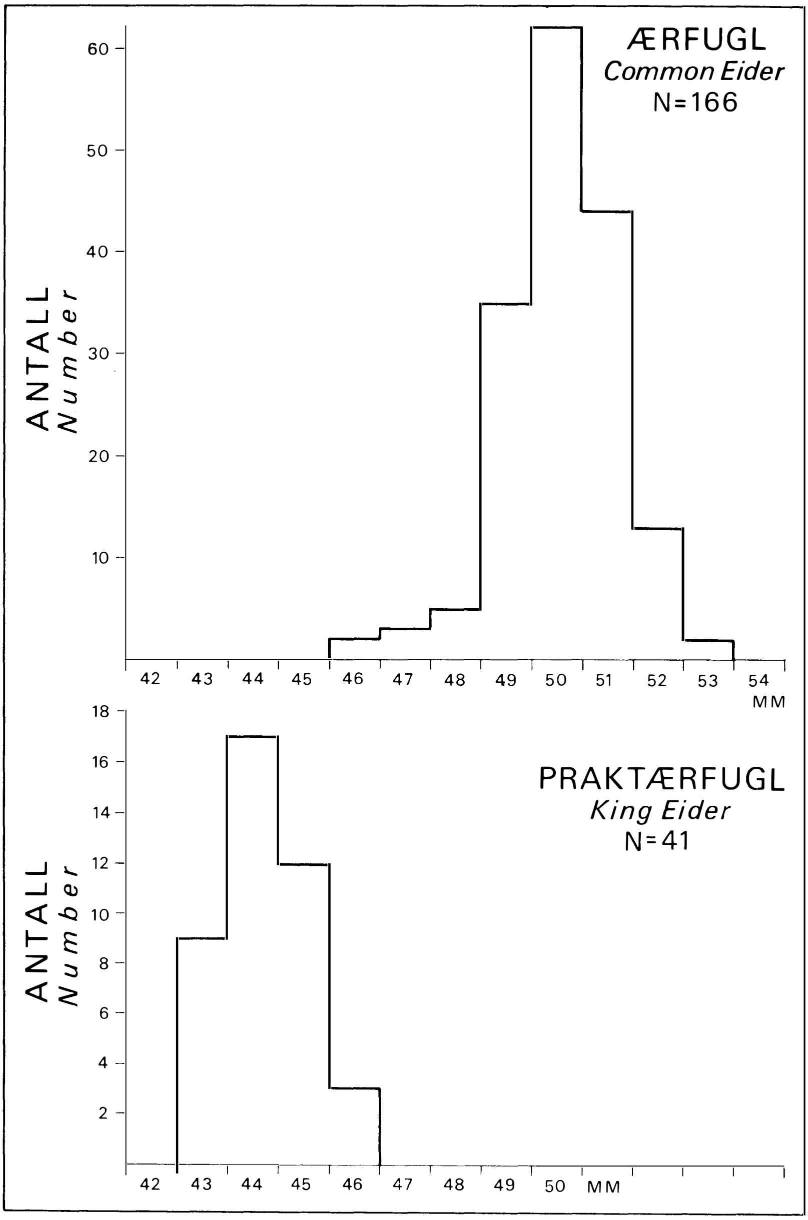

Fig. 6. *Variasjon i eggbreddı hos ærfugl og praktærfugl på Svalbard.*
Egg width variations for Common Eider and King Eider in Svalbard.

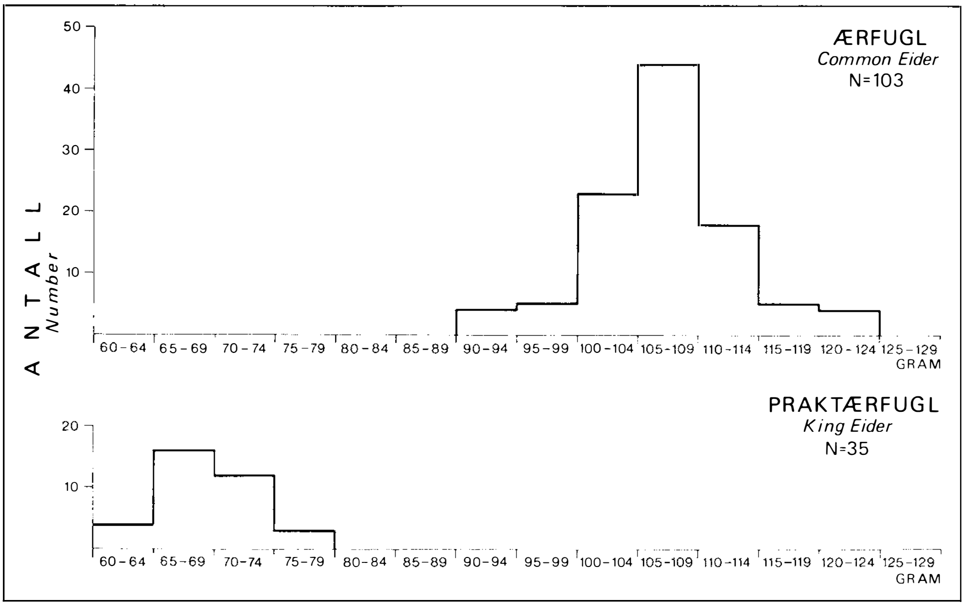

Fig. 7. *Variasjoner i eggvekt hos ærfugl og praktærfugl på Svalbard.*
Egg weight variations for Common Eider and King Eider in Svalbard.

Tabell 1

Sammenligning av mål og vekt på egg av praktærfugl og ærfugl på Svalbard*
Comparison of egg measurements and weights* for the King Eider and the Common Eider in Svalbard

		Somateria spectabilis	*Somateria mollissima*
Lengde (Length)	Gjennomsnitt (Mean)	65.3 mm	76.2 mm
	Maksimum (Maximum)	71.2 mm	83.1 mm
	Minimum (Minimum)	61.9 mm	67.2 mm
	N	41	166
Bredde (Width)	Gjennomsnitt (Mean)	44.7 mm	50.2 mm
	Maksimum (Maximum)	46.9 mm	53.3 mm
	Minimum (Minimum)	43.0 mm	46.2 mm
	N	41	166
Vekt (Weight)	Gjennomsnitt (Mean)	69.0 g	106.7 g
	Maksimum (Maximum)	78.0 g	121.0 g
	Minimum (Minimum)	62.0	91.0 g
	N	35	103

* *Eggvekter fra første uke etter egglegging.*
Weights from first week after egglaying.

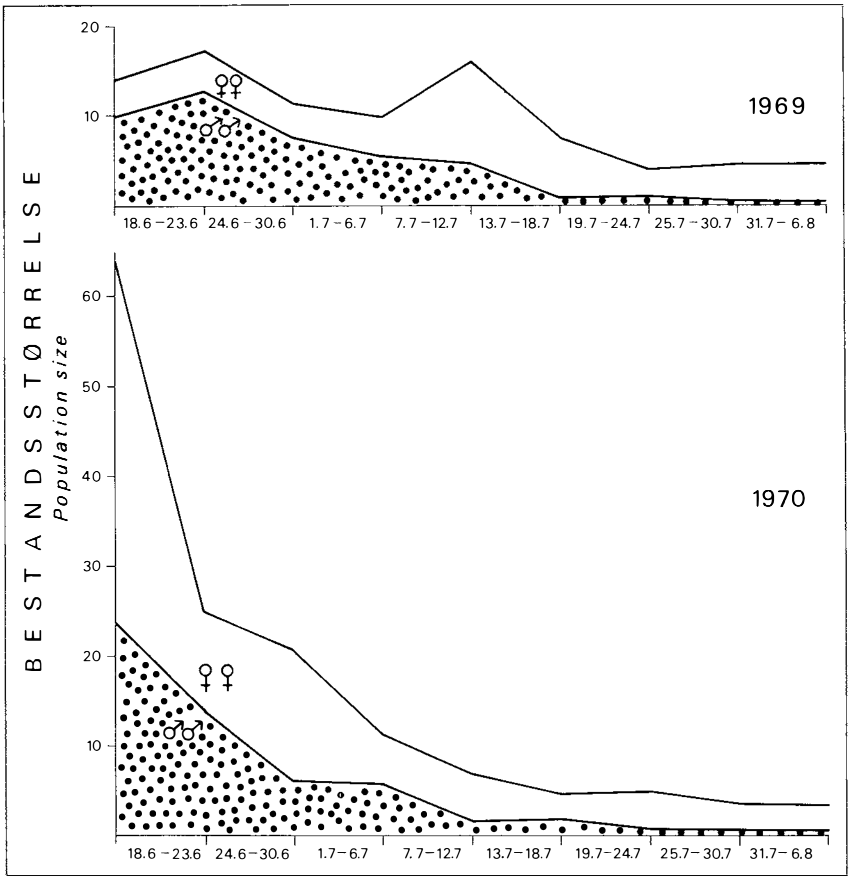

Fig. 8. *Endringer i bestandsstørrelse og bestandssammensetning i løpet av sommeren hos praktærfugl, Kapp Linné, Svalbard, 1969 og 1970.*
Population size and composition changes during the summer at Kapp Linné, Svalbard, 1969 and 1970.

Bemerkninger vedrørende praktærfuglens adferd på hekkeplassen

I eggleggingstiden og den første tiden etter at rugingen er påbegynt, oppholder hannen seg ved reiret eller i nærliggende ferskvannsdam. I den perioden hannen oppholder seg ved reiret, fjerner den seg til bens når noen nærmer seg, for så å ta til vingene. Hunnen trykker normalt, men forlater reiret om inntrengeren kommer for nær. I begynnelsen av rugetiden forlater hunnen oftest reiret ved å ta direkte til vingene og fly lavt over bakken et godt stykke. På dette punkt avviker hun fra ærfuglhunner i samme område, som normalt går (eller flyr) bare 5–20 m bort ved forstyrrelse. Senere i rugetiden trykker hunnen hardere og synes i større utstrekning å forlate reiret gående ved forstyrrelser. Hannene forlater rugeplassen gradvis, slik tilfellet også er hos ærfuglen på Svalbard (HAGELUND og NORDERHAUG 1975). Se forøvrig Fig. 8.

Før mytetrekket tar til samler også praktærfuglhannene seg litt etter litt i grupper nær rugeplassen. Ved et av reirene der bare hunnen kunne sees, ble hun skremt og fløy til nærmeste dam, der flere hanner oppholdt seg. Hannene søkte umiddelbart hunnen for kurtise, men ble da stadig bortjaget av en enkelt hann, sannsynligvis maken, som dernest fulgte hunnen på land og la seg ved siden av reiret da hun gjenopptok rugingen. Under opphold i ferskvannsdammer nær rugeplasser, fremkaller hannene en svært karakteristisk, trillende kurring, helt forskjellig fra vanlige ærfuglhanners lyd.

Bemerkninger vedrørende bestandsforhold

Regionale bestandsundersøkelser for praktærfugl er ikke foretatt på Svalbard. I 1968 ble det imidlertid gjort en bestandsberegning i Nordenskiöld Land, på kysten fra Kapp Linné til Kapp Martin (45 km). Undersøkelsen foregikk ved bruk av kikkert til fots 21–22 juni, d.v.s. på det tidspunkt da praktærfuglene parvis søker til land for å påbegynne eggleggingen (kfr. Fig. 4). I dette området ble det registrert totalt 248 individer, hvorav 170 var hanner og 78 hunner. Samtlige hunner inngikk i etablerte par. De overskytende hannene (92 stk.) var med ett unntak hanner i praktdrakt.

Et rimelig bestandsanslag (1968) for kystslettene fra Kapp Linné (Isfjorden) til Kapp Martin (Bellsund), skulle etter dette ligge på omkring 80–100 par. Årsaken til det betydelige overskuddet av hanner er ikke kjent. Disse hannene

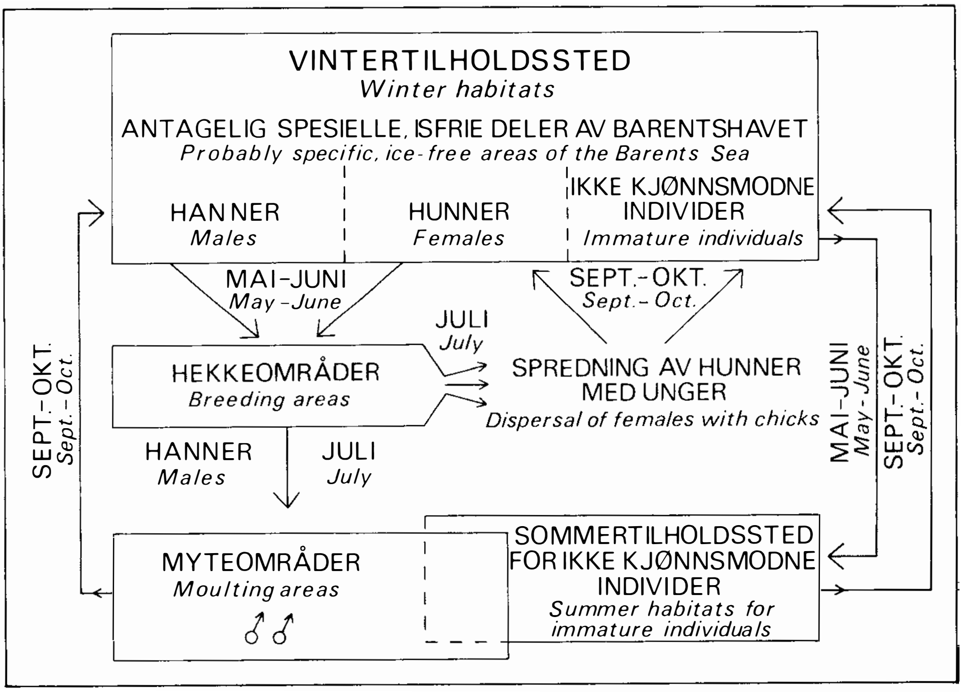

Fig. 9. *Sannsynlige hovedtrekk ved praktærfuglens livssyklus.*
Sketch showing the probable life cycle of the King Eider.

forekom i mindre grupper, fordelt langs det meste av kysten, og etter alt å dømme dreide det seg om hanner som ennå ikke var etablert i par.

I ett område (Kapp Linné) ble endringene i populasjonsstørrelse og sammensetning gjennom sommersesongen studert i årene 1969 og 1970. Fra de to sesongene foreligger daglige registreringer over henholdsvis 48 og 45 døgn (foretatt av K. HAGELUND). Resultatene fremgår av Fig. 8. Særlig registreringene fra 1970 synes klart å vise hvordan et ikke ubetydelig antall praktærfugler i den første delen av juni passerer dette området på vei til hekkeplasser andre steder.

Praktærfuglens årssyklus på Svalbard

Hos praktærfuglen kan vi, som hos ærfuglen, skille ut minst tre ulike populasjonssegmenter med ulikt levesett:

— kjønnsmodne hanner
— kjønnsmodne hunner
— ikke kjønnsmodne individer.

Årssyklus for de enkelte gruppene på Svalbard er ennå ikke tilfredsstillende klarlagt, men tilgjengelige informasjoner, kombinert med den viten som finnes fra andre hold (i første rekke SALOMONSEN 1968 og USPENSKIJ 1972), gjør det mulig å sette opp følgende grovskisse (se for øvrig Fig. 9):

1. *Vintertilholdssted*

Vintertilholdsstedet for Svalbard-populasjonen er ikke kjent da ringmerkinger ikke er utført. Det er imidlertid grunn til å tro at den tilbringer vinteren i de sørlige isfrie deler av Barentshavet. Vinteren 1966/67 (frem til mai/juni) var praktærfuglen for eksempel ganske tallrik rundt Bjørnøya (NORDERHAUG 1969). Muligens finnes også praktærfugler fra Svalbard i de nordnorske kyststrøk. Særlig i Finnmark er den ganske tallrik (HAFTORN 1971).

I hvilken utstrekning de ulike populasjonselementer nytter ulike områder vinterstid, er ikke kjent.

2. *Vårtrekk*

LØVENSKIOLD (1964) angir at trekkinformasjonene fra Svalbard er sparsomme, men nevner at det foreligger et par april-observasjoner. Til Kapp Lee (Edgeøya) ankom arten 7. juni 1969 (DE KORTE 1972). Ved Bjørnøya såes 115 individer 29 mai 1970 (WILLIAMS 1971), hvorav 60% var hunner og ca. 40% unghanner. Bare en utfarget hann ble sett. Så sent som 1 juni såes flokker av praktærfugl i de fleste av buktene på Bjørnøya.

Gjennomgående er det grunn til å regne med at populasjonen i løpet av mai–juni beveger seg nordover til Svalbards kystfarvann, der pardannelse og spredning til hekkeområdene finner sted.

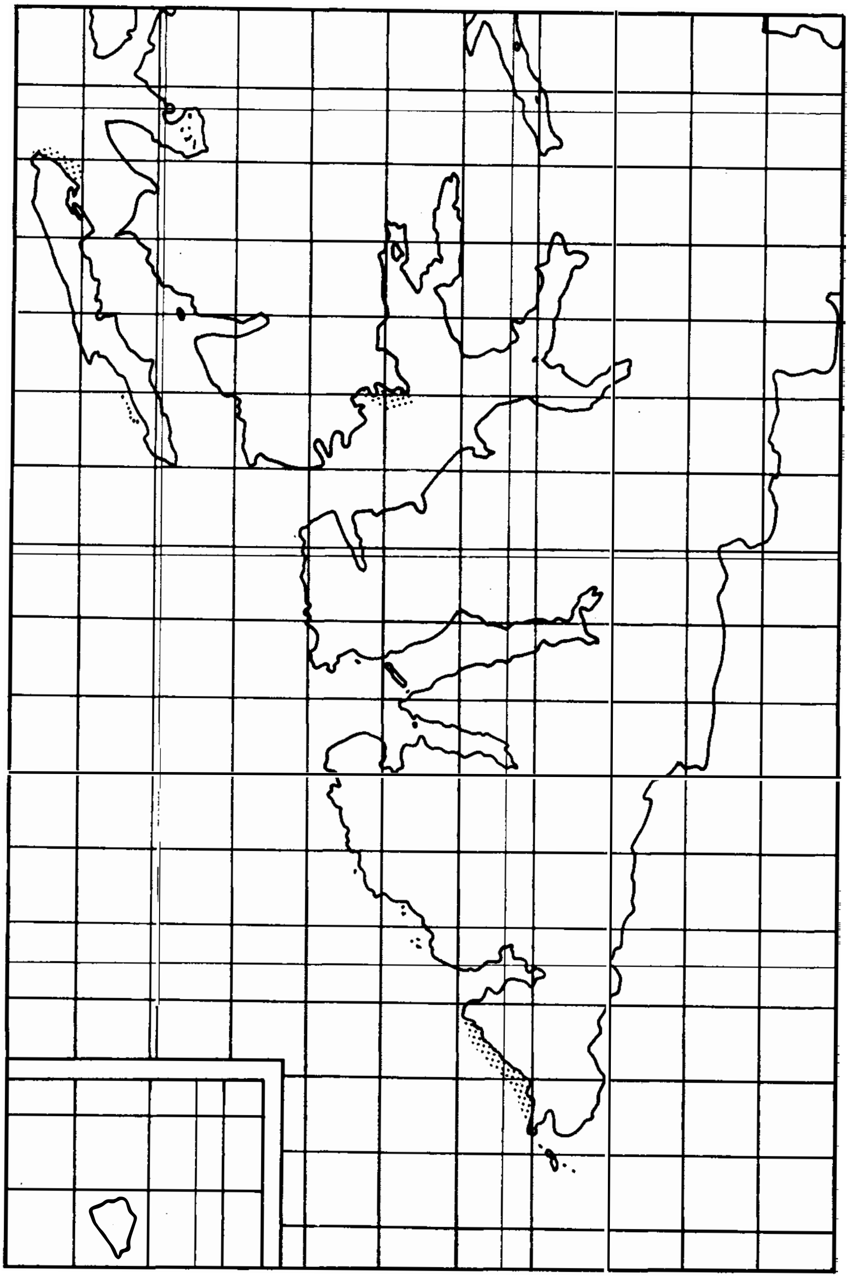

Fig. 10. *Kjente myteplasser for praktærfugl på Svalbard.*
Known moulting areas for King Eiders in Svalbard.

3. *Hekkeperioden*

Det fremgår av beskrivelsen foran at praktærfuglen på Svalbard danner par i løpet av juni. Etter at rugingen er påbegynt i slutten av juni, forlater hannene litt etter litt hekkeplassene for å myte. Etter klekkingen drar sannsynligvis hoveddelen av hunnene med unger gradvis og spredt sørover langs Spitsbergens vestkyst.

4. *Myteperioden*

Fra SALOMONSEN (1968) er praktærfuglens tradisjonelle mytetrekk i området Vest-Grønland/De nordkanadiske øyer godt dokumentert. Et tilsvarende, lokalt vandringsmønster finner sannsynligvis sted hos den lille praktærfuglbestanden på Svalbard. Fra Svalbard er det hittil kjent tre områder som sannsynligvis må regnes som myteplasser for praktærfugl (hovedsakelig hanner i ulike aldersklasser) (Fig. 10). Det ene, og sannsynligvis viktigste, er kystområdene sør for Hornsund (i den nåværende Sør-Spitsbergen nasjonalpark), oppdaget av LØVENSKIOLD (1954). I dette området fantes minst 1800 individer, hovedsakelig hanner, i første uke av august 1964 (HEINTZ og NORDERHAUG 1966). Av et utvalg på 200 var ca. to tredjedeler praktærfugl.

5. *Høsttrekk*

Som påpekt av LØVENSKIOLD (1964) foreligger få direkte observasjoner av høsttrekk av praktærfugl, men han omtaler S. KRISTOFFERSEN's observasjoner fra Sørkapp-området i 1924, da sørtrekket nådde en topp i september. Etter alt å dømme skjer sørtrekket gradvis og til dels spredt i løpet av september–oktober. USPENSKIJ (1972) understreker imidlertid at borttrekket nok varierer noe fra år til år, avhengig av når isdannelse finner sted.

Fig. 11. *Praktærfugl (3 par) på hekkeplassen før egglegging er påbegynt. Spitsbergen, juni 1977.*
King Eider (3 pairs) in breeding area before egglaying has started. Spitsbergen, June 1977.
Photo: M. NORDERHAUG

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Observations on the snow petrel *(Pagodroma nivea)* in Vestfjella, Dronning Maud Land*

By Lauritz Sømme[1]

Contents

Abstract

Colonies of the snow petrel (*Pagodroma nivea*) were observed at several localities in Vestfjella, Dronning Maud Land, in January and February 1977. The colonies varied in size from only a few to more than one thousand occupied nests. The nests were situated under large stones on mountain slopes, mostly facing north and northwest. The chicks were hatched by the middle of January, and the parents remained on the nests until between 20 and 25 January. Some observations were made on flying habits and feeding. Beside snow petrel, the South polar skua (*Catharacta maccormicki*) and a few pairs of the Antarctic petrel (*Thalassoica antarctica*) were breeding in Vestfjella. Some specimens of Wilson's storm petrel (*Oceanites oceanicus*) were observed.

Introduction

The snow petrel (*Pagodroma nivea*) is one of the most common birds of the Antarctic. It breeds on several of the Antarctic islands and at numerous localities on the Antarctic Peninsula and continent (Watson 1975). The nests are found on mountain slopes, and although the birds are entirely dependent on marine food, some of the colonies are more than 300 km from the coast.

The snow petrel is known from several of the mountain areas of Dronning Maud Land. Dalenius and Wilson (1958) considered it most likely that the species breeds in Borgmassivet, and colonies were found in Mühlig-Hofmannfjella and Wohlthatmassivet at a distance of 180 to 250 km from the ocean

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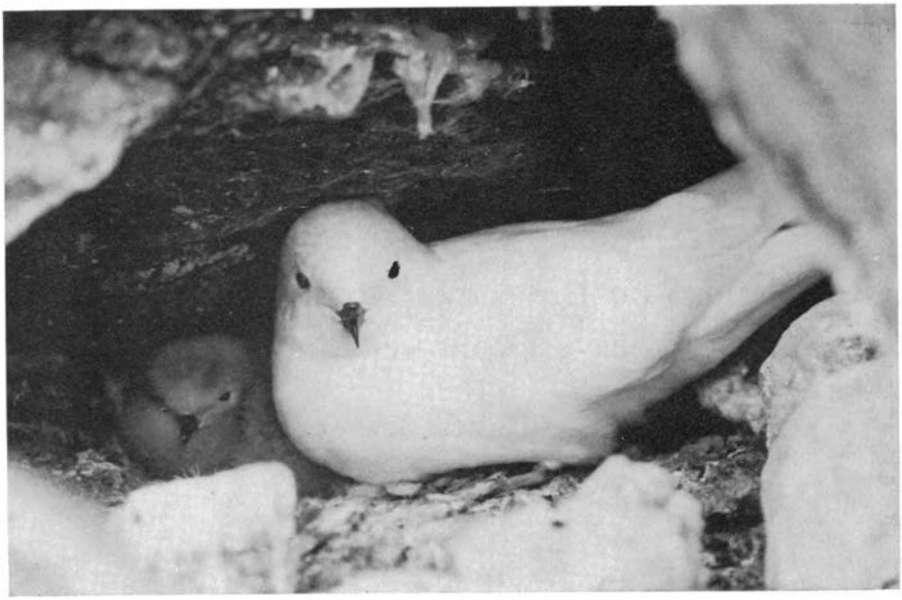

Fig. 1. *Snow petrel with young on nest under stones in Vestfjella.*

(KONOVALOV 1962). AUTENBOER (1964) discovered colonies of the snow petrel in Sør-Rondane, and LØVENSKIOLD (1960) reported that T. S. WINSNES found colonies 200 to 300 km from the coast in Orvinfjella. The discovery of snow petrels in Heimefrontfjella and Tottanfjella (ARDUS 1964; BOWRA et al. 1966) are of special interest, since the distance to the ocean exceeds 300 km. Several thousand birds were breeding in these mountains during the summer of 1963–64. Both in Heimefrontfjella (ARDUS 1964) and in Orvinfjella (LØVENSKIOLD 1960) chick mortality was very high, probably because the long distance to the coast made it difficult for the parents to obtain enough food.

Normally the snow petrels arrive at their breeding sites from September to November (WATSON 1975). The nest itself is only sand or gravel, and is placed under some overhanging rocks or under large stones or boulders. This is an important protection against the South polar skua (*Catharacta maccormicki*). Each snow petrel nest contains one egg only, and the chick usually hatches in the first part of January. The young are brooded for an additional 8 to 10 days (Fig. 1) before the adults leave the nests in search of food. This consists mainly of smaller fishes, cephalopods and krill.

Snow petrels were observed at several localities in Vestfjella by members of the Norwegian Antarctic Expedition 1968–69 (T. S. WINSNES pers. comm.). As participant in the Norwegian Antarctic Expedition 1976–77 visiting Vestfjella from 18 January to 10 February 1977, I had the opportunity to make further observations on the occurrence and biology of this species.

The Vestfjella are situated at about 13° to 15°W and 73° to 74°S. They include several mountains, arranged in three groups and isolated from each other by surrounding glaciers. The most southern group is Utpostane (Fig. 3) while the central group include several large mountains, like Steinkjeften, Kjakebeinet, Muren, Pagodromen and Skansen (Fig. 2). Northeast of the central group there are several small nunataks and two large mountains named Plogen and Basen. The distance from Utpostane to the central group is about 30 km, and from the central group to Plogen and Basen about 60 and 80 km, respectively. Vestfjella are relatively close to the coast, but the Riiser-Larsen ice-shelf outside the coast is more than 100 km wide. The distance that snow petrels have to fly from their breeding sites to open water will be in the order of 120 to 150 km.

A map of Vestfjella has been published by Norsk Polarinstitutt, based on air photographs taken in 1950–52, and on triangulation carried out by the Norwegian Antarctic Expedition 1968–69. The same expedition carried out geological investigations (HJELLE and WINSNES 1970). Most of the mountains are composed of basaltic lava, but a large part of Utpostane are made of gabbro. In both kinds large parts of the mountain slopes are covered by screes, with several areas of large rocks forming hollows suitable for snow petrel nests.

Distribution of snow petrels in Vestfjella

Snow petrel nests are used year after year, and are easily recognized by layers of guano gathering around the opening. By studying the mountain sides through binoculars it was thus possible to estimate the number of nests present. Only part of them, however, were inhabited, and since the birds are hidden among the stones, it could only be determined at close hand whether a nest was occupied or not. In areas where the breeding sites could be reached at foot, occupied and not occupied nests were counted. Several colonies, however, were situated in steep, inaccessible mountainsides, or in mountains that could not be approached due to dangerous cracks in the surrounding glacier. In these cases the nests could only be counted from a distance, and estimates of occupied nests could not be made. Finally, difficulties were encountered in estimating the number of birds in the largest colonies, due to lack of time. For these reasons the present study can only give an approximate estimate of the snow petrel population in Vestfjella.

Results of the counts are presented in Figs. 2 and 3. The locations of colonies are marked on the maps. When possible, the number of occupied nests are given, while a dash indicates that it was impossible to count the number of occupied nests. The total number of nests are given in parentheses.

Since the camp of the expedition in 1977 was situated by the Pagodromen mountain, the most detailed observations were done in the central part of Vestfjella (Fig. 2). The northwest slopes of Pagodromen contained a fairly large colony of snow petrels, consisting of approximately 140 occupied nests. Beside this, there were two small colonies in Pagodromen. In the slopes of Skansen, north of Pagodromen, there were several small colonies of which the largest one included 10 occupied nests. The Kjakebeinet and Steinkjeften mountains also contained several small colonies. Many of these were not

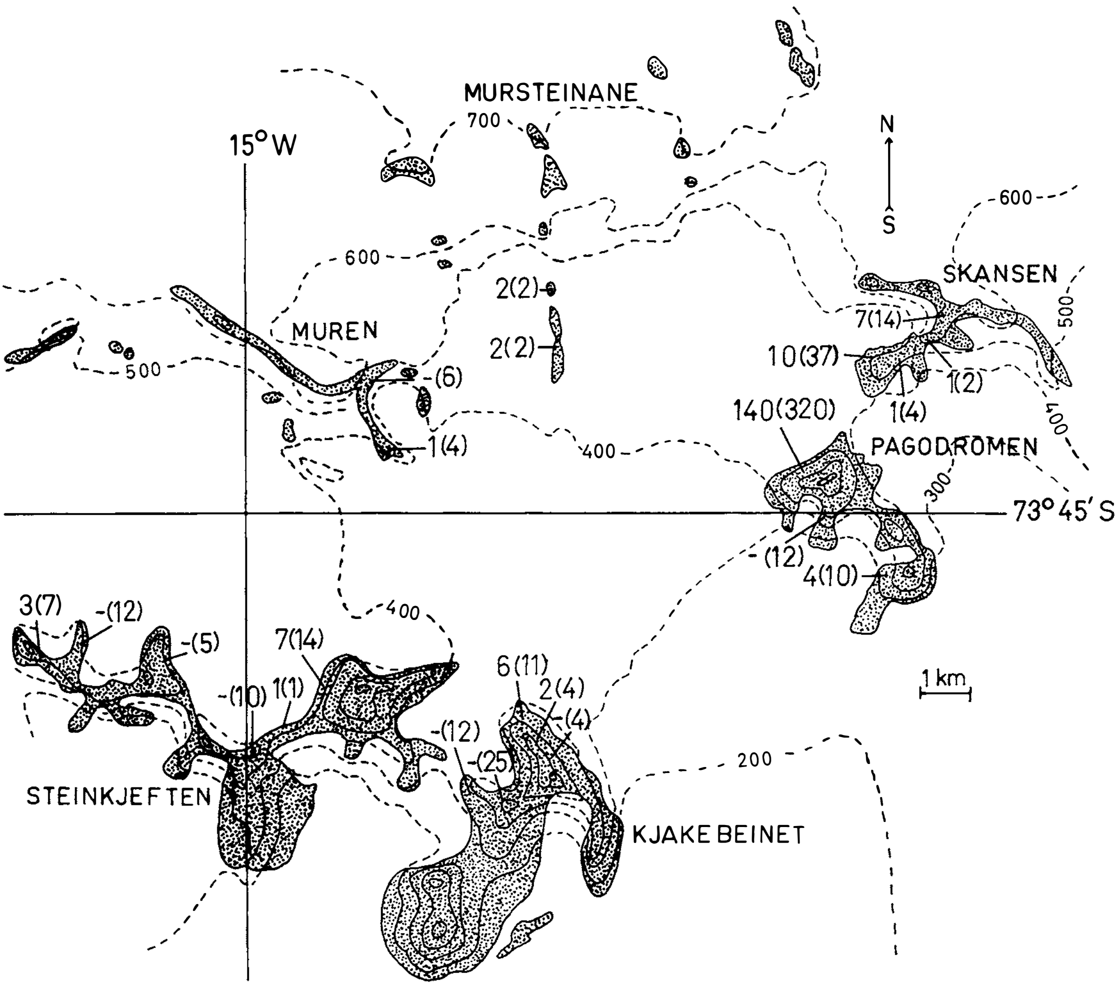

Fig. 2. *The distribution of snow petrels in the central parts of Vestfjella. Numbers of occupied nests, with total numbers of nests in brackets, are given. "A" indicates that number of occupied nests could not be counted. Vertical distance between contour lines is 100 m. The contour lines are stippled on glaciers.*

accessible, and the number of nests could only be counted from the distance. In colonies where counts could be made, each consisted of up to 6–7 occupied nests.

Most of these colonies were situated on northern and northwestern slopes, which are the most sunexposed sides of the mountains. Some colonies were also found on northeastern slopes, but none on the southern sides of the mountains. In Muren and Mursteinane the snowfree areas mainly consist of steep southern slopes. With the exception of a few nests in Muren, situated towards southwest and southeast, no snow petrels were observed in these mountains. Finally a few occupied nests were seen on the western slopes of a small, nameless nunatak east of Muren.

At Utpostane (Fig. 3) the number of snow petrels was much larger than in

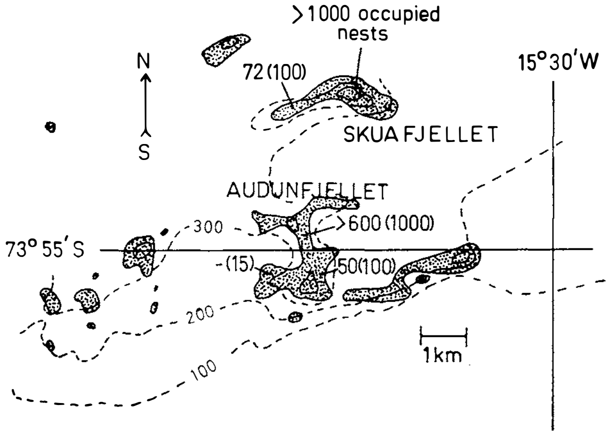

Fig. 3. *The distribution of snow petrels at Utpostane, Vestfjella. Numbers of occupied nests with total numbers of nests in brackets are given. — indicates that number of occupied nests could not be counted. Vertical distance between contour lines is 100 m. The contour lines are stippled on glaciers.*

the central group of Vestfjella. Large colonies were seen in those parts of Utpostane which are composed of gabbro. These mountain sides are more decomposed and less steep than the basalt rocks, and are covered by large stones, forming numerous hollows. Relatively large accumulations of sand and gravel between the stones make these hollows very suitable as snow petrel nesting sites. In some places a large number of nests were found on a small area, like in Audunfjellet, where 70 nests were seen on an area of approximately 100 m^2. Fortyfive of these nests were occupied, and assuming a similar density in the rest of the colony, it was estimated to include approximately 600 nests in use. On a small area in Skuafjell, 72 of 100 nests were found to be inhabited. The colony occupied a large part of the northern slope of this mountain, and it is reasonable to assume that it consisted of more than 1000 occupied nests. Beside the large colony, two smaller ones were found in Audunfjellet, but no snow petrels were observed on a nameless basaltic nunatak east of Audunfjellet. The small nunataks in the western and southern parts of Utpostane were not investigated.

The Plogen and Basen mountains in the northern part of Vestfjella were not visited during the present study. During the expedition in 1968, however, snow petrels were observed both at these and at two other northern localities (T. S. Winsnes pers. comm.). The snow petrel is thus found all over Vestjella.

Biological observations

When the first observations of snow petrels were made in Vestfjella on 20 January during the present study, the chicks had hatched, but the adults still remained on their nests (Table 1). Adults were also observed on some of the nests on 24 January, but at this time the young were mostly left to themselves. Out of 22 nests in Pagodromen, kept under daily surveillance from 28 January, adults were only present in two of them on this date, but in none on 31 January. These observations show that the general exodus of adult birds in central parts of Vestfjella took place between 20 and 25 January during

Table 1.

No. of nests with adults and chicks, and with chicks only, observed at various localities in Vestfjella during January and February 1977

Date	Locality	No. of nests: Adults and chicks	No. of nests: Chicks only
20 January	Pagodromen	8	1
22 January	Skansen	6	1
23 January	Pagodromen	7	4
24 January	Pagodromen	2	9
26 January	Audunfjellet	2	45
28 January	Muren	0	6
28 January	Pagodromen	2	20
30 January	Skansen	1	8
31 January	Pagodromen	0	22
2 February	Kjakebeinet	1	8
3 February	Skuafjell	3	69
4 February	Steinkjeften	0	10

1977. In other parts of the Antarctic the adult snow petrels usually leave the chicks from 10 to the end of January (Bowra et al. 1966).

At Audunfjellet and Skuafjellet in Utpostane the first observations were made after the exodus of the adult birds. Both on 26 January and 3 February almost only chicks were present on their nests in these mountains.

When the chicks are left to themselves the adults are flying back and forth to the ocean in search of food. At Pagodromen the arrival of birds could be observed at all times of the day. Observations of this kind were made early in the morning, as well as after midnight, but the highest frequency of arrivals took place between 5 and 9 p.m. The birds always reached Pagodromen from higher altitudes, and sailed in large turns down the mountainside. In the vicinity of the nest, the turns became smaller until the bird landed and disappeared between the stones. The adult was always welcomed by loud sounds from the chick.

During feeding, which was observed in several instances, the young is given regurgitated food. The mouth of the adult is opened as high as possible, and the food floats down into the lower beak. The beak of the chick is introduced sideways in the adult's beak, and by shivering movements the food is taken up in the lower beak of the chick. While the adult is regurgitating more food, the chick continuously shrieks for more by a series of "chirp, chirp, chirp" in rapid succession.

The feeding only lasted a short time, and the adults were frequently observed to leave their nests within 15 to 30 minutes. They always flew upwards along the mountainside, and continued in large circles above the mountain top. At high altitudes, barely visible to the eye, they often remained circling above the mountain for several minutes before leaving in the direction of the ocean.

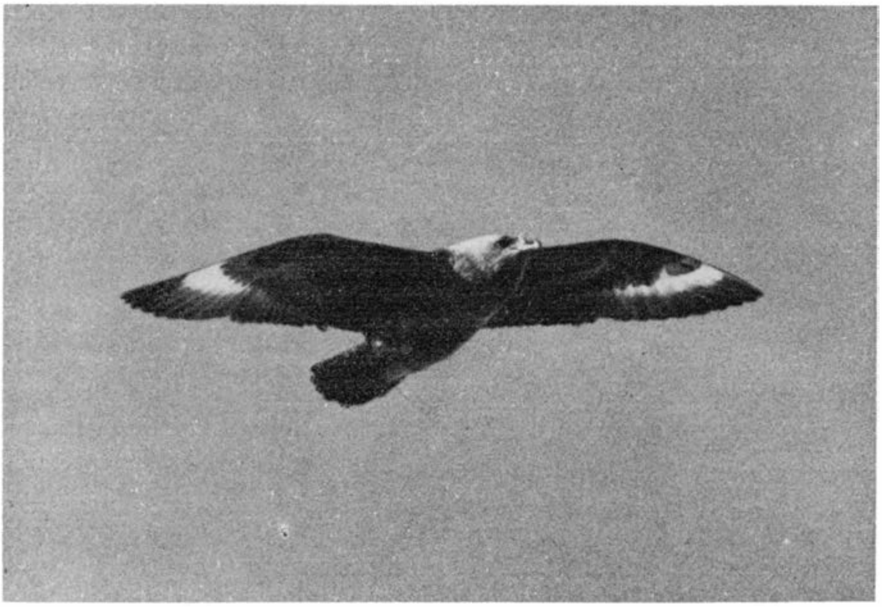

Fig. 4. *South polar skua at Utpostane, Vestfjella.*

As was the case with arrivals, departures too were most frequent in the evening and at night. Between 8 and 10 p.m. groups of 12 to 15 birds could be seen circling above Pagodromen before departing alone or two or three together.

The young are thus mostly left to themselves. When alarmed they spit furiously for a distance of up to 1 m. The spit has an unpleasant smell, and turns red when the chick has recently been fed on krill. The group of 22 chicks kept under observation was growing, and no mortality occurred before the expedition left on 10 February. At this time the chicks were still covered by gray down. This is in agreement with observations by other authors, and the young are usually not ready to leave their nests before the middle of March or still later (WATSON 1975).

Other birds in Vestfjella

Beside snow petrels, the South polar skua (*Catharacta maccormicki*) (Fig. 4) was found to be common in Vestfjella. The species was also observed at several localities by the expedition in 1968–69 (T. S. WINSNES pers. comm.). In 1977 four skuas were frequently seen around the camp at Pagodromen, and on one occasion eight birds were gathered in the early morning. At Utpostane two breeding pairs were found, each with one chick. Large amounts of feathers, bones and skulls around the nesting place of the skuas, clearly showed that adults as well as chicks of snow petrel are their main food source. A total of ten skuas were seen at Utpostane, and it is likely that more than two pairs were breeding.

One specimen of Wilson's storm petrel (*Oceanites oceanicus*) was seen at Utpostane, and one at Pagodromen. The species was also observed by the expedition in 1968–69, both in the central mountains, and at three more northern localities (T. S. WINSNES pers. comm.). It seems likely that Wilson's storm petrel is breeding in Vestfjella, but this needs confirmation. Four pairs of the Antarctic petrel (*Thalassoica antarctica*) on the other hand, were found breeding at Pagodromen in 1968 (T. S. WINSNES pers. comm.), and one pair at the same locality in 1977.

Acknowledgements

I am most grateful to Mr. T. S. WINSNES for permission to publish his observation on snow petrels during the Norwegian Antarctic Expedition 1968—69. I would also like to thank my colleagues from the Norwegian Antarctic Expedition 1976—77, Mr. A. HJELLE, Mr. H. FURNES and Dr. R. LØVLIE for valuable help during the present study. The investigation was carried out with financial support from the Norwegian Ministry of the Environment.

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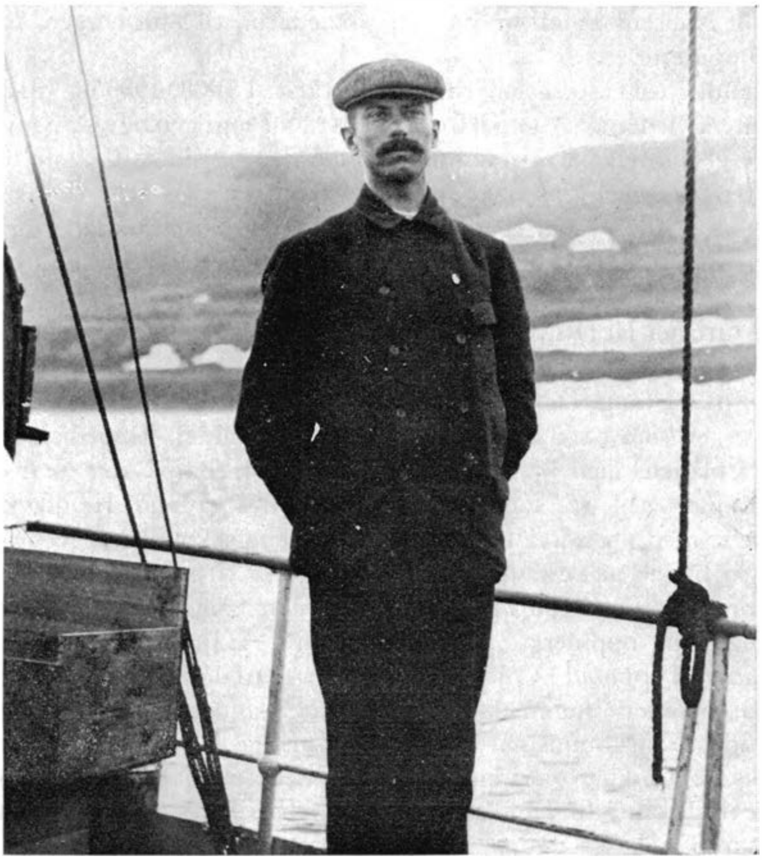
Gunnar Holmsen

AV OLAV LIESTØL



Statsgeolog GUNNAR HOLMSEN døde 25. januar 1976 i en alder av 95 år. Med ham er en av pionérene for den norske utforsking av Svalbard gått bort.

GUNNAR HOLMSEN ble født på Røros 24. november 1880. Han fikk sin videregående skolegang på Hamar Katedralskole, hvor han tok artium 1899. Etter å ha gått Krigsskolen begynte han på realfagstudiet og tok sin eksamen i 1905. Holmsen var knyttet til Norges geologiske undersøkelse så å si hele sitt yrkesaktive liv selv om han de første årene bare arbeidet for denne institusjon i sommermånedene, mens han var lærer ved Aars og Voss skole. Han arbeidet den første tiden som vanlig kartleggende geolog, men det var først og fremst kvartærgeologi, fysisk geografi og praktiske problemer i forbindelse med disse disipliner som sto hans hjerte nærmest.

HOLMSENS befatning med Svalbard må man si var relativ kort, men den etterlot ikke desto mindre flere skrifter og artikler, bl.a. hans doktoravhandling om jordbunns-is. Man må heller ikke glemme hans mer populære bok fra den tid, «Spitsbergens Natur og Historie», den første i sitt slag fra denne del av landet.

Noe av hensikten med å dra nordover var for HOLMSEN å skaffe seg erfaring i hva som skjer med løsmasser i et arktisk klima. Man ville da bedre kunne forstå flere av de kvartærgeologiske fenomener i Norge, mente han. I sin søknad til Fridtjof Nansens Fond for sin siste ekspedisjon til Spitsbergen, fremhever han nettopp dette.

Han deltok i tre ekspedisjoner til Spitsbergen: I 1908, 1909 og 1912. På den første som var ledet av ADOLF HOEL, deltok han som geolog. Oppgaven var å annektere et kullfelt på østsiden av Grønfjorden og siden å samle fossiler til Universitetet. Ferden gikk med agnbåten «Holmengrå», først til Grønfjorden og videre til Virgo Havn. Is hindret to forsøk på å komme videre til Woodfjorden hvor man hadde planlagt å samle forsteninger. I stedet måtte man snu og foreta innsamlinger i området rundt Isfjorden.

I 1909 utrustet HOLMSEN sin egen ekspedisjon. Planen var å undersøke kullforekomstene mellom Isfjorden og Van Mijenfjorden. Han fikk leiet en kutter, «Maria», på 24 tonn. Den førte bare seil, og det ble vel den siste ekspedisjon til Spitsbergen som bare brukte dette fremdriftsmiddel. Ekspedisjonen i land gikk etter planen, men hjemreisen var dramatisk. Båten kom ut i en storm ved Hornsund og ble så skadet at den måtte settes på land. Heldigvis kom de i forbindelse med noen hvalbåter som skaffet dem skyss til Norge.

Holmsen hadde på sine vandringer lagt merke til alle de forskjellige frostjordsformer som finnes på Spitsbergen. Spesielt kom jordbunnsisen til å tiltrekke seg hans oppmerksomhet. Hans kone, HANNA RESVOLL HOLMSEN, hadde under et opphold i Colesdalen lagt merke til de store forekomster av slik is der. Han planla derfor en ekspedisjon dit for å studere dette fenomen nøyere. På den tid ble jordbunnsisen diskutert av mange forskere uten at man fikk noen skikkelig brukbar teori om dens dannelse. Colesdalen viste seg å være et utmerket studieområde. Her kom HOLMSEN ved sin systematiske gransking til at jordbunnsis ikke er dannet ved overleiringer av grus og jord. En meget viktig ting han fant ut var at isen ikke var særlig gammel og således ikke en rest fra en tidligere glasiajon som enkelte forskere mente. HOLMSEN kunne påvise at den lå under den marine grense og deler av den under et nivå svarende til den postglasiale varmetid. Han kom derfor til den konklusjon at isen måtte være dannet in situ ved frysing av vann nede i jorden, men han kom ikke inn på hvorledes denne frysing egentlig foregår. Dette har da senere vist seg å være en meget komplisert mekanisme som man ennå ikke har riktig oversikt over.

Man kunne kanskje si at HOLMSEN var like meget geograf som geolog. Han interesserte seg for så mange aspekter innenfor disse fag, men det var som nevnt først og fremst de løse jordlag som kom til å beskjeftige ham mest. De fleste av de over 160 nummer i hans bibliografi behandler da også slike emner. Det er ikke plass i denne artikkel til å gå inn på alle hans aktiviteter, men man kunne kort nevne noen, bl.a. hans undersøkelse av «setene» i Østerdalen, et senere meget omdiskutert problem, og arbeidet med norske myrer som opptok ham i mange år. Geoteknikk må heller ikke glemmes, spesielt leirfall og studier av leire som byggegrunn. I de senere år, for det meste etter han hadde gått av som statsgeolog, utførte han et stort arbeid med en kvartærgeologisk kartlegging av landet i målestokk 1:250 000. Han arbeidet med dette helt til han nærmet seg 90, og ble ferdig med i alt seks blad. Før vi fikk et eget vannkontor ved Norges geologiske undersøkelse var Holmsen vår store vannekspert. Han trodde ikke mye på ønskekvisten, men sto likevel på god fot med «kvistmennene» rundt omkring på Østlandet. Han har forresten skrevet en artig artikkel om ønskekvisten i *Teknisk Ukeblad* (1948).

Som eksempel på en av hans ikke-geologiske aktiviteter, kan nevnes hans studier av begrepet snøgrense som er et uklart begrep med en masse definisjoner og meninger. HOLMSEN foreslo å bruke et områdes hypsografiske kurve og arealet av evig snø og is til å definere snøgrensen. Dette er en metode som i motsetning til de andre definisjonene ikke bygger på mer eller mindre subjektive vurderinger.

Det sto respekt av HOLMSEN's person, og han kunne ofte virke ganske morsk, i alle fall for dem som ikke kjente ham. Men de som var så heldige å arbeide sammen med ham, spesielt ute i felten, opplevde en omgjengelig person med lun humor og et vell av historier fra hans i høy grad mangesidige virke.

GUNNAR HOLMSEN var æresmedlem av Norsk Geoteknisk Forening og ridder av St. Olavs orden.

Glaciological work in 1976

(Гляциологические работы в 1976 г.)

By Olav Liestøl

Contents

Abstract

In 1976 mass balance measurements were made on three glaciers in Norway by Norsk Polarinstitutt. As the winter accumulation was large in the western part of the country, and in spite of the fact that the summer temperature was above normal, the glaciers here had a positive balance. In the central and eastern mountains the balance was negative. Mass balance measurements were carried out on two glaciers in Spitsburgen, and both showed a negative balance as in the ten previous years.

Length fluctuations of seventeen glaciers were measured; five were advancing, five retreating, and one stationary.

Аннотация

Сотрудниками Норвежского Полярного Института (Norsk Polarinstitutt) в 1976 г. был измерен вещественный баланс трех ледников в Норвегии. В результате большой зимней аккумуляции в 1975 г. в западной части страны, здешние ледники обнаружили положительный вещественный баланс несмотря на более чем нормальную летнюю температуру. В средних и восточных горах баланс оказался отрицательным. Также на двух ледниках Шпицбергена были выполнены измерения вещественного баланса, оказавшегося отрицательным, каким он остается уже одиннадцать лет.

Измерены колебания длины одиннадцати ледников, из которых наступали пять, отступали пять, тогда как стационарным остался один.

Storbreen, Jotunheimen

The snow accumulation pattern in South Norway was much like the conditions in the mass balance years of 1972–73 and 1973–74 with high figures in the west and moderate accumulation east of the watershed. The snow accumulation map published by the Norwegian Meteorological Institute

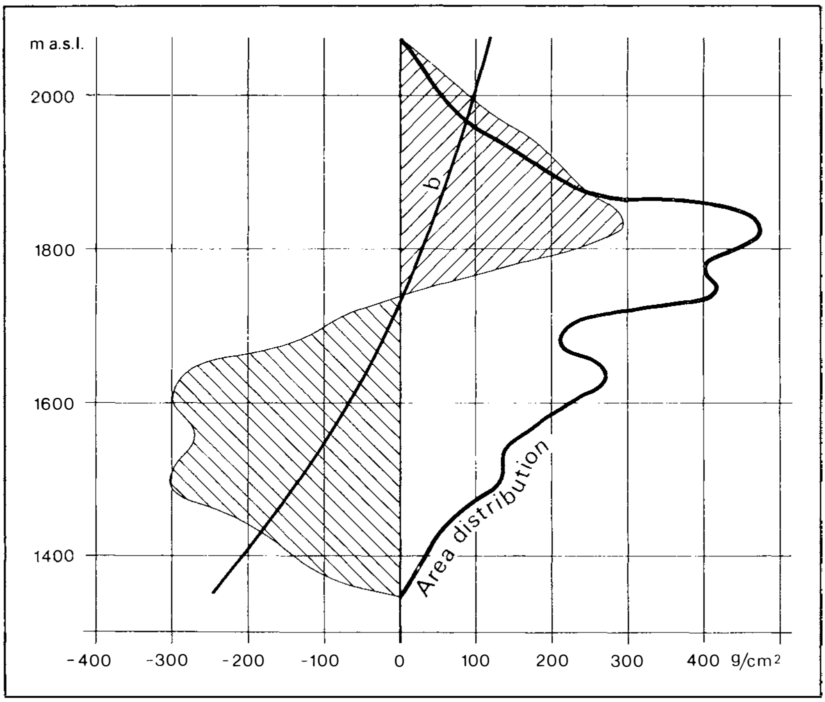


Fig. 1. *Mass balance variations on Storbreen 1975–76 in relation to height above sea level.*
Вариации вещественного баланса ледника Storbreen в 1975-76 г. в зависимости от высоты над уровнем моря.

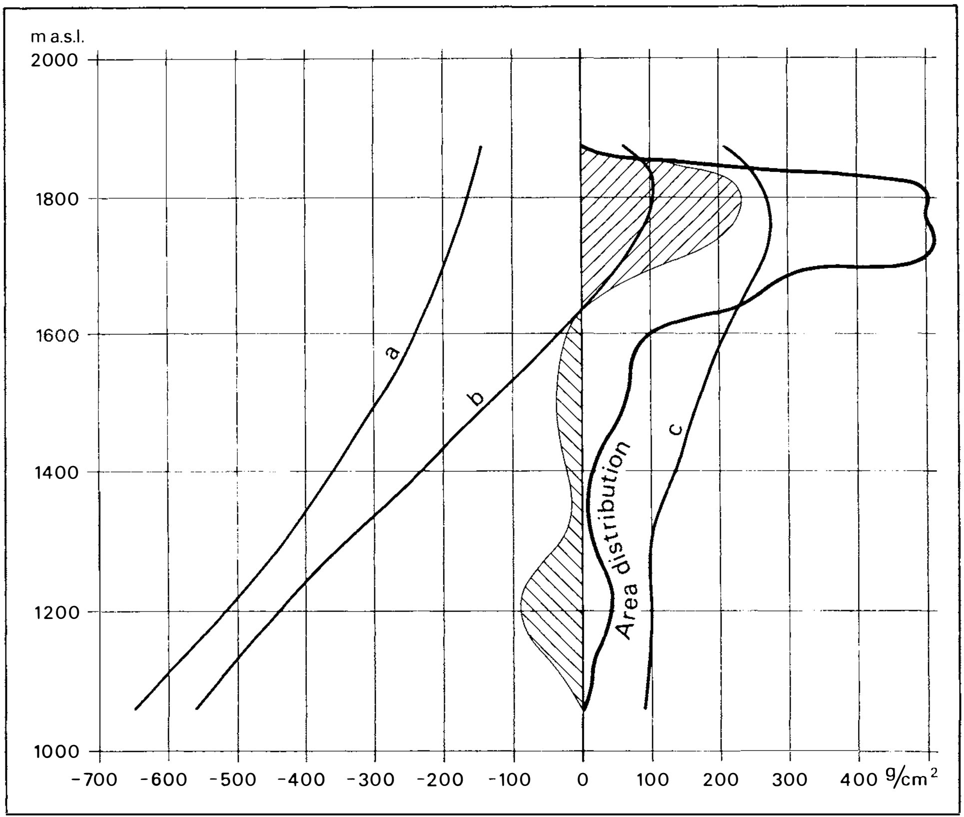


Fig. 2. *Mass balance variations on Hardangerjøkulen 1975–76 in relation to height above sea level.*
Вариации вещественного баланса ледника Hardangerjøkulen в 1975-76 г. в зависимости от высоты над уровнем моря.

showed a 150–200% above normal accumulation in the main glacier areas in the central and western part of the country.

The Storbreen glacier, located approximately on the watershed, is greatly influenced by the western climate and there is good correlation between precipitation at Storbreen and precipitation measured at meteorological stations in Western Norway. The accumulation was 181 g/cm² and this is 130% of the mean of 27 years of measurements at Storbreen. The summer of 1976 was one of the warmest in this century and the ablation was therefore also large and more than counterblanced the great accumulation. The ablation figure was 190 g/cm² and the balance thus —9 g/cm² (Fig. 1).

Hardangerjøkulen

The climatic conditions on Hardangerjøkulen were almost the same as on Storbreen. Precipitation figures for the autumn and winter at the nearby

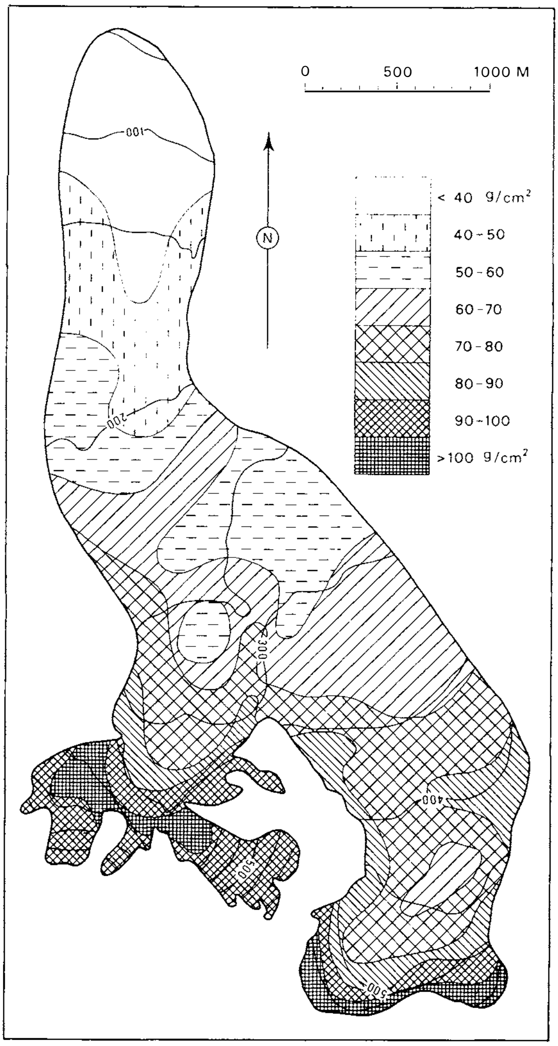


Fig. 3. *Distribution of snow accumulation on Austre Brøggerbreen 1975–76.*
Распределение снегонакопления ледикна Austre Brøggerbreen в 1975-76 г.

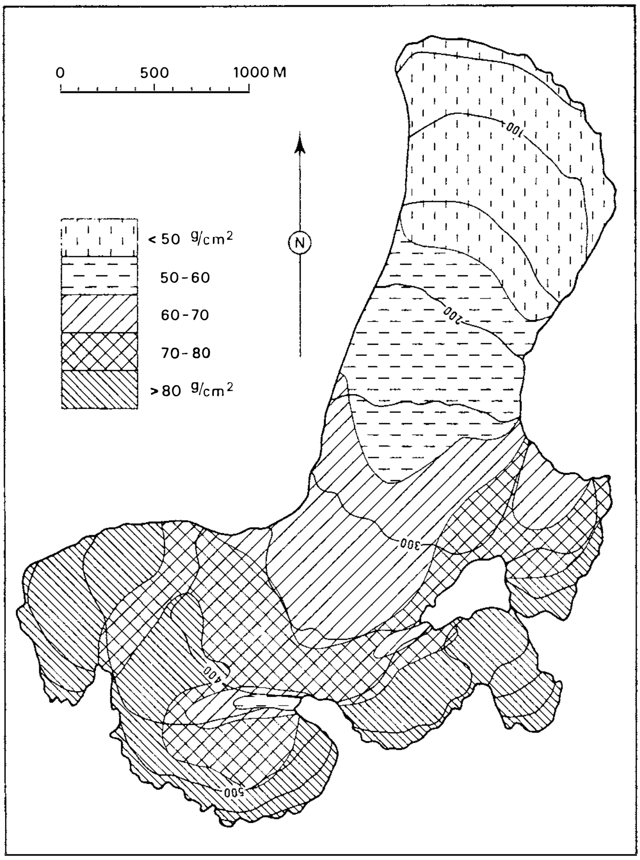


Fig. 4. *Distribution of snow accumulation on Midre Lovénbreen 1975–76.*
Распределение снегонакопления ледника Midre Lovénbreen в 1975-76 г.

Table 1

Mass balance figures in g/cm² for Austre Brøggerbreen and Midre Lovénbreen 1967-76

Year	Austre Brøggerbreen			Midre Lovénbreen		
	$\bar{c}$	$\bar{a}$	$\bar{b}$	$\bar{c}$	$\bar{a}$	$\bar{b}$
1966–67	77	142	—65			
1967–68	57	67	—10	48	51	— 3
1968–69	40	133	—93	41	125	—84
1969–70	37	91	—54	36	89	—53
1970–71	65	123	—58	70	116	—46
1971–72	95	126	—31	98	120	—22
1972–73	74	82	— 8	82	84	— 2
1973–74	75	167	—92	70	159	—89
1974–75	78	109	—31	83	104	—20
1975–6	72	117	—45	75	110	—35
1967–76	66	113	—47	67	106	—39

meteorological stations were about 170% above normal. This caused a large accumulation and as usual this also made reliable snow depth measurements difficult to obtain. Only three ablation stakes were visible above the snow surface near the top of the glacier, making it difficult to check the snow soundings on the rest of the glacier. The measurements showed an accumulation of 245 g/cm², one of the highest measured at this glacier. New stakes were drilled into the glacier to replace the lost ones, but by the last visit to Hardangerjøkulen in September, most of the stakes had disappeared again.

The ablation was large, owing to the warm summer, 230 g/cm², and nearly counterbalanced the accumulation. The net balance was +15 g/cm², but due to the measurement difficulties the uncertainty is probably ±20 g/cm².

Glaciers in Spitsbergen

In Spitsbergen mass balance studies were carried out on the glaciers Midre Lovénbreen and Austre Brøggerbreen as in the previous year. Accumulation measurements are normally much easier to carry out on the Spitsbergen glaciers than on glaciers in Norway where the snow depths are much larger. In the last years with negative balances the previous summer surface is also easy to locate, being solid ice over the greater part of the glacier area. Figs. 3 and 4 show the distribution of snow on the two glaciers. In addition to the winter snow, the superimposed ice formed in the autumn and spring is part of the accumulation. This ice is measured by core drilling at intervals up the whole glacier.

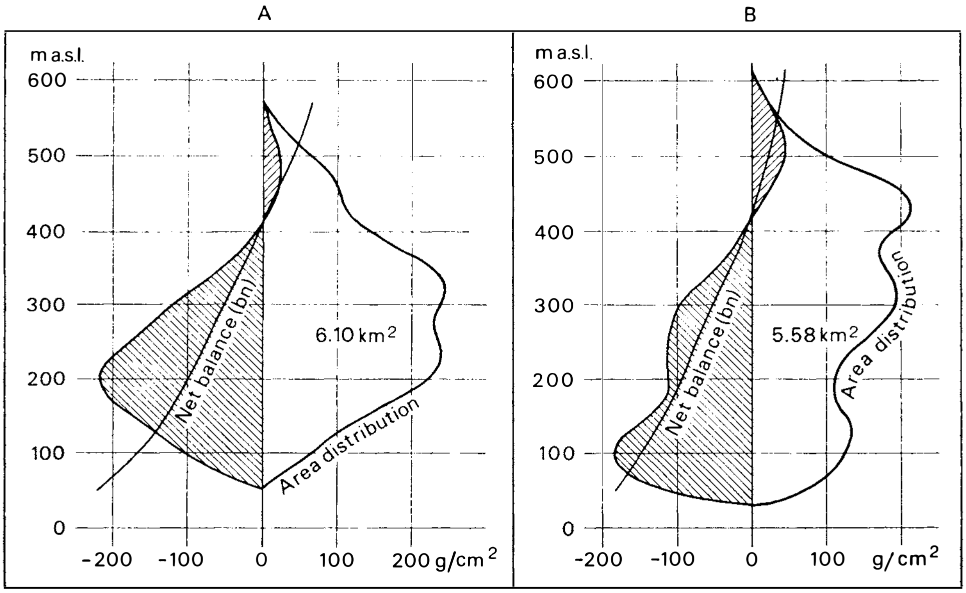


Fig. 5. *Mass balance variations in relation to height above sea level of Austre Brøggerbreen (A) and Midre Lovénbreen (B) 1975–76.*

Вариации вещественного баланса в зависимости от высоты над уровнем моря на ледниках Austre Brøggerbreen (A) и Midre Lovénbreen (B) в 1975-76 г.

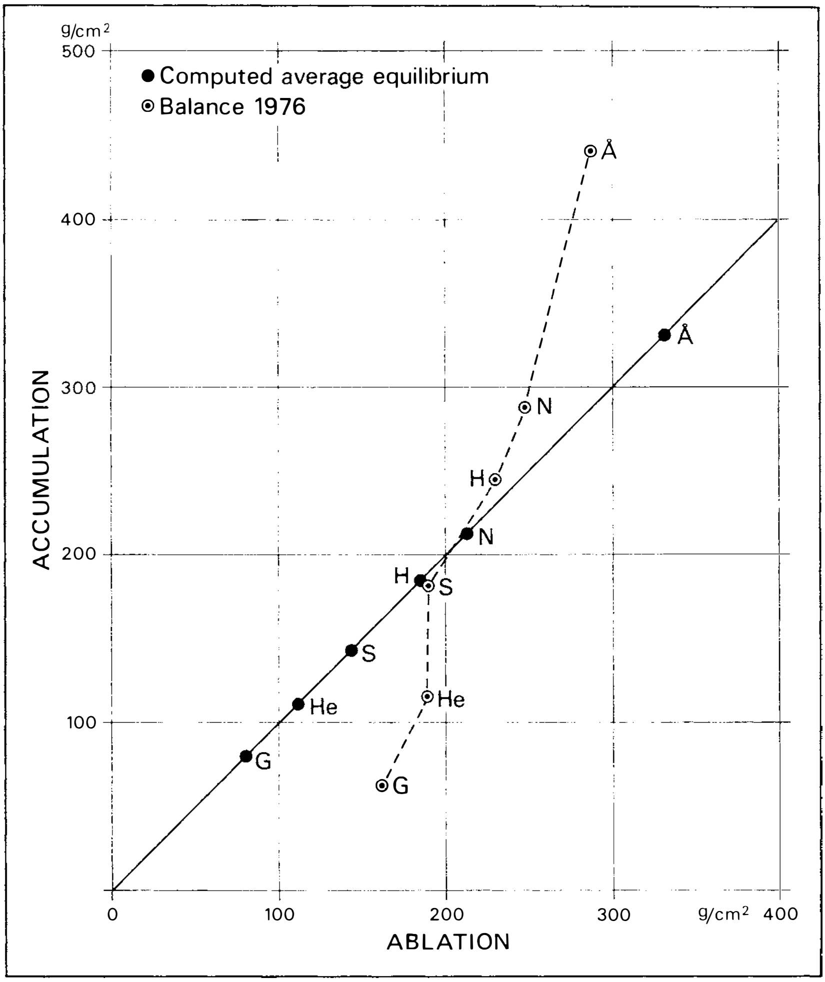


Fig. 6. *Relation between accumulation and ablation compared to the mean of a year with a computed balance budget and a "normal" mass exchange.*

G =*Gråsubreen*	*N* = *Nigardsbreen*
H = *Hardangerjøkulen*	*S* = *Storbreen*
He = *Hellstugubreen*	*Å* = *Ålfotbreen*

Взаимоотношения между аккумуляцией и абляцией в сравнении со средними значениями года с рассчитанным балансированным бюджетом и ,,нормальным'' вещественным обменом. .

Ablation measurements were based on registrations at 12 stakes on Brøggerbreen and 15 on Lovénbreen, on both along the center line of the glaciers. The accumulation was slightly above the average for the nine years of mass balance measurements on these glaciers. As mentioned in previous reports, this average does not represent a glacier in equilibrium but a glacier in constant decrease. In spite of an about average ablation, the net balance figure was therefore negative for both glaciers as in the previous ten years (Fig. 5 and Table 1).

Table 2

Mass balance measurements of different glaciers in Norway and Spitsbergen 1975-76

Name of glacier	Area Km²	Winter balance g/cm²	Summer balance g/cm²	Net balance g/cm²
South Norway				
Ålfotbreen	4.8	440	287	153
Blomsterskardbreen	45.7	—	—	140
Hardangerjøkulen	17.3	245	230	15
Nigardsbreen	47.2	288	248	40
Storbreen	5.3	181	190	— 9
Hellstugubreen	3.3	116	189	— 73
Gråsubreen	2.5	62	162	—100
North Norway				
Engabreen	38.0	386	145	241
Høgtuvbreen	2.6	366	275	91
Spitsbergen				
Austre Brøggerbreen	6.1	72	117	— 45
Midre Lovénbreen	5.8	75	110	— 35

Table 3

Fluctuations in length in metres of some glacier tongues

Jotunheimen		*Jostedalsbreen*	
Tverråbreen	—14	Briksdalsbreen	+30
Styggbreen	— 5	Fåbergstølbreen	—30
Hellstugubreen	—10	Stegaholtbreen	— 9
Illåbreen N	— 8	Nigardsbreen	— 1
Illåbreen S	— 7	Tunsbergdalsbreen	— 6
Storbreen	—10	Austerdalsbreen	+ 9
Leirbreen	— 8		
Styggedalsbreen	0	*Svartisen*	
		Engabreen	+ 7
Folgefonni			
Bondhusbreen	+ 5		
Buarbreen	+ 2		

Other investigations

The Norwegian Water Resources and Electricity Board carried out measurements on six glaciers in Norway of which two, Engabreen and Høgtuvbreen, are situated in Northern Norway. The mass balance figures for these glaciers and for the five mentioned in this paper, are presented in Table 2. Mass balance figures for glaciers in Southern Norway are also presented graphically in Fig. 6.

Glacier tongue fluctuation measurements were carried out on seventeen glaciers and the results are presented in Table 3.

The weather in Svalbard in 1976

BY VIDAR HISDAL

Previous reports on "The weather in Svalbard" were to a great extent based on observations taken at Isfjord Radio. Unfortunately, this station ceased to observe in July 1976. We have chosen Svalbard Lufthavn (Airport) as the new station for our weather diagram. This is a well-equipped meteorological station, situated at the south coast of Isfjorden, close to Longyearbyen, about 48 km ENE of Isfjord Radio.

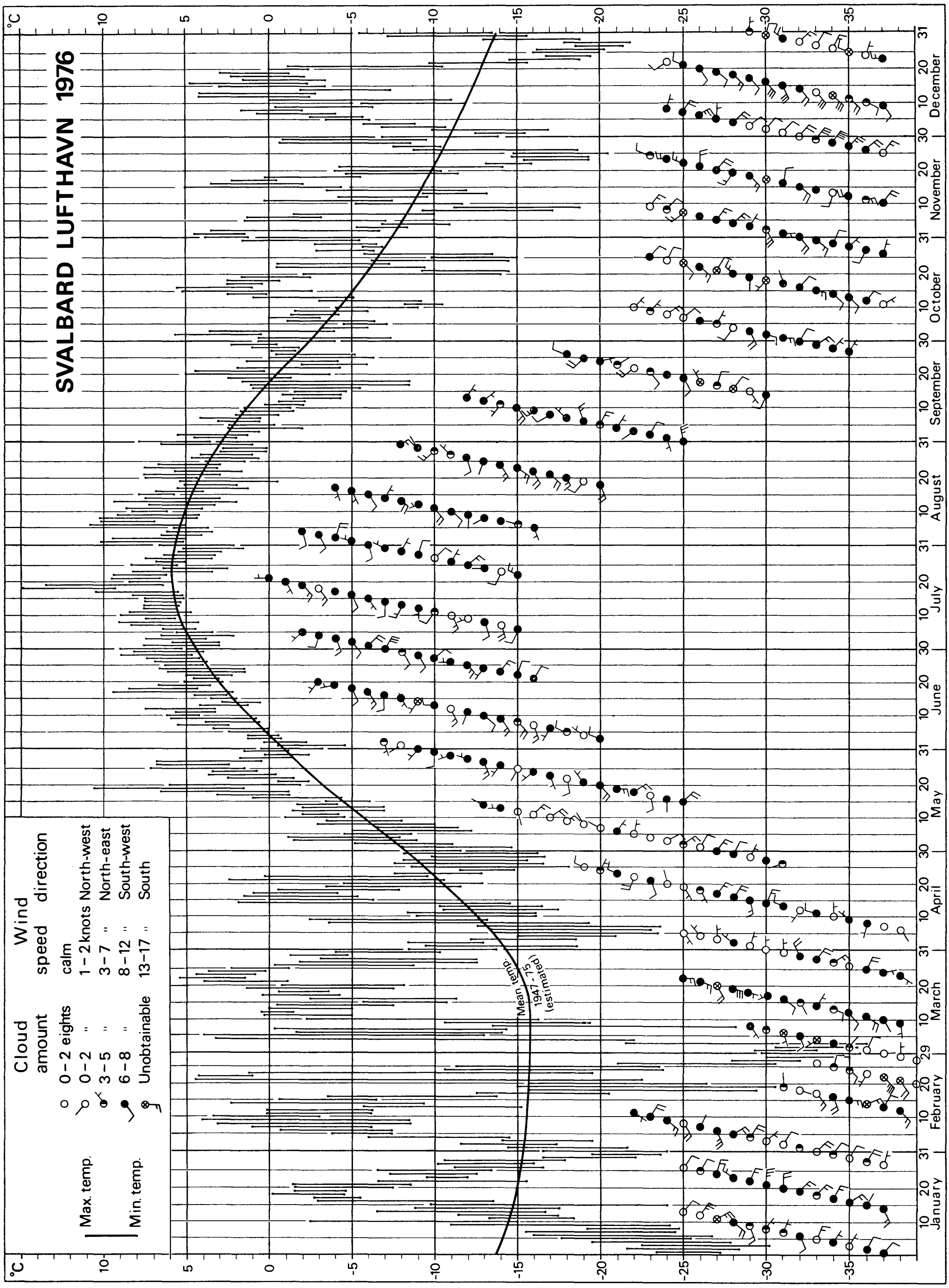
The station has been in operation only since August 1975. However, we have estimated mean monthly temperatures for the period 1947–75 by assuming the small differences between corresponding monthly means for Svalbard Lufthavn and Longyearbyen to be approximately constant from year to year, and by applying the relationship between the two comparatively long, parallel temperature series from Longyearbyen and Isfjord Radio. These estimates are supposed to form a usable picture of "normal" temperature conditions at the new station.

Svalbard Lufthavn has a somewhat more continental climate than Isfjord Radio. Thus, the estimated mean temperatures in winter are 3°–4°C lower at the former station, and in the middle of summer about 1°C higher.

The diagram presents the following meteorological elements observed at Svalbard Lufthavn during 1976: daily maximum and minimum temperatures, cloud amount, and direction and speed of the wind. The cloud and wind observations entered are those taken at 12 GMT. The figure also shows the estimated mean annual temperature variation for the period 1947–75. The symbols used are explained by examples in the diagram.

The table contains monthly mean temperatures for 1976, as well as their deviations from the corresponding means based on the years 1947–75. As indicated above, the term "normal" used in the following refers to this latter period.

The cold easterly to northerly air flow that dominated the weather of December 1975, continued during the first days of the new year. On 9 January a milder, partly strong cyclonic air circulation took over. Particularly the days from the 16th to the 21st of the month had above normal temperatures. On


SVALBARD LUFTHAVN 1976
°C
Max. temp.
Min. temp.
Cloud amount
0–2 eights
0–2 "
3–5 "
6–8 "
Unobtainable
Wind speed
calm
1–2 knots North-west
3–7 " North-east
8–12 " South-west
13–17 " South
direction
Mean temp. 1947–75 (estimated)
January
February
March
April
May
June
July
August
September
October
November
December

about 26 January the situation changed again. A high pressure area to the northeast stretched towards Svalbard and gave comparatively calm, cold weather. During the first half of February a series of cyclones passed from southwest, and brought considerably milder air to the islands. Thus, at the airport seven days during this period had maximum temperatures above 0°C. The rest of the month as well as the first few days of March had clear, cold weather, except for a short mild and stormy spell from 21 to 23 February, with a maximum temperature as high as 4.4°C. The lowest temperature of the year at Svalbard Lufthavn, —36.0°C, occurred about two weeks later, on 3 March. It is a characteristic feature of the weather conditions in this region that the next day had a maximum temperature of 3.2°C, i.e. a temperature rise of nearly 40°C! This marked the start of an exceptionally mild period in connection with strong cyclonic activity, lasting to the end of the month. During this period, 11 days had maximum temperatures exceeding 0°C, with 5.4° on 22 March as the highest value. The first week of April had mostly light, easterly to northerly winds and relatively low temperatures, while the middlemost part of the month was inluenced by cyclone passages, and the temperatures were about or above normal. The air circulation during the last week of April was governed by an anticyclone over Greenland, and colder air from the north entered the region. During the first half of May the anticyclone was situated more to the north or northeast, and the weather over large parts of Svalbard was comparatively clear and sunny, with temperatures varying about the average for the season. In the middle of the month, however, depressions started to pass over or near the area, and the weather was mostly mild, especially in front of the depressions. On 19 May the temperature reached 10.6°C, which is unusually high for this time of the year. The pressure pattern during the greater part of June was dominated by a high pressure area over or near Svalbard. However, the weather was frequently distinguished by humid air masses and a cloudy sky.

During July and August a long series of depressions passed. Especially in August some of them were quite intense for the season, and were accompanied by relatively large amounts of precipitation and, in exposed places, by strong winds. As a whole, the summer weather was not very pleasant, although most of the time the temperature kept somewhat above normal. The annual temperature maximum at the airport, 14.9°C, occurred on 18 July. The greater part of September was cool, with a northerly air stream betwen high pressure areas to the west or north, and cyclonic centres passing over or near the Barents Sea. A couple of times cyclones passing over Svalbard gave short, mild spells. As is normally the case, strong temperature fluctuations became gradually a more and more dominating feature of the weather conditions as the winter approached. This fact is of course closely connected with the increasing temperature contrast between Arctic air masses and air drawn northwards by the travelling cyclones. Considering the last three months of the year, the following dates indicate the most pronounced cold spells: 20–26 October, 22–26 November, and 23–29 December. A mild, cyclonic weather type prevailed during the following periods: 14–19 October, 29 October – 7 November, 11–20 November and 4–21 December. It is noteworthly that during the long, mild period in December, Svalbard Lufthavn had 11 days in all with maximum temperatures between 0° and 5°C.

It appears from the diagram as well as the tabulated data that the year as a whole was mild. For the three stations in the table only January and September had normal or below normal mean temperatures. The mildest months in relation to the long-term average were February and, especially, March, and also December. It is a notable fact that the means for March are considerably higher than those for April, a repetition of the situation in 1974, when this anomaly was perhaps still more marked.

August was the "wettest month" at all stations. The airport received 60 mm during this month, or nearly one fourth of the total annual amount. It may be added that several of the mildest days in the winter season had precipitation in the form of rain.

Monthly mean temperatures for 1976 (T) and their deviations (d) from the means of the period 1947–75.

		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Svalbard Lufth.	T	–14.8	–12.8	–7.8	–10.7	–2.5	3.2	5.9	4.7	–0.9	–3.9	–7.8	–8.0
(estimated:)	d	0.0	2.8	7.9	0.9	1.8	1.1	0.3	0.1	–1.4	1.2	1.4	4.4
Hopen	T	–14.9	–8.9	–5.8	–7.8	–4.2	0.2	3.8	4.1	0.1	–2.2	–6.3	–6.3
	d	–2.1	3.5	7.8	2.9	0.5	0.6	1.9	1.9	–0.7	0.8	1.0	4.3
Bjørnøya	T	–9.1	–3.9	–2.3	4.1	0.1	3.0	6.6	5.9	2.0	–0.1	–2.7	–3.9
	d	–1.7	3.2	5.2	1.2	1.5	1.1	2.3	1.6	–0.8	0.1	0.3	1.9

Sea ice conditions in 1976

By TORGNY E. VINJE

Contents

Introduction

Because of the large variations observed in the sea ice distribution from year to year, a graphical mean of the sea ice border may be somewhat artificial in many areas, moreover difficult to define, particularly in areas with a complex distribution. A socalled median border has therefore been estimated, limiting the areas in which sea ice concentrations higher than 3/8 are observed in less/more than 50% of the observations made during the ten-year period 1966–1975 (VINJE (1976)). Together with the ice borders for 1976, the median border as well as the enveloping curves for maximum and minimum extension of sea ice concentrations higher than 3/8 for the mentioned ten-year period, are given in Fig. 1. The ice charts edited by the US Fleet Weather Facility have mainly been used for 1976. These charts are based on information from the ordinary daylight and infrared satellite imageries and information obtained in the microwave band. All borders and envelopes in Fig. 1 refer to the end of each month.

Sea ice conditions in 1976

Considering the ice conditions in 1976 and their relation to conditions in the ten-year period, Fig. 1 is more or less self-explanatory. It may be of interest, however, to compare some of the most marked deviations from the median border with the monthly average atmospheric circulation and its deviation from normal.

At the end of January the ice border has an extreme southern position in the Icelandic Sea, while there is less ice than usual in the Greenland Sea. This deviation from the median distribution corresponds with a deviation in the

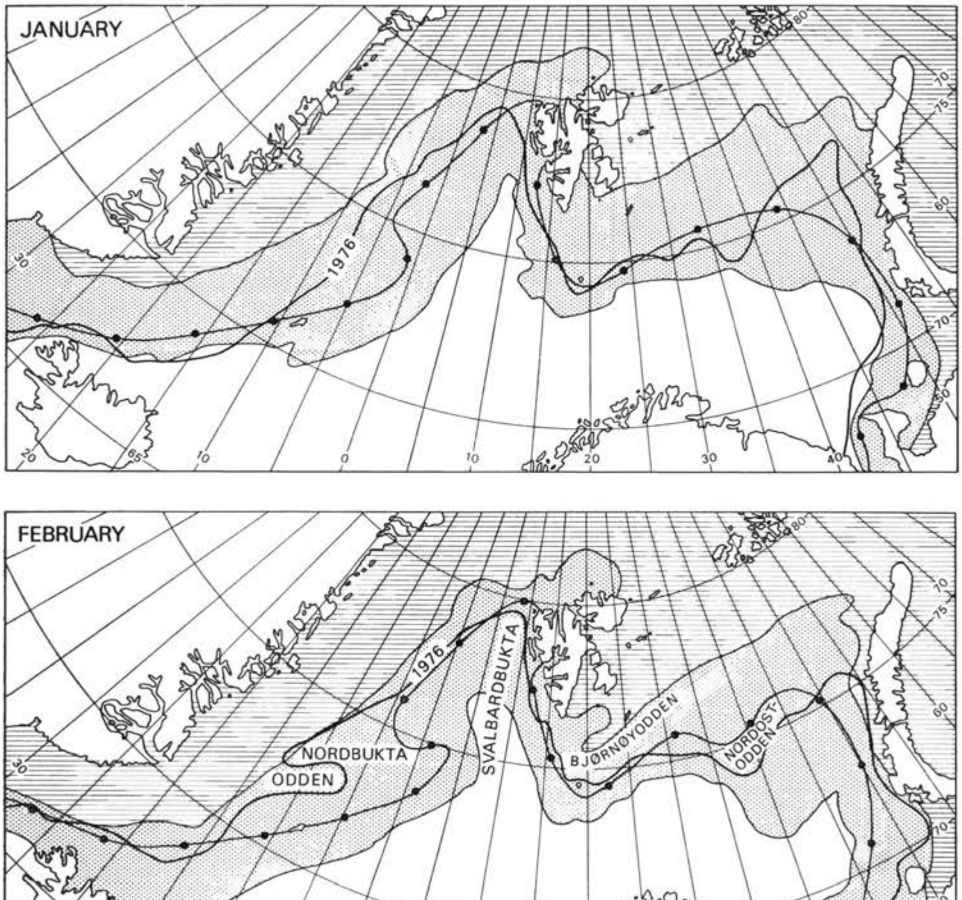
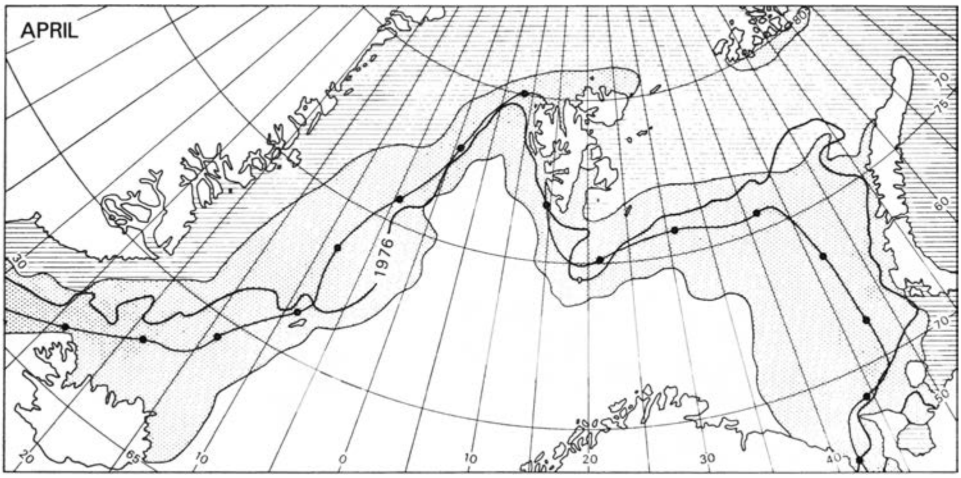
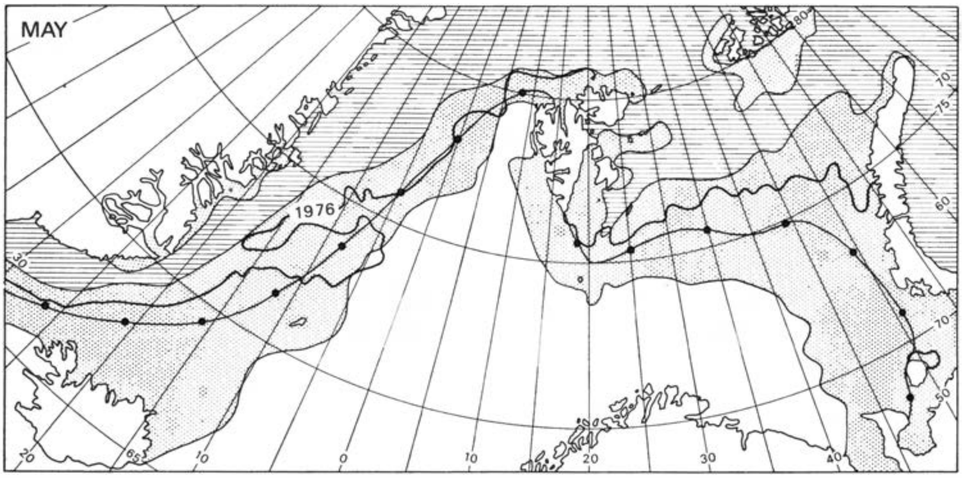


Fig. 1. *Sea ice conditions at the end of each month of the year. ———: enveloping curves indicating the most northern or southern extension of sea ice concentrations above 3/8 for 1966–75. —•—: median border south of which sea ice (concentration above 3/8) is observed in less than 50% of the cases in the ten-year period 1966–75.*


APRIL
1976
80
70
75
60
70
50
30
20
65
10
0
10
20
30
40


MAY
1976
80
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60
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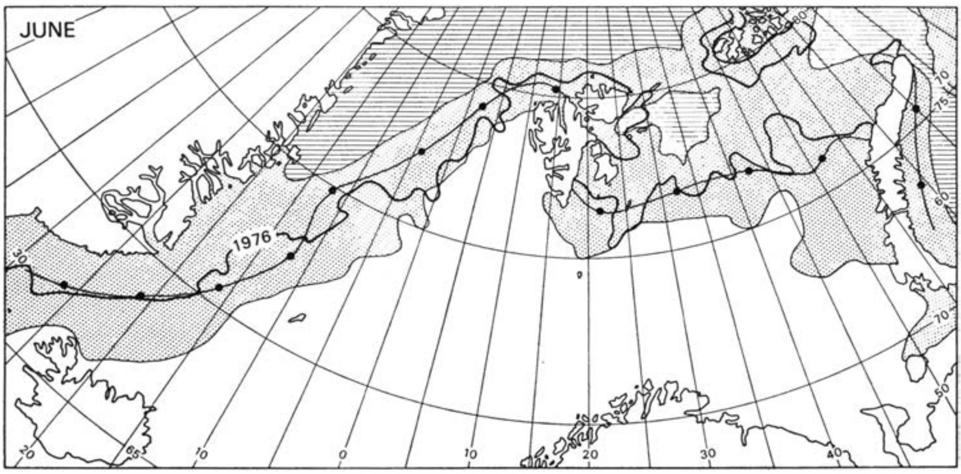
JUNE
1976
80
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0
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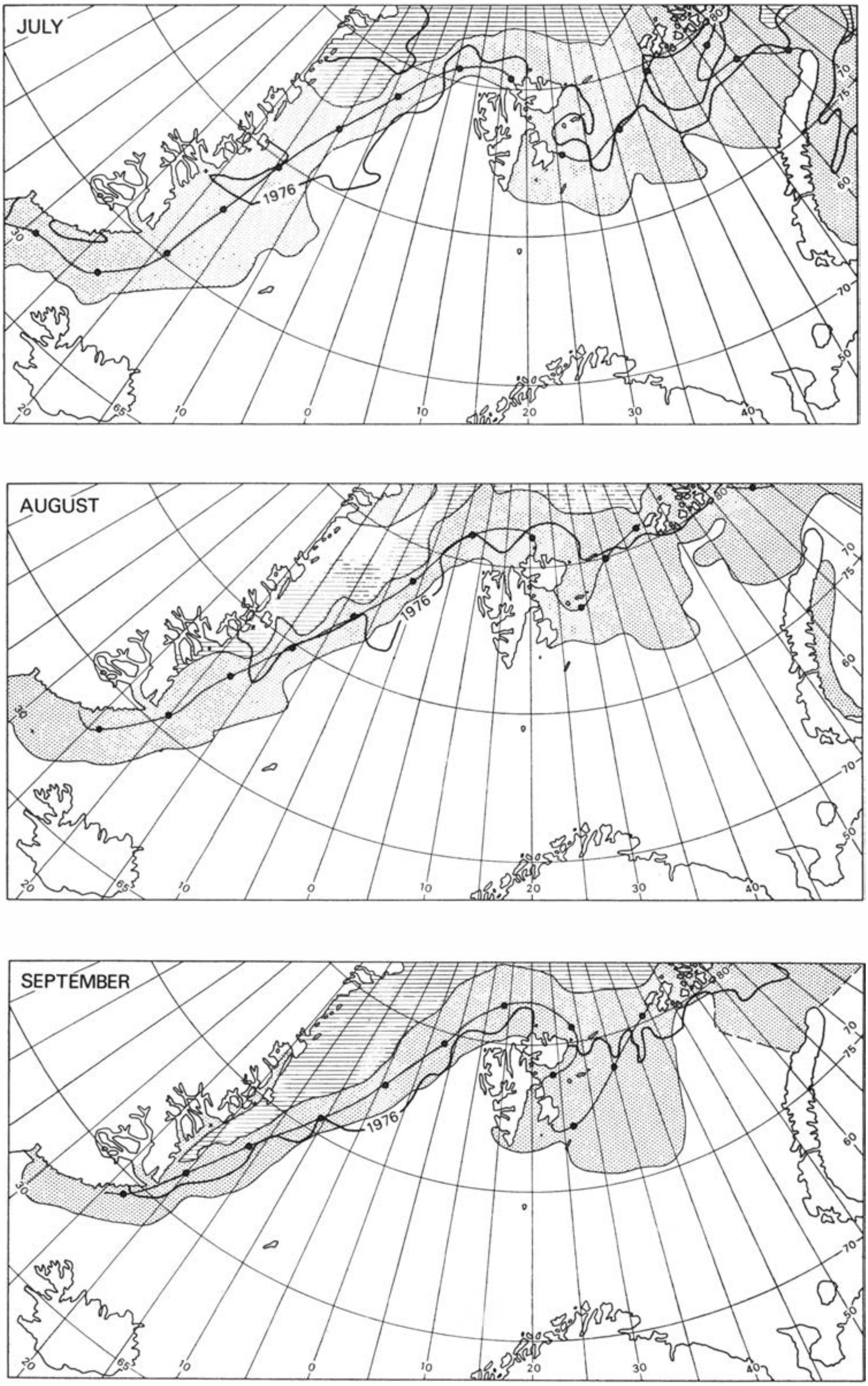
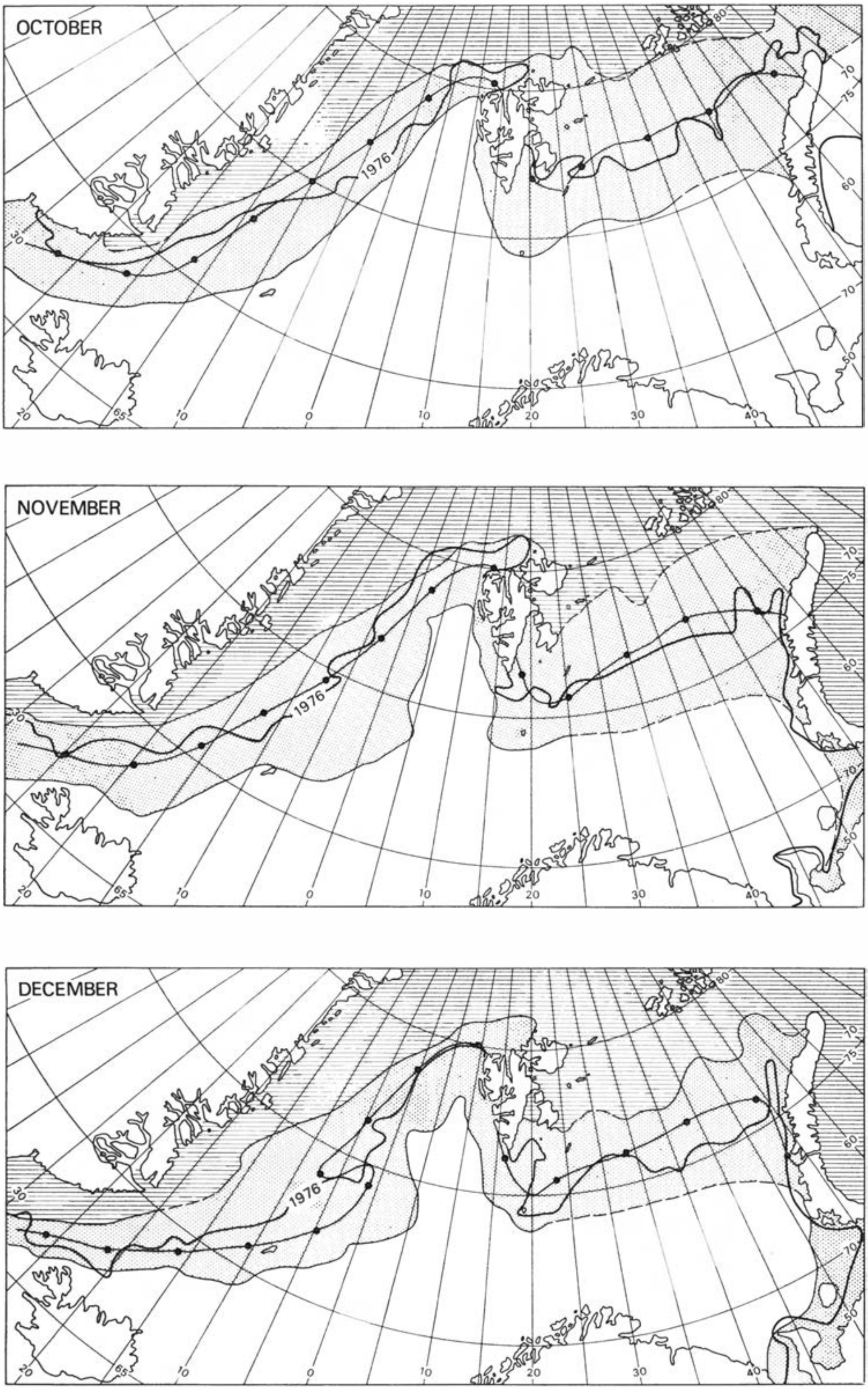

JULY
1976
AUGUST
1976
SEPTEMBER
1976


OCTOBER
1976
NOVEMBER
1976
DECEMBER
1976

average position (1900–1939) of the main center of the Icelandic Low which for January 1976 is located in the Norwegian Sea. This causes a prevalence of colder north-north-easterly winds over the Greenland Sea, and divergent northerly weak winds over the Icelandic Sea. The average temperature at Jan Mayen has thus been 2.6°C below the normal (1931–1969).

In the eastern Barents Sea there is less ice than usual in the northeastern part while there is an extreme westward extension of the drift ice in the southern part for the last eleven years. This is in accordance with the above mentioned displacement of the Icelandic Low. For January there is an average outflow of cold continental air from east-south-east over the area. In the southeastern part of the Barents Sea the air temperature is thus 5–7°C below normal.

At the end of February the features Odden and Nordbukta can be recognized. Their dimensions may indicate that the Jan Mayen Gyro has a relatively small extension at that time. They also have a far more westerly and somewhat more northerly position than may be indicated from the ice distribution in previous years (Cf. VINJE (1976)). A persistency of this westerly position as well as the smaller extension may have existed over a period of some months in 1976 as the features are observed again from 11 May to 8 June in the same area. It is noted that the amount of ice in the considered area is far less than usual both at the end of February and March, and that the amount of ice between Iceland and Greenland is at its minimum for the last eleven years at the end of March. This is in great contrast to the *maximum* southward position in part of the Icelandic Sea at the end of January as mentioned above. This marked change in the sea ice distribution is in accordance with the comprehensive change in the atmospheric circulations which has taken place since January. For this month the deviation from the average monthly air pressure at 70°N and 20°W is thus estimated to be +5 mb while the figure is about —12 mb at the end of February and March.

There is more ice than usual in the central part of the Barents Sea at the end of February, and the feature Nordoostodden is relatively pronounced. At the end of March the situation has changed markedly as the amount of ice in this area is unusually small north of 70°N. This may be effected by a change in the air flow over the area which from January to March changes from being east-south-easterly to west-south-westerly. The change from the normal in the temperature deviation varies from about —5°C in January to about +4°C in March.

A relatively broad north-eastward extending bight is observed southeast of Spitsbergen at the end of March. This feature is reflected in the enveloping curve as well, both for February and March, indicating perhaps a disintegrating effect on the ice of the branch from the West-Spitsbergen Current running north-eastwards in this area.

At the end of July there is relatively little ice in the Icelandic and southern part of the Greenland Sea. Between 75° and 77°N, however, a maximum eastward extension of sea ice is observed for the last eleven years. The extraordinary large area of open water off the northeast coast of Greenland may be noted in this connection. The average atmospheric circulation is very weak in the area in July. The extreme distribution is supposed mainly to be caused by a relatively intense anticyclonic oceanic circulation observed in the area during May, June, and July (VINJE (1977)).

At the end of August as well as in September, there is far less ice than usual in the eastern part of the Svalbard archipelago. This is probably, at least partly, caused by the atmospheric circulation during the summer. From a Nimbus-6 buoy on an ice floe a north-north-easterly transport of ice is observed in this area for the relatively long period, 25 June to 11 August.

The southward movement of the ice border during the last months of the year shows little deviation from the usual trend. An exception, however, is the extraordinary southern extension of the ice at the end of October in the Kara Sea (western part). This corresponds with a relative increase in the outflow of continental air. There is thus a deviation from the mean temperature of about —3°C and the deviation from the mean air pressure in the area is about —5 mb for this month.

Final remarks

The review above shows that there is a fair accordance between the deviation of the sea ice distribution from the median border and the atmospheric circulation and its deviation from the normal. This should be expected in the marginal areas where the ice is relatively free to move within limits which towards the south are mainly determined by the position and heat capacity of the warm currents, and towards the north mainly by the concentration of the ice and the ridging possibilities.

The large scale undulations of the sea ice border in the total area considered, reflects to a high degree the oceanic circulation. In certain areas there is an indication, however, that this circulation may differ markedly from year to year causing pronounced deviations of the sea ice distribution over large areas. In a ten-year review (VINJE (1976)), several indications were thus found that a southerly/northerly position of the sea ice border in the Icelandic Sea coincides with the absence/clear development of the features called Odden and Nordbukta. Compared with previous years, these features had a distinctly more westerly position as well as a relatively smaller extension when observed during the spring of 1976. It is assumed that this, together with a favourable atmospheric circulation, may have had a reducing influence on the amount of sea ice further south. As mentioned above, a minimum of sea ice was observed in the Icelandic Sea during the last eleven years at the end of March, and for the rest of the spring and summer, the ice amount in these waters was on an average less than usual. This indicates that the oceanic circulation in the Greenland Sea may vary significantly from year to year and that oceanic observations in these waters may be of great value for sea ice prognoses.

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Radiation conditions in Spitsbergen in 1976

By Torgny E. Vinje

Contents

Introduction

Continuous radiation measurements were started in Ny-Ålesund (78°50′N, 11°30′E) in the beginning of 1974 with the purpose of learning more about the local climate and, particularly, of studying the heat budget of the extensive area of open water which may be found at these high latitudes all year round.

To avoid impurities on the glass and polyethylene domes, all instruments are artificially ventilated. They are inspected daily by the personnel tending the observatory. A description of instruments and the calibration methods is given by Vinje in Norsk Polarinstitutt Årbok 1974.

Results

The monthly sums of some of the radiation components registered are given in Table 1, together with the albedo of the surface.

The annual sum of the global radiation (G) is about 50 200 ly. This is as much as 6.0 % below the ten-year average observed at Isfjord Radio between 1951 and 1960 (Spinnangr (1968)).

The relatively low albedo observed during the spring is mainly due to warm weather with relatively heavy rain during March. This caused a marked change of the surface which in several places became covered with a 10 cm thick layer of solid ice. The snow disappeared from the instrument area on about 10 June. The albedo then became 0.12 which is an ordinary value for the bare tundra near Ny-Ålesund.

The annual radiation balance of the land surface (BL) may vary considerably from year to year. For 1974, 1975 and 1976 this quantity has thus been observed to be 11 017, 6305, and 11 808 ly, respectively (Vinje (1975, 1976)).

The relatively low value in 1975 may partly be due to the corresponding low value in the atmospheric counter radiation which was 5–7% lower this year than in 1974 and 1976. Table 1 shows that the annual net radiation of the land surface (BL) is markedly higher than that of a sea surface with a given temperature of 0°C. An increase of the sea temperature of 5°C would cause an increase in the radiation loss of about 1500 ly month^{-1}. As a sea temperature of 5°C is measured during the summer and autumn months in the area considered, the annual net radiation of an open water area may well become negative at these latitudes. The values given in Table 1 are therefore to be considered as maximum values.

Table 1.

Monthly sums, ly month $^{-1}$, of radiation components at Ny-Ålesund in 1976.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
G		65	1500	6775	12890	11294	11138	4326	2237	218			50220
a			0.779	0.761	0.697	0.199	0.117	0.116	0.596	0.76			
A	14813	13950	17100	14711	16595	19136	21027	20754	17532	18039	15505	16854	205327
BL	—1538	—1521	—632	—376	1827	6693	7211	3053	35	—273	—1079	—1425	11808
BS	—5721	—6525	—2084	274	7662	8767	9828	3933	—989	—2300	—5029	—3680	4135

G = *global radiation*
a = *albedo*
A = *long-wave radiation from the atmosphere*
BL = *total radiation balance of the surface*
BS = *calculated total balance of a sea surface of temperature 0°C and with an albedo of 0.1*

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Observations of animal life in Svalbard in 1976

(Наблюдения над фауной Свальбарда в 1976 г.)

By Thor Larsen

Contents

Abstract

Observations of birds and mammals in Svalbard were collected from 24 expeditions and persons in 1976. Most observations are from the west coast of Spitsbergen, Nordaustlandet, and Bjørnøya. There are several interesting observations from Bjørnøya, data on arrival of migratory bird species, egg laying dates, and others. A banded ivory gull (*Pagophila eburnea*) turned out to come from Station Nord on northeast Greenland. Two species have been observed in Svalbard for the first time in 1976, the ringed-billed gull (*Larus delawarensis*) and the red-breasted flycatcher (*Muscicapa parva*). There has been an alarming decrease in the population of muskox (*Ovibos moschatus*) which probably counted only a dozen animals in 1976. 90 polar bears (*Ursus maritimus*) were seen at Svartknausflya on Nordaustlandet in one month in July/ August, and as many as 27 in one day.

Аннотация

Результаты набдюдений птиц и млекопитающих на Свальбарде поступили от 24 экспедиций и лиц в 1976 г. Большинство набдюдений было выполнено на западном берегу Шпицбергена, на Северо-Восточной Земле и острове Медвежьем. Особенно интересно несколько результатов произведенных на о-ве Медвежьем наблюдений: данные о прилете перелетных птичьих видов, о датах кладки яиц и т. п. Окольцованная белая чайка (Pagophila eburnea), показалось, прилетела со станции Nord на северо-востоке Гренландии. Два вида были впервые отмечены на Свальбарде в 1976 г.: ,кольчатоклювая' чайка (Larus delawarensis) и малая мухоловка (Muscicapa parva).
Произошло тревожное уменьшение популяции овцебыков (Ovibos moschatus), возможно насчитывавших только дюжину в 1976 г. 90 белых медведей (Ursus maritimus) были наблюдены на тундре Svartknausflya на Северо-Восточной Земле за месяц в июле/ августе, а целых 27 в один день.

Introduction

Information on the fauna of Svalbard has been obtained from several Norwegian and foreign expeditions and visitors to the archipelago in 1976. Observations are mainly from the west coast of Spitsbergen, from Nordenskiöld Land, and from Nordaustlandet. There are several interesting observations from Bjørnøya. Observations on reindeer (*Rangifer tarandus platyrhynchus*) in Spitsbergen are published by the MAB personnel, and data on the reindeer in Nordaustlandet has been published by the author (LARSEN 1977). I am grateful to the following persons and groups for their contribution of data and information to this article: I. BRATTBAKK (IB) from Kongsfjorden, K. H. BROX (KHB) from Fuglehuken, D. ELGVIN (DE) from Nordaustlandet, Föreningen För Arktisk Natur (FAN) from Colesdalen – Adventdalen and the Ny-Ålesund area, R. GÜNTHER (RG) from Kongsfjorden, H. GRØNLIEN and J. REISEGG (HG/JR) from Daudmannsodden and Daudmannsøyra, J. HALVORSRUD (JH) from Nordaustlandet and Kvitøya, T. HANSEN and T. JACOBSEN (TH/TJ) from Svartknausflya on Nordaustlandet, K. HUSEBY and S. STOKKE (KH/SS) from Kapp Martin, H. JACOBSEN (HJ) from Bjørnøya, P. KYRRE REYMERT (PKR) from the north side of Van Mijenfjorden and Blomstrandhalvøya, Ø. LAURITZEN (ØL) from Grønfjorden, I. LUND-MATHIESEN (ILM) from Nordaustlandet and Kvitøya, H. L. MAGNÉE (HLM) from Isfjorden, Magdalenefjorden and Kongsfjorden, Ø. MEHLUM (ØM) from Dicksonfjorden, AA. MAGNUSSON (AAM) from Fugelfjella – Longyearbyen, J. NORDLAND (JN) from Nordaustlandet, B. ROTHÉ (BR) from Isfjorden, H. RUSTAD (HR) from Bjonahamna, O. SALVIGSEN (OS) from Svartknausflya, Nordaustlandet, E. SENDSTAD (ES) from Kongsfjorden, T. TRULSEN (TT) from Langneset, and R. AABAKKEN (RAA) from Nordenskiöld Land and Moffen.

Most information has been given on the questionnaires, but some is from letters and typewritten reports (Föreningen För Arktisk Natur 1976; AABAKKEN 1976). The greater part of the observations are from the summer of 1976, but from Bjørnøya there are also spring observations, including information on bird migration and egg laying dates.

Mammals

M u s k o x (*Ovibos moschatus*): See Table 1.

P o l a r b e a r (*Ursus maritimus*): A total of 45 polar bears – seven adults, five juveniles, and twelve family groups – were observed between Kinnvika and Kapp Platen on Nordaustlandet in March and April (LARSEN 1976). About 24 bears were observed in August by the expedition from Norsk Polarinstitutt along the north coast of Nordaustlandet and Kvitøya (JH, ILM, JN). 90 polar bears were seen at Svartknausflya between 23 July and 27 August, and as many as 27 in one day, on 3 August (OS). This mass occurrence is difficult to explain, but it may be partly due to ice conditions in Erik Eriksenstretet at that time. There was open water when SALVIGSEN and his assistants

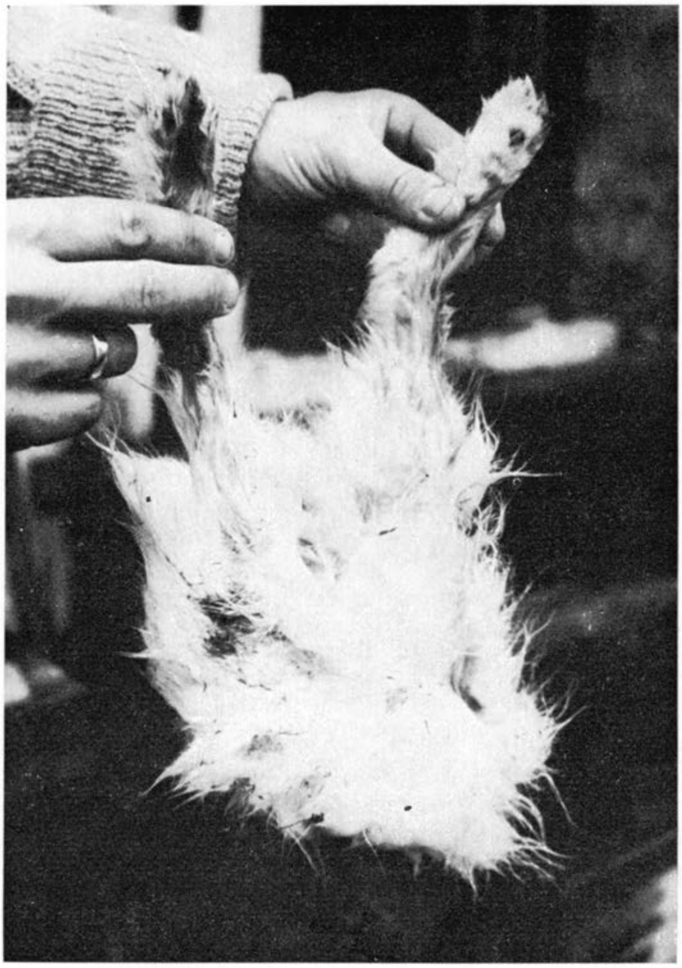

Fig. 1. *A carcass of an arctic hare* (Lepus arcticus groenlandicus) *was found on Fuglehuken in July.*
Photo: K. H. BROX
Труп арктического зайца (Lepus arcticus groenlandicus) был найден на мысе Fuglehuken. в июле.

arrived, but bears were still present in the area. However, when the ice arrived on 29 July, there was also a marked increase in bear abundance.

Svalbard reindeer (*Rangifer tarandus platyrhynchus*): One adult was seen on Mitrahalvøya on 25 and 28 July (FAN). Other information is from areas where reindeer normally occur, but cannot be used quantitatively.

Arctic hare (*Lepus arcticus groenlandicus*): A carcass of an arctic hare was found at Fuglehuken on 12 July (KHB) (Fig. 1).

Walrus (*Odobenus rosmarus*): Various expeditions visited Moffen during 1976, but more than six animals were never observed (AABAKKEN 1976). North of Kvitøya, five adults were seen on the ice (JN) and three in the sea (DE).

Table 1.

Observations of muskox (Ovibos moschatus) *in Svalbard in 1976*
Наблюдения овцебыков (*Ovibos moschatus*) на Свальбарде в 1976 г.

Locality/date Местность/дата	Number Число	Observer/remarks Наблюдатель/примечания
Grumantbyen 11/7	2 ad., 1 juv.	FAN
Fuglefjella 22/7	4 ad., 2 juv.	FAN
Jansondalen 23/7	2 ad.	FAN
Longyearbyen 30/7	1 ad.	FAN
Bjørndalen 1/8	1 ad.	FAN
Nordenskiöld Land, 29/5–13/9	11 ad.	RAA (AABAKKEN 1976). 12 animals probably died in 1975/76.

Common seal (*Phoca vitulina*): At least five individuals were observed at Fuglehuken during July (KHB). There is probably a small population of common seals at Forlandet now.

Birds

Black-throated diver (*Gavia arctica*): One adult was seen on Svartknausflya on 27 July (TH/TJ).

Barnacle goose (*Branta leucopsis*): See Table 2.

Brent goose (*Branta bernicla hrota*): One adult was seen at Ny-Ålesund on 30 July (FAN), three at Beistkollen on 31 July, two and one on Helvetesflya on 3 and 4 August, respectively (JH), and two on Prins Oscars Land on 6 August (JN).

Pink-footed goose (*Anser fabalis brachyrhynchus*): See Table 3.

Whooper swan (*Cygnus cygnus*): One juvenile was seen at Kapp Martin on 23 July (KH/SS) and one adult at Daudmannsodden on 9 to 12 August (HG/JR).

Table 2.

Observations of Barnacle goose (Branta leucopsis) *in Svalbard in 1976*
Наблюдения белощеких казарок (*Branta leucopsis*) на Свальбарде в 1976 г

Locality/date Местность/дата	Number Число	Observer/remarks Наблюдатель/примечания
Krillvatnet, Bjørnøya 19/5	11 ad.	HJ
Kapp Forsberg, Bjørnøya 25/5	4 ad.	HJ
Daudmannsodden 31/7	about 40 ad./juv.	HG/JR
,, 1–4/8	19 ad., 25 juv.	HG/JR
,, 12/8	53 ad.	HG/JR
Kapp Martin 15/7–22/8	60 ad., 90 juv.	KH/SS
Lågnesflya 7/8	about 100 ad./juv.	KH/SS

Table 3

Observations of pink-footed goose (Anser fabalis brachyrhynchus) *in Svalbard in 1976*
Наблюдения короткоклювых гуменников (*Anser fabalis brachyrhynchus*) на Свальбарде в 1976 г.

Locality/date Местность/дата	Number Число	Observer/remarks Наблюдатель/примечания
Krillvatnet, Bjørnøya 19/5	2 ad.	HJ. First observation
Lågnesrabbane 1/8	12–15 ad.	KH/SS
Daudmannsodden 6/8	30 ad., 35 juv.	HG/JR
,, 11/8	26 ad., 49 juv.	HG/JR
,, 25/8	40 ad.	HG/JR
Adventdalen 9/8	18 ad., 16 juv.	FAN

Teal (*Anas crecca*): Five adult birds were seen in Nordhamna on Bjørnøya on 12 May (HJ). The observation has been confirmed on a photograph.

Wigeon (*Anas penelope*): One adult was seen in Nordhamna, Bjørnøya, on 4 May (HJ). The observation has been confirmed on a photograph.

Tufted duck (*Aythya fuligula*): One male was seen in Nordhamna, Bjørnøya, on 10 May, and three males and one female in Avtjernet, Bjørnøya, on 23 May (HJ). The observations have been confirmed on photographs.

Scaup (*Aythya marila*): Two adult birds were seen on Bjørnøya on 30 May (HJ).

Eider (*Somateria mollissima*): There are several observations of eiders, but few of them give quantitative information of interest. One report states that there were more than 700 eiders between Ny-Ålesund and Forlandet (FAN) and about 100 adults were seen on 3 August at Svartknausflya (TH/TJ).

King eider (*Somateria spectabilis*): There are several reports about occasional observations of king eiders. One observation of 50 males in Adventfjorden (FAN) and one of 50 males at Kapp Martin on 19 July (KH/SS) should be mentioned.

Common scoter (*Melanitta nigra*): One adult bird was seen at Daudmannsodden on 6 August (HG/JR).

Long-tailed duck (*Clangula hyemalis*): Four females with a total of 22 ducklings were seen in Ny-Ålesund and about 30 males in inner Kongsfjorden (FAN). At Kapp Martin four males and one female were seen between 15 and 30 July (KH/SS). About 65 adults were seen at Daudmannsodden in August (HG/JR).

Greenland falcon (*Falco rusticolus candicans*): One bird was seen in Rijpfjorden on 29 March by the author.

Oystercatcher (*Haematopus ostralegus*): Three adults were seen at the station on Bjørnøya on 14 April (HJ).

Ringed plover (*Charadrius hiaticula*): Although the ringed plover is not a common bird in Svalbard, several observations of this species were made in 1976, as in previous years. 12 pairs were probably present or breeding in the Longyearbyen/Adventdalen area (FAN).

G o l d e n p l o v e r (*Pluvialis apricaria*): Two adults were seen at Grunntjern, Bjørnøya, on 20 May, and two at the station on 22 and 24 May (HJ).

L a p w i n g (*Vanellus vanellus*): One adult was seen at the station on Bjørnøya on 31 May (HJ).

L i t t l e s t i n t (*Calidris minuta*): Three adult birds were seen at the station on Bjørnøya on 27 May (HJ).

P e c t o r a l s a n d p i p e r (*Calidris melantos*): Two adults were observed in Herwighamna on Bjørnøya on 18 May (HJ).

D u n l i n (*Calidris alpina*): There are several observations of this species from Bjørnøya and the west coast of Spitsbergen. At least three pairs defended territories in the Longyearbyen area (FAN) and five to ten birds at Daudmannsodden on 1 to 7 August (HG/JR).

K n o t (*Calidris canutus*): One adult was seen in Longyearbyen on 16 July (AAM), one on Kapp Martin on 20 July (KH/SS), and one on Daudmannsodden on 18 July (HG/JR).

S a n d e r l i n g (*Crocethia alba*): One adult was seen in Nordhamna, Bjørnøya, on 2 June (HJ) and one on Kapp Martin on 29 July (FAN).

B r o a d - b i l l e d s a n d p i p e r (*Limicola falcinellus*): At Kapp Forsberg, Bjørnøya, one adult was seen on 19 May (HJ).

W h i m b r e l (*Numenius phaeopus*): One adult was seen at Kapp Forsberg on 19 July (HJ).

G r e a t s k u a (*Stercorarius skua*): There are single observations from Bjørnøya on 16 March (HJ) and from Kapp Martin between 26 July and 20 August (KH/SS). Breeding is reported from Brandallaguna and southwestern Mitrahalvøya (FAN). A breeding which resulted in two young is also reported from Kvadehuksletta on 4 July (IB). Other visitors reported a breeding at Brandalpynten, which, however, has not been confirmed (IB).

H e r r i n g g u l l (*Larus fuscus*): Three adults were seen on Bjørnøya on 21 April (HJ). One was later found dead, and the species was confirmed by Tromsø Museum which examined the carcass.

B l a c k - h e a d e d g u l l (*Larus ridibundus*): One adult was seen on Bjørnøya on 25 February. Seven adults and two juveniles were seen at the station on 21 May (HJ).

S a b i n e ' s g u l l (*Larus sabini*): A questionable observation was made in Sabinebukta on 9 August, and two safe observations off Isispynten on 13 August (JH). One adult was seen off Kapp Wijk on 31 August (ILM).

I v o r y g u l l (*Pagophila eburnea*): Several scattered observations were made along the north coast of Nordaustlandet, where several small colonies of the species can also be found. Other observations are from Bjørnøya, where five adults were seen on 25 February, and 20 adults and ten juveniles were observed on 29 April. One of the latter adult birds was banded, and the observer was able to read the number on the ring. The Zoological Museum in Copenhagen informed that the bird had been banded at Station Nord in northeast Greenland in 1967 (HJ).

Fig. 2. *A ringed-billed gull* (Larus delawarensis) *was observed at Ny-Ålesund on 20 July. This is the first observation of the species in Svalbard.*

Photo: R. GÜNTHER

‚Кольчатоклювая' чайка (Larus delawarensis) была отмечена у поселка Ny-Ålesund 20 июля, что представляет собой первое на Свальбарде наблюдение данного вида.

Ringed-billed gull (*Larus delawarensis*): One adult bird was seen in a flock of kittiwakes (*Rissa tridactyla*) at Ny-Ålesund on 20 July (RG). The observation has later been confirmed by the Zoological Museum, Oslo, on the basis of photographs of the bird (Fig. 2). This is the first observation of the species in Svalbard.

Razorbill (*Alca torda*): Two adult birds were seen in Adventfjorden on 15 July (HLM).

Short-eared owl (*Asio flammeus*): One bird was seen on Kapp Dunér, Bjørnøya, on 27 March (HJ). The observation is confirmed by a photograph.

Swallow (*Hirundu rustica*): One adult was observed on Bjørnøya on 12 May (HJ).

Sky lark (*Alauda arvensis*): One pair was seen at Lakselva, Bjørnøya, on 20 and 25 May (HJ).

Meadow pipit (*Anthus pratensis*): Twenty birds were seen on Bjørnøya on 24 February (HJ).

Rock pipit (*Anthus spinoletta*): A possible observation was made off Isispynten on 13 August (JN).

Yellow wagtail (*Motacilla flava*): One adult was seen at the station on Bjørnøya on 21 May (HJ).

White wagtail (*Motacilla alba*): One adult was seen on Bjørnøya on 18 May (HJ).

Starling (*Sturnus vulgaris*): One adult was seen on Bjørnøya on 24 February, and 15 on 14 April (HJ). One was found dead at Fuglehuken on 13 July (KHB).

Hooded crow (*Corvus corone cornix*): One observation was made on Bjørnøya on 18 May (HJ).

Red-breasted flycatcher (*Muscicapa parva*): The species was observed at the station on Bjørnøya on 3 June (HJ). The observation was later confirmed on a photograph, by the Zoological Museum, Oslo. This is the first observation of the species in Svalbard.

Whinchat (*Saxicola rubetra*): One adult was seen on Bjørnøya on 19 May (HJ).

Wheatear (*Oenanthe oenanthe*): Eight adult birds were seen on Bjørnøya on 24 February, and one single observation was made on 10 May (HJ).

Redstart (*Phoenicurus phoenicurus*): One adult male was seen at the station on Bjørnøya on 20 and 23 May (HJ).

Fieldfare (*Turdus pilaris*): One observation was made at the station on Bjørnøya on 20 May (HJ).

Blackbird (*Turdus merula*): An observation of one adult male was made at the station on Bjørnøya on 16 April (HJ).

Redwing (*Turdus iliacus*): One adult bird was seen on Bjørnøya on 16 April (HJ). The observation was later confirmed on a photograph by the Zoological Museum Oslo. One dead specimen was found on Fuglehuken on 7 July (KHB).

Brambling (*Fringilla montifringilla*): Four males and one female were seen on Bjørnøya on 17 May (HJ). The observation was later confirmed on a photograph, by the Zoological Museum, Oslo.

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Preliminary report of the 1976/77 Norwegian Antaratic Research Expedition *

By Olav Orheim

The expedition was organized and led by Norsk Polarinstitutt, with the author as expedition leader. The expedition ship was M/V "Polarsirkel", a Norwegian icebreaker/sealer built in 1976. She left Norway in late November 1976, and returned at the end of March 1977.

The expedition consisted of 21 Norwegian scientists, one visiting Argentine scientist, and a two-man film crew. During the months of January and February the scientists conducted research in the Weddell Sea and on Dronning Maud Land, working as two separate parties, a land party and a marine party.

The land programme

Nine scientists worked ashore during the expedition. Five worked on Riiser-Larsenisen, in part conducting meteorological studies at the base camp, and in part conducting glaciological studies at various localities on the ice shelf. The base was named Camp Norway 3, and was located at 72°19'S and 16°14'W. The meteorological studies were aimed at a better understanding of the air circulation just above and just below the snow/air interface. The glaciological studies included establishment of stakes for repeated measurements of ice movements and accumulation, and collection of ice cores and other snow samples for later laboratory studies of isotopes and chemical content of the snow. The latter work will give information on climatic trends and on evolution of global atmospheric pollution, and was a pilot study for more extensive investigations in a subsequent season.

Four scientists worked in Vestfjella, establishing their base, Camp Norway 4, at 73°44'S, 14°46'W, about 160 km inland from the Camp Norway 3. Three of them studied the geology and paleomagnetism of the mountain group to develop the history of the volcanic events and to relate these rocks to other rocks in Antarctica and other parts of Gondwanaland, the old supercontinent. The fourth scientist studied the cold adaption of collembola and mites, and brought

*Publication No. 1 of the Norwegian Antartcic Research Expeditions. (1976/77).

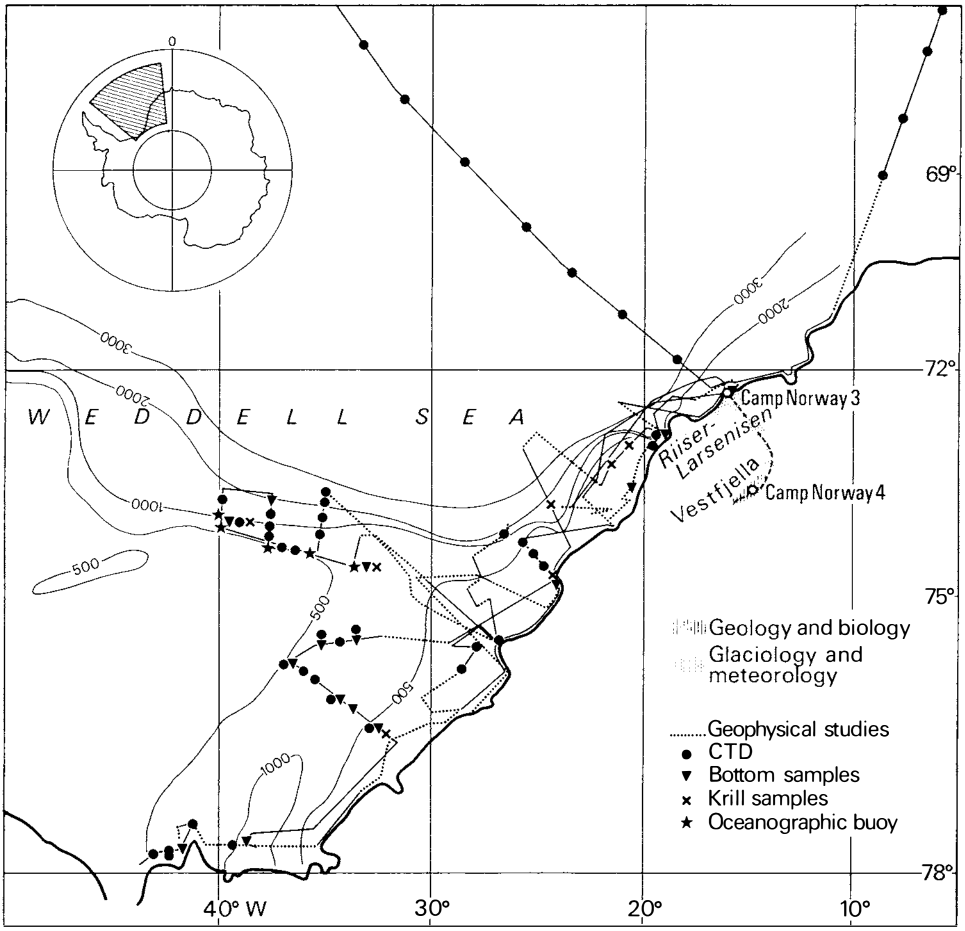

Fig. 1. *Area studied by the 1976—77 Norwegian Antarctic Research Expedition. At some localities the symbols "CTD" and "Bottom Samples" represent more than one sample station.*

mites alive back to Norway for further laboratory studies. He also collected bird samples for laboratory studies of environmental toxicology.

One automatic weather and positioning station was established in Vestfjella. It transmitted information on air and ground temperatures at eight intervals to the NIMBUS-6 satellite, which passed the data to USA, and from there they were sent to Norsk Polarinstitutt. The positioning capabilities of the station were used to obtain a check on the absolute positions of Vestfjella.

The shore parties used four snowmobiles for transport, and they travelled a combined total of about 7,000 km during the field season.

The shipboard programme

Whereas the land programme was in many respects a traditional form of Antarctic research, the shipboard programme introduced some new techniques and instruments to the Weddell Sea and in some cases to the Antarctic. The

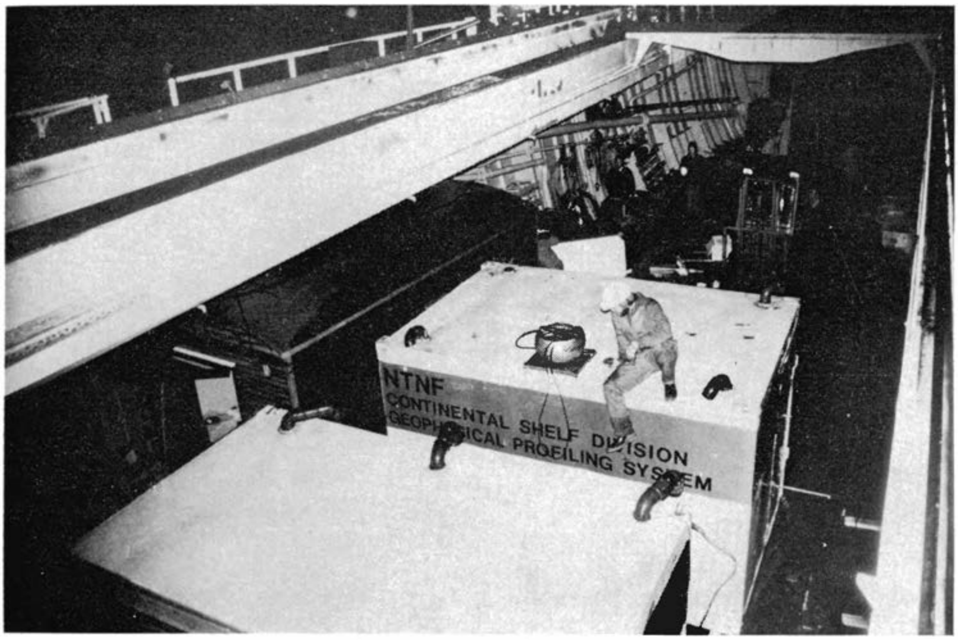

Fig. 2. *View below deck of M/V POLARSIRKEL, showing three of the five containers used as scientific laboratories. The drum with seismic cable can be seen in the background.*
Photo: K. BRATLIEN

main programmes were in oceanography and marine geophysics, with less extensive studies of marine geology, marine biology, sea ice, and of the ice shelf. Groups from several Norwegian research organizations and universities contributed with personnel and equipment to outfit "Polarsirkel" to become a very modern mobile laboratory. Under deck the ship had a 200 m² open room where we placed five container-module laboratories and various scientific equipment including the seismic gear. And on the deck above we had altogether six winches for use of the various scientific programmes. Fig. 1 shows the ship track and the research done in the Weddell Sea and in Dronning Maud Land, Fig. 2 shows some of the containers below deck, Fig. 3 shows the arrangement of winches above deck, while the frontispiece of this Årbok 1976 shows M/V "Polarsirkel" breaking annual ice by the barrier.

The oceanographic work was done by a three-man group with assistance from the visiting Argentine scientist. It was a continuation of the successful cooperation with USA and Argentina under the IWSOE Programme. Over 100 CTD-soundings of salinity, temperature and depth were done using a Neil Brown CTD-sonde. The deepest of these soundings were done to 3,000 m, and at water depths of 1,000 m or less they were usually taken to the sea bed, which revealed hitherto unsuspected phenomena in the lower tens of meters of the water column. Ten Aanderaa current meters, recording temperature, currents, and salinity, were placed near the sea bed at water depths of 4–600 m, around 74°S, and between 34° and 40°W. Half of the meters were supplied by the USA,

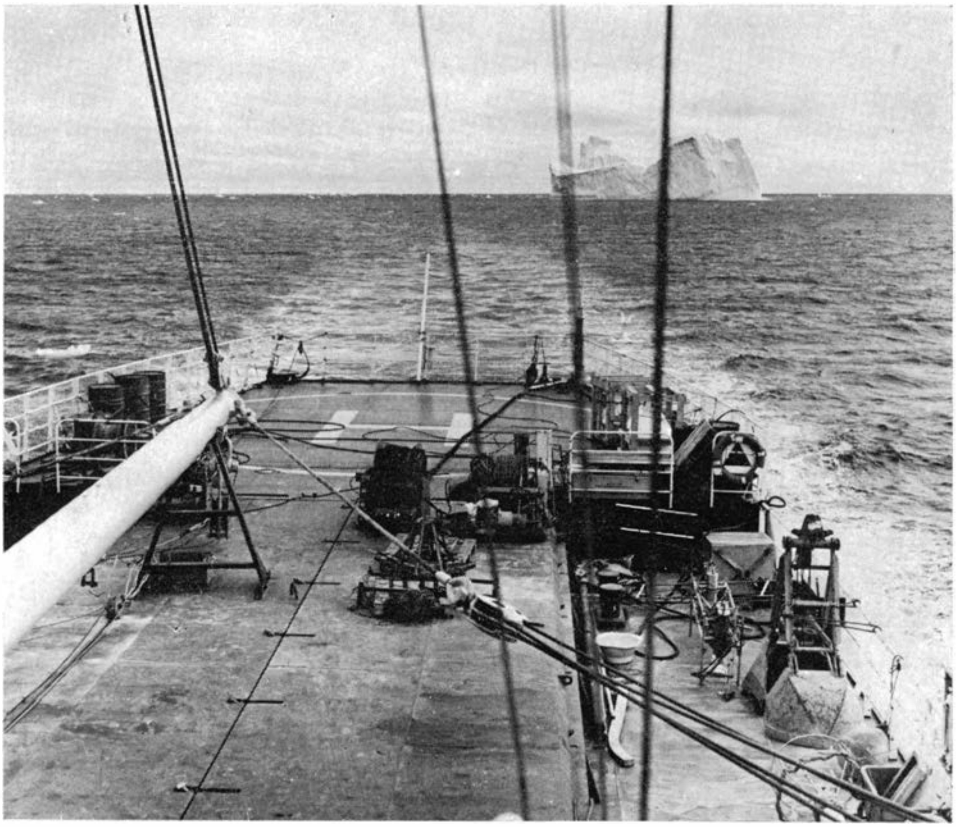

Fig. 3. *Some of the scientific equipment deployed from the deck of M/V POLARSIRKEL. In the centre are winches for magnetometer (partly hidden behind the boom), sparker, side seeking sonar, and a small grab. On the right rear are (white) drifting buoys ready for deployment, in front of this a rig for underwater photography, sparker equipment, a large grab, and various oceanographic equipment. Further forward are the winches for the oceanographic sondes and the marine biology and geology programs.*

Photo: B. Fossum

and they will all record data every hour for one year. Two tide gages recording at the same time intervals were placed in the same area. Detailed studies of potentially supercooled water were done at the edge of the Filchner ice shelf, in position 77°45'S, 41°45'W.

The marine geophysical programme was done by a four-man group from two institutions. Magnetometry was done throughout most of the cruise, covering about 2,000 km within the Weddell Sea area and even longer distances during the crossing to and from Antarctica.

Gravimetry was done on all track lines shown except the most easterly, as there was instrument failure at that time. Bathymetry soundings, to 6,000 m, were also done all the time apart from the most easterly track.

Seismic studies were done by two techniques. About 1,100 km were covered by reflection and refraction studies, using airguns as the energy source, a 1.5 km long sixteen-channel streamer, sonar buoys, and a DFS-5 instrument. Signals were obtained down to about 6 km depth. Reflection studies of about 1,200 km length were done with a sparker as energy source, these gave reflections down to about 500 m depth.

To study the sea bed conditions a side-seeking sonar was used over about 220 km, with results obtained down to 400 m water depths. These showed highly variable bottom topography. The combined cruise lines of the seismic and sonar studies are shown in Fig. 1 under the heading "geophysical studies".

The geological programme consisted of sampling at 27 localities, both dredging and coring, and at seven of these bottom photography was also obtained. The localities were selected based on the geophysical surveys, and most of the geological stations are shown in Fig. 1. Numerous types of bottom fauna were also obtained together with the geological samples.

The marine biological programme was mostly a study of the nutrient content of krill and the biochemical and bacteriological processes of its decomposition. Krill samples were collected (Fig. 1) and in part frozen, in part allowed to deteriorate and studied at various time intervals. A two-man group conducted these studies, and they also took general biological registrations of animal life encountered.

The sea ice studies and the ice shelf studies were done by one man, the main programme being a general registration of the sea ice conditions, to be used as ground control for the satellite sensed information, and a study of the ice shelf thickness and position, to determine mass outflow rates for this part of Antarctica.

Both this mapping programme, and the various other shipboard programmes were dependent upon precise position information. To this aid the ship carried two separate satellite navigation systems. It is estimated that travelling at full speed along a cruise line the ship's positions were at all times known within 200 m, and if for special purposes we stayed in a fixed position, this could be determined to within about 10 m. Two men were responsible for the navigation system, and this was operative throughout the cruise.

Bouvetøya

After completing the work in Dronning Maud Land and the Weddell Sea, the expedition spent three days working at Bouvetøya. An automatic weather station, transmitting data on temperature, pressure, and wind, was established on the western side of the island. This station is expected to be in operation for $1\frac{1}{2}$ year, and is transmitting its data via NIMBUS-6. The expedition also did tide measurements, studied the biology and geology ashore, and did oceanographic and marine biological studies in the surrounding sea.

Conclusion

This expedition demonstrated that this icebreaker was an efficient mobile research platform permitting the use of modern techniques to perform studies in the ice covered waters of the Antarctic. The programme of the expedition was planned to obtain information on some of the questions which SCAR

(Scientific Committee on Antarctic Research) feels must be investigated in order to provide the Antarctic Treaty Nations with the necessary information to make well-founded decisions on the difficult questions of resources in the Antarctic. As the expedition has recently returned we cannot yet present many results, but over the next months the data will be analyzed and presented to the international community. We can already see, however, that many more such studies are needed, and we intend to repeat this kind of expedition in the 1978/79 season.

Norsk Polarinstitutts virksomhet i 1976

AV TORE GJELSVIK

Organisasjon og administrasjon

PERSONALE

Norsk Polarinstitutt (NP) hadde 34 faste stillinger i 1976, det samme som foregående år. Pr. 31.12. var en stilling som laborant, en stilling som topograf og en stilling som kontorassistent ubesatt.

Følgende sluttet ved NP i 1976:

Topograf BJØRKE, JAN T., 30.9.
Hydrograf I CHRISTIANSEN, JOHAN H., 4.5.
Ingeniør NETELAND, EINAR, 30.6.
Kontorassistent VOLLEN, LEIF, 5.12.
Laborant VABRÅTEN, KNUT, 31.12.

Ansettelse ved NP i 1976:

Hydrograf I FJØRTOFT, JON H., fra 12.7.
Hydrograf I MOEN, ERIK, fra 9.9.

Direktør TORE GJELSVIK, som er innvilget ett års permisjon (forskningsfriår) fordelt over tidsrommet 1975/77, tok ca. fem måneder av denne permisjon i tiden 1.1.–24.5.1976. Under hans fravær fungerte underdirektør KAARE Z. LUNDQUIST som direktør.

Midlertidig engasjerte:

BREKKE, ANNEMOR	redaksjonssekretær
HUSETH, ROLF EGIL	assistent
JØRGENSEN, MARIT	kontorassistent (deltidsstilling)
KNUDSEN, ELSA	kontorassistent
KOPPERUD, ESPEN	tegneassistent, fra 5.5.
MØLLER, JON ERIK	laborant
ROTHÉ, BRUNO	geolog, fra 16.5. (lønnet av NTNF på Barentshav-prosjektet)
RYNNING, ANNE METTE	kontorassistent, fra 22.11.

Stipend og forskningsbidrag er gitt til:

Cand. mag. ØYSTEIN HAGA, kr. 9.000,— til dekning av reiseutgifter og opphold på Svalbard i forbindelse med hovedfagsoppgave i kvartærgeologi.

Cand. mag. EINAR ANDA, kr. 3.000,— til dekning av reiseutgifter og opphold på Jan Mayen i forbindelse med hovedfagsoppgave i glasiologi.

Cand. mag. ASBJØRN HIKSDAL, kr. 3.000,— til dekning av reiseutgifter og opphold på Jan Mayen i forbindelse med hovedfagsoppgave i kvartærgeologi.

Cand. mag. AAGE TØRRIS EKKER, kr. 12.000,— til dekning av reiseutgifter og opphold på Svalbard i forbindelse med hovedfagsoppgave om kortnebbgås på Svalbard.

Cand. mag. KNUT KIRKEMO, kr. 2.200,— til dekning av reiseutgifter i forbindelse med hovedfagsoppgave om sedimentspektrografiske studier på Bjørnøya.

Stud. real. MAX AAGE EIEN og stud. real. TORBJØRN THRONDSEN, kr. 2.000,— hver til dekning av reiseutgifter i forbindelse med palynologiske undersøkelser i området sør for Sassenfjorden.

TORE ROLF LUND, kr. 11.400,— til dekning av utgifter i forbindelse med hovedfagsoppgave i limnologi om fytoplankton og primærproduksjon i Dieset-vatna, Mitrahalvøya.

Professor ALV EGELAND, Det norske institutt for kosmisk fysikk, bidrag på kr. 10.000,— til bygging av instrumenter for rakettoppskytinger fra den amerikanske Siple-stasjonen i Antarktis.

Studentene ARVE BREEN, MORTEN MORLAND og YNGVE ROBERTSEN, kr. 5.000,— til dekning av reiseutgifter i forbindelse med vitenskapelige undersøkelser om drivisproblemer ved havneutbygging på Svalbard.

Professor JOHN KROG, Zoofysiologisk Institutt, kr. 15.500, — til delvis dekning av utgifter til forskningsprosjekt om fysiologiske undersøkelser på Svalbardrein.

Oppnevnelser og tillitsverv:

THOR LARSEN (1) oppnevnt som medlem i Critical Marine Habitats Group av International Union for the Conservation of Nature (IUCN) og (2) oppnevnt som «Independent expert» til IUCN Preparatory Meeting on proposed Convention on the Conservation of Migratory Species of Wild Fauna.

OLAV LIESTØL (1) oppnevnt som representant for Norsk Polarinstitutt i Norsk Hydrologisk komité og (2) oppnevnt som medlem av NTNF's Utvalg for permafrost.

TORGNY VINJE oppnevnt som medlem av styringskomité for NTNF-prosjektet «Drivende bøyer for ARGOS».

OTTO SALVIGSEN oppnevnt som sensor i geografi ved Universitetet i Oslo.

REGNSKAP FOR 1976

Kap. 950. Poster:	*Bevilget:*	*Medgått:*
1. Lønninger	kr. 3.420.000	kr. 3.848.400
9. Deltaking i Antarktisekspedisjon, overførbar	« 1.500.000	« 992.700
10. Kjøp av utstyr	« 60.000	« 63.900
15. Vedlikehold	« 5.000	« 0
20. Ekspedisjoner til Svalbard og Jan Mayen	« 2.100.000	« 2.345.400
21. Forskningsstasjonen på Svalbard	« 1.900.000	« 1.900.000
22. Vitenskapelig samarbeid i Arktis	« 600.000	« 0
29. Andre driftsutgifter	« 1.300.000	« 1.450.000
70. Stipend	« 75.000	« 75.100
	kr. 10.960.000	kr. 10.676.100
Kap. 31. Fyr og radiofyr på Svalbard	kr. 50.000	kr. 30.100

Kap. 3950. Inntekter:	*Budsjettert:*	*Regnskap:*
01. Salgsinntekter	kr. 70.000	kr. 103.600
03. Inntekter ved diverse tjenesteyting	« 10.000	« 0
52. Refusjon fra Svalbardbudsjettet	« 900.000	« 900.000
	kr. 980.000	kr. 1.003.600
Kap. 4905. Tilfeldige inntekter	kr. 0	kr. 1.500

Kommentarer til regnskapet

Kap. 950

Post 1. Lønninger. — Merforbruket skyldes økte lønnsutgifter som følge av lønnsreguleringer 10.10.1975 og 1.5.1976, samt gjennomføring av den nye stillingsstruktur med virkning fra 1.5.1975.

Post 20. Ekspedisjoner til Svalbard og Jan Mayen. — Merforbruket skyldes ekstraordinær stigning av fartøyleier. Posten er tillatt overskredet mot innsparing på post 22.

Post 22. Vitenskapelig samarbeid i Arktis. — Forslag om samarbeid om isbjørnundersøkelser i Arktis bortfalt for 1976.

Feltarbeid

NORGE

Geofysikk

Massebalansen på Storbreen i Jotunheimen og Hardangerjøkulen ble på samme måte som tidligere år utført av LIESTØL med assistanse av hovedfagsstudenter. Forenklede balansemålinger ble foretatt på Blomsterskardbreen av B. WOLD. På grunn av den store vinternedbøren viste breer vest for vannskillet overskudd i balansen mens breer østenfor, deriblant Storbreen, viste underskudd.

Bretungenes lengdevariasjoner ble målt ved 18 breer. Av disse viste tre fremrykking mens resten viste tilbakegang. Briksdalsbreen gikk 30 m frem og ligger nå lenger fremme enn den har gjort på 28 år.

SVALBARD

Geofysikerne arbeidet vesentlig om våren i Ny-Ålesundområdet. Det var en biologisk ekspedisjon til Nordaustlandet med snescootere i mars–april. Begge grupper hadde flystøtte.

Instituttets sommerekspedisjon til Svalbard ble organisert og ledet av operasjonssjef THOR SIGGERUD. Ekspedisjonsfartøy var M/S «Polarstar». Utstyr ble lastet i Bodø 16.7. og losset igjen samme sted 4.9. M/S «Polarstar» gikk via Longyearbyen og Ny-Ålesund til Nordaustlandet med Kvitøya og oppholdt seg her hele tiden til ekspedisjonen ble avsluttet. To stk. Bell 206 (Jet Rangers) helikoptre var leiet for ekspedisjonen og ble fraktet mellom Norge og Longyearbyen med kullbåt. Helikoptrene fløy til og fra Nordaustlandet.

Hydrograferingsfartøyet M/S «Olaf Scheel» lastet i Bodø 9.7. og alt hydrograferingspersonale reiste med dette. Returen til Bodø var 30.8.

Hovedekspedisjonen arbeidet på Nordaustlandet, med ekspedisjonsfartøyet M/S «Polarstar» som flytende mobil base. Hovedinnsatsen var lagt på geologi, både når det gjaldt det faste fjell og kvartærgeologi. Dessuten var det med topografer og en glasiolog for prøvetaging på Austfonna. Partiene ble dels lagt ute i felten og flyttet med helikoptrene, dels arbeidet de direkte ut fra båten. Etter hvert ble dette tilfelle for nesten alle. Værforholdene var ikke helt gode, med korte godværsperioder og meget vind. Det kom tidlig sne, men det var ikke drivisproblemer. Fire dager ble det ikke fløyet med helikoptrene, en dag på grunn av tåke og tre dager på grunn av for sterk vind.

To geologpartier arbeidet i Isfjorden.

Hydrograferingen foregikk med det større hydrograferingsfartøyet utenfor vestkysten av Spitsbergen med landstasjoner for HI-FIX systemet på Kapp Martin og Daudmannsodden. Inne i Isfjordens nordlige armer foregikk hydrografering på to skift med hydrograferingsbåten før denne hadde motorhavari som avsluttet sesongen.

Det var i alt 37 ekspedisjonsdeltagere pluss fem en kortere del av sommeren. Dessuten var det et parti på tre for spesielle oppgaver i forbindelse med kontinentalsokkelundersøkelser. Besetningene på fartøyer og helikoptre er ikke inkludert. Av de 37 deltagere, var 14 ansatt ved Norsk Polarinstitutt, to ekstrahydrografer var engasjert. 21 var assistenter, de fleste med spesielle kvalifikasjoner i forhold til det arbeid de skulle gjøre. De fem som deltok kortere tid var alle ansatt ved Norsk Polarinstitutt.

Ekspedisjonen ble gjennomført etter programmet og uten ulykker eller uhell. Et parti på sydkysten av Nordaustlandet var imidlertid plaget av isbjørnbesøk. Sysselmannen ytet verdifull helikopter-assistanse for M/S «Olaf Scheel» ved avhenting av et parti på Daudmannsodden under vanskelige omstendigheter i dårlig vær.

Hydrografi

I feltsesongen ble det med hydrograferingsbåten «Svalis» foretatt oppl odding i målestokken 1:50 000 i Dicksonfjorden. Arbeidet ble ledet av HELGE

HORNBÆK, assistert av engasjert hydrograf KJELL BRAADLIE samt SIVERT UTHEIM, FINN JENSEN, ØIVIND FINNEKÅSA og ØIVIND MEHLUM. Det ble arbeidet i to skift.

Hydrograferingstoktet med M/S «Olaf Scheel» ble ledet av hydrograf FJØRTOFT. I tilknytning til fjorårets arbeid ble det foretatt opploddinger av området mellom Bellsundbanken og Forlandsbanken med utgått loddedistanse på ca. 2100 naut. mil.

Som assisterende hydrograf var engasjert LEIF O. NORDLI. LUNDQUIST og NETELAND var med fartøyet en uke under montering og igangkjøring av HI-FIX systemet. Assistentene SIGRID STOKKE, KJELL HUSEBY, HARALD GRØNLIEN og JON REISEGG betjente landstasjonene på Kapp Martin og Daudmannsodden. På grunn av de usedvanlig dårlige værforhold ble arbeidet avsluttet en uke tidligere enn planlagt.

Geodesi-topografi

De geodetiske og topografiske feltarbeidene som bestod i signalsetting, triangulering og passpunktmåling på nord- og vestsiden av Nordaustlandet, ble utført av to partier som brukte ekspedisjonsbåten M/S «Polarstar» som base. Helikopter ble brukt under arbeidet. I alt ble det boltet elleve varder, observert åtte trigpunkter og bestemt 33 passpunkter.

OLA STEINE med IVAR LUND-MATHISEN som assistent ledet det ene partiet samtidig som han var leder av kartleggingen. KJELL REPP som hadde LARS BAKKETUN til assistent, ledet det andre partiet til han reiste tilbake til Norge den 10.8. BJØRKE som ankom dagen før, overtok ledelsen av partiet for resten av sesongen med samme assistent.

En ny permanent tidevannsmåler — TG-3A — ble montert i Ny-Ålesund av STEINE. Måleren registrerer trykk og temperatur for hver halve time.

Geologi

Feltarbeidet bestod vesentlig i en konsentrert innsats i utforskningen av Nordaustlandet. Til hjelp hadde man M/S «Polarstar» og to helikoptre. Et kvartærgeologisk parti, SALVIGSEN med to assistenter, hadde egen feltleir på sydkysten. TORE GJELSVIK, TORE S. WINSNES, AUDUN HJELLE og YOSHIHIDE OHTA med hver sin assistent, arbeidet vesentlig med båten som base langs nordkysten og på øyene i nord og øst. Hensikten var kartlegging og undersøkelse av lagrekken i Hecla Hoek og innsamling av prøver for å kunne bestemme alderen av bergartskompleksene. ØRNULF LAURITZEN med to assistenter arbeidet i indre del av Isfjorden med undersøkelser av øvre Mesozoikum og Trias. Som et ledd i Barentshavprosjektet samlet ROTHÉ med to assistenter prøver fra Isfjordområdet med henblikk på diageneseundersøkelser. HARALD MAJOR ledet i tidsrommet 20.5. til 20.6. den geologiske del av stratigrafiske boringer i Ny-Ålesund-feltet etter anmodning av Kings Bay Kull Comp.

Geofysikk

LIESTØL oppholdt seg i Ny-Ålesund fra 20.5. til 18.6. Med assistanse av KJELL REPP foretok han målinger av akkumulasjonen på Brøggerbreen og Lovénbreen. Dessuten ble det foretatt kjerneboringer på Brøggerbreen og tatt prøver av isen for hver 15 cm ned til 7 m dybde. Prøvene ble tatt for tritiummålinger i samarbeid med Isotoplaboratoriet ved NTH. Man håper at denne metode kan brukes til å bestemme akkumulasjonen i andre områder av Svalbard. Under oppholdet i Ny-Ålesund ble det også foretatt en del trianguleringsarbeider ved hjelp av termistorkabel. Målingene viste at permafrosten nådde ned til ca. 140 m under overflaten.

I tiden 19.6. til 24.6. oppholdt LIESTØL seg i Longyearbyen. Under oppholdet ble det 21.6. gjort forsøk på å komme til Finsterwalderbreen med helikopter stilt til disposisjon av Sysselmannen, for å få målt akkumulasjonen og fjorårets ablasjon. På grunn av dårlig vær ble bare en stake funnet, og forsøket måtte oppgis. 22.6. ble det med samme helikopter foretatt en tur til en «pingo» innerst i Adventdalen, der det ble tatt vannprøver og registrert temperatur.

KJELL REPP foretok en kjerneboring på Austfonna for radiologiske undersøkelser.

VIDAR HISDAL oppholdt seg ved Forskningsstasjonen i Ny-Ålesund i tidsrommet 20.5. til 22.6. Han fortsatte intensitetsmålingene av direkte solstråling med to Volz spektralpyrheliometre. Ved hjelp av et Hagner fotometer ble belysningen observert i klart og i overskyet vær, og ved forskjellige solhøyder. Et Eppley pyranometer utstyrt med halvkuleformet Schott fargefilter ble benyttet til å utføre en rekke målinger av globalstrålingens og den diffuse himmelstrålings intensitet for bølgelengder henholdsvis over og under 700 mm.

VINJE foresto et samarbeidsprosjekt mellom Meteorologisk Institutt ved C. KOLDERUP JENSEN og Norsk Polarinstitutt. Midler til prosjektet var bevilget av Den norske nasjonalkomité for Global Atmospheric Research Programme (GARP) og av NTNF — Barentshavprosjektet. Prosjektet omfatter bruk av automatiske satellittstasjoner på drivisen rundt Svalbard for bl.a. å få kjennskap til isdriften og de meteorologiske forhold i området. I alt fem stasjoner ble satt ut med fly, et Cessna 185, som landet på isen. Operasjonen ble gjennomført i april–mai av Polarnavigasjon ved flyverne O. RØDBERG og I. PEDERSEN med utgangspunkt i Ny-Ålesund og Stasjon Nord på Grønland. VINJE deltok i utsettelse og klargjøring i Ny-Ålesund i april.

Under oppholdet her arbeidet VINJE også ved Forskningsstasjonen med strålingsmålinger. Her registreres en rekke strålingskomponenter som er av betydning for det regionale strålingsklima og således også for isforholdene.

Biologi

LARSEN, assistert av CLAUS SANDE, drev i tiden 10.3. til 29.4. isbjørnundersøkelser og hi-registreringer langs nordkysten av Nordaustlandet. Feltutstyr var satt ut i 1975 og selv ble de fløyet til og fra feltområdet.

Det var ikke noen egen biologisk feltaktivitet under Norsk Polarinstitutts hovedekspedisjon ut over faunaregistreringer som ble utført av NP's øvrige feltpartier og av andre ekspedisjoner og enkeltpersoner.

MAB-programmet (Man and the Biosphere) fortsatte etter planene. Programmet ledes av NILS A. ØRITSLAND som har det vitenskapelige og feltmessige ansvar, mens Norsk Polarinstitutt har ansvaret for regnskapet og for å lede den praktiske gjennomføring av prosjektet.

Fyr og radiofyr

Ettersynet av fyr og radiofyr ble utført av KÅRE BRATLIEN, assistert av mannskap fra M/S «Nordsyssel». Til fyrettersynet ble brukt M/S «Nordsyssel» samt det helikopter som Sysselmannen på Svalbard har leid.

I 1976 ble lyktene på Brandalspynten, Kapp Ekholm og Akseløya lagt om fra gass til elektrisk batteridrift, slik at det av de i alt tolv fyr og lykter på Svalbard, bare er en lykt (Kapp Amsterdam) som er gassdrevet.

JAN MAYEN

OLAV ORHEIM veiledet i tiden 14.–17.6. hovedfagsstudentene EINAR ANDA og ASBJØRN HIKSDAL som med stipendium fra Norsk Polarinstitutt oppholdt seg på Jan Mayen i juni–august for å foreta glasiologiske og kvartærgeologiske undersøkelser.

Under oppholdet foretok ORHEIM en tur til Sørbreen hvor alle stakeposisjoner ble kontrollert og en del nye staker satt ut. Studentene ble instruert i bremålinger og det kvartærgeologiske programmet ble diskutert. En del av terrenget mellom Ullerenglaguna, Nordlaguna og Båtvika ble gått over.

JOHN SUNDSBY assisterte i tiden 5.8. til 11.9. geodet BJØRN G. HARSSON, Norges geografiske oppmåling, med tyngdemålinger på stasjoner fra 1974. I tillegg til dette arbeidet fikk SUNDSBY utført en del magnetiske målinger samt ny innmåling av stasjoner hvor dopplermålinger tidligere er foretatt.

ANTARKTIS

30. november forlot M/S «Polarsirkel» Bergen med felt- og vitenskapelig utstyr for Den Norske Antarktisekspedisjonen 1976/77. Etter et kort opphold i Brest for å ta ombord et sjøgravimeter utlånt fra Frankrike, fortsatte skuta til Rio Grande d.s., Brasil, hvor bunkers ble tatt ombord og derfra til Port Stanley, Falklandsøyene, med ankomst 2. januar 1977.

28. desember fløy de 23 norske ekspedisjonsdeltagerne fra Oslo til Buenos Aires og videre til Port Stanley neste dag. Deltagerne inkluderte åtte mann fra Universitetet i Bergen, fire fra Institutt for Kontinentalsokkelundersøkelser, to fra Fiskeridirektoratet/Norges Fiskeriforskningsråd, to fra NRK/Fjernsynet, en fra Universitetet i Oslo, en fra Teledirektoratet og fem fra Norsk Polarinstitutt. Ekspedisjonen ble ledet av ORHEIM. En argentinsk gjesteforsker sluttet seg til ekspedisjonen i Buenos Aires. Deltagerne gikk den 3. januar ombord i M/S «Polarsirkel» som samme dag forlot Falklandsøyene med kurs for vestlige Dronning Maud Land.

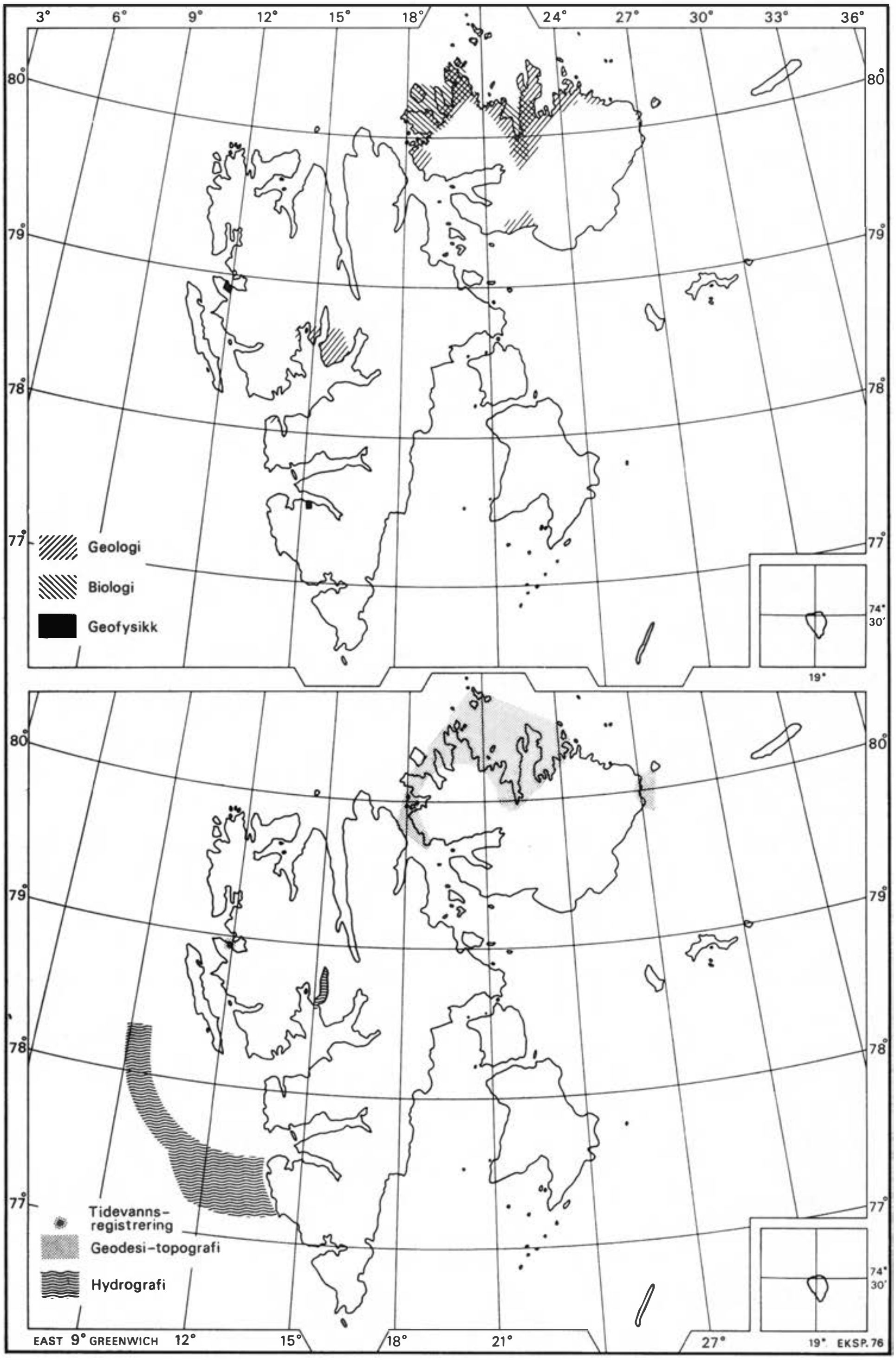

Fig. 1. *Geologiske, biologiske, geofysiske og geodetiske, topografiske og hydrografiske arbeidsområder i 1976.*

Arbeid ved avdelingene

(Se også under Publikasjoner)

Hydrografi

HORNBÆK utførte redaksjonelt arbeid i forbindelse med trykking av nye utgaver av sjøkartene 504, 505 og 513 samt trykking av nye opplag av sjøkartene 509 og 510. Han planla og tilrettela utgivelsen av de nye sjøkart 506 — det østlige Barentshav — og 523 — Isfjordområdet. Videre redigerte han ekkogrammene og utarbeidet hydrografisk original for HI-FIX-loddingen i 1975 og 1976.

CHRISTIANSEN (fratrådte 4.5.) bearbeidet hydrografisk materiale fra 1974 og 1975 og bisto i det rutinemessige arbeid ved avdelingen.

FJØRTOFT (tiltrådte 1.7.) og MOEN (tiltrådte 9.9.) rentegnet hydrografiske originaler med HI-FIX-lodding fra 1972 og 1973, redigerte ekkogrammer og utarbeidet hydrografisk original fra tilsvarende lodding for 1974 og 1975. Videre konstruerte og kontrollerte de redaksjonsgrunnlag for sjøkart nr. 506, 514 og 515. MOEN har også kontrollert beregninger for LORAN sky-wave korreksjoner til sjøkart nr. 505, og FJØRTOFT ble veiledet i det tekniske opplegg av Instituttets HI-FIX utstyr av ingeniør NETELAND (nå i firmaet Geoteam) som overhalte og testet dette.

Geodesi-topografi

Det ble i 1976 utført videre beregninger til bruk for hovedkartverket Svalbard 1:100 000. Ved hjelp av Wild A 7 autograf ble det utført bildetriangulering over Edgeøya. Kart over kystområdene rundt Barentsøya i målestokk 1:100 000 ble konstruert, og et nytt omriss av Kvitøya i samme målestokk ble laget etter satellittbilder (NASA Landsat-2) og flybilder. Det ble også arbeidet på kartbladet C11, Kvalvågen og på B10, Van Mijenfjorden og C9 Adventdalen i forbindelse med nye utgaver, alle i målestokk 1:100 000. En tredje utgave av Svalbard 1:1 000 000 og en ny utgave av Svalbard 1:2 000 000 ble utgitt.

På grunnlag av det nye fotografiske materialet fra 1975 ble det nye landet og det forandrede landskapet etter vulkanutbruddet i 1970 konstruert i målestokk 1:20 000, med henblikk på ny utgave av Jan Mayen 1:50 000. I samme målestokk ble konstruert et område på Sør-Jan som tidligere manglet fotografisk dekning. Videre ble brepartiet Kerckhoffbreen–Sørbreen konstruert i målestokk 1:20 000 med 10 m høydekurver.

Geologi

Under sin forskningstermin bearbeidet GJELSVIK geologisk materiale fra N-Spitsbergen og utarbeidet en avhandling om dette området. Minneforelesningen om utforskningen av Barentshavet ble tilrettelagt for publisering.

MAJOR utførte kullpetrografiske undersøkelser og deltok i forberedelser av boringer i Ny-Ålesundfeltet. Han var sykmeldt i det siste halvåret.

WINSNES har i vesentlig grad vært engasjert med administrativt arbeid som leder for den geologiske avdeling, med Barentshavprosjektet og faglig gjennomgåelse av manuskripter for publisering. En del bearbeidelse av materiale fra Antarktis og feltmateriale fra 1975 ble utført.

HJELLE har bearbeidet materiale fra Antarktis og fra nordvestre del av Svalbard og utarbeidet manuskripter om disse områdene. Han har også deltatt i forberedelsene til Antarktisekspedisjonen.

OHTA har arbeidet med analyser av de metamorfe bergarter fra Spitsbergen og sedimentære bergarter fra Antarktis. Han har gjort ferdig flere manuskripter med resultater av disse analysene.

SALVIGSEN har bearbeidet de kvartærgeologiske observasjoner fra 1975 og 1976 og satt seg inn i problematikken vedrørende den postglasiale landhevning av Nordaustlandet. Det er foretatt flere C-14 dateringer av strandvoller. Han har også virket som veileder for en hovedfagsstudent med arbeid fra Svalbard.

LAURITZEN har arbeidet med observasjonsmateriale fra Isfjordområdet, særlig stratigrafi og utviklingen av evaporittene i dette området. Han har også samlet materiale for et oversiktskart nord for Isfjorden.

ROTHÉ ble ansatt ved Barentshavprosjektet fra 16. mai. Han har vært engasjert med undersøkelser av porøsitet og permeabilitet av bergarter fra Isfjordområdet.

Laborant MØLLER har vært beskjeftiget med fremstilling av tynnslip og andre bergartspreparater samt ordning av bergartsmaterialer. Han har også hjulpet materialforvalteren med klargjøring av utstyr i forbindelse med ekspedisjonsforberedelsene.

Geofysikk

HISDAL fullførte en oversikt over Svalbards geografi for publisering. Arbeidet med å beskrive resultatene av en undersøkelse av sol- og himmelstrålingens spektralfordeling fortsatte, og sommerens observasjoner fra Ny-Ålesund ble bearbeidet.

LIESTØL bearbeidet glasiologisk og annet feltmateriale fra Norge og Svalbard. Arbeidet for øvrig har bestått av litteraturstudier, forberedelser til møter, kollokvier og forelesninger. Meget tid er også medgått til konsulenttjeneste og veiledning av studenter.

ORHEIM arbeidet i det vesentlige med forberedelse av Norsk Polarinstitutts Antarktisekspedisjon 1976/77. I tillegg bearbeidet han glasiologiske data fra Jan Mayen og Supphellebreen og data fra Landsat-2-bilder av Antarktis. Han var også veileder for to hovedfagsstudenter.

VINJE gjorde ferdig en isoversikt for området Island–Novaja Zemlja for de ti årene 1966–1975 som Norsk Polarinstitutt har satellittdekning for. Han gjorde videre ferdig en oversikt over isforholdene for skipsfarten på Svalbard i 1975. Materialet fra fire automatiske satellittstasjoner plassert på isflak for undersøkelse av drift ble ferdig behandlet og rapportert hver tredje måned før disse Landsat- (tidligere ERTS-) undersøkelser i Svalbard–Grønlandområdet ble sendt til NASA. Norsk Polarinstitutt har i alt fått 480 satellittbilder derfra av dette området i 1976 og disse har vært studert fortløpende. Kvitøya viser seg å være omkring 2,6 ganger større enn tidligere antatt.

Forberedelser til Antarktisekspedisjonen 1976/77 har foregått spesielt mot slutten av året.

Biologi

LARSEN fortsatte bearbeidelsen av innsamlet vitenskapelig materiale. Et arbeid om reinen på Nordaustlandet er publisert i Norsk Polarinstitutt Årbok 1976. I likhet med tidligere år har det vært en utstrakt konsulentvirksomhet for myndighetene, institusjoner og enkeltpersoner.

En påbegynt utarbeidelse av dataprogram for faunistiske registreringer er overtatt av Norges Landbrukshøgskole. Det er foretatt en del endringer i programmet som nå på det nærmeste er ferdig. Det har i 1976 vært en rekke henvendelser til Norsk Polarinstitutt om hovedfagsarbeider på Svalbard. To studenter er i gang med biologiske arbeidsoppgaver på Svalbard, mens oppgaver planlegges og tilrettelegges for ytterligere tre studenter.

Biblioteket

I 1976 ble det registrert 416 titler, herav bl.a. 49 innkjøpte bøker, 31 av gammel bestand, 66 særtrykk og småskrifter, 41 bøker fra bytteforbindelser og 72 som gaver. Særtrykksamlingen er 6100 stk. Det er etablert fem nye bytteforbindelser og tegnet to nye abonnenter.

Registrerte utlån var i alt 520, derav 318 til instituttets personale, 174 til personer utenfra og 28 til andre biblioteker.

Konsulent- og informasjonsvirksomhet

Instituttet har i likhet med tidligere år vært konsultert om polare spørsmål av norske myndigheter og av enkeltpersoner i inn- og utland.

GJELSVIK har i egenskap av president i SCAR deltatt i arbeidet med ressurs- og miljøutredninger vedrørende Antarktis, som organisasjonen er blitt bedt om å lage for de pågående politiske drøftelser under Antarktistraktaten. Han har gitt orienteringer om polarspørsmål til radio, fjernsyn og presse.

LUNDQUIST og forskerne besvarte, innenfor sine respektive fagområder, henvendelser fra massemedier vedrørende instituttets arbeidsoppgaver og virksomhet i polarstrøkene.

Reiser, møter og kursvirksomhet

BJØRN ARNESEN og STEINE deltok i mars i «Kartdagene 1976» som ble arrangert i Stavanger av Norges Kartttekniske Forbund. ARNESEN besøkte ved denne anledning Norges sjøkartverk, Stavanger.

BJØRKE deltok i juli i XIIIth Congress of the International Society of Photogrammetry (ISP) i Helsinki.

BRATLIEN deltok i juni i første del av seminaret «Utdanning i prosjektarbeid», avholdt i Morgedal, og i september i annen del av samme seminar som ble avholdt på Bolkesjø.

GJELSVIK deltok i oktober/november i møter i USA og Sør-Amerika i egenskap av president i SCAR. Han deltok først i årsmøtet til International Committee of Scientific Union (ICSU) i Washington D.C. og ledet deretter det 14. SCAR-møte som ble avholdt i Mendoza, Argentina. Han besøkte også Antarktis-institusjoner i Santiago og Buenos Aires. I Norge ledet GJELSVIK halvårsmøtet i Nasjonalkomitéen for Polarforskning i februar og tilsvarende møte i oktober. Han deltok for øvrig i drøftelser av prinsipiell art, spesielt i forbindelse med Antarktisekspedisjonen 1976/77.

HISDAL deltok i april i Tenth International Polar Meeting i Zürich. I august deltok han i Symposium on Radiation in the Atmosphere, avholdt i Garmisch-Partenkirchen.

LARSEN deltok i mai i møte i Critical Marine Habitats Group og Survival Service Commission, begge arrangert av IUCN i Morges, Sveits. I juli deltok han i Preparatory Meeting on Convention on Migratory Fauna, avholdt i Bonn, og i desember i møte i IUCN Polar Bear Specialist Group, avholdt i Morges, Sveits.

LUNDQUIST deltok som medlem av den norske delegasjon i to forhandlingsmøter med Sovjet om grensespørsmål i Barentshavet, henholdsvis i Moskva (juni) og i Oslo (desember).

LIESTØL deltok som guide i Geografisk institutts feltkurs i Finseområdet i juni.

ORHEIM deltok i september i to rådsmøter i International Glaciological Society (IGS), Cambridge, og i symposiet «Applied Glaciology» arrangert av IGS samme sted. Han deltok i mars i Nordisk glasiologmøte, avholdt i Tvärrminne, Helsinki. I oktober deltok han i det XIV. møte i SCAR som norsk representant i arbeidsgruppene for glasiologi og logistikk. Han foretok også flere reiser i Norge i forbindelse med forberedelsene av Antarktisekspedisjonen 1976/77.

SALVIGSEN deltok i desember i et symposium om kvartære dateringsmetoder, arrangert i Stockholm av de nordiske arbeidsgruppene for International Geological Correlation Program (IGCP). Han besøkte samtidig Naturgeografiska Institutionen ved Stockholm Universitet, for å diskutere kvartærgeologisk arbeid som tidligere er gjort av ekspedisjoner arrangert av institusjonen.

VINJE foretok i januar en studiereise til Cambridge i forbindelse med forberedelsen av Antarktisekspedisjonen 1976/77. I mars deltok han i Nordisk havismøte, arrangert i Åbo, og i mai deltok han i POLEX-møte i Toronto som representant for Den norske nasjonalkomitéen for GARP. Videre deltok han i august i det 10de nordiske meteorologmøte i Reykjavik og i september i møte for nordiske havisforskere, avholdt i København.

WINSNES deltok i juni/juli i et møte i Paris om mineralressursene i Antarktis som ledd i forberedelsene til Det IX. konsultative møte under Antarktistraktaten.

Forelesnings- og foredragsvirksomhet

Instituttets medarbeidere har i 1976 holdt følgende foredrag:

GJELSVIK: «Om Barentshavets geologi». Oslo Geofysikerforening, Oslo, i januar.

— «NORGE-ferdens vitenskapelige og geografiske betydning». Geografisk Selskaps festmøte, Oslo, i mai, i anledning 50-årsjubileum for NORGE-ferden.

— «Råstoffmuligheter og transportproblemer i arktiske områder». Forsvarets Høgskole, Totalforsvarskurset, Oslo, i august.

— «Om Svalbard». Seniorgruppen, Polyteknisk Forening, Oslo, i desember.

LARSEN: «Hiregistreringer Nordaustlandet». Åpent møte i Longyearbyen i april.

— «Isbjørnundersøkelser i Arktis». Groruddalen ungdomsskole, i oktober.

— «Økologiske isbjørnundersøkelser». Veterinærinstituttet, i oktober.

LIESTØL: Foreleste i vårsemesteret 1976 i glasiologi ved Universitetet i Oslo og ledet kollokvium for hovedfagsstudenter med emner innenfor glasiologi og permafrost. Han var også sensor ved åtte hovedfagseksamener i limnologi og fysisk geografi.

LUNDQUIST: «Kartlegging av våre polare områder». Rogaland Karttekniske Forening, Stavanger, i januar, samt i Hedmark og Oppland Karttekniske Forening, Lillehammer, i november.

OHTA: «Blue schist metamorphism in Spitsbergen». Kollokvium ved Geologisk Museum, Oslo, i mars.

ORHEIM: Holdt fire forelesninger i glasiologi ved Universitetet i Tromsø vårsemesteret 1976.

— «Om Antarktis». Geologisk Klubb, Tromsø, i mars.

— «Norwegian scientific participation in RISP (Ross Ice Shelf Project)» og «Norwegian planned activity on Riiser-Larsen-isen». Begge foredrag holdt ved Symposium on Ice Shelf Drilling Projects, Mendoza, i oktober.

— «Antarktis — en av nøklene til vårt miljø i fortid og fremtid». Selskapet til Videnskabens Fremme, Bergen, i desember.

VINJE: «Om norske havisundersøkelser». Møte for nordiske havisforskere, København, i september.

Publikasjoner

Skrifter:

Nr. 163 – WERNER HINZ: Zur Ökologie der Tundra Zentral-Spitsbergens.

Nr. 164 – W. B. HARLAND, C. A. G. PICKTON, N. J. R. WRIGHT, C. A. CROXTON, D. G. SMITH, J. L. CUTBILL and W. G. HENDERSON: Some coal-bearing strata in Svalbard.

Meddelelser:

Nr. 105 – ODD LØNØ: Norske fangstmenns overvintringer – Del III 1892–1905.

Nr. 106 – TORE GJELSVIK: Utforskningen av kontinentalsokkelen i Barentshavet – fra Fridtjof Nansens tid til i dag (særtrykk av Fridtjof Nansens Minneforelesninger XII holdt 10. oktober 1975 og utgitt av Det Norske Videnskaps-Akademi).

Polarhåndbøker:

Nr. 2 — Vidar Hisdal: Geography of Svalbard — a short survey.

Årbok 1974:

Ohta, Yoshihide: Interlocking antiperthite from the Smeerenburgfjorden area.
Worsley, David and Marc B. Edwards: The Upper Palaeozoic succession of Bjørnøya.
Edwards, Marc B.: Depositional environments in Lower Cretaceous regressive sediments, Kikutodden, Sørkapp Land, Svalbard.
— Sedimentology of Late Precambrian Sveanor and Kapp Sparre Formations at Aldousbreen, Wahlenbergfjorden, Nordaustlandet.
Bjærke, Tor, Marc B. Edwards, and Bindra Thusu: Microplankton from the Janusfjellet Subgroup (Jurrassic–Lower Cretaceous) at Agardhfjellet, Spitsbergen. A preliminary report.
Johnson, G. L. and J. Campsie: Morphology and structure of the Western Jan Mayen Fracture Zone.
Austegard, Atle: Earthquakes in the Svalbard area.
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— On the salt excretion in the Little Auk, *Plotus alle* (L.).
Nyholm, Erik S.: Monthly general rhythm pattern variations in the Nordenskiöld-Sabine Land population of the Svalbard reindeer (*Rangifer tarandus platyrhynchus*).
Alendal, Einar and Ingvar Byrkjedal: Population size and reproduction of the reindeer (*Rangifer tarandus platyrhynchus*) on Nordenskiöld Land, Svalbard.
Brattbakk, Ingvar, Arne Frisvoll og Erling Sendstad: Vegetasjon, mikrofauna og rein på Reinsdyrflya.
Alendal, Einar: The muskox population (*Ovibos moschatus*) in Svalbard.
Müller-Haeckel, Agnes und John O. Solem: Tagesperiodik von Kieselalgen und Grünalgen in einem Gewässer Spitsbergens.
Liestøl, Olav: Glaciological work in 1974.
Hisdal, Vidar: The weather in Svalbard in 1974.
Vinje, Torgny E.: Sea ice conditions in 1974.
— Radiation conditions in Spitsbergen in 1974.
Larsen, Thor: Observations of animal life in Svalbard in 1974.
Lundquist, Kaare Z.: Norsk Polarinstitutts virksomhet i 1974.
— The activities of Norsk Polarinstitutt in 1974.
— Main field work of scientific and economic interest carried out in Svalbard in 1974.

Notiser:

Orheim, Olav: Bremålinger på Jan Mayen.
Edwards, Marc B.: Growth faults in Upper Triassic Kapp Toscana Group, Kvalpynten, Edgeøya, Svalbard; a preliminary report.
Edwards, Marc B. and P. N. Taylor: A Rb-Sr age for granite-gneiss clasts from the late Precambrian Sveanor Formation, Central Nordaustlandet.
Bjærke, Tor and Bindra Thusu: Cretaceous Palynomorphs from Spitsbergenbanken, NW Barents Shelf.
Ginsburg, Leonard et Philippe Janvier: Un noveau gisement à Plésiosaures dans le Jurassique du Spitsbergen (Archipel du Svalbard).
Byrkjedal, Ingvar, Einar Alendal, and Odd F. Lindberg: Counts of sea-birds between Norway and Spitsbergen in the summer 1973.

Sjøkart:

504 Svalbard. Fra Sørkapp til Bellsund, 1 : 200 000. Ny utgave.
505 Svalbard. Fra Bjørnøya til Isfjorden, Storfjorden og Hopen, 1 : 750 000. Ny utgave.

513 Svalbard: Havner, ny utgave

Ny-Ålesund	1 : 25 000
Forlandsrevet	1 : 60 000
Adventfjorden	1 : 25 000
Sveagruva	1 : 15 000

Landkart:

Svalbard 1 : 2 000 000 (også som bilag til Polarhåndbok Nr. 2).
Svalbard 1 : 1 000 000. Ny utgave.

Annen publisering:

Instituttets medarbeidere har utenom instituttets serier publisert:

THOR LARSEN: Northeast Svalbard Nature Reserve. *Naturopa* nr. 25 1976. Pp. 21–23.
— Landscape and habitat protection in Svalbard. *Nature and Natural Parks* **14** (54) 1976. Pp. 2–4, 15–17.
OLAV LIESTØL: Glaciological investigations at Nigardsbreen, Norway. *Norsk Geografisk Tidsskrift* nr. 30. Pp. 187–219. 1976.
KAARE Z. LUNDQUIST: Norsk Polarinstitutt. Publisert i *Norske interesser i Polarområdene*. NRK Skoleradioen.
YOSHIHIDE OHTA: Neighbour-grain coordination of feldspar and quartz in porphyroblastic domain. *Jour. Geol. Soc. Japan* **81** (11). Pp. 671–682. (1975 Nov) Tokyo.
OLAV ORHEIM: Hva gjør Norge i Antarktis? Publisert i *Norske interesser i Polarområdene*. NRK Skoleradioen.
OTTO SALVIGSEN: Kvartærgeologi ved Norsk Polarinstitutt. *Kvartærnytt* nr. 1, 1976.
THOR SIGGERUD: Utforskningen av Svalbard. Publisert i *Norske interesser i Polarområdene*. NRK Skoleradioen.
TORGNY VINJE: Sea ice studies in the Spitsbergen-Greenland area, 5th quarterly report on Landsat investigations to NASA, nov. 1976. Annonseres i NIIS, US Dep. of Commerce.

Forskningsstasjonen på Svalbard

Oversikt og drift av de forskjellige faste forskningsprosjektene

1. *Strålingsmålinger:*

Norsk Polarinstitutt, Oslo. Det har i perioder forekommet en del feil ved utstyret. Dette gjelder både datalogger og strålingsmålere. Registreringene er dog tilfredsstillende.

2. *Tidevannsmåleren:*

Norsk Polarinstitutt, Oslo. Datalogger for tidevann- og temperaturregistreringer ble installert 13. juli. Registreringene ble foretatt hver halve time med tape og batterikapasitet for seks måneder. Test på utskrift av dataene blir foretatt ca. to ganger pr. måned. Kontroll av data viser at registreringene går tilfredsstillende.

3. *Oseanografi:*

Havforskningsinstituttet, Bergen. Sjøprøver ble tatt opp i juli og august fra stasjon A og B. Utstyret er svært mangelfullt.

4. *Luftforurensning:*

Norsk institutt for luftforskning, Kjeller. Det har vært en del problemer med utstyret som er plassert i luftskipsmasten et stykke vekk fra Forskningsstasjonen. 28.9. ble utstyret demontert og diverse modifikasjoner utført. Utstyret ble startet for normal drift 19.10. Det fungerte normalt frem til 15.11. da vakuumpumpen låste seg. Denne ble demontert og overhalt. Service er svært vanskelig å utføre i vintersesongen.

5. *Meteorologi:*

Det Norske Meteorologiske Institutt, Blindern. Observasjonene er tatt etter det oppsatte programmet. Utstyret fungerer tilfredsstillende.

6. *Glasiologi:*

Norsk Polarinstitutt, Oslo. Massebalansemålinger har vært utført ved de to breene Austre Brøggerbreen og Midre Lovénbreen. I forbindelse med disse målingene ble vannføring, slamtransport og oppløste stoffer målt i bre-elvene.

7. *Seismisk stasjon:*

Jordskjelvstasjonen, Bergen. Stasjonen fungerer meget godt og kun små korrigeringer har vært nødvendige. I begynnelsen av august instruerte en tekniker fra Jordskjelvstasjonen i Bergen personalet ved FST i den tekniske oppbyggingen av stasjonen. Stasjonen ble kalibrert og diverse tester ble utført.

Forsker PER OPTUN underviste i avlesning av skjelvdiagram ved FST i tidsrommet 2.12.–8.12.

8. *Ionosfærefysikk:*

Universitetet i Tromsø. Den vitenskapelige assistent ved Forskningsstasjonen hadde avtale med Nordlysobservatoriet om driftsmålinger i forbindelse med Nordlysobservatoriets pågående eksperiment. På grunn av forsinkelser i leveringer av instrumenter, har ikke Nordlysobservatoriet kunnet sende opp utstyr. Vit. ass. har derfor arbeidet med teoretisk ionosfærefysikk denne perioden.

Riometrene:

Nordlysobservatoriet, Tromsø. Alle riometre har denne perioden fungert tilfredsstillende. Noen små feil har vært reparert av teknikeren på FST.

9. *Magnetometer:*

I begynnelsen av perioden var det en del problemer med fremtrekksurverket. Urverket ble skiftet ut og virket tilfredsstillende. Nyoverhalt pendelur for tidsmarkering ble montert i september. To av komponentene i registreringene forsvant 18.11., sannsynligvis forårsaket av uvær. Korrigeringer av utstyr blir normalt foretatt av folk fra Nordlysobservatoriet og teknisk informasjon ved stasjonen var mangelfull. En del justeringer ble foretatt, og fra 28.12. gikk registreringene normalt.

10. *All-sky-camera:*

Nordlysobservatoriet, Tromsø. Kameraet var montert klart for registreringer 28.9. En del problemer ble løst og utstyret har siden fungert tilfredsstillende.

Diverse

1. *Aurora, 25 fot plastsjark:*

Etter istandsetting ble båten satt på vannet i midten av juli. Etter en kort sommersesong ble båten sendt med M/S «Polarstar» til Norge 28. august for full overhaling. Båten ble delvis brukt til å hente sjøprøver, samt flere turer til Kapp Mitra i forbindelse med biologisk virksomhet. Det gamle jernlagret ble gjort klart som vinteropplag for Aurora i løpet av sommeren.

2. *Småbåter:*

FST disponerer en 14 fots Ranabåt i plast i god stand, en 16 fots Mørebas, en 8 fots plastjolle i god stand og to gummibåter. Båtene ble satt i opplag 4. oktober.

3. *Snøscootere:*

Stasjonen disponerer to snøscootere.

4. *Annet utstyr, arbeidsrom, etc.:*

Det er en del generelt utstyr ved Forskningsstasjonen til utlån til gjestende forskere og til bruk for det faste personell.

5. I løpet av vårsesongen ble kapasiteten for å motta gjestende forskere om sommeren betydelig utvidet idet seks mindre og ett større rom i en hittil ubenyttet betongbygning ble pusset opp og satt istand for sommerbruk. Lokalene er utstyrt med arbeidsbenker, etc. Sommeren 1976 ble disse lokaler hovedsakelig benyttet av MAB-prosjektet.

Bruk av stasjonen, gjestende forskere

1. Det blir etter hvert flere brukere ved stasjonen. Ca. 25 forskere fra følgende institusjoner har arbeidet ved eller ut fra stasjonen i perioder fra en uke til tre måneder:

   Universitetet i Bergen, Jordskjelvstasjonen
   Universitetet i Tromsø, Nordlysobservatoriet
   Universitetet i Oslo, Fysisk institutt
   Norsk Polarinstitutt
   Man and the Biosphere prosjektet, Norsk Polarinstitutt
   Stipendiater, Norsk Polarinstitutt

2. Videre har det vært en rekke besøk ved stasjonen av representanter for myndigheter og almenheten, med statsminister NORDLI i spissen. Det har også vært en rekke besøk av folk fra presse, kringkasting og TV.

Personale

1. *Første halvår:*

   Stasjonssjef Jan Haugland (sammen med Kings Bay Kull Comp.)
   Vitenskapelig assistent Arvid Hegstad
   Ingeniør Jens Angard

2. *Annet halvår:*

   Stasjonssjef Kjell Glorvigen (sammen med KBKC)
   Vitenskapelig assistent Monica Kristensen
   Ingeniør Birger Amundsen

The activities of Norsk Polarinstitutt in 1976

Extract of the annual report

By TORE GJELSVIK

The director of the Institute, T. GJELSVIK, has been granted one year's sabbatical leave to be taken during 1975–1977. Part of this leave was taken 1 January–24 May 1976, and KAARE Z. LUNDQUIST was acting director during his absence.

Norsk Polarinstitutt had 34 permanent positions in 1976. In addition, eight employees were appointed on limited-term contracts.

Field work

NORWAY

Glaciology

Glacier mass balance measurements at Storbreen and Hardangerjøkulen were conducted by O. LIESTØL with assistants, and at Blomsterskardbreen by B. WOLD. Due to the large winter precipitation, glaciers west of the drainage divide showed positive balances, whereas glaciers to the east, i.e. Storbreen, had a negative balance.

Changes in frontal positions were measured for eighteen glaciers. Fifteen glaciers were retreating while the remaining three were advancing. Briksdalsbreen has advanced 30 m to a position not exceeded in the last 28 years.

SVALBARD

The summer expedition to Svalbard was carried out with M/S "Polarstar" and headed by T. SIGGERUD. The vessel sailed from Bodø on 16 July via Longyearbyen and Ny-Ålesund to Nordaustlandet and Kvitøya. Arrival in Bodø was 4 September.

Two Bell 206 (Jet Rangers) helicopters were rented for transport in the field. The helicopters arrived in Longyearbyen by cargo ship and was flown to Nordaustlandet.

The expedition worked on Nordaustlandet with the main emphasis on paleozoic and quaternary geology. Topographic surveys were also conducted. M/S "Polarstar" was used as a mobile base. Some field parties were stationed in the field and moved by helicopters while other parties worked out of the vessel. Weather conditions were variable with strong winds. The helicopters were grounded for four days – one day due to fog and three days due to strong winds.

The ice conditions were good, but the snow arrived early.

The summer's hydrographic work was carried out on the west coast of Spitsbergen from M/S "Olaf Scheel". The vessel sailed from Bodø on 9 July and returned on 30 August.

Soundings were also conducted from the small surveying boat "Svalis" in the smaller fiords on the northern side of Isfjorden. However, engine trouble curtailed the season.

Two geological field parties worked in Isfjorden.

The field season was successfully completed with no accidents of any kind. A field party on the south coast of Nordaustlandet, however, was troubled by frequent visits of polar bears.

Geology

The field work focussed on investigations on Nordaustlandet supported by M/S "Polarstar" and two helicopters. A field party for quaternary geological studies headed by O. SALVIGSEN with two assistants was stationed on the south coast. T. GJELSVIK, T. WINSNES, A. HJELLE, and Y. OHTA with respective assistants, worked mainly on the north coast and on the islands to the north and east, using the vessel as a base. The main objective was mapping and sampling of the Hecla Hoek series for better age determinations.

Ø. LAURITZEN, with two assistants, studied Upper Mesozoic and Triassic sequences in the inner part of Isfjorden.

As part of the Barents Sea Project, sampling for diagenetic studies was carried out in the Isfjorden area by B. ROTHÉ with two assistants.

H. MAJOR was in the period 20 May–20 June in charge of geology during a stratigraphic drilling program in Ny-Ålesund, carried out by Kings Bay Kull Comp.

Geophysics

LIESTØL worked in Ny-Ålesund from 20 May to 18 June and later in Longyearbyen until 24 June. Assisted by K. REPP, he measured the accumulation on Brøggerbreen and Lovénbreen. Brøggerbreen was cored and sampled every 15 cm down to a depth of 7 m for tritium measurements as part of a cooperative program with the Isotope Laboratory at Norges Tekniske Høyskole. The results may be used to estimate the accumulation on glaciers in other parts of Svalbard.

Temperature measurements were carried out in a hole drilled by Kings Bay

Kull Comp. near Brøggerbreen and indicated that the permafrost extended down to a depth of 140 m at this site. Water samples were collected and temperature measurements carried out on a "pingo" in Adventdalen.

V. HISDAL worked at the research station in Ny-Ålesund from 20 May to 22 June, mainly engaged in measuring direct solar radiation intensities at various wavelength bands, and observing the illuminance for different weather conditions and solar altitudes.

T. VINJE carried out field work in a project to study ice drift and meteorological conditions by radio buoys. Data transfer is by telemetry to satellite. Five stations were established in April with a Cessna 185, landing on the ice. This is a cooperative project between Meteorologisk Institutt and Norsk Polarinstitutt, funded by Den norske nasjonalkomité for Global Atmospheric Research Programme (GARP) and NTNF as part of the Barents Sea Project.

Biology

T. LARSEN, assisted by C. SANDE, carried out registrations of polar bear dens along the north coast of Nordaustlandet in March and April. Field supplies had been deposited in 1975, so that transport from Longyearbyen to the area of operation was possible by a light airplane.

The MAB program (Man and the Biosphere) in Svalbard is led by N. A. ØRITSLAND. Field work is proceeding as planned.

JAN MAYEN

O. ORHEIM on a short visit (three days) to the island, instructed two students who carried out studies in glaciology and quaternary geology from June through August.

J. SUNDSBY assisted B. G. HARSSON, Norges Geografiske Oppmåling, with gravity measurements at observation points first measured in 1974.

ANTARCTICA

M/V "Polarsirkel" sailed from Bergen on 30 November with field- and scientific equipment for the Norwegian Antarctic Expedition 1976/1977. A sea gravimeter provided by France was picked up in Brest. Bunker was replenished in Rio Grande, Brazil, and the vessel continued to Port Stanley on the Falkland Islands where the 23 members of the expedition together with an Argentine scientist joined on 3 January 1977. M/V "Polarsirkel" departed for the western Queen Maud Land on the same day. The expedition which was headed by OLAV ORHEIM, represented five different Norwegian scientific institutions. Five members from Norsk Polarinstitutt participated. The Tele-Directorate had one observer on the expedition, and the activities of the expedition were covered by a reporting two-member team from NRK/TV.

Preparation of data

Hydrography

H. HORNBÆK worked on new editions of charts 504, 505, and 513 and prepared reprinting of 509 and 510. New charts 506 – the eastern Barents Sea – and 523 – Isfjorden – were completed.

J. FJØRTOFT and E. MOEN edited soundings from 1972–1975, and also charts 506, 514, and 515.

Geodesy – topography

Work on the geodetic net in Svalbard has continued. Triangulation from air photographs of Edgeøya was carried out, and maps covering the coastal area of Barentsøya were constructed at a scale of 1:100,000. The outline of Kvitøya was updated based on satellite (NASA Landsat-2) and air photography. New editions were prepared of maps C9 Adventdalen, C11 Kvalvågen, and B10 Van Mijenfjorden. A third edition of Svalbard at a scale of 1:1,000,000 and a new edition of Svalbard at a scale of 1:2,000,000, were published.

Air photographic coverage obtained over Jan Mayen in 1975 was used to construct and update maps in the area of the 1970 volcanic eruption at Sør-Jan at a scale of 1:20,000.

Geology

GJELSVIK (on sabbatical leave) prepared a publication on the geology of N-Spitsbergen.

MAJOR conducted coal petrographical studies and planning for further drilling in the Ny-Ålesund area.

WINSNES administered the geological activities of the institute, the Barents Sea Project and reviewed scientific publications in geology. Further work was carried out on geologic material collected in Antarctica and during the 1975 field season.

HJELLE worked on publications on the structural geology of an area in Antarctica and the northwestern part of Svalbard. Preparations for the Antarctic Expedition were also made.

OHTA carried out analyses and prepared publications on metamorphic rocks from Spitsbergen and sediments from Antarctica.

SALVIGSEN worked on field observations of the Quaternary geology of Svalbard made in 1975 and 1976 and supervised students working on related problems. A number of C-14 dates have been obtained from raised beaches.

LAURITZEN studied the stratigraphy and the development of evaporites in the Isfjorden area. A general map for the area north of Isfjorden is being prepared.

ROTHÉ (on the Barents Sea Project) carried out diagenetic studies on rocks from the Isfjorden area.

J. P. MØLLER has prepared thin sections for the staff and organized the rock collection at the institute.

Geophysics

HISDAL completed a survey of the geography of Svalbard, later published as *Polarhåndbok Nr. 2*, and continued a report on an investigation of the spectral distribution of radiation from sun and sky.

LIESTØL worked on glaciological data from Norway and Svalbard. A number of lectures and colloquia have been given as well as consultative services.

ORHEIM was mainly engaged in preparations for the Norwegian Antarctic Expedition 1976/77. Studies of Landsat-2 imagery of Antarctica were conducted. Work was done on glaciological data from Jan Mayen and Supphellebreen. He was adviser for two graduate students.

VINJE completed a compilation of the ice situation for the area Iceland–Novaja Zemlja for the decade 1966–75 where adequate satellite coverage is available. Material from four automatic radio buoys placed on ice floes for drift investigations was treated, and quarterly reports on Landsat- (earlier ERTS-) investigations in the Svalbard-Greenland area were submitted to NASA.

Norsk Polarinstitutt received 468 satellite photographs from this area in 1976 and this data has been studied concurrently. Kvitøya appears to be 2.6 times larger than indicated on current maps.

Biology

LARSEN prepared for publication a study of the reindeer on Nordaustlandet. As in previous years he rendered consultative services to governmental and other institutions as well as to private persons. Development of a computer oriented system for organization of faunistic registrations has been undertaken in cooperation with the Norwegian Academy of Agriculture. Two graduate students were working on biological problems in Svalbard and topics for three additional students are being prepared.

The research station at Ny-Ålesund

Data-collection within a number of long-term scientific programmes have continued as in previous years. During the spring, six smaller and one large room in an unoccupied concrete building was redecorated and put in order for use in the summer.

The activities at the Research Station in 1976 encompass the following:

Radiation measurements
Tidal registrations
Oceanography (water sampling July–August)
Air pollution measurements
Synoptic weather observations
Seismic registrations

Hf absorption measurements by rhiometres
Registration of the geomagnetic field
Night sky photography by all-sky-camera.

The number of visiting scientists at the station has increased. 25 scientists used the facilities for periods ranging from one week to three months. Other visitors included a number of government officials headed by Prime Minister NORDLI. Representatives from the press, radio and television also visited Ny-Ålesund in 1976.

Main field work of scientific and economic interst carried out in Svalbard in 1976

By TORE GJELSVIK

Nationality	Institution or company (residence) Name of expedition	Name(s) of leader(s) Number of participants	Area of investigation Period	Work
Norwegian	Norsk Polarinstitutt	THOR SIGGERUD 41 (+ transport crew, 2 ships, 1 boat, 2 helicopters)	Isfjorden, Nordaustlandet July–September	Hydrography, topography, geology, geophysics, and biology. See pp. 336–339.
	MAB- (Man and the Biosphere) Program	NILS A. ØRITSLAND 14	Brøggerhalvøya, Adventdalen, Berzeliusdalen, Reinsdyrflya, Edgeøya, Grønfjorden January–December	Evertebrate zoology, vegetation mapping, reindeer biology.
	Institutt for Kontiental-sokkelundersøkelser	MARC B. EDWARDS 4	Sør-Spitsbergen, Barentsøya, Edgeøya, Kong Karls Land 5 August–10 September	Geology
	Jordskjelvstasjonen, University of Bergen	EIRIK SUNDVOR 6	Kapp Berg, Kaffiøyra	Seismological investigations
	University of Bergen	RON STEEL 3	Adventdalen, Svea, Van Keulenfjorden, Bjørnøya July–October	Geology
	University of Oslo	KNUT BJØRLYKKE 5	Adventdalen, Sassendalen 12–26 August	Geology
	Miljøverndepartementet/ University of Tromsø	PER KYRRE REYMERT 3	Tempelfjorden, Van Mijenfjorden, Hornsund, Ny-Ålesund 8 July–2 September	Registration of relics of ancient culture
	Arctic Exploration Co. A/S	JAN HATLE 7	WNW Spitsbergen	Coal and ore prospecting

	Scholarship given by Norsk Polarinstitutt	ÅGE TØRRIS EKKER 2 17 July–26 August	Vårsolbukta, Ingeborgfjell, Midterhuken	Ornithology
	,,	TORE ROLF LUND 2	Mitrahalvøya 17 June–15 July	Limnology
	,,	REIDULF LARSEN 3	Ny-Ålesund 17 June–15 July	Ionospheric investigations
American	St. Louis University	BRIAN MITCHELL 4	Longyearbyen and surroundings June–August	Seismological investigations
British	Cambridge Spitsbergen Expedition 1976	W. B. HARLAND 5	Western Spitsbergen	Geology
German	Not known	MATTHIAS KUHLE 2	Dicksonfjorden, Eckmannsfjorden 1–29 June	Geographical investigations
	,,	H. USINGER 3	Isfjord radio, Longyearbyen, Ny-Ålesund 29 July–2 September	Botany
	University of Hamburg	SEWERYN J. DUDA 4	Isfjorden, Wedel Jarlsberg Land, Sarstangen	Geophysics
Polish	Polish Academy of Sciences	K. MAŁKOWSKI	Van Keulenfjorden July–September	Palaeontology
	,,	ANDRZEV ZAWADA 7	Isfjord Radio	Geodynamical investigations
Soviet	Institute of Geography, Moscow	EVGENY SINGER 13	Larsbreen, Longyearbyen, Svea, Ny-Ålesund, Pyramiden	Glaciology
Swedish	Not known	LENNART PETTERSEN 2	Nordenskiöld Land	Ornithology

Notiser

Årsmorener foran Nathorstbreen?

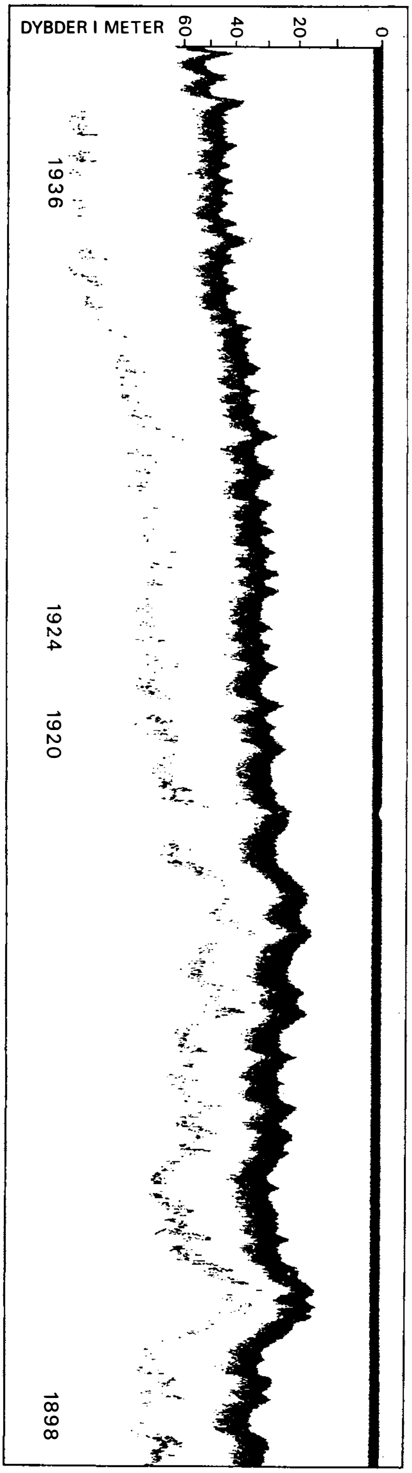
Abstract. — A description is given of a series of ridges found at the bottom of Van Keulenfjorden in front of the Nathorstbreen glacier. The ridges are supposed to be year-moraines formed by the glacier advance during the winter.

I 1966 fulgte forfatteren med M/S «Signalhorn» inn Van Keulenfjorden hvor noen av Norsk Polarinstitutts geologer skulle landsettes innerst i fjorden på Nathorstbreens front. Under turen inn og ut var ekkoloddet hele tiden i gang. Båtens omtrentlige posisjon ble med mellomrom notert på ekkogrampapiret. Båtens fart var ikke konstant da man måtte navigere forsiktig i dette tidligere uopploddede farvann. Isfjell gjorde også at små kursforandringer stadig ble foretatt. Nøyaktigheten i posisjonsangivelsen ble derfor mindre god.

Fig. 1 som er et utsnitt av ekkogrammet, viser en rekke tydelige rygger. Høyden på ryggene varierer fra ca. 1 til ca. 5 m og de synes å være noenlunde symmetriske i formen, uten noen forskjell mellom proksimal og distalside. Det kan være fristende å anta at dette er årsmorener skjøvet opp av Nathorstbreen under dens fremrykning om vinteren.

Nathorstbreens hastighet ble av forfatteren ved hjelp av fotogrammetri sommeren 1950 målt til ca. 20 cm pr. døgn på den sentrale del av fronten. Nå vil hastigheten normalt være større om sommeren enn resten av året. Hastigheten på Kongsvegen, en bre av omtrent samme størrelse, er om sommeren i perioder over dobbelt så stor som den gjennomsnittlige vinterhastighet. Det kan derfor være vanskelig å si hvor stor hastigheten på Nathorstbreen kan være i resten av året. Dersom de beskrevne rygger er «push»-morener, må de være dannet om vinteren i den tid det ikke smelter og ingen kalving foregår. Sjøisen går normalt opp omkring 1. juli. Når den legger seg på fjorden igjen varierer meget, men stort sett kan man anta at breens tilbaketrekning foregår i løpet av ca. tre måneder; i de resterende ni måneder vil den være i fremrykning. At den virkelig går frem er blitt observert flere ganger ved overflygning av breen om våren. Man kan da se hvordan sjøisen skyves sammen foran brefronten. Dersom hastigheten ved fronten settes anslagsvis til mellom 10 og 20 cm pr. døgn, skulle dette gi en fremrykning på noe mellom 30 og 60 m pr. år.

Breen har trukket seg betraktelig tilbake i de siste 80 år. Det kommer av at avsmeltingen om sommeren er adskillig større enn framrykningen resten av året. Kartet på Fig. 2 viser hvordan tilbaketrekningen har foregått. Brefrontens posisjon i 1898 er avtegnet fra Hambergs fotogrammetriske kart over Van Keulenfjorden. Nøyaktigheten er vanskelig å angi, men feilen burde være innenfor $\pm$ 100 m. Fronten fra 1920 og 1924 er adskillig bedre da disse er direkte triangulert inn. Posisjonen for 1936 er hentet fra Norsk Polarinstitutts topografiske kart over området bygget på moderne fotogrammetri. I de senere år har forfatteren triangulert inn fronten med ca. to års mellomrom samtidig som også flyfoto er benyttet. Posisjonen fra 1976 er tegnet inn etter satellittbilder. Man har dermed visse holdepunkter for når ryggene er dannet og om de i avstand passer til å være årsmorener. Man ser av figuren at avstanden



mellom ryggene ikke er konstant, hva man heller ikke kunne vente da både brefrontens fremrykning og tilbaketrekning må forventes å variere. Man kan også være i tvil om hva som eventuelt skal tolkes som årsmorener for enkelte partier av profilet. I de ytre deler, ved brefrontens posisjon omkring 1900, er det ganske store formasjoner. Dette kan være den opprinnelige bunntopografi som gjenspeiler seg overleiret av bunnmorenene og eventuelle årsmorener. Mellom 1924 og 1936 er det for mange rygger og det er vanskelig å avgjøre hva man skal ta med. Ved å sammenstille utgående og inngående profil kan flere av de små, tvilsomme rygger imidlertid elimineres som årsmorener.

Som man vil se av Fig. 1, er det i gjennomsnitt relativt god overensstemmelse mellom antall «årsmorener» og de antall år som ligger mellom de fikserte posisjoner for brefrontene. Det skulle derfor være grunn til å anta at disse rygger virkelig har sammenheng med breens årlige variasjoner. Morsomt ville det være om man ved å ta opp kjerner fra sedimentene mellom ryggene kunne finne årsvarv som kunne sammenstilles med morene, i likhet med hva man har funnet i Mellom-Sveriges leirsedimenter. Sjansene for det er vel små, da man her har med sedimentasjon i saltvann å gjøre.

Fig. 1. *Del av ekkogram i Van Keulenfjorden foran Nathorstbreen. Årstallene viser den omtrentlige posisjon til brefronten i de respektive år.*

Part of echogram obtained in Van Keulenfjorden in front of Nathorstbreen. Dates indicate approximate position in relation to the glacier front in the years concerned.

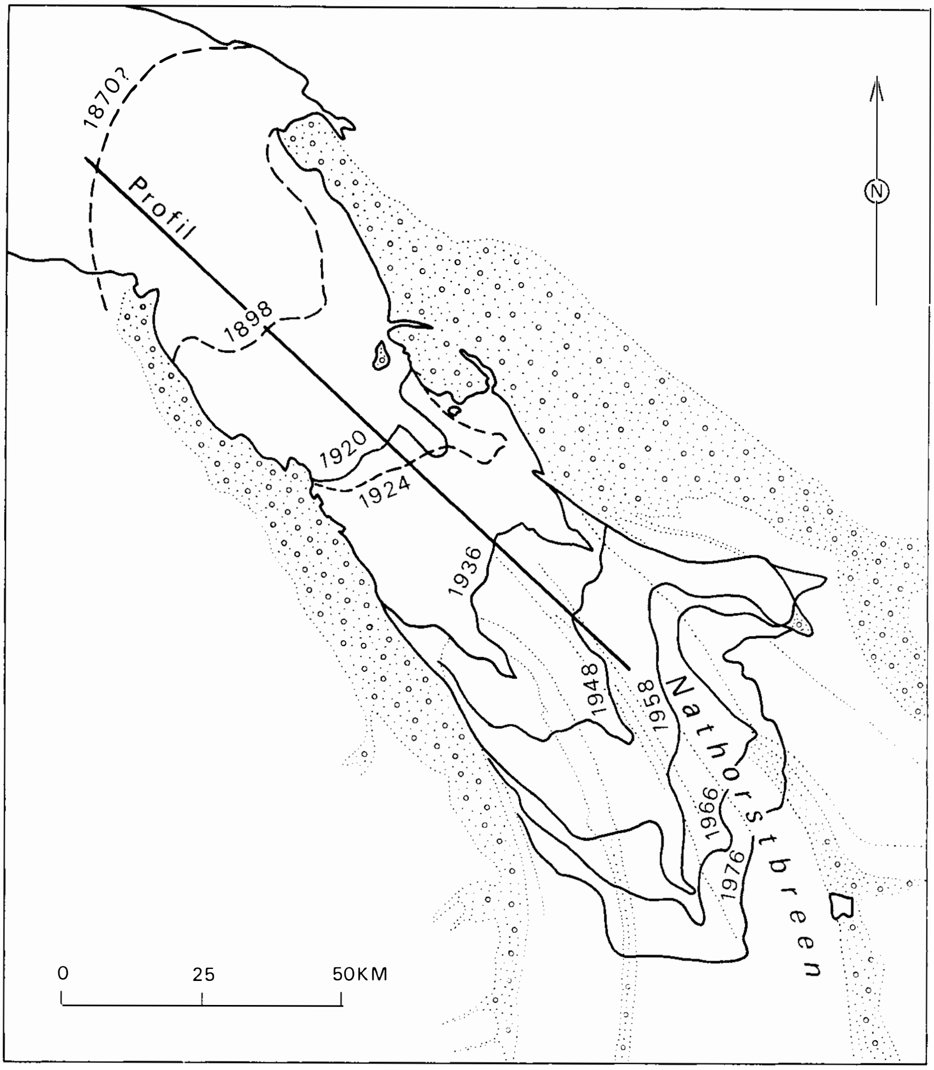


Fig. 2. *Kartskisse over Nathorstbreens fluktuasjon. Den angir også hvor dybdeprofilet i Fig. 1 er tatt.*

Map showing the fluctuation of Nathorstbreen and indicating where the depth profile in Fig. 1 was measured.

Olav Liestøl

An observation of palsa-like forms in Nordaustlandet, Svalbard

Abstract. — Ice cored peat mounds from two isolated areas at Svartknausflya, Nordaustlandet, are described.

Palsa is a widely used term for any mound of soil or peat with a core of ice, usually occurring in the zone of sporadic permafrost. Various types of ice cored mounds from continuous permafrost areas have also been described (see references). No such forms have hitherto been described from Svalbard, but J. ÅKERMAN, University of Lund, Sweden, has observed palsa-like forms at Kapp Linné, Spitsbergen (pers. comm. 1975; JAHN 1975).

During the summer of 1976 I studied raised beaches at Svartknausflya, Nordaustlandet (Fig. 1). Two isolated areas with peat mounds were then found, the first one lying about 6–7 m a.s.l. and about 300 m from the present shoreline. The beach shingle would normally have sparse or no vegetation at all, but in this area thick moss peat vegetation formed mounds of different sizes. Five elongated dome-shaped mounds could well resemble palsas found in many places in northern Fennoscandia. Height, length, and width of the largest one were respectively about 1 m, 4 m, and 2 m. The peat cover had some cracks, about 5 cm wide, but there were no other signs of erosional processes. The surrounding ground had sparse vegetation and was rather dry, and one mound was completely surrounded by coarse beach shingle (Fig. 2). The unfrozen layer was 20–30 cm deep, but no excavations were made in this area.

The second peat mound area, lying about 20 m a.s.l., 2.5 km inland, behind beach ridges in an old lagoon area, was examined most thoroughly. The ground was wet with peat moss vegetation, and the ground sediments were mainly sand. In several places the peat cover was rising, varying in height from 20 cm to 1 m. Ten peat mounds were very similar to the palsa forms described in the first area, both in shape and size, but in this last mentioned area they were all surrounded by waterponds and completely water-

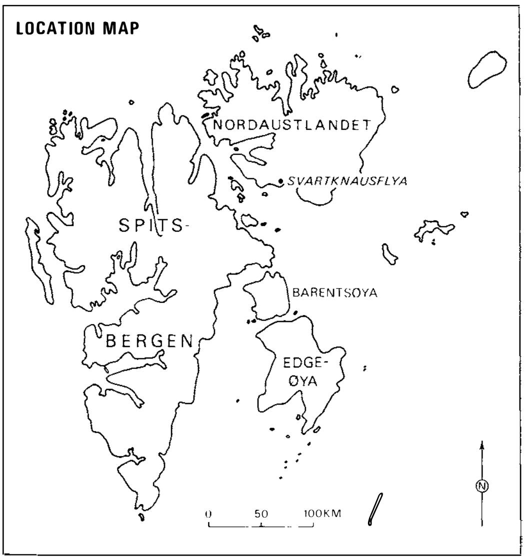


Fig. 1. *Location map.*

Fig. 2. *Peat mound lying by itself in the first mentioned area, near to, but 0.5 m higher than a little water stream. There was no vegetation in the neighbourhood.*

Fig. 3. *Peat mound from the last mentioned area, surrounded by watersoaked peat material. The height is about 85 cm.*

soaked material (Fig. 3). In one peat mound with height, length, and width of respectively about 1 m, 4 m, and 3 m, an excavation was made to examine the inner structure (see Figs. 4 and 5). This unfrozen material, about 30 cm deep, consisted of peat with a layer of sand. The frozen part was mainly ice containing some peat, mostly in the upper part. The peat material in the ice was rotten, letting out a very evil-smelling gas when the ice was picked. Small remnants of sea weed were also seen in the dirty ice, and in another, smaller mound, a great deal of sea weed was found.

Veins of clean ice, probably waterfilled frostcracks, were remarkable. One vertical vein, about 2 cm thick, went straight from the top to the bottom of the frozen part, while smaller horizontal veins near the unfrozen layer were seen in the lower section.

The layer of sand within the peat layer in the upper part of the mound must have been deposited there before the upheaval started, indicating that this peat mound is rather young compared to the surrounding old beach.

The mechanism of the formation of these ice-cored peat mounds at Svartknausflya cannot be understood solely from this summer observation. One sketchy possibility is that when the talik starts freezing in the beginning of the frost season, it causes different hydrostatic pressures in the ground, and this initiates in some places a heaving of the peat cover with the best isolating quality. From these spots the bigger ice cores have been built up by segregation ice.

Whether or not the term palsa should be used about the peat mound at Svartknausflya, is questionable. They do not fit in with any of the four types of mounds discussed by J. LUNDQUIST (1969).

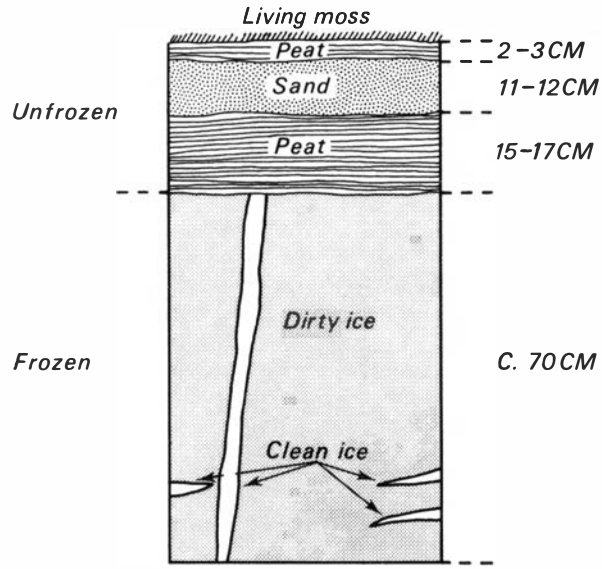


Fig. 4. *Sectional view from the excavation on 15 August 1976 of a palsa-like form at Svartknausflya, Nordaustlandet.*

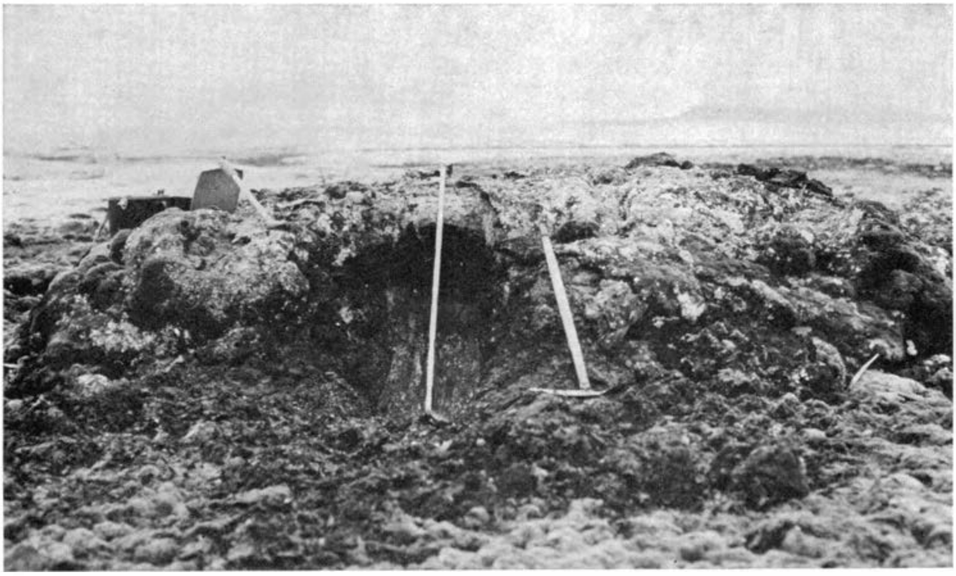


Fig. 5. *Photo from the excavation outlined in Fig. 4.*

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Otto Salvigsen

Observations on birds and seals at Bouvetøya*

Abstract. — The total number of chinstrap penguins (*Pygoscelis antarctica*) and macaroni penguins (*Eudyptes chrysolophus*) at Bouvetøya during the summer of 1977 was estimated to 25,000 to 30,000 specimens. The king penguin (*Aptenodytes patagonicus*) was observed on Bouvetøya for the first time, and the first observation of breeding southern giant fulmar (*Macronectes giganteus*) was made.

The population of elephant seals (*Mirounga leonina*) at present includes about 200 animals, and of fur seals (*Arctocephalus tropicalis*) about 1000 individuals.

The Norvegian Antarctic Expedition 1976–77 visited Bouvetøya on 22 to 24 February 1977. During these days some observations on the avifauna were made, as well as counts of fur seals (*Arctocephalus tropicalis*) and elephant seals (*Mirounga leonina*).

Due to the difficult accessibility of Bouvetøya, its fauna has been poorly investigated. According to HOLGERSEN (1960), based on observations from 1927 and 1928, six species of birds have been found breeding on the island.

* Publication No. 5 of the Norwegian Antarctic Research Expeditions. (1976/77).

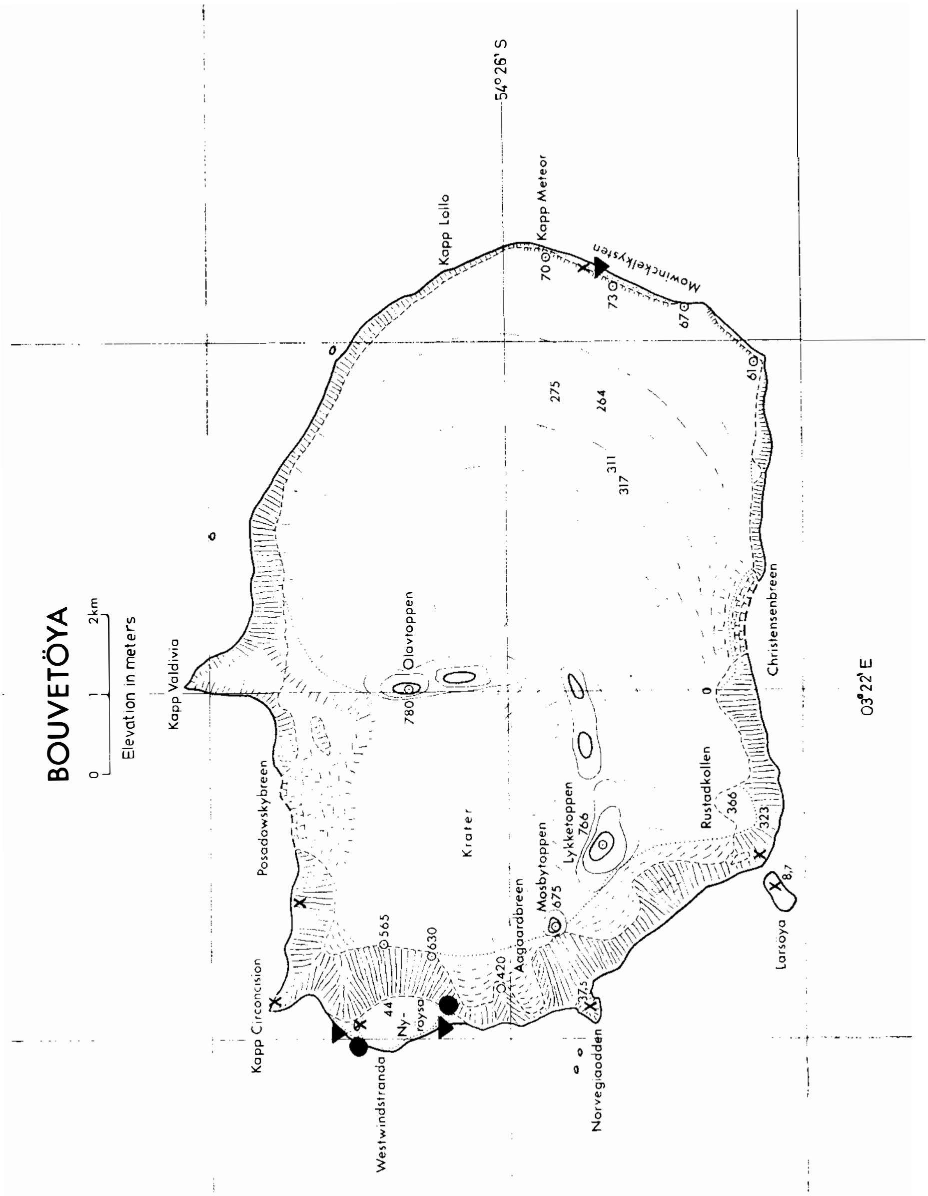

Fig. 1. *Map of Bouvetøya (from* Winsnes *1966). Penguin colonies (X) and the occurrence of elephant seals (▼) and fur seals (●) are marked.*

Two more species were added to the list by Soljanik (1959). Six more species have been observed around the island (Holgersen 1960), among them the Southern giant fulmar (*Macronectes giganteus*).

Penguins

Penguin colonies are found on several localities, but little is known about their sizes. In 1928 the largest colony was found at Larsøya (Holgersen 1960), while two smaller colonies were discovered on the main island itself. Chinstrap penguins (*Pygoscelis antarctica*) and macaroni penguins (*Eudyptes chrysolophus*) were dominating, but a few Adélie penguins (*Pygoscelis adeliae*) were also observed. Between 1956 and 1958 a volcanic eruption resulted in the formation of Westwindstranda (Fig. 1) (BAKER and TOMBLIN 1964). The northern part of this land is suitable for penguin colonies, and was already inhabited in 1958 (SOLJANIK 1959). At this time the colony consisted of about 800 chinstrap, 150 macaroni, and 56 Adélie penguins while in March/April 1964 about 600 chinstrap and 100 macaroni penguins were observed (HOLDGATE et al., 1968).

During the present study the penguin colony at Westwindstranda (Fig. 1) was photographed in detail from ashore, and an estimate of its size made from the colour slides. The colony consisted of chinstrap and macaroni penguins, while no Adélie penguins were observed. The size of the colony had increased greatly since 1958, and the total size in 1977 was estimated to approximately 7500 penguins. Of 544 specimens identified from the colour slides, 82 percent were chinstrap penguins.

Except for a small colony at the beach of Mowinckelkysten, which consisted of 10 chinstrap and 2 macaroni penguins, other colonies were not visited from ashore. The colony at Larsøya, however, was photographed at close hand from a rubber boat. Very few individuals could be identified to species from the slides, but of 37 identifiable, 73 percent were chinstrap and 27 percent were macaroni penguins. The total size of the colony at Larsøya was estimated to about 2000 penguins.

The largest penguin colony of Bouvetøya is situated on Kapp Circoncision. No estimate of the size of this colony have been published previously. During the present study the colony was photographed with a 500 mm telephoto lens from the expedition ship at a distance of approximately 800 m. It is difficult to make accurate counts from the colour slides, but it appears that the size of the colony is somewhere between 15,000 and 20,000 penguins. The species could not be identified, but are probably chinstrap and macaroni penguins.

In addition penguin colonies were observed at three other localities. On the main island, right across from Larsøya, a small colony of 80 penguins was present. Fairly large colonies were observed from a distance at Norvegiaodden and between Kapp Circoncision and Posadowskybreen.

One specimen of King penguin (*Aptenodytes patagonicus*) was observed on the beach of Mowinckelkysten. This is the first record of the King penguin at Bouvetøya, but it is not known if the species is breeding. The King penguin is found at several of the other Antarctic islands (WATSON 1975), and it is not unlikely that it may breed on Bouvetøya as well.

Other birds

The Southern fulmar (*Fulmarus glacialoides*) is a very dominant species of Bouvetøya, breeding in the steep cliffs of the island. According to LUNDE (1965) ten thousands of these birds are present. This estimate was confirmed during the present study. Numerous Southern fulmars were breeding in the cliffs behind Westwindstranda, all the way up to the glacier. From colour slides of the cliffs about 4000 specimens could be counted. The cliffs below Rustadkollen contained about 2500 Southern fulmars, and large numbers were present all the way between Larsøya and Norvegiaodden.

On the northern part of Westwindstranda, 20 to 25 chicks of the Southern giant fulmar (*Macronectes giganteus*) were found. The chicks were almost fully grown, but not yet able to fly. This is the first evidence that the Southern giant fulmar is breeding on Bouvetøya.

Seals

In 1928 the population of elephant seals (*Mirounga leonina*) was estimated to 70–80 individuals (OLSTAD 1929). These animals were found on a small beach on the main island right inside Larsøya. As far as we could judge during our visit in 1977, this beach no longer exists, and only a few penguins were observed at this locality. According to LUNDE (1965) several hundred elephant seals were found at Westwindstranda in 1964, while WINSNES (1966) only observed 20–30 specimens.

During the present study, elephant seals were found at both the northern and southern beach of Westwindstranda, as well as on Mowinckelkysten (Table 1, Fig. 1). According to our estimates the total population was less than 200 specimens. The size of the populations will change from year to year, and with the time of the year. Compared to the counts from 1928 (OLSTAD 1929), the new beaches available at Westwindstranda appear to have resulted in a larger population of elephant seals.

The population of fur seals (*Arctocephalus tropicalis*) was estimated to 1000–1200 individuals by OLSTAD (1929). About 100 of these were found at Norvegiaodden while the others were counted at Larsøya. During the present visit we did not observe seals at Larsøya, and it appears that the population has moved to Westwindstranda. At this locality WINSNES (1966) found 500–600 fur seals, and HOLDGATE et al. (1968) about 500, while our estimate is approximately 1000 individuals (Table 1). Apparently the fur seal population has remained at about the same size.

Table 1

Approximate numbers of elephant seals and fur seals at Bouvetøya February 1977.

	Westwindstranda northern beach	Westwindstranda southern beach	Mowinckel-kysten
Elephant seals	80	50	40
Fur seals	700	320	—

Conclusions

From the present study it appears that the total number of penguins at Bouvetøya during the summer of 1977 was at least 25,000 to 30,000 specimens. This is a much higher figure than previously reported (HOLGERSEN 1960; SOLJANIK 1959).

The King penguin was observed at Bouvetøya for the first time, and the first observation of breeding Southern giant fulmars was made. Compared to counts in 1928 (OLSTAD 1929) the population of elephant seals has increased slightly, and at present includes about 200 animals. The population of fur seals remains at a size of about 1000 individuals.

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Observasjoner av tyvjo *(Stercorarius parasiticus)* i Hornsund, Spitsbergen, 1963 og 1964

(*Observations on Arctic Skua* (Stercorarius parasiticus) *in Hornsund, Spitsbergen, 1963–1964*)

Abstract. — In 1964, 25 pairs of breeding Skuas were located on the north side of Hornsund. Only one of the birds was of dark phase. The breeding started in the last week of June. Measurements were taken from 26 eggs (length 54–64.2 mm, breadth 38.2–43.3 mm, average 58.2 × 41.0 mm) and two young the first days after hatching (Table 1).

Tyvjoen er en fugl som er vanlig over hele Svalbard. Sommersesongene 1963 og 1964 samlet jeg inn en del biologiske data vedrørende tyvjoen i Hornsundområdet.

Langs hele nordsiden av Hornsund hekker store mengder av alkekonger. Lenger inne i fjorden ligger fuglefjellet Sofiekammen, hvor det blant annet hekker krykkje. Disse store ansamlinger av alkekonge, krykkje og andre arter gir godt næringsgrunnlag for tyvjoen. Den er spesialist på å røve fra krykkjer, og den setter stor pris på egg og unger av ærfugl, unger av alkekonge og andre fugleegg og unger den får tak i.

Sesongen 1963 ble det på nordsiden av Hornsund, fra Torellbreen til Sofiekammen, lokalisert 11 reir, og i 1964, 17 reir. I 1963 fikk jeg bare undersøkt deler av området, mens hele ble undersøkt i 1964. Dette kan forklare denne forskjellen. I 1964 ble det også observert 7 par som hevdet territorium uten at en kunne finne deres reir, slik at totalt hekket det ca. 25 par denne sesongen.

Blant tyvjoene forekommer det både lyse og mørke fargevarianter. Av de som hekket i 1964 var det kun ett individ som tilhørte den mørke varianten. Dette gir en andel på 2% mørkt fargede individer, noe som stemmer godt overens med den andel (0,95% i 1938 og 2% i 1948) som angis fra Bjørnøya (LØVENSKIOLD 1964). Samtidig sies det hos LØVENSKIOLD at det bare ved to tidligere anledninger er funnet hekkende individer av mørk variant sammen med lyst fargede på Svalbard. Lenger syd i Norge forekommer slike blandede ekteskap ofte (HAFTORN 1971).

I løpet av de to sesonger ble det ikke påvist reir som kan karakteriseres som 2. kull. I Hornsund legges det derfor normalt bare ett kull. I de kull som ble lagt var det normale antall egg to, kun i tre av 17 fullagte reir ble det funnet ett egg.

På 26 egg ble det målt henholdsvis lengde og bredde: lengde 54,0–64,2 mm, bredde 38,2–43,3 mm, gjennomsnittlig 58,2 × 41,0 mm. Lignende data fra Svalbard foreligger ikke, men i Norge er det målt 72 egg: lengde 50,9–62,9 mm, Tabell 1

Mål i mm fra to tyvjo-unger de første dager etter klekking.
Measurements in mm from two young skuas the first days after hatching.

		I			II		
	17.7–1200	18.7–2000	20.7–1500	21.7–1100	19.7	20.7–2000	21.7–1100
Nebb	Unge	13.2	15,0	15,3		13,5	13,8
(bill)	(juv.)						
Ving	Klekket	26,2	27,0	31,7	Unge	24,0	26,0
(wing)	(hatched)				(juv.)		
Tars	Våt	20,2	21,5	24,8	Klekket	20,0	20,5
(tarsus)	(wet)				(hatched)		

bredde 36,7–43,5 mm, gjennomsnittlig 57,1 × 40,0 mm (HAFTORN opi.ct.). I relasjon til de norske egg, er eggene fra Hornsund gjennomsnittlig både lengre og bredere, henholdsvis 1 mm for begge verdier. To av de 26 eggene, henholdsvis 63,2 og 64,2 mm, var lengre enn det lengste norske egget, ellers faller verdiene innenfor de grenseverdier som oppgis fra Norge.

I kull med 2 egg legges normalt andre egget innen et tidsintervall på 24–48 timer, opptil 72 timer kan forekomme (HAFTORN op.cit.). LØVENSKIOLD (op.cit.) sier: «It seems that the eggs can be laid within an interval of some days and also that incubation must begin with the first egg». I fem to-eggskull var det

Fig. 1. *Tillitsfull tyvjo.*
Confident Arctic Skua.

mulig å følge klekketidspunkt for de enkelte egg. I fire av kullene klekket begge egg innen 24–48 timer, mens i det femte kullet foregikk klekkingen av andre egget i løpet av tredje døgnet etter det første var klekket.

Denne forskjell i klekketidspunkt for de to egg i det enkelte kull viser at rugingen starter med første egget. For beregning av tidspunktet for eggleggingen ble det brukt en rugetid på 26 døgn (HAFTORN op. cit.). Ved ni reir ble klekkingen fulgt. En kunne beregne følgende datoer for legging av første egg i det enkelte kull: i 1963 — 22.6, 24.6, 26.6, 26.6, 27.6, 28.6 og 3.7; i 1964 — 21.6 og 2.7. I syv av ni reir begynte eggleggingen altså i siste uke av juni. Det er noe tidligere enn det LØVENSKIOLD (op.cit.) angir: «The ordinary time for the birds to lay will be in the first fourteen days of July.»

Data vedrørende unger etter klekking finnes ikke fra Svalbard. I ett av de reir hvor jeg fulgte klekkingen forsøkte jeg å følge ungenes utvikling. Dessverre viste dette seg meget vanskelig å gjennomføre da ungene bare få dager etter klekkingen gjemte seg så godt at det var umulig å finne dem igjen. Hos to unger ble nebb, ving og tars målt de første døgn etter klekking (Tabell 1).

Dette reir ble besøkt daglig over en tre ukers periode. Ved de første kontrollene angrep begge fuglene som ventet meget heftig da jeg og min assistent nærmet oss redet. Men etter kort tid avtok dette. Spesielt den ene av fuglene ble meget tillitsfull. Da vi nærmet oss ved de siste kontrollene, angrep de oss aldri. Ved en avstand av ca. 50–70 meter kom de oss i møte og sirklet bare langsomt rundt over oss. Ved målingene av egg og unger satte den ene seg ned i en avstand av 5–7 meter, mens den mest tillitsfulle, plasserte seg oppe på hodet av den som målte (Fig. 1). Der satt den rolig.

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M/S «Fortuna» beset and wrecked in the East Greenland Sea

The night of 25 March 1976, the sealer M/S "Fortuna" was, according to her skipper, ODD HENRIKSEN, beset in the east Greenland Sea at 74.9°N—10.18°W. During the following days she drifted more or less undamaged in spite of periodically strong northerly winds. On 13 April a heavy packing and ridging took place damaging the ship severely at 71.57°N—16.67°W. When the drift ice diverged again, the ship sunk while the crew was rescued by an airplane.

During the dramatic days when the ship was beset, she drifted with an average speed of 22 km per day. A maximum speed of 44 km per day from a direction close to north, was observed during the period 28—30 March under conditions with NNE winds of force 6—9. During the period 3—5 April the ship drifted towards NNW when there was SSE winds of force 4—6. The drift was thereafter mainly towards the south.

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