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Redaksjonssekretær: ANNEMOR BREKKE

Fagkomité:

THORE S. WINSNES, PETER HAGEVOLD

VIDAR HISDAL, THOR LARSEN

Trykt mars 1977

Helikopterbesøk i geologleiren på Palassfonna i juli 1975. Fjellet i bakgrunnen bærer det staselige navnet Palasset, og over skaret kan man se fjelltoppen Svea som tilhører Tre Kroner.

Helicopter visit in July 1975 to the Palassfonna geologist camp near the magnificently named mountain Palasset (the Palace). Svea, one of the three Kronbreen nunataks called Tre Kroner (Three Crowns), is seen in the background.

Photo: Ørnulf Lauritzen

Innholdsfortegnelse

Pingos, springs, and permafrost in Spitsbergen

Пинго (булгунняхи, гидролакколиты), источники и многолетняя мерзлота на Свальбарде

By OLAV LIESTØL

Contents

Abstract

Permafrost covers the entire land area in Svalbard with depths varying between 200 and 450 m in the interior. The significance of the thawed zone underneath the glaciers for the groundwater supply is described.

A probable self-regulating mechanism of water penetration through the permafrost zone and the formation of pingos are discussed.

The temperatures measured in boreholes indicate an influence of the milder climatic period starting about 1920.

The last part of the article contains a description of the different pingos, pingo-like features, and springs known in Svalbard.

Аннотация

Вся площадь суши Свальбарда охвачена слоем многолетней мерзлоты, имеющем глубины, во внутренних частях колеблющиеся от 200 до 450 м. Описано значение находящейся под ледниками талой зоны для запасов грунтовой воды.

Обсуждаются вероятное наличие саморегулирующегося механизма водного проникновения сквозь мерзлотную зону и образование пинго (гидролакколитов).

Измеренные в скважинах температзры указывают на влияние начавшегося около 1920 г. более мягкого в климатическом отношении периода.

В последней части статьи содержится описание известных на Свальбарде пинго, пинговых черт и источников.

Introduction

Pingos and springs in Spitsbergen have been described from many localities, of which A. K. ORVIN's paper "Litt om kilder på Svalbard" (1944), is the most comprehensive. Most of the pingos known until 1944 are described in his paper. Since the term "pingo" was probably unknown to him, he used the

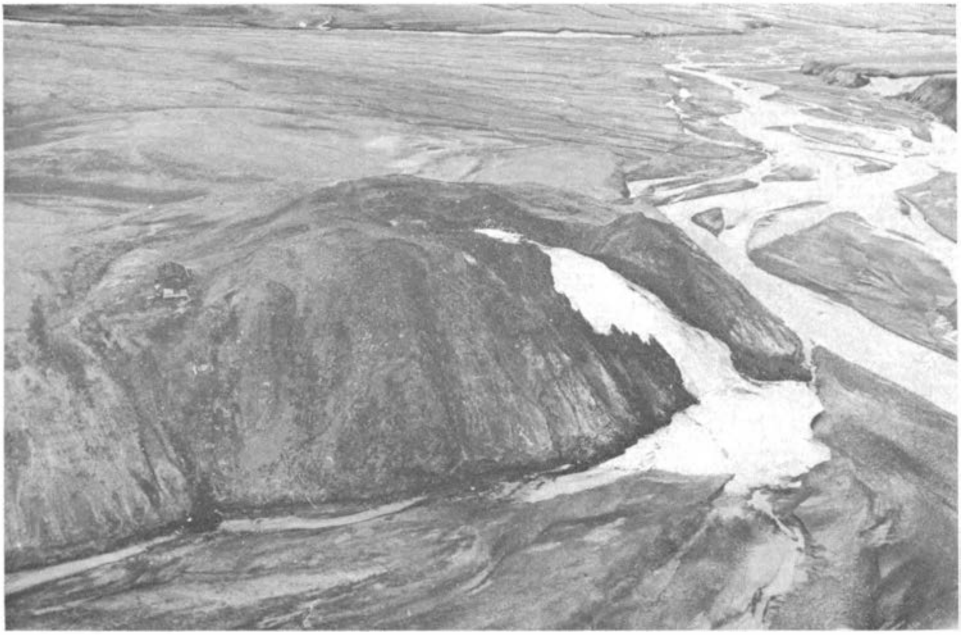

Fig. 1. *Photo of the pingo in Adventdalen near Janssonhaugen, taken from helicopter on June 22, 1976. The rest of the icing built up during winter is seen on the right-hand side.*
Снятая с вертолета 22 июня 1976 г. фотография расположенного в долине Adventdalen у горы Janssonhaugen пинго. Справа виден остаток образовавшейся зимой наледи.

Norwegian expression "kildehaug", which means something like "spring mound". His paper also deals with "ordinary" springs not occurring in connection with pingo mounds, and his descriptions are followed by chemical analyses of the water. Other papers dealing with pingos in Spitsbergen are found in the reference list.

This paper gives a short description of the pingos and springs in Spitsbergen. Information has been taken from aerial photos, and some locations have been visited in the field or reviewed from literature. The enclosed maps show the location of known pingos and springs.

Pingos or hydrolaccolits are supposed to fall genetically into two groups. One is known as the Greenland type, where the hydrostatic pressure from below the permafrost together with the freezing expansion is blowing up strata into mounds. The other is called the Mackenzie Delta or closed-system group (class), and is believed to be formed by the expansion following the progressive freezing of a lake filled with sediments. BOSTRÖM (1967) interpretes the Mackenzie Delta pingos as being similar to the Greenland ones and believes that the distinction between the two types may be artificial. He thinks that the Mackenzie pingos form in areas with subsidence. As recent sediments pass through the base of permafrost, compaction becomes possible. The expulted water could produce an artesian pressure and penetrate the permafrost layer thus forming pingos at the surface.

The mean temperature in Svalbard is well below zero at all meteorological stations. This would indicate that permafrost is found in the entire area. The annual standard normals of the air temperatures 1931–60 are —3.9°C for Isfjord Radio, —4.8°C for Longyearbyen, and —1.5°C for Bjørnøya. This period, however, was extremely warm and the temperature has been a lot lower both earlier and later, especially in the winter. WERENSKIOLD (1922) in his calculation of the permafrost depth used —8°C which is, on the other hand, obviously too low. There are large variations between the coast and the inland. Another complication is the fact that the air temperature does not represent the temperature in the surface. The variation in the thickness of the snow cover is here of great importance. In the winter the snow would insolate and modify the loss of heat from the ground. This is especially the case in the bottom of the valleys where, in addition, water left in the river bed after the summer drainage, represents local heat reservoirs. On the other hand, layers of snow and ice will delay the warming-up in the summer. Although inversions are common in the interior, temperature will normally drop with height. All in all, surfaces in the mountains have a lower average temperature than in the valleys and on the plains. Radiation will cause local variations as south-facing slopes get more energy than north-facing hill sides.

Close attention should be given to the glaciers and their influence on the permafrost and the ground-water system. All glaciers of some magnitude in Spitsbergen are of the socalled subpolar type with melting temperatures in the higher accumulation area. This phenomenon causes openings in the continuous permafrost layer, through which water will sink into the ground below the glacier bed and cause a groundwater stream to flow downwards under the permafrost layer and out to the coast and sea (Fig. 2). The greater part of the meltwater will, however, particularly in the summer, follow the glacier bottom through tunnels in the ice and emerge in front of the glacier.

In the winter too water will be seen coming out from underneath the glacier

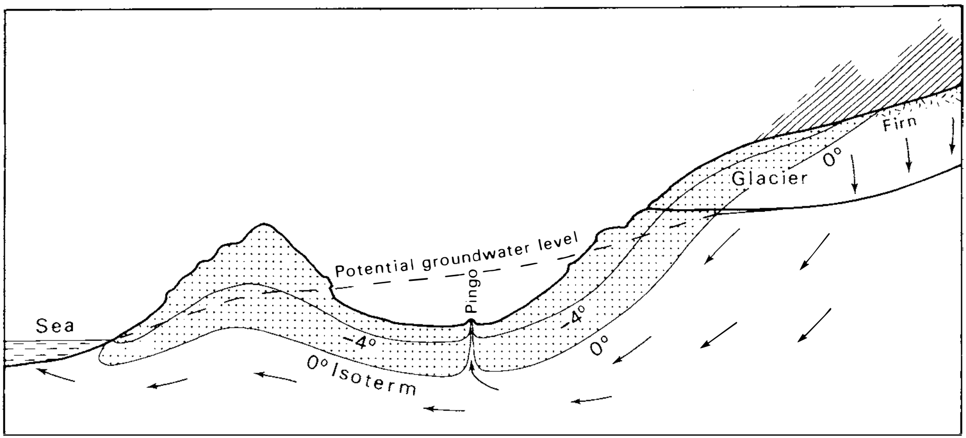

Fig. 2. *Vertical profile of the permafrost layer and groundwater movement from the glacier accumulation out to the coast.*

Вертикальный профиль мерзлотного слоя и течения грунтовой воды с места ее ледникового накопления на берег.

snout, but in much smaller quantities, making conspicuous large icings, some more than 5m thick, and covering areas of more than one square kilometre. These icings show whether a glacier is polar or subpolar. As mentioned above, they are very noticeable in the field and are clearly visible on air photos taken in mid-summer when the snow cover has melted while these thick layers of ice still remain. Measurements of the water in the winter show a more than ten times higher conductivity than the ordinary summer melt water. This difference indicates that a high percentage of groundwater is mixed with the "glacial" groundwater and the sub-glacial bottom meltwater. The bottom melting is of the order 0.2 l $sec^{-1}km^{-2}$. The quantity of water stored in the glacier after the summer melting is unknown, but it must be assumed that part of this volume gradually drains during the winter. It has been presumed that salts in the glacier ice gradually migrate out of the ice. In the winter, when discharge from the glacier is low, this salt could be responsible for part of the high conductivity measured.

Lakes will also greatly influence the permafrost. Lake ice seldom exceeds a thickness of 2 m and even small lakes have large heat reservoirs. WERENSKIOLD (1922) made some theoretical calculations of the permafrost depth and the influence of sea and glaciers. He found that the permafrost would stretch some 200 m off the shoreline in shallow water and with a sea temperature of 0°C. The same would be the case with a lake or a glacier with a bottom temperature of 0°C. If lakes and glaciers measure less than 400 m across, the permafrost should form a continuous layer underneath. Otherwise there would be no connection with the subpermafrost groundwater under small glaciers and lakes.

Few direct measurements of the permafrost thickness have been made. According to ORVIN (1944), the temperature in the coal mines at Ny-Ålesund in N.W. Spitsbergen passed melting temperature at between 130 m and 140 m near the foot of the steep mountain side of Zeppelinfjellet, but further out on the plain 0°C was not reached at 150 m depth. In 1976 the author measured a permafrost depth of 140 m in a borehole near Brøggerbreen in the same area. LUTKEVICH (1937) reports that the Russians drilling for coal at Colesbukta penetrated the permafrost at a depth of 75 m. In the coalmines in Adventdalen the thickness is between 250 m and 450 m. These mines go through steep mountains where deep permafrost would be expected.

The author measured the temperature in a "stoll" underneath the glacier tongue of Larsbreen. Where the overlying rock was about 50 m thick and the glacier thickness above was about 100 m, the temperature was —2.4°C. With a temperature gradient of 1°C to 40 m, the 0° isotherme should be found at about 250 m. About the same depth was found under the glacier Foxfonna (LIESTØL 1973). In a 64 m deep borehole to the bottom of this glacier the temperature was —3.3°C and in the mine 220 m below the surface, —0.2°C.

In 1956 H. MAJOR (pers. comm.) measured temperatures in two boreholes on the southern side of Adventdalen and three near the Svea coal mines at the head of Van Mijenfjorden. He lowered cables each with six thermistor resistence thermometres into the water filled drill holes and remeasured until

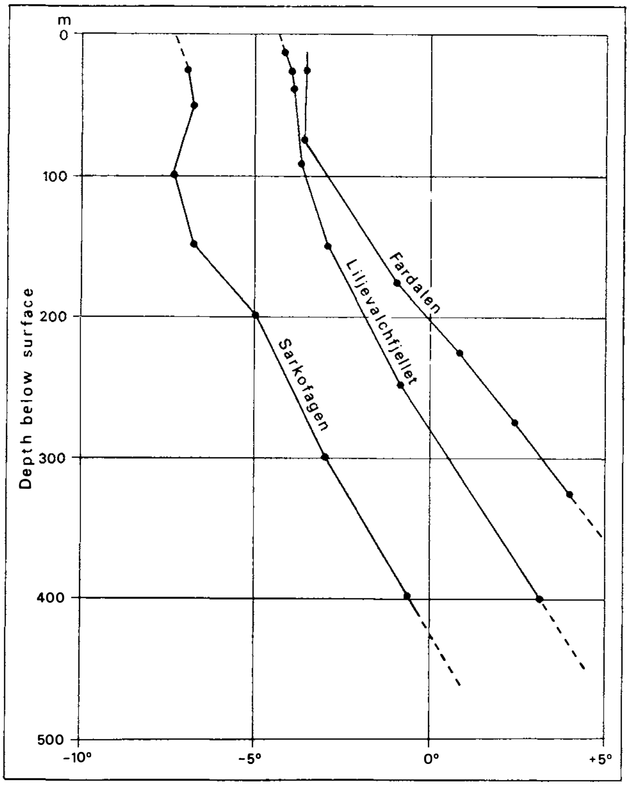

Fig. 3. *Temperature curves from three different boreholes: in the middle from Liljevalchfjellet near Sveagruva, to the right from the Endalen valley, and to the left from the Sarkofagen mountain ridge near Longyearbyen. Note the upper part of the curves perhaps reflecting the milder climate starting about 1920.*

Температурные кривые трех различных скважин: на горе Liljevalchfjellet, недалеко от рудника Sveagruva (в центре), в долине Endalen (справа) и на горном кряже Sarkofagen, в окрестности поселка Longyearbyen (слева). Верхняя часть кривых отражает начавшийся около 1920 г. более мягкий тип климата.

conditions were stabilized. The permafrost depth in Sarkofagen, a 500 m high mountain ridge S.W. of Longyearbyen, was 450 m, and the temperature gradient about 50 m/dgr. in the lower part. The other measurement, made 5 km further south at the bottom of Endalen, showed a depth of 200 m and a temperature gradient of about 40 m/dgr. The temperature gradients are in good agreement with theoretical calculations according to which the gradient is steeper below a valley than below a mountain. As stated below, these calculations are rather problematic due to climatic variations. One of MAJOR's measurements near Sveagruva was made in a hole 500 m a.s.l. halfway up the slope of Liljevalchfjellet. The depth to the 0° isotherme was 280 m. The other two holes were drilled in the flat area between the sea and the mountain foot. The reliability of measurements made in these two holes was not as good as in the others, but gave an indication of a permafrost thickness of more than 200 m. A much deeper permafrost would be likely at the first hole on Liljevalchfjellet. Reasons for this shallow depth might be the influence of the glaciers in the neighbourhood and the black shale absorbing more radiation energy in the south-facing mountain slope.

As Fig. 3 shows, the upper part of the temperature curve has an almost vertical gradient. The explanation might be the warm climatic period between 1920 and 1960. Such large and long-lasting warm periods should manifest themselves in a warming-up of the upper layers of the permafrost. Theoretic calculations also show that the depth of this heat wave caused by the climatic change is reasonable. The same phenomenon is observed in boreholes in Alaska (GOLD and LACHENBRUCH 1973).

As mentioned above, the groundwater flow will percolate from the firn area of the glaciers under the permafrost base down to the coast. The longer the distance from the sea, the higher the groundwater table. Under the impermeable permafrost layer the groundwater can act as artesian water over rather large areas (Fig. 2). The pressure is highest in low inland vallies where the difference between the land surface and the water table is largest. The groundwater will not always flow parallel with the permafrost subsurface, the geological structures also being a directing factor for the course of the water flow. Impermeable layers may force the water down to large depths where geothermal heat is absorbed and later brought to the surface as warm springs.

In the following description of springs and pingos it will be seen that all, with a few exceptions, are located in broad vallies or below slopes facing the coastal plains. This is natural as the water tries to find its way to the surface where the pressure is high and the permafrost layer thin. But how can this water start penetrating the frozen layer? ORVIN (1944) reflects on this subject. He thinks that the springs are relics from the postglacial warm period when the temperature was perhaps 2°–3°C higher than today. He also mentions the postglacial uplift, and as most of the springs and pingos are below the marine limit, they could have started as submarine springs.

Warm springs and springs with a large discharge have enough heat capacity to escape through the permafrost and keep a channel open. As will be mentioned later, the discharge from the Trollosen spring in Sørkapp Land was 10 m^3/sec and the temperature +4°C which means a potential heat quantity of 40 000 kcal/sec to be lost before freezing. When the author visited the spring near Kongsfjordneset at the mouth of Kongsfjorden in May 1975, no icing was seen. The water temperature was +1.7°C and the discharge 10 l/sec. This heat quantity was sufficient for the water to reach the sea before freezing.

It is considerably more difficult to understand how small quantities of water at freezing point can penetrate and keep open passages through the frozen layer. Water from the pingo near Jansonhaugen in Longyeardalen penetrates the surface through a hole with a diameter of about 1.5 cm and a discharge of about 100 cm^3/sec. This may be possible if the water, as suggested above, is forced to a large depth and warmed before starting its upward movement. On the other hand, the surface water temperature is —0.3°C and the salt content c. 5 g/l, which means that the water is at its freezing point. The same is the case in other pingos where temperature measurements have been made. It is difficult, therefore, to explain why the water reaches this temperature just at the surface. The water may in the upper part of the passage be in contact with ice which will melt or freeze according to variations in the outer temperature. Another source of heat is the energy lost by friction when water is forced to the surface by artesian pressure. This friction and decrease in pressure is dependent upon the width of the water channels. A drop of one bar equals an about 0.02°C rise in the water temperature. In the above mentioned pingo in Adventdalen, where the discharge is 100 cm^3/sec, this equals about 2 cal/sec. It is possible that a passage is kept open by a self-regulating mechanism as the climate changes. When the climate gets cooler, the width of the hole decreases because of freezing. This leads to a larger pressure gradient and friction which again compensate for the higher loss of heat. This means that the velocity and pressure must drop in other parts of the water channel system or that the water head must increase.

Many pingos have no signs of subpermafrost water and seem at present to be inactive. It might be that the connection through the permafrost has been sealed off in thecold climate starting with the subatlantic time. ORVIN (1944) as mentioned above, is also of the opinion that the springs and pingos are relics from the postglacial warm period. The areas where most of them are found today were then situated below sea level and the permafrost layer was much thinner.

SVENSSON (1970) is of the opinion that the pingos in Adventdalen were formed as "closed system" types when the sea level gradually subsided. At present these pingos are more likely of the "open system" type, as subpermafrost water is found in the form of large icings in the winter.

How the pingos get their typical form is still a difficult question. ORVIN (1941) thinks that ground ice might form in the autumn when water in the valley sides is forced in between the permafrost and the new, gradually increasing impermeable frost layer at the surface. This could also be adopted to the formation of pingos. A similar phenomenon is seen in the winter when the ice dome on top of the pingo is broken up when water trapped between ice layers freezes (Fig. 10). The artesian pressure could also play a part in the process.

As seen in the description, the regular-shaped cones are not typical of Spitsbergen pingos. It seems as if the active part has changed its position over a large area leaving a cluster of more or less defined cones and craters of different ages. Erosion and thermokarst phenomena together with solifluction have also to a large extent altered the original shapes. Some of the features described are not real pingos but just crack-patterned mounds with no sign of water having ever reached the surface.

Some pingos are developed in localities flooded by tidewater. At the head of Woodfjorden, on the large and wide delta-plain, for example, the tide flows more than 2 km further inland past the mounds. We might think that permafrost would not form so easily here. In the autumn, however, water on the plain gradually freezes to the bottom to a height that prevents further tide flooding. Thus permafrost is likely to be found right out to the delta front more than 4 km further out.

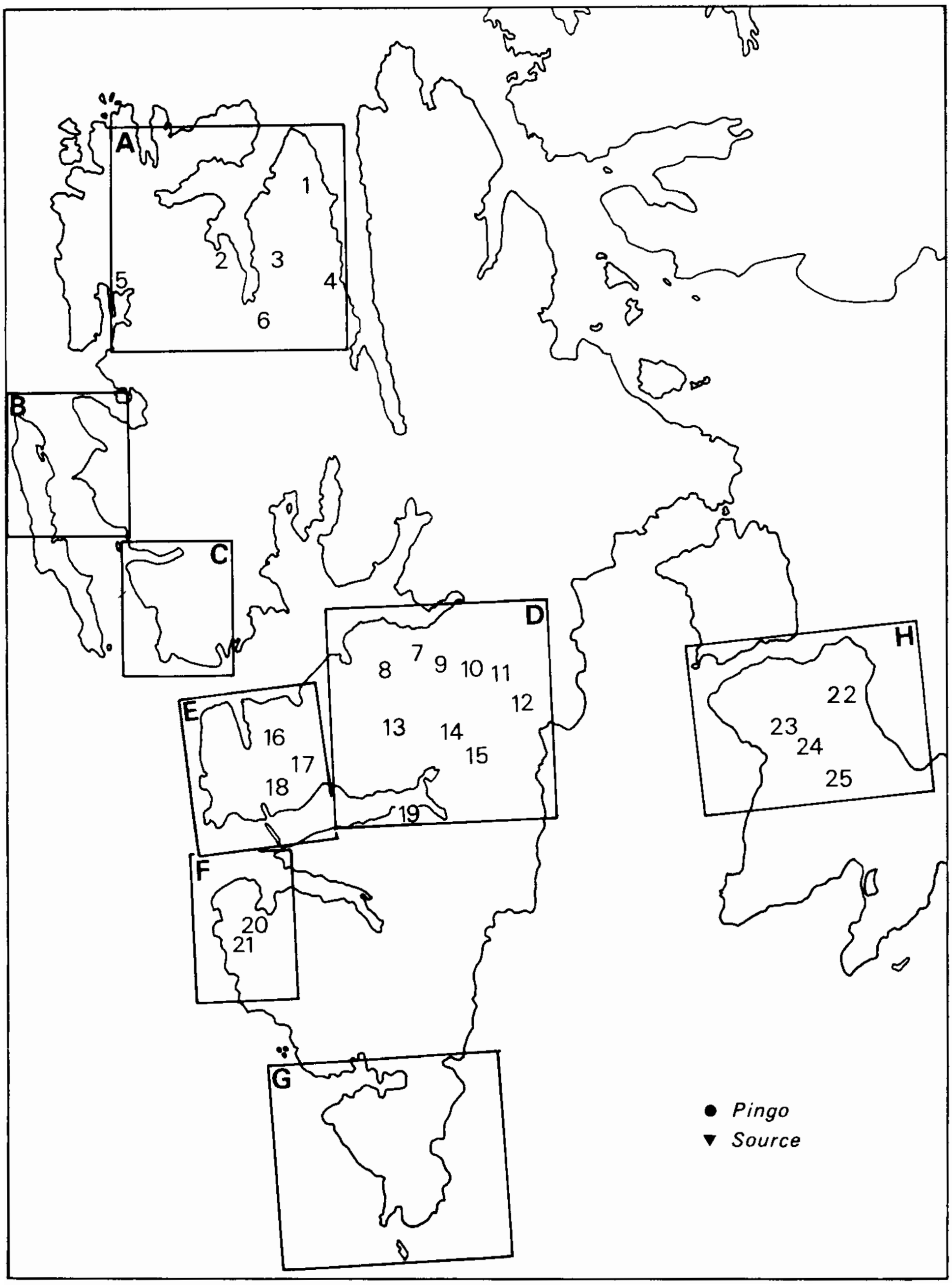

Fig. 4. *Outline map of the more detailed maps showing the site of the different pingos and springs described.*

Обзорная карта, показывающая расположение более подробных карт местонахождений описанных пинго и источников.

Description of the pingos and springs in Spitsbergen

PINGOS

On the map in Fig. 4 each locality with a pingo or a pingo group has a number which is referred to in the text, starting in the north.

1. A regular elliptic-shaped cone with the long axis E-W, is situated on the north side of Vatnedalen about 6 km from the west coast of Wijdefjorden. There is a 5 m wide depression on the top but no typical crater. This locality is possibly the same as that which KURT WEGENER (1913 p. 140) observed in the winter of 1912 with steaming salt water.

2. This locality in Bockfjorden is well known for its warm springs and will be dealt with later in this paper. There are also some pingo-like features on the delta plain at the head of Bockfjorden. One regular cone just outside the terminal moraine of Karlsbreen, is during most of the summer surrounded by a sheet of ice produced in the winter by sub-permafrost water. There is no crater at the top but a few cracks across the cone. Another pingo lies on the delta plain below the slope of the quaternary Sverrefjellet volcano. It is irregular in shape and partly eroded.

3. On the north side of Stjørdalen, about 8 km from the east side of Woodfjorden, is a 100 by 50 m mound that could be a pingo. No winter ice is seen on air photos and it might be a fossil form.

4. About 2 km from the west side of Wijdefjorden on the south side of Purpurdalen, is an about 30 m high and 700 m long pingo. It has a 70 m wide, circular crater at the top. There are concentric, caldera-like rings inside the crater, but no lake. It is developed in raised-beach sediments and the light colour inside the crater indicates a still active type. The pingo was observed by P. F. FRIEND (1959) during the Cambridge Spitsbergen Expedition 1958.

5. The occurrence of two pingos just outside the terminal moraine of Supanbreen near Krossfjorden, was observed by field parties of the 1962 and 1964 Norsk Polarinstitutt Expeditions and described by TONY VAN AUTENBOER and WALTER LOY (1966). The southernmost and largest cone shows a perfect circular section with a 20 m wide crater. The northern and slightly smaller one has a typical horseshoe section indicating rupturing and overflow of water. An interesting fact is that the upheaval of the pingos affects the hard mica quartzite bedrock. It is possible that the formation of the pingos is connected with a minor fracture or joint perpendicular to the general orientation of the geological formation.

6. Five pingos or pingo groups are found in Woodfjorddalen. The northern and outermost one is a 200 m by 100 m mound with a large NW-SE-going crack (Fig. 1). It is very conspicuous on the absolutely flat delta plain and has got a special name, Tantaliholmen, named by a Swedish expedition in 1900. The soft-clay ground, flooded at high tide, makes it impossible to walk across to the hill in the summer. The next and smaller one, also situated in the tidal area, has three crater rings linked together, the southern being the youngest.

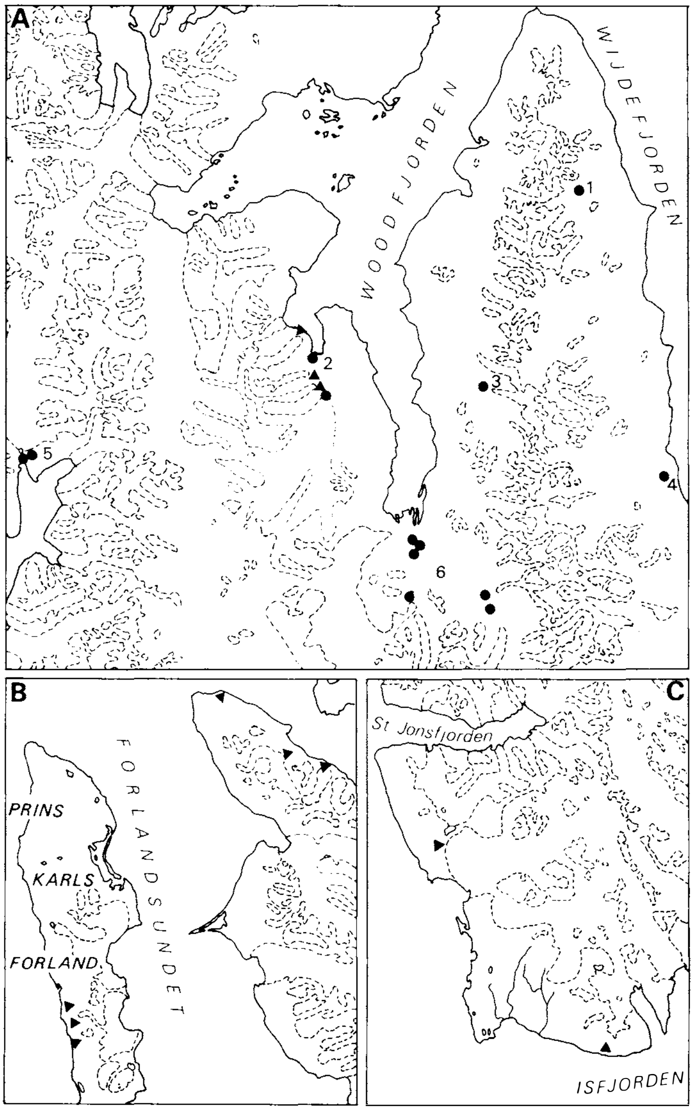

Fig. 5. *Map of the pingos and springs in A: the area between Krossfjorden and Wijdefjorden, B: Prins Karls Forland and Brøggerhalvøya, and C: the southern part of Oscar II Land.*

Карта распространения пинго и источников: в области между заливами Krossfjorden и Wijdefjorden (A), на острове Prins Karls Forland и полуострове Brøggerhalvøya (B) и в южной части района Oscar II Land (C).

A 500 m by 250 m pingo group or cluster is situated on the southern side of the valley plain (Fig. 2). There are no distinguished shapes except a characteristic 50 m wide caldera-like depression on the western side. Mounds 10 km further up the valley and in the southern tributary valley, Piræusdalen, have a diffuse shape and may have been inactive for some time.

7. Near Kreklingpasset in De Geerdalen are two pingo mounds. The northern one is about 300 m long and rather diffuse, the southern one is more

Fig. 6. *Pingo cluster on the south-west side of Woodfjorddalen.*
Группа пинго на юго-западной стороне долины Woodfjorddalen.

clear in shape and has a large E-W crack. They do not seem to be active at present and no winter ice has been observed. These pingos have the highest elevation above sea level of all the pingos in Spitsbergen, about 190 m, which is well above the marine limit.

8. Pingos in Adventdalen. Easily accessible, situated near the mining town Longyearbyen, the pingos in this area are the best known in Spitsbergen. They are described by ORVIN (1944), PIPER and PORRITT (1965), and SVENSSON (1970).

The outermost is situated on the eastern bank of Moskuslaguna. From a morphological point of view it is not a real pingo and ORVIN describes it as a mud and clay soup with ice, through which water percolates from below. A chemical analysis of the water gave a salt content of 4.20 g per 1.

5 km further up the valley below Ugledalen is a low 300 m wide mound. The age of this pingo is dated to less than 2,650 years B.P. by means of a radio carbon dating of drift wood found by SVENSSON (1970). No spring has been noticed on this pingo.

The next mound below Bassenfjellet is not so pronounced, but its area is much larger, 825 m by 275 m. This pingo area appears to be much more active. During a visit in the winter of 1971, large ice domes were found. The owner of a hut on the top of the mound had noticed that running water was visible every winter. Chemical analyses from 1924 (ORVIN 1944) show a salt content of 5.15 g per l, much the same as with the pingo at Moskuslaguna, but with a much larger percentage of Cl and SO_4.

The highest pingo in Adventdalen is the one lying in the centre of the valley near the mouth of Helvetiadalen. PIPER and PORRITT (1966) made a map of the pingo in 1964, according to which it is 410 m from east to west and 200 m from north to south. The height above the river plain is 28 m. Adventelva flows around the south side of the pingo causing a steep erosion slope. The author visited the place in April and August 1972 and in June 1976. During the first visit, a 3 to 4 m thick ice dome was found over the highest part of the pingo. The ice was broken and pressed upwards (Fig. 10) and water was running from a crack at the top of the ice in spite of an air temperature of —17°C. At the later visit in August the same year, the ice had melted, but ice was found below a thin layer of shale debris. Water came to the surface through a 1.5 cm wide hole in the ice. The temperature was —0.3°C and the discharge about 100 cm^3/sec. Chemical analyses were made by Limnologisk Institutt, Universitetet i Oslo, from probes taken in 1972 and 1976 and some of the components are listed below together with analyses made in 1924 (ORVIN 1944) from the same place.

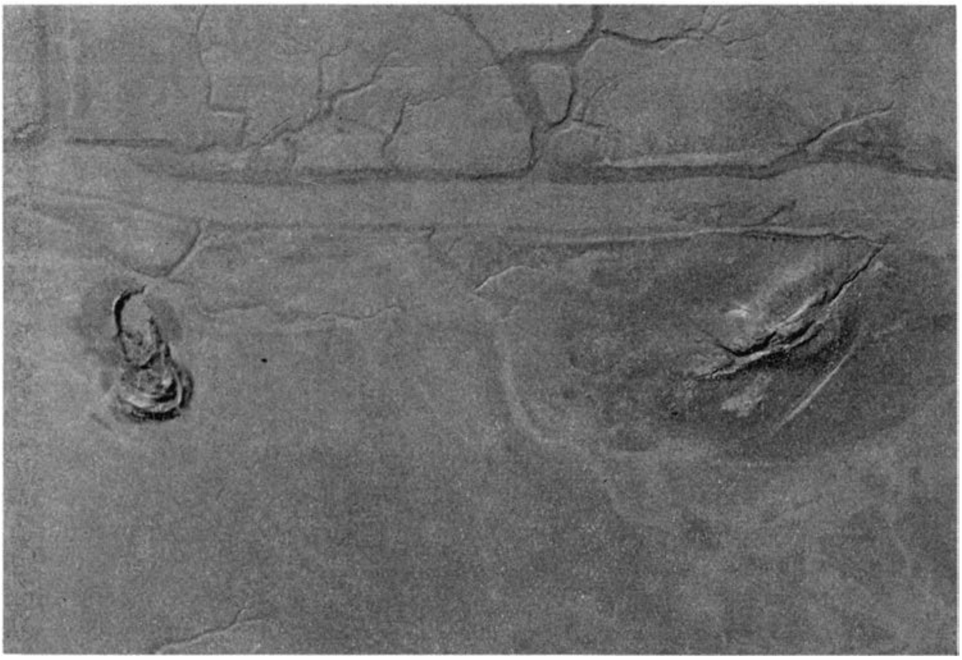

Fig. 7. *Pingos in the outer part of Woodfjorddalen. The surrounding flats, flooded at high tide, are soft with sticky clay, making it impossible to walk across to the mounds. The pingo to the right is a conspicuous feature in this totally flat area and was named Tantaliholmen by a Swedish expedition in 1900.*

Пинго во внешней части долины Woodfjorddalen. Окружающие равнины, заливаемые приливом, мягкие с липкой глиной, не позволяющей переход человека на поднимающиеся среди них холмы. Стоящее справа пинго, являющееся бросающейся в глаза чертой в этой совершенно плоской местности, было названо Tantaliholmen („Танталовым островком") членами Шведской экспедиции 1900-го года (теперешнее название — Tantalushaugen — „Танталов холм").

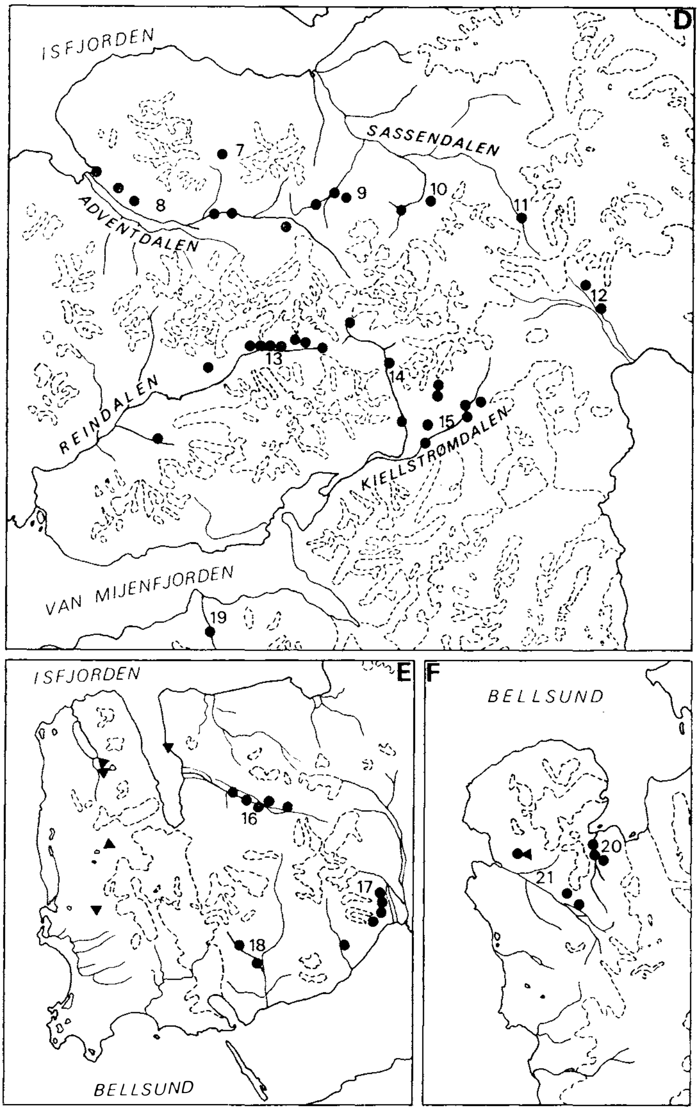

Fig. 8. *Map of the area between Isfjorden, Agardhbukta and Van Mijenfjorden.*
Карта области между заливами Isfjorden, Ahardhbukta и Van Mijenfjorden.

	Cl	SO_4	Na	Ca	Mg
1924	0.22 g/l	2.35 g/l	0.97 g/l	46 mg/l	150 mg/l
1972	1.55 »	0.00 »	2.50 »	28 »	24 »
1976	1.60 »	0.01 »	4.35 »	27 »	0 »

There is a striking difference between the analyses. The one from 1924 showed more than 2 g per l of SO_4, while there was no provable quantities of the same component in the analysis from 1972 and almost negligible quantities in that from 1976. On the other hand, the probes from 1972 and 1976 contained much more Cl than the old one. The discrepancy between the analyses is difficult to explain. A photograph from 1930 shows that the ice dome was at the same place then as today.

About 1.5 km upstream from the pingo mentioned above is a single pingo dome. According to PIPER and PORRIT (1966) it is 90 m by 50 m and 7.8 m high. It is situated in the river bed. The surface is irregular with several small domes and is being eroded at the margins. During a visit by the author in the spring of 1972, no water and retrozen ice could be seen.

The uppermost pingo in Adventdalen is situated on the southern side not far from the terminus of Drønnbreen. This pingo has a rather smooth surface.

9. Eskerdalen. In the upper part of the valley near the junction of Juvdalen is an about 400 m long mound in the centre of the rather narrow valley. The river has cut a gorge on each side and the northern river branch has cut through the eastern low parts of the hill. In the middle of the mound is a dome with regular and radial cracks. This pingo is an active one with permanent running water.

Further down the valley on the south side are two small circular mounds with cracks on the top. A fourth feature in the lower part ot Trehøgddalen could be a pingo. The river erosion has excavated a large part of it.

Fig. 9. *The pingo north of Janssonhaugen in Adventdalen. This photo was taken on April 18, 1972, when, in spite of an air temperature of —17°C, water flowed out of the ice on top of the mound, and spread far out on the snowcovered river plain before freezing.*

Эта фотография расположенного севернее горы Janssonhaugen в долине Adventdalen пинго была снята 18 апреля 1972 г., когда несмотря на температуру воздуха в —17° C вода вытекала с ледяной вершины холма, распространяясь, до замерзания, далеко по покрытой снегом речной равнине.

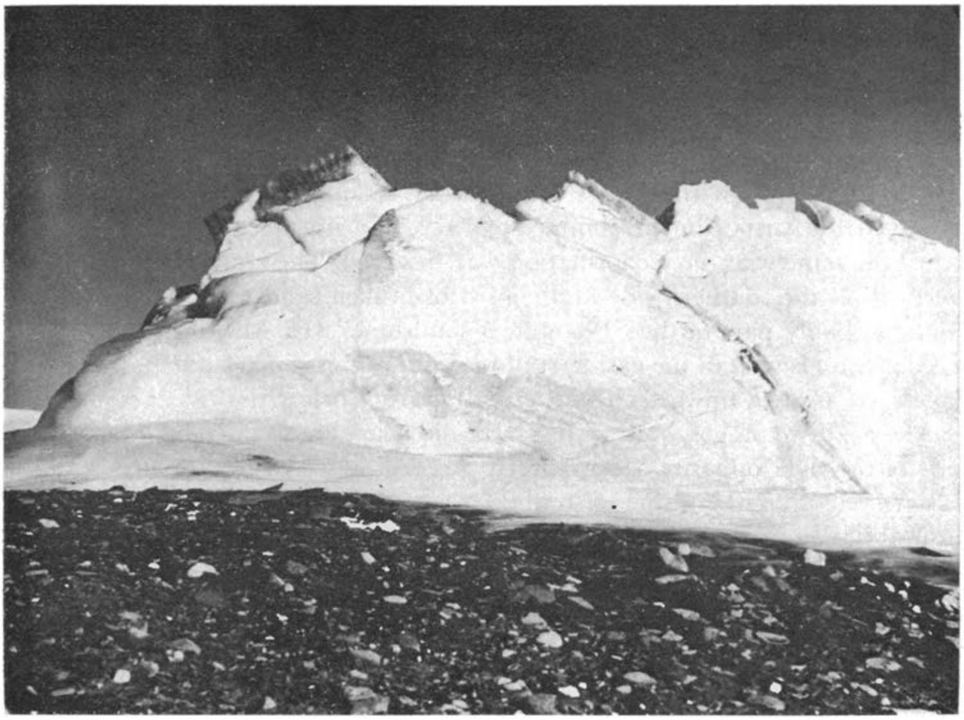

Fig. 10. *Close-up of the faulted and broken ice dome at the top of the mound in Fig. 9. The height of the ice is about 5 m.*

Крупным планом снимок сбросового и сломанного ледяного купола, представленного на рис. (Fig.) 9 на вершине холма. Высота льда около 5 м.

10. A high pingo which is very distinctive from the flat river plain is found in Vendomdalen, a tributary valley to Sassendalen. The sides are steep but rather irregular with no crater on the top. Further down the valley, eroded mounds with cracks on top might be remnants of a larger pingo group.

11. Just below the advancing Marmorbreen in Fulmardalen is a high irregular cone. It has a crater on the top and seems to be active.

12. In Agardhdalen is a large cluster of pingos in the centre of the broad, flat valley plain. No marked crater is seen and the rises are partly eroded on the east side. A single pingo on the lower slope of Roslagenfjellet has large crevasses but no crater-like features.

13. Pingos in Reindalen. The largest and most typical pingo features in Spitsbergen are found in Reindalen. They are marked on the geological map "Adventdalen" and have been studied by HARALD MAJOR (1972) and RICHARD ÅHMAN (1973).

The easternmost pingo is found at the terminal moraine of Vegbreen. The southernmost one goes in fact partly into the moraine itself. This is also the highest with a caldera surrounding a central cone. The northernmost pingo is a smooth dome with small radial cracks. The northern side is partly eroded by the river. A small low dome lies 100 m to the west of the latter. Further down the valley, on the north side of the river below Agardhfjellet, two other low rises are found. They have only a few cracks and no crater features.

The next pingo in the centre of the river plain below the Bergmøya mountain is one of the highest and most remarkable pingos in Spitsbergen. ÅHMAN measured the height to 42 m above the river plain and the length to 320 m. The central part of the top is occupied by a small lake. No drainage was observed by ÅHMAN in the summer of 1972, and during the author's visit in April the same year, no ice formation was observed. The crater sides are nearly vertical on the southern side and consist of broken sandstone beds which are most probably part of the "Festningen sandstone" (H. MAJOR pers. comm.). A coal seam is seen in the east part of the crater. It is remarkable how the rock layers are pressed upwards to this elevation from below the river sediments.

The next two pingos, both with craters and lakes, are situated on the northern side of the river opposite Marthabreen. According to ÅHMAN the height of the eastern one is 28 m and the western 20 m above the flood plain. The drainage from the lakes was negligible at ÅHMAN's visit and there was no ice-formation at the author's visit in the spring.

About 1.5 km further west is a circular dome-shaped rise or blister on the slope from Merckollfjellet. An east-west crack system goes through the highest part of this ice blister. The dome is bordered by another circular crack system.

A large 750 m long and 36 m high pingo is found in front of Kokbreen. There is no typical crater, but a 50 m long east-west depression crosses the top.

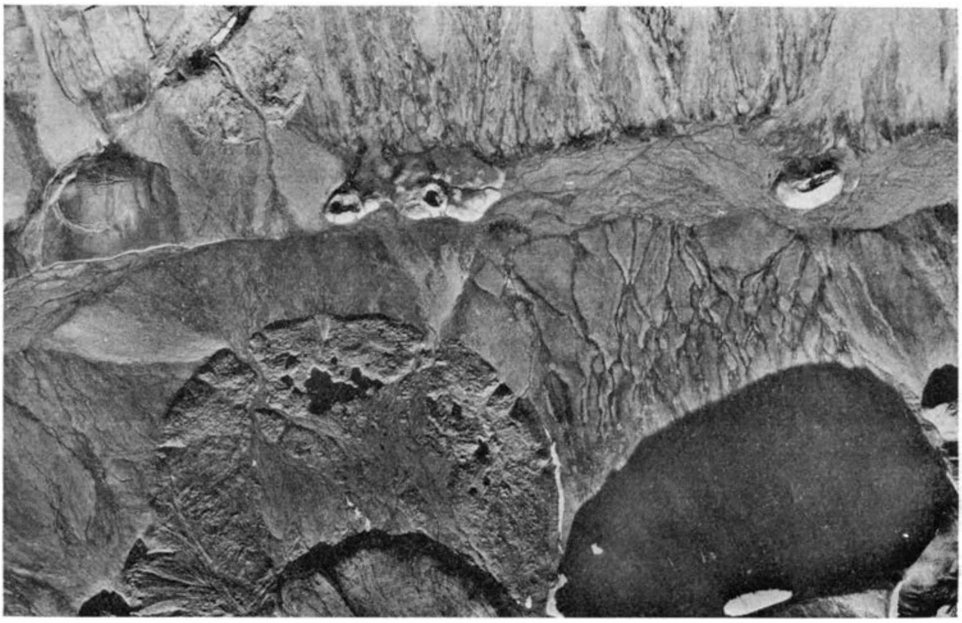

Fig. 11. *Pingos in Reindalen. The snout and moraine field of Marthabreen is seen in the lower left part of this air photo. An "ice blister" is seen in the upper left part.*

Пинго в долине Reindalen. Слева внизу видны фронт и моренное поле ледника Marthabreen. Слева наверху виден ,,ледяной волдырь''.

As is the case with the pingo below the Bergmøya mountain mentioned above, this also partly consists of 'Festningen sandstone' from Upper Cretaceous. The layers are tilted from the centre to both sides indicating an upward pressure in the centre.

The last pingo to be described in Reindalen is a small crevassed rise on the river plain just west of Johan Ankerfjellet. There is no crater, and no ice left from the winter was observed.

14. In Lundströmdalen, three pingos have been observed. At the mouth of the valley is a 200 m by 100 m hill with the long axis across the valley in a NE-SW direction (mentioned by Piper and Porritt 1966).

In the valley below Statsbreen, in the middle of the deep gorge cut by the river in the alluvial sediments, are the remnants of a small pingo. Cracks and what seems to be part of a crater, are still visible. Further down the valley where the terminal moraines of Glitrebreen and the glacier from Slottsmøya meet, there is a mound with a lake on the top which could be a pingo. It has not been visited in the field and could be remnants of a moraine.

15. In the upper part of Kjellströmdalen on both sides of the river plain below Storbullen are two pingos. The one on the northern side is a high, single, regular cone with a small lake on the top. The southern is rather a complicated group of pingos with calderas and erosion shapes.

Below Edvardbreen on the alluvial cone, are irregular cracked mounds which go partly into the terminal moraine.

Two groups of mounds lie in the middle of the narrow valley between Storlengja and Storknausen just in front of the advancing glacier. Weak traces of cracks are found on the top.

Further down Kjellströmdalen, near the junction of Lundströmdalen, is an irregular group of low mounds which might be a fossil pingo group. Just outside, in the middle of the broad valley plain, is a single feature which is also most likely an erosion form of a pingo.

16. Pingos in Grøndalen described by Orvin (1944), are situated in the middle of the valley on the north side about 10 km from the coast. The mounds are elliptic-shaped with the long axes in a NE-SW direction. The northern one is still of the same shape as described by Orvin with a small pond about 20 m in diameter on the upper side. The pond on the other pingo could not be identified on air photos from 1960. According to Orvin this pond was fed from a spring giving about 3 l water per sec. There are cracks along the ridge of both hills, and from the southern one a mud-flow-like feature goes out onto the river plain. Large icings were seen during a visit in the spring of 1976.

Two other groups of pingo hills seeming less active are found on the other side of the river. Other inactive pingos are located, one about 2 km upstream and two further down the valley.

17. A few mounds of uncertain origin on the east slope of Rypefjellet, might be pingo-like features. On the southern side, however, is a large pingo with a regular 60 m wide crater lake. There are no cracks or erosion forms indicating any recent activity.

Fig. 12. *Pingo at the north slope of Dunderdalen.*
Пинго у северного склона долины Dunderdalen.

18. On the broad river plain in Berzeliusdalen about 5 km from the coast and 12 m above sea level, is a double pingo. The eastern one has a marked caldera ring with a diameter of about 50 m with a regular 15 m high cone inside. This pingo is also described by ORVIN observing water with gas bubbles coming up from a spring in the pingo. Icings and running water were also seen in the spring of 1976.

Further up in Aurdalen is a pingo group. The easternmost one is cone-shaped with a light colour indicating less vegetation and therefore perhaps recent activity.

19. A small mound with cracks, most likely a fossil pingo, is located at the west side of Danzigdalen about 4 km from the southern shore of Van Mijenfjorden.

20. Four pingo-like hills are situated at the bottom of Chamberlindalen south of Recherchefjorden. They have irregular shapes with cracks and are partly eroded by the river. There does not seem to be any recent activity.

21. One of the most typical pingos in Spitsbergen is found on the northern side of Dunderdalen. As Fig. 12 shows, the top has caldera-like depressions on the top and the cone-shaped mound is very regular. This one is not situated in the middle of the valley as most pingos are, but at the lower slope of the valley side. The geological map shows its location just at the border between a tillite and a greenstone-schist.

2 km further up the valley is another typical pingo with a small cone and crater at the west side, also situated at the geological border. A third small cracked mound lies beneath Dunderfjellet. About 100 m from the latter, a spring is flowing from beneath one of the characteristic talus accumulations leaving a large sheet of ice from the winter's freezing.

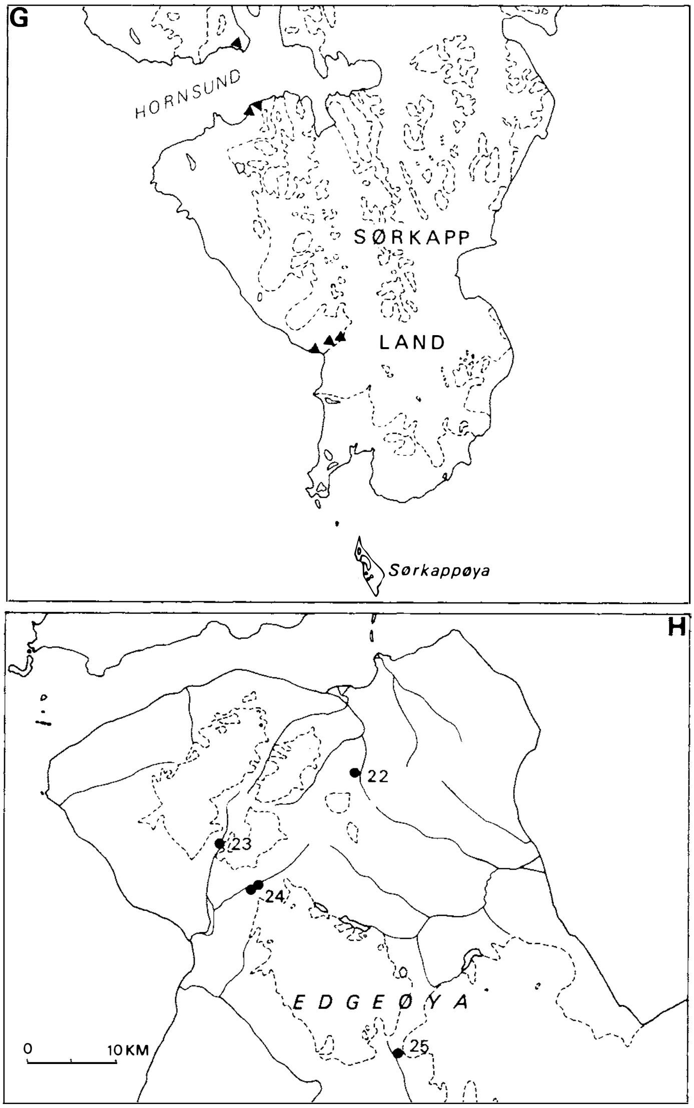

Fig. 13. *Map of Sørkapp Land and Edgeøya.*

Карта полуострова Sørkapp Land и острова Edgeøya.

Pingos in other parts of Svalbard

As will be seen on the map, most of the pingos are concentrated in the central part of Spitsbergen especially between Isfjorden and Van Mijenfjorden. In other parts of Spitsbergen they are scarce or hitherto not found at all. This is the case with Ny Friesland, Olav V Land, Oscar II Land, Torell Land, and Sørkapp Land.

On the other islands of Svalbard only a few on Edgeøya have been found until now, and they will be briefly described here.

22. A small pingo lies in the river bed about 10 km up Raundalen.

23. In Raddedalen between Kvitisen and Blåisen is a small pingo with cracks but no crater.

24. In Smelldalen are two groups of pingos. The easternmost, described by A. WIRTHMANN (1964), is the most conspicuous one, with a near to circular shape and a lake in the centre.

25. The last one is a high cone-shaped pingo almost in the centre of the island at the end of Dyrdalen between Storskavlen and Edgeøyjøkulen.

SPRINGS

As mentioned above, many of the springs in Svalbard are described in detail by ORVIN (1944). The below description is short and deals also with a few new findings. It does not include springs connected with pingo mounds, nor does it include water emerging from underneath almost all larger glaciers. On the enclosed maps, springs are marked with a triangle.

Springs in Bockfjorden. These springs have been known for a long time and are described by HOEL and HOLTEDAHL (1913). There are a total of eight, all lying on a north-south line near a large fault zone. Two are located north of the quaternary Sverrefjellet volcano and the rest about 5 km south of the volcano. Large tuff terraces with shallow basins are built up in connection with the springs especially below the southern ones. The highest temperature, 28.3°C, has been measured in one of the southern springs and the mineral content was 2.41 g/l. Their locations indicate a volcanic origin.

On the northern side of Kvadehuken, near the coast west of Kongsfjordneset, is a large spring feeding a creek with running water all year round. Small wintering fish have been observed. The water discharge, 10 l/sec, was measured by the author in May 1975. Water temperature was 1.7°C and air temperature —6°C.

At the foot of Zeppelinfjellet, south of Ny-Ålesund, is a small lake called Tvillingvatnet from which water is flowing late in the autumn after all surface drainage has stopped. Measurements of the water conductivity in the summer of 1974 showed a much higher value than in the near-by creeks. It is believed, therefore, that the lake is fed by a spring at the bottom. At a drilling for coal prospecting near this lake, high pressure water was hit at 18 m depth. The thickness of the permafrost at this place is about 140 m.

5 km further east, in front of Midre Lovènbreen, is a spring with high salt

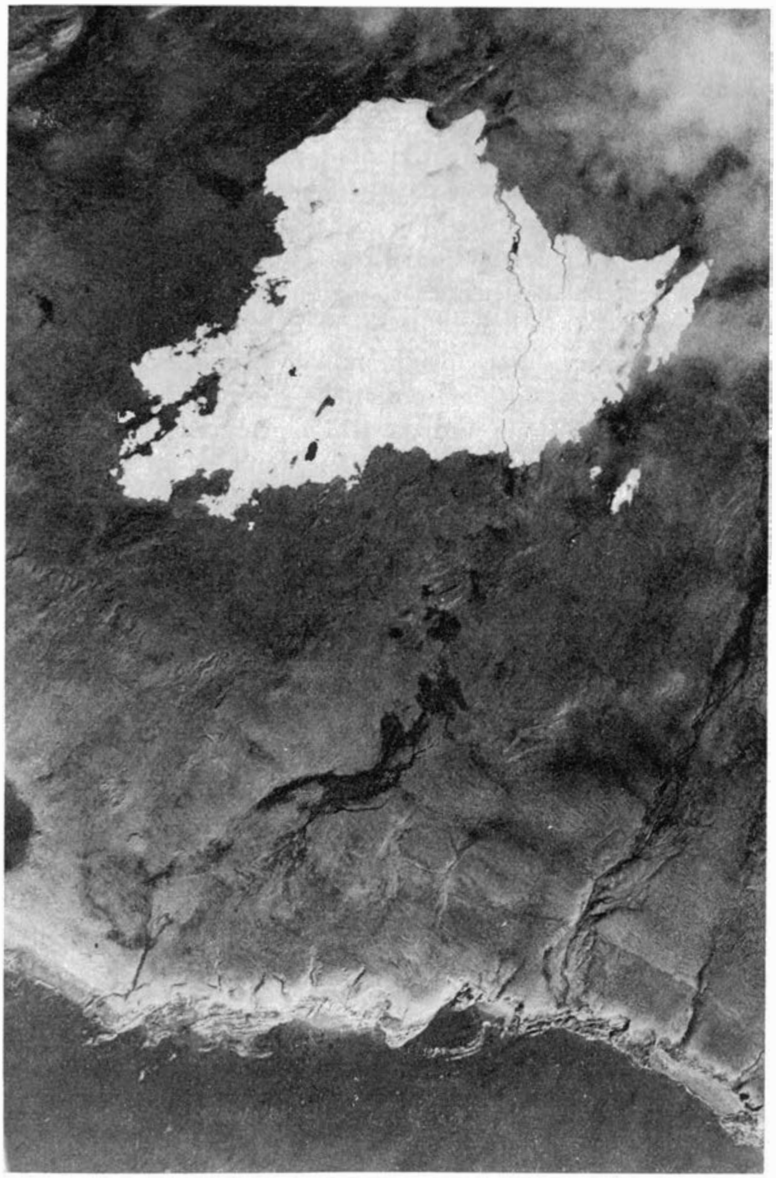

Fig. 14. *Icing from a spring west of Alkhornet on the north side of Isfjorden. In the winter the ice will stretch out right to the sea about one kilometre from the source, covering a much larger area than on this air photo taken on 25 August 1970.*

Происходящая из расположенного западнее горы Alkhornet на северном берегу залива Isfjorden источника наледь протягивается до самого моря, примерно на километр от него, покрывая гораздо большую плошадь, чем на настоящей воздушной фотографии, фотографии, снятой 25 августа 1970 г.

content. In the winter, very large ice sheets are formed in front of the spring, stretching about 1.5 km right down to the coast.

The locations on the strandflat north of Isfjorden and on the west side of Prins Karls Forland, have not been visited by the author, but large icings have been seen from the sea and on aerial photographs. Especially the one just west of Alkhornet builds up a very large ice sheet covering the strandflat from the mountain foot right to the sea (Fig. 14).

The area between Linnévatnet and Kongressvatnet, south of Isfjorden, has at least three springs. The outlet river from Kongressvatnet is running throughout the winter, which is an indication of the existence of subaquatic springs, and it is serving as watei supply for the mining town of Barentsburg.

On Finneset, on the east side of Grønfjorden, is a small spring. The discharge is measured to about 10 l/min and the temperature was 5.5°C when ORVIN visited the place in 1926. Gas, mainly metane, bubbled up with the water.

Springs of the same type as those on the strandflat north of Isfjorden are found along the hillfoot between Kapp Linné and Bellsund. One of them, on the north side of Orustdalen, is mentioned by ORVIN. He saw a large ice sheet in front of the spring indicating winter discharge.

In Dunderdalen, on the north side, water comes out below a talus accumulation. Further out on the plain is an ice blister which is perhaps formed in connection with this spring.

ORVIN has a detailed description of the springs in the Hornsund-Sørkapp area. They all seem to have connection with the limestone found in a belt from Stormbukta to the north side of Hornsund.

One of the springs is located below Sofiekammen on the northern side of Hornsund, two others on the southern side below Tsjebysjovfjellet. Orvin did not measure the temperature but estimated it to about 10–12°C.

The largest known spring in Spitsbergen is named Trollosen and is located at the shore north of Stormbukta. At high tide the sea might reach the outer part of it. WERENSKIOLD (1920) measured the discharge to 10 m^3/sec and a water temperature of 4.0°C. Later observations by H. MAJOR and T. WINSNES (personal comm.) showed that the discharge in some small springs further west had large variations, and it seems to change in the same way as in the near-by glacial rivers. The greyish and green colour also indicates a glacial origin of the water. ORVIN (1944) thinks the water may come from the glacier field behind Hilmarfjellet, draining through limestone covers to the coast. The water has to go deep below the permafrost border to absorb the large amount of heat, 40,000 kcal/sec. The large variations in discharge on the other hand, indicate a short drainage distance.

Some smaller springs are found in the same area. Just north of Olsokbreen, WERENSKIOLD (1920) measured a temperature of 10°C and a discharge of 0.15 m^3/sec in one of them. In two smaller springs further west, the temperature was 15°C. Later WINSNES measured the temperature in one of them to be 16.3°C. Chemical analyses (WERENSKIOLD) from the former showed per litre: 0.315g Ca, 0.062g Mg, 2.150g Na, 0.256g K, 4.016g Cl, and 0.046g SO_4. This means that about 80% of the salt content is NaCl. The possibility of sea water leaking into this water system is not unlikely, the spring lying near sea level.

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Setevatnet, a glacier dammed lake in Spitsbergen

By Olav Liestøl

Abstract

The glacier dammed lake described has a special topographic location, lying in an ice-filled pass between the two glacier streams, Kongsvegen and Uversbreen. When filled, the lake is partly subglacial. In spring 1975, it had a sudden catastrophic draining when water surged out of a one kilometre long crack further down the Kongsvegen glacier. The drainage mechanism is difficult to explain, but possible causes for depletion are described. The filling period of the lake is calculated to be about three years.

Glacier dammed lakes are common in Spitsbergen, but most of them are small and short lived. Some are just shallow ponds on the ice surface. The larger and deeper ones are more or less bordered by land. The lake described here — Setevatnet — is of an uncommon type, partly subglacial, and located in a low ice-filled pass between Kongsvegen and Uversbreen, the two large glacier streams east of Kongsfjorden.

The existence of the lake has been known for a long time, and it was first named on a map made by the Monaco expedition in 1909. It is also found on the map made by the German expedition in 1964 and on a map published by Norsk Polarinstitutt based on air photographs from 1966.

The lake covers about 1.5 km^2, but only a small part on the northern and southern sides is open water — the rest is subglacial. The height of the lake surface when filled, is about 270 m a.s.l., which is about 100 m below the glacier equilibrium line in the area. Ice is flowing in to the depression from both sides, especially from Uversbreen and the small tributary glacier, Veslebreen. Large areas of the floating ice are covered by morainic material originating from side and middle moraines further up the glaciers.

When visiting the locality at the end of May 1975, the author found the lake just emptied. The highest water level could be identified on the northern and southern sides as a sharp line below which last winter's snow had disappeared. Where the lake had subsided, crevasses marked the outline of the subglacial part. The ice surface in the depression, now far below the height of the previous shore line, was still snow-covered, indicating that it had not been flooded by lake water (Fig. 1).

Fig. 1. *In the foreground the pass between Uversbreen and Kongsvegen glaciers with the now empited lake. The previous shoreline is seen in the snow on the mountain side. Crevasses on the ice surface indicate the extent of the subglacial lake. In the background the one kilometre long crevasse where water surged out and swept away snow down the glacier.*

Photo: J. Angard

In order to survey the lake, a base line was measured and from each end points on the surface of the subsided ice and the shore lines were intersected. As it was difficult to link this local survey to the main trig net, the height of the left station was estimated to 300 m a.s.l., using the contour lines on the maps. Using this height as a reference, the shore line of the open part was 268 m a.s.l. while the bottom line was 223 m. The height of the previous floating ice was about 240 m a.s.l. in the center part. This means that prior to depletion, the height was 268 m, plus 1/10 of the ice thickness. If the ice is, say, 100 m thick, the subglacial water layer will be 38 m. As the rock bottom and the ice surface vary, this layer will also vary in thickness. The sketch in Fig. 2, demonstrates how a vertical profile through the sadel point may look. The total water volume stored is roughly calculated to about $40 \times 10^6 m^3$.

Most remarkable is the emptying of this lake which took place in the middle of May (Fig. 3). The catastrophe was neither seen nor heard in this remote area, but traces of it were extraordinary. On the Kongsvegen glacier, about 2 km downstream from the lake, a long crack appeared, making a 1–10 m high step on the glacier surface. The crack was about one kilometre long with an inclination of 45°. Water surging out of the crack, swept away the thick snow layer over large areas right to the sea about ten kilometres further down (Figs. 1 and 3). Large blocks of ice broke away from the crack and were brought downwards by the flood (Fig. 4). A large part of the water had been concentrated on the left margin along the side moraine. Further down, the water stream went first supraglacial and then subglacial through large moulins along the glacier side.

The drainage mechanism of this glacial lake is difficult to explain. It may be quite complex, and many facts about the lake, as for instance depth, the form of bedrock, and the subglacial draining systems are unknown. Fig. 2 shows a vertical profile from Uversbreen to Kongsvegen through the glacier dammed lake. Water is draining to the lake from the glacier surface on both sides. When the water level has reached a height equalling about 9/10 the thickness of the glacier ice in the lowest centre part, it starts floating and the subglacial water layer will begin increasing.

The emptying of the lake should theoretically start when the water reaches the critical level which is 9/10 of the damming ice, in this case on the Kongsvegen side. This process will not lead to any depletion of the lake by itself, as a balance between the pressures of the ice and the water at the bottom will occur instantly. Thus, still theoretically, only a water volume corresponding to the supply into the lake will be drained. The explanation for the occurrence of a catastrophic depletion might be that the water level reaches a height some metres above the critical one, and then a sudden break-through will take place. This may be said to be a normal way glacier lakes deplete. The extraordinary phenomenon in this case was the lifting of the glacier, forming the large fault in the ice where the water surged out. The water from the lake may have escaped under the ice as some kind of sheet-flow and increased its pressure in relation to the glacier ice as it forced its way down along the bedrock. The most spectacular feature of this extraordinary event is the length of the fault and the water coming in such large quantities out of the crack along its entire length.

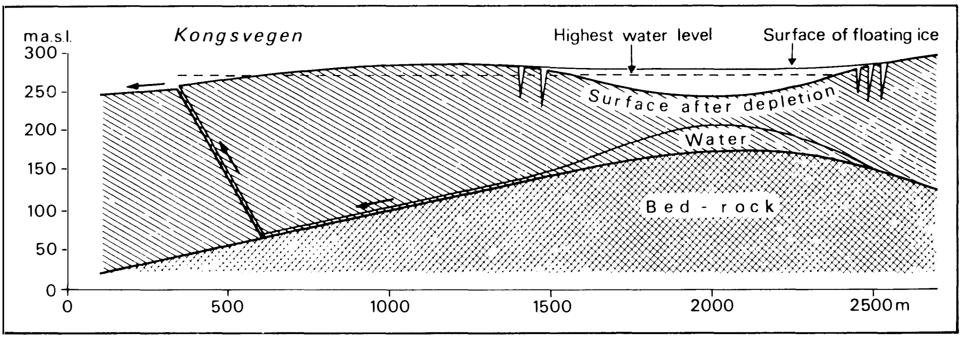

Fig. 2. *A sketch of a profile through the glacial lake indicating conditions before and after depletion.*

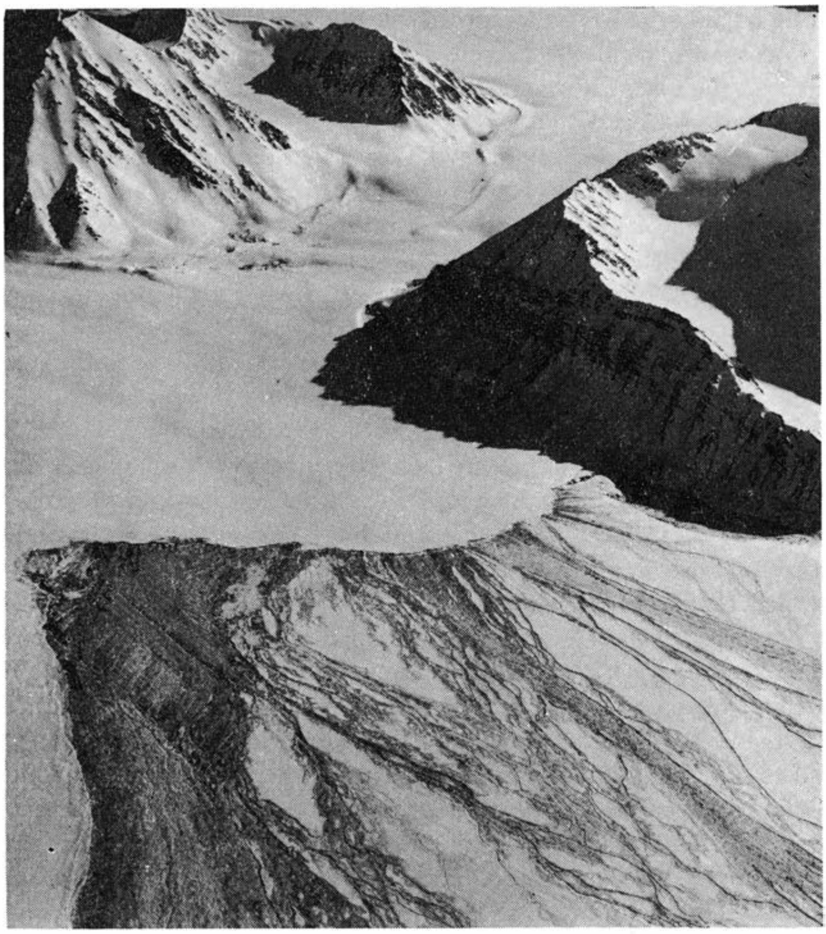

Fig. 3. *In the foreground the fault where the water surged out and in the background the pass where the lake was dammed.*

Photo: J. ANGARD

As the height of the fault line is approximately 255 m a.s.l., which is many metres above the lake bottom, only part of its stored water could escape here. Water below this level must find other ways out.

Like most other glacier dammed lakes, also this one must have periodic fillings and drainings. The length of the period is dependent upon the size of the catchment area and the precipitation rate, or in this case, ablation rate, of the glacier. The intake area is approximately 15 km^2, but the precipitation is not known. According to mass balance measurements on Brøggerbreen and Lovénbreen further west, ablation plus summer precipitation would amount to about 1000 mm/year. This means that filling of the lake will take about three years. The influx to the lake is limited to the short summer melting season. It is therefore astonishing that the depletion took place in the spring at a time when the lake level had remained constant for about eight months.

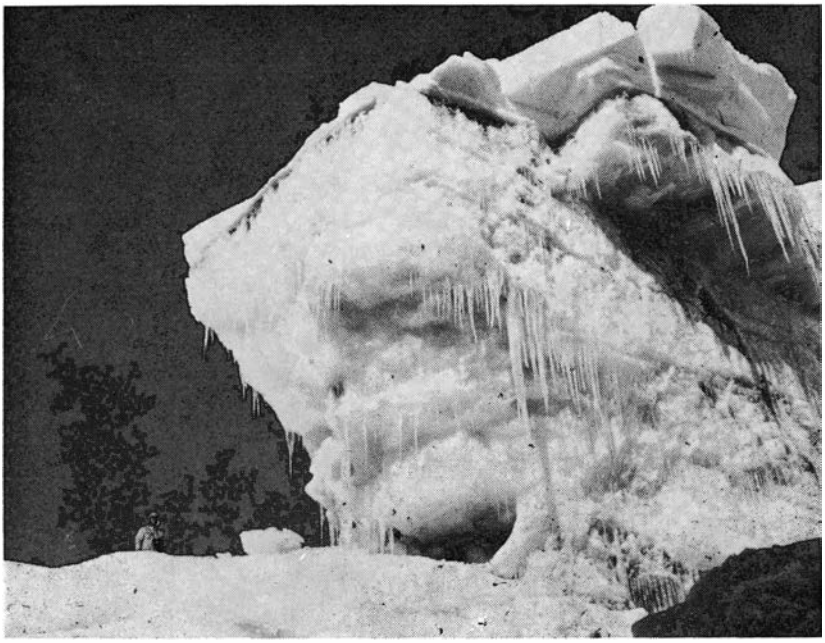

Fig. 4. *One of the ice blocks being broken off from the crack by the flood. Note the snow which still remains on top of the block.*

Photo: K. Repp

Seismic survey of Jan Mayen

By ANDERS SØRNES[1] and TORSTEIN NAVRESTAD[2]

Contents

Abstract

A seismic refraction survey was carried out at Jan Mayen in August 1973 to determine the crustal velocity model so that local earthquakes can be located more precisely with the new permanent tripartite seismic array on the island. Twenty-five depth charges (135 kg TNT each) were detonated around the island. The detonations were recorded by the permanent array and also by three temporary field stations. The following average crustal velocity structure has been calculated from the data assuming layering with constant velocities in each layer: Layer 1 is <0.2 km thick near Jan Mayen and increases in thickness along two profiles trending NW and SE from the island (reaching 1.4 km to the SE if 2 km/sec is assumed); Layer 1 is 0.5 km under the island assuming a velocity of 2.5 km/sec; Layer 2 (3.14 ± 0.17 km/sec) reaches a depth of about 3 km; Layer 3 (6.33 ± 0.13 km/sec) reaches about 18 km; Layer 4, below a depth of 18 km, may have a velocity as great as 8.27 km/sec.

Introduction

The Norwegian Defence Communication Administration established a new modern tripartite seismic array on Jan Mayen in the second half of 1971. The main purpose of the array is to monitor the local seismic acitivity on this

[1] Seismological Observatory, University of Bergen, 5000 Bergen, Norway.
[2] Statens Oljedirektorat, 4000 Stavanger, Norwav.

volcanic island. The intensity and pattern of the local seismic activity may provide valuable warnings of impending volcanic activity for the small community on this isolated arctic island. Investigation of the data from a one-component seismic station run by the University of Bergen on Jan Mayen from 1962 to 1970 revealed that events located by the international network of stations have large errors in the focal parameters (Austegard 1974). The investigation emphasized the need to determine the velocity structure in this area by controlled explosions. Another investigation of the data from the same station showed that most of the events recorded are local events within a range of 100 km (Navrestad and Sørnes 1974). The latter study also presents local earthquake frequency-time data against which future frequency can be compared. It also presents epicenter maps covering different time intervals: An 18-year interval to show the general seismic pattern, and various 31-month intervals to show the variation in the seismic pattern before and after the September 1970 Beerenberg eruption. All these epicenters are for events located by distant stations, and the corresponding magnitude threshold is just below $m_b = 4$.

In order to extend these continuing investigations to local earthquakes of lower magnitude, and also to increase the location accuracy of the larger events, a carefully determined seismic velocity model is needed for Jan Mayen. This paper presents the data and interpretations of such a study done in August 1973.

The field observation program

The shooting program

The data for the shots are given in Table 1, and the shot-array is shown in Figure 1. The shooting program was performed by the Norwegian Navy frigates "Stavanger" (shots 1–16) and "Trondheim" (shots 17–25) on August 15 and 16, 1973. The shots were detonations of depth-charges of 135 kg TNT each at a depth of 92 m. This is the optimum depth for a charge of this size in order to record distant P_n arrivals (Jacob 1970).

Timing for both the shooting and the field recording parts of this survey was provided by local broadcasting of the coded one-second pulses from the permanent seismic station on Jan Mayen. The timing signals were transmitted by the 362 kHz transmitter of the Jan Mayen radio-beacon (0.1 kW). The shooting ship announced each shot 10 minutes in advance by short-wave radio (2.356 MHz). These messages were repeated on the same frequency by the other ship which was on the opposite side of the island. During most of the survey from shot 1 onwards, the main Jan Mayen Radio also repeated the messages on the same frequency, and during most of the later part of the survey the messages were also repeated by interrupting the otherwise continuous time signals from the radio-beacon transmitter.

The shot times were recorded on magnetic tape by recording the output from a hydrophone in an outside-hull watertank on the shooting ship. Another channel on the tape-recorder recorded the timing signals from the radio-

Table 1

Shot data August 1973 (See text about data in parentheses)

No	Date	Soundings (m)	Latitude	Longitude	Shot time (GMT)
1	15	(2240)	71°43.41′N	11°09.11′W	17 17 13.22
2	15	(2100)	71°32.38′N	10′40.36′W	(17 58 42.6)
3	15	(1640)	71°23.07′N	10°14.19′W	(18 38 24.46)
4	15	(820)	71°14.04′N	09°50.29′W	(19 18 25.95)
5	15	212	71°05.82′N	09°21.64′W	19 57 03.77
6	15	435	71°02.40′N	09°08.20′W	20 35 29.62
7	15	365	70°58.80′N	08°55.70′W	20 55 41.82
8	15	188	70°47.35′N	09°06.60′W	21 34 43.97
9	15	120	70°47.62′N	08°48.00′W	21 55 25.92
10	15	115	70°50.32′N	08°38.60′W	(22 09 39.62)
11	15	120	70°45.30′N	08°32.25′W	(22 29 45.67)
12	15	250	70°34.57′N	08°21.10′W	(23 08 25.90)
13	15	410	70°23.47′N	08°09.67′W	23 47 51.27
14	16	750	70°13.24′N	07°54.95′W	00 25 47.51
15	16	(1280)	70°02.87′N	07°44.36′W	01 03 38.87
16	16	(1255)	69°52.43′N	07°31.74′W	01 41 55.13
17	16	117	70°59.73′N	08°41.75′W	02 40 11.24
18	16	130	71°01.70′N	08°31.33′W	02 56 45.28
19	16	150	71°07.83′N	08°18.50′W	03 28 54.68
20	16	105	71°09.47′N	08°07.83′W	03 44 43.50
21	16	140	71°08.66′N	07°54.83′W	04 10 45.90
22	16	115	71°01.90′N	07°56.42′W	(04 39 04.79)
23	16	120	70°58.82′N	08°06.16′W	05 01 21.63
24	16	130	70°56.60′N	08°19.58′W	05 20 51.80
25	16	117	70°56.12′N	08°28.67′W	05 34 07.10

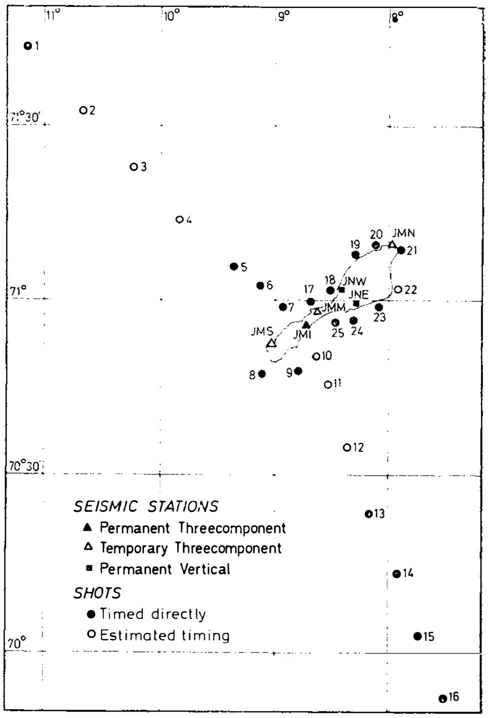

Fig. 1. *Map of shots and recording stations.*

beacon transmitter. The recorded time was corrected for the travel time of the direct water wave between the drop-point and the position of the ship at the time of detonation. The ship travelled an average distance of 350 m before detonation. To obtain this distance accurately, a man at the stern of the ship measured the elapsed time between the drop and the detonation with a stop-watch ($\pm$0.5 sec.). The speed of the ship was known to within five percent. The velocity of the shock wave in water (1465 m/sec) was calculated from the water temperature measurements routinely taken by the staff at Jan Mayen (4.87°C), an assumed salinity of 34‰ (PICARD 1963, Fig. 11 pp. 43) and a table of sound velocity in sea water (MATTHEWS 1939). A variation in the salinity of 1‰ will make only 1.2 m/sec difference in the computed velocity. In this way the distance from the hydrophone to the shotpoint could always be estimated to within $\pm$20 m and it was possible to calculate the shot time to within an overall accuracy of $\pm$0.02 sec.

The shot time for shot 22 was lost due to practical difficulties on board the shooting ships. The shot times for shots 2–4 and 10–12 were inadvertently lost, because the recording tape was flipped on the recorder which was modified to record the seismic channels on one track and the radio-transmitted timing signals on the other track. Thus, the recording for shots 5–9 erased the recording for shots 2–4 and similarly shots 13–16 erased shots 10–12. Estimated shot times for the erased shots are given in parentheses in Table 1, and were estimated as follows: Dummy shot times were first assumed; the resulting dummy travel times were used along with the real travel times of all the other refraction arrivals from the main crustal layer in time-term calculations. The calculated dummy time-terms were subtracted from the dummy travel times, and an average time-term of the nearby shots was added instead. The resultant estimated shot time is believed to be correct to within $\pm$0.2 sec.

An independent method was used to estimate some of the erased shot times. The shots 1–5 gave very clear T-phase arrivals at the temporary three-component field station JMS. These phases were transmitted through a low velocity channel in the ocean, the Sofar channel, before impinging on the island. The arrival data of shots 1 and 5 indicated a water velocity of 1454 m/sec for the T-phase (against the calculated surface water velocity of 1465 m/sec mentioned above). Shot times calculated from the T-wave velocity resulted in shot times within $\pm$0.3 sec of shot times calculated by the first method.

No geological conclusions have been drawn about the shot sites for the shots having estimated shot times. However, the data for these shots do contribute valuable information concerning the station sites. The estimated shot times given in Table 1 were calculated in order to use the recordings for purposes which do not require shot times of the highest precision, such as the record sections described later.

The positions of the drop-points for shots 17–25 were determined by radar. This method is believed to provide a location accuracy of better than two percent of the distance to the known target. The positions of the drop-points for the shots 1–16 were determined by the Norwegian Sea Chain LORAN C

(SL3) from stations X Bø (Norway) and Y Sandur (Iceland). The drop-points for shots 6–11 were also determined by radar to calculate the different corrections for the X and Y readings in order to achieve the necessary accuracy on the two profiles pointing away from Jan Mayen. For shots 1–5, X is corrected by +2.0 μsec and Y by +9.5 μsec while for shots 12–16, X is corrected by ÷2.0 μsec and Y by +9.5 μsec. The overall accuracy for all positions of the shots is better than ±200 m.

The recording stations

The data for the station sites are given in Table 2, and locations of the recording stations are also shown in Figure 1. In addition to the three stations of the permanent seismic array at Jan Mayen (site Nos. 2, 4, and 5), three field stations were temporarily established for this survey (site Nos. 1, 3, and 6). Sites 1 and 6 are nearly inaccessible by land from the main camp at Jan Mayen and were occupied, therefore, by teams landed and recovered by the shooting ships.

The positions of the temporary field stations are read from the maps (1:20 000) and are believed to be correct to within ±40 m. The positions of the permanent sites are given by a geodetic field team from Norsk Polarinstitutt, and are thought to be much more accurately located than the temporary ones.

The seismometers of the permanent seismic array are operated at a resonant frequency of 1 Hz, and these represent the high-pass filter of the system. The output is transmitted by surface cables to the main camp and recorded FM-modulated on magnetic tape at a speed of 15/160 inches per second. The recording part of the system represents the low-pass filter of the system and is 3dB down at 31 Hz. The timing system of the seismic station receives signals from an outside standard oscillator system with a long-term stability of better than 2×10^{-11} per month and with a short-term stability which is conservatively rated at less than 7×10^{-12} rms average over a one-second period. For this survey only the short term stability is relevant, because the same timing signals were used at all recording sites as well as both the shooting ships.

The field instrument system used at station sites 1, 3, and 6 is described by BERCKHEMER (1970). In the particular version employed here, the signals from one vertical and two horizontal Geospace HS-10 1 Hz-geophones were recorded. The horizontal geophones were aligned parallel and perpendicular to the long axis of the island.

Table 2

Recording station site data

No	Code	Latitude	Longitude	Elevation (m)
1	JMS (T)	70°52.58′N	09°01.87′W	10
2	JMI	70°55.70′N	08°43.85′W	211
3	JMM (T)	70°57.89′N	08°37.88′W	20
4	JNE	70°59.39′N	08°17.81′W	57
5	JNW	71°01.72′N	08°25.69′W	95
6	JMN (T)	71°09.55′N	07°59.13′W	10

T indicates temporary station.

Data reduction

Corrections

The observed travel times had to be corrected for the variations in elevation at the recording stations as well as for the varying water depth below the shot points. Therefore, we used mean sea level as a common datum plane for both the shots and the stations.

All shots were fired at a water depth of 92 m. The travel time was corrected for the time delay due to the water by replacing the water with a layer having the same seismic velocity observed for the uppermost crustal layer (3.1 km/sec). It was possible to calculate this velocity without applying the small water depth correction beforehand, because of the shallow water for shots nearest the island. These corrections, as well as the corrections for the sedimentary layer mentioned below, were calculated as the differences in time-terms to the refractor in question for the different phases in the assumed model and the datum model after trial calculations to determine approximate velocities and depths.

The water depth below each shot was determined by a shipboard echo-sounder with the following exceptions: The depths for the shots 1–4 are estimated from the bathymetric map by JOHNSON and HEEZEN (1967, Fig. 4), and the depths for the shots 15 and 16 are estimated from Consol Lattic Chart L113.

Using the same reasoning as above, the recording station corrections were calculated by adjusting the station to sea level and using a velocity of 2.5 km/sec for the removed material.

The thickness of layer 1 along the two profiles away from Jan Mayen is very difficult to calculate by the present data, because layer 2 is only observed as a first arrival between approximately 3 and 10 km. Therefore the uppermost sedimentary layer was replaced with the 3.1 km/sec layer along the two profiles at the same time as the datum corrections were carried out. The thickness of the uppermost layer along the two profiles was estimated from an isopach map of total sediment thickness (ELDHOLM and WINDISCH 1974, Fig. 5). The following sedimentary thicknesses were found to be significant:

Shot site	Thickness (km)
1	0.62
2	0.62
3	0.50
13	0.44
14	0.92
15	1.20
16	1.42

The velocity for these sediments was assumed to be 2 km/sec as postulated by ELDHOLM and WINDISCH.

Search for lateral anomalies

The travel times (reduced by 6 km/sec) are plotted against distance for all clear first arrivals in Figure 2. Table 3 gives the data shown in Figure 2 together with a few other doubtful first arrivals. Velocity changes exist at approximately 10 and 80 km. An enlarged version of Figure 2 around the velocity inflection at 10 km (0–20 km) shows that the arrivals plotted as triangles might be caused by a local velocity anomaly or by a local departure from the horizontal of an upper refracting layer. Such anomalies are not surprising in this volcanic area. The other arrivals (plotted as dots) for distances less than 10 km line up very well as a straight line.

Because the interpretation of the "early" arrivals around 10 km is important, studies other than travel-time investigations were carried out to see if any other parameter has the same areal coverage as the "early" arrivals. The following shot-station connections comprise the triangles in Figure 2: 18–4, 23–4, 24–4, 24–5, 25–2, 25–4, 25–5.

One of the studies involved the reading of the apparent dominating period of the first few cycles of each identified phase from all records. The recordings from the permanent stations appeared to have much noise (more than the field stations) within the signal frequency range, probably because of longer electronic data transmission, and were therefore later dropped in this analysis. The observed apparent dominant period was used in the following scheme. A map of Jan Mayen was divided by a network of meridians (for each 10′EW) and parallels (for each 4′NS). Then a line was drawn from the shots to those field stations providing a period reading for the phase in question. Thus, a map was made for the period readings for the waves refracted at the top of each crustal layer. Each rectangle of the network was then assigned a value equal to the mean of the period associated with shot station lines crossing that rectangle. Isolines can be drawn to separate areas assigned different values as shown in Figure 3, which shows the results for the waves refracted at the top of the 6.3 km/sec layer and recorded at the field stations. This group of waves yield the most data. The other groups of data are small and show no clear areas separable by isolines.

The isoline with the highest value encloses an area elongated parallel to the length of the island and to a line through Eggøya and the new land formed during the 1970-eruption. Farther south the isoline with the highest value encloses an area at sea south of Rekvedbukta, and in this area the parameter shown has the most abrupt variations. The area where the "early arrivals" have passed is centered about Rekvedbukta.

Upper sedimentary layer 1

The present data cannot accurately reveal the thickness of the upper sediments along the two profiles away from the island as mentioned above. The thickness of the upper sedimentary layer plotted in Figure 4 is estimated from the isopach map of total sediment thickness given by ELDHOLM and

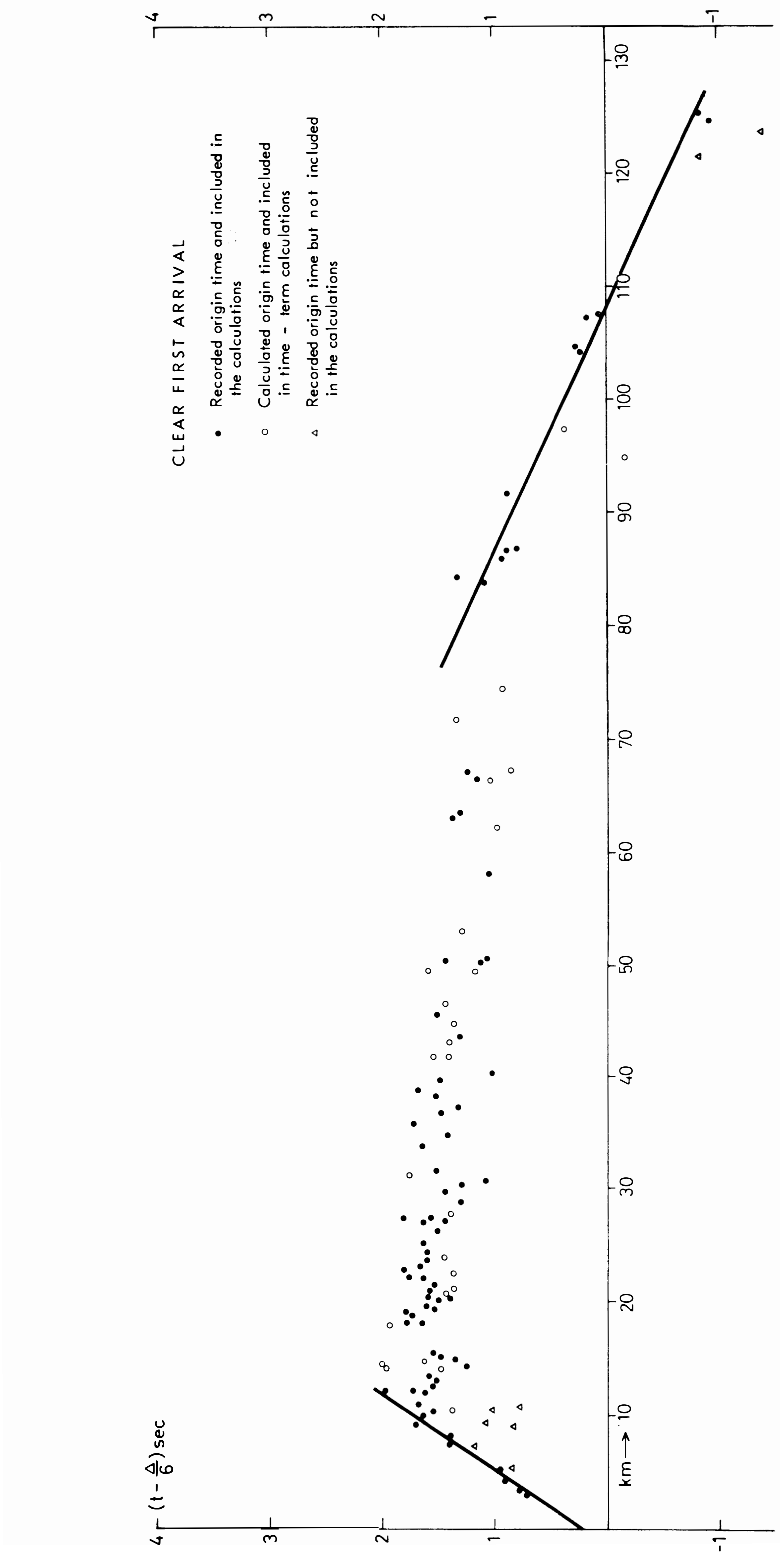

Fig. 2. First-arrival travel times plotted against distance.

WINDISCH (1974). The velocity used in this calculation is the same as that used by ELDHOLM and WINDISCH: 2 km/sec.

The shot-station observation in the present data with the shortest distance is 21–6 at 3.10 km and a travel time of 1.23 sec. The observation indicates that the velocity in the upper sediments at Jan Mayen is most likely higher than 2 km/sec and is arbitrarily set to 2.5 km/sec.

It is necessary to determine the velocity in crustal layer 2 in order to calculate the thickness of the sedimentary layer close to and at the island itself. The following seven shot-station observation comprise the data points which define a travel-time line in Figure 2: 7–2, 17–2, 17–3, 18–3, 18–5, 20–6, 21–6. The other observations at short distances (Table 3) which are not included here comprise those "early arrivals" mentioned earlier. The seven observations quoted above line up as a straight travel time curve with the following parameters calculated by least squares: $v = 3.14 \pm 0.17$ km/sec and intercept 0.24 ± 0.27 sec. The latter is taken to be 0.24 sec even though it statistically is not different from zero. The model itself is evidently only partially correct, because of the existence of the "early arrivals". Statistically good results are therefore not expected, but the above calculated results are acceptable because they give a satisfactory picture for explaining the observed travel times.

The observations belonging to shots around the island used for these calculations are not corrected for any sedimentary layer as are the observations for shots at longer distances along the two profiles away from the island. Therefore, we can set the average sedimentary time-term equal to half the intercept for the shots near the island and for the stations. This means that the sedimentary layer of 2.5 km/sec averages 0.5 km in thickness.

Upper crustal layer 2

The velocity in layer 2 is found to be 3.14 ± 0.17 km/sec. This layer gives rise to first arrivals out to nearly 10 km. Therefore, one can only be certain that this layer exists near the island. The next branch of the travel time curve covers the distance range approximately between 10 and 80 km. Several solutions were obtained for this part of the travel time curve as described in the next paragraph. The thickness of the 3.14 layer is calculated from all the time terms of the selected solution for the first arrivals from shots with timing in the 10–80 km distance range.

Main crustal layer 3

The first arrival data in the distance range 10–80 km were divided into several subsets which, in turn, were put into a straight-line least squares program, and time-term programs applying either constant velocity in the refractor or velocity increasing with depth. No significant difference was found between the shooting profile to the NW or the one to the SE. The conclusion from many tests was that all first arrivals in the distance range 10–80 km can combine into one single data set. The solution which was selected was calcu-

Table 3

Travel times and distances for all first arrivals

Shot no.	JMS (1)	JMI (2)	JMM (3)	JNE (4)	JNW (5)	JMN (6)
1	121.25		123.57			
	(e4) 19.36		(e4) 19.20			
2	94.69		97.37	104.99		
	(i4) (15.60)		(i4) (15.64)	(e4) (15.59)		
3	71.49	Too weak	74.42			84.52
	i3) (13.21)		i3) (13.28)			e) (14.75)
4	49.49	52.64	52.99	62.02		67.19
	i3) (9.84)	(3) (10.39)	i3) (10.11)	i3 (11.30)		i3) (12.04)
5	27.39	29.63	30.31	40.40	34.65	50.15
	i3) 6.14	e3) 6.38	i3) 6.35	e3) 7.75	e3) 7.19	i3) 9.48
6	18.67	19.32	20.20	31.02		43.71
	3) 4.85	i3) 4.75	i3) 4.77	(e3) 6.27		i3) 8.58
7	12.17	9.22	10.95	23.00	18.97	39.58
	i3) 3.98	i2) 3.25	i3) 3.50	e3) 5.50	i3) 4.95	i3) 8.09
8	10.14	20.83	26.28	37.21	36.52	58.14
	i3) 3.33	e3) 5.05	i3) 5.89	i3) 7.54	e3) 7.56	e3) 10.74
9	12.52	15.23	20.07	28.59		50.42
	i3) 3.64	i3) 4.04	i3) 4.85	i3) 6.08		e3) 9.48
10	14.81	10.50	14.08	21.08	22.60	43.03
	i3) (4.09)	i3) (3.12)	i3) (3.84)	i3) (4.87)	(e3) (4.89)	i3) (8.58)
11	22.61	20.59	23.66	27.64		49.38
	i3) (5.17)	i3) (4.88)	i3) (5.41)	i3) (6.02)		3) (9.42)
12	41.81	41.70	44.57	46.20		66.42
	i3) (8.43)	i3) (8.42)	i3) (8.81)	e3) (9.16)		i3) (12.15)
13	62.98	63.53	66.32	66.98	71.80	85.94
	i3) 11.86	e3) 11.88	i3) 12.19	i3) 12.38	(e3) 12.50	i4) 15.25
14	83.76	84.21	86.81	86.60	91.76	104.38
	i4) 15.04	2) 15.34	i4) 15.27	i4) 15.31	e4) 16.16	i4) 17.65
15	104.26		107.57	107.13		124.ND
	e4) 17.62	Too weak	i4) 18.01	e4) 18.01		e4) 19.77
16	125.22	125.96	128.55			
	e4) 20.03	e4) 19.82	e4) 20.59			
17	18.07	7.61	4.15	14.52	10.41	31.55
	i3) 4.67	2) 2.66	2) 1.59	3) 3.68	3) 3.27	e3) 6.68
18	25.14	13.50	8.12	9.25	3.42	24.30
	i3) 5.82	3) 3.82	i2) 2.75	( ) 2.72	2) 1.34	i3) 5.65

(Notes to table 3 see next page) (contd)

Table 3 (contd)

Shot no.	JMS (1)	JMI (2)	JMM (3)	JNE (4)	JNW (5)	JMN (6)
19	38.67	27.28	21.88	15.70	12.17	12.08
	i3) 8.10	3) 6.37	e3) 5.30	3) 4.17	3) 3.76	i3) 3.63
20	45.36	33.62		19.69	18.00	5.23
	i3) 9.07	3) 7.24		3) 4.88	3) 4.78	i2) 1.86
21	50.43	38.21		22.13	22.65	3.10
	i3) 9.84	3) 7.90		3) 5.46	3) 5.60	i2) 1.23
22		30.99		13.77	17.71	14.33
		3) 6.73		i3) 4.06	i3) 4.70	i3) 4.21
23	35.81	23.61	No	7.14	13.00	20.41
	i3) 7.69	i3) 5.53	timing	(i) 2.37	3) 3.69	i3) 5.01
24	26.80	14.85		5.30	10.21	27.07
	i3) 6.12	3) 3.82		(i) 1.72	( ) 2.71	i3) 5.94
25	21.26	9.26		8.97	10.56	30.71
	i3) 5.07	( ) 2.62		(i) 2.31	( ) 2.53	e3) 6.20

Notes to Table 3:

a) Upper real number for each observation is the distance in km and lower real number is the travel time in seconds after the corrections mentioned in the text have been added.

b) Lower integer numbers 2), 3) and 4) are phase identifications referring to the 3.1, 6.3, and 8.3 km/sec travel time curve segements, respectively.

c) Phase identification numbers in brackets indicate observations not included in final analysis because of reading uncertainties or an assumed anomalous travel time.

d) Travel time in brackets indicates assumed origin time.

e) No record obtained is indicated by empty space in the table.

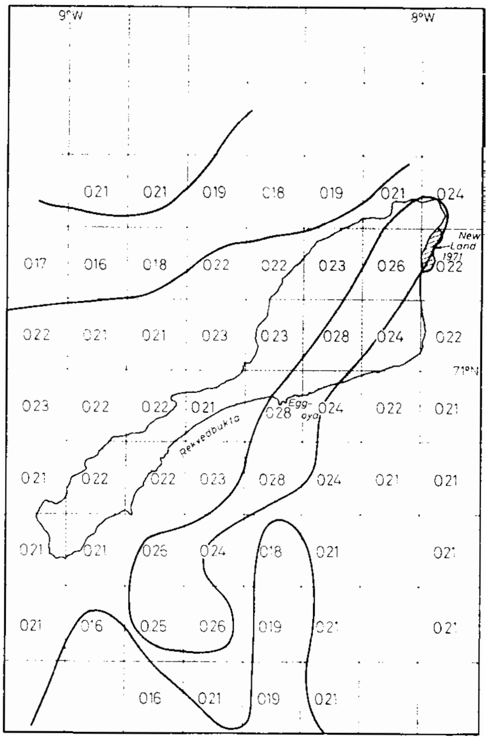

Fig. 3. *Isolines for apparent dominating periods in the records (see text).*

lated by the time term program applying a constant velocity. The calculated parameters of the selected solution employing 85 shot-station connections are as follows:

$V = 6.33 \pm 0.13$ km/sec.

Sum of square residuals 0.82 sec^2.

Standard deviation of one time observation 0.12 sec.

The resulting time terms which were used in the calculations of the thickness of layer 2 were adjusted by the program so that the time terms of shot 17 and station 3 were equal. This choice of interchange was taken for subjective reasons, because all the solutions indicated no major structural variations between these two nearby sites (4.15 km). The time terms for the shot sites with no recorded origin time were not used in any further calculations, but these shots did contribute in full to the station time terms. The 85 shot-station connections used in the time term calculations are given in Table 3.

The same 85 observations have also been tested with the time term program to determine if the velocity increases with depth in the refractor. Using the following formula:

$$T_{ij} = a_i + b_j + \Delta_{ij}/V_o \div V_1 \Delta_{ij}^2/V_o^2$$

the calculated velocities are:

$V_o = 5.59 \pm 0.23$ km/sec

$V_1 = 0.011 \pm 0.003$ sec^{-1}

Sum of squared residuals 0.48 sec^2.

Standard deviation of one time observation 0.09 sec.

The apparent velocity (V_a) in the case of this travel time relation is

$$V_a = \frac{V_o^2}{V_o \div 2V_1}$$

This means that the apparent velocity is 5.82 km/sec at 10 km and 8.16 km/sec at 80 km. The time terms of this solution show much the same general pattern, and no time term is allocated an unacceptable value.

Despite the apparent better data fit, the latter solution is discarded, because of the strong increase in apparent velocity which might be caused by poor areal coverage and the known departure from the layered model indicated by the "early arrival" for layer 2 as mentioned above. It does indicate, however, that some velocity increase with depth is present in layer 3. This will make layer 3 still thicker and also reduce the high velocity contrast to layer 4 as discussed in the next paragraph.

Layer 4

Only shots 13–16 along the SE profile leg provided sufficient distance range for arrivals which were refracted at the top of layer 4. For this distance range the NW profile leg, only shot 1 has recorded origin time. The latter group of

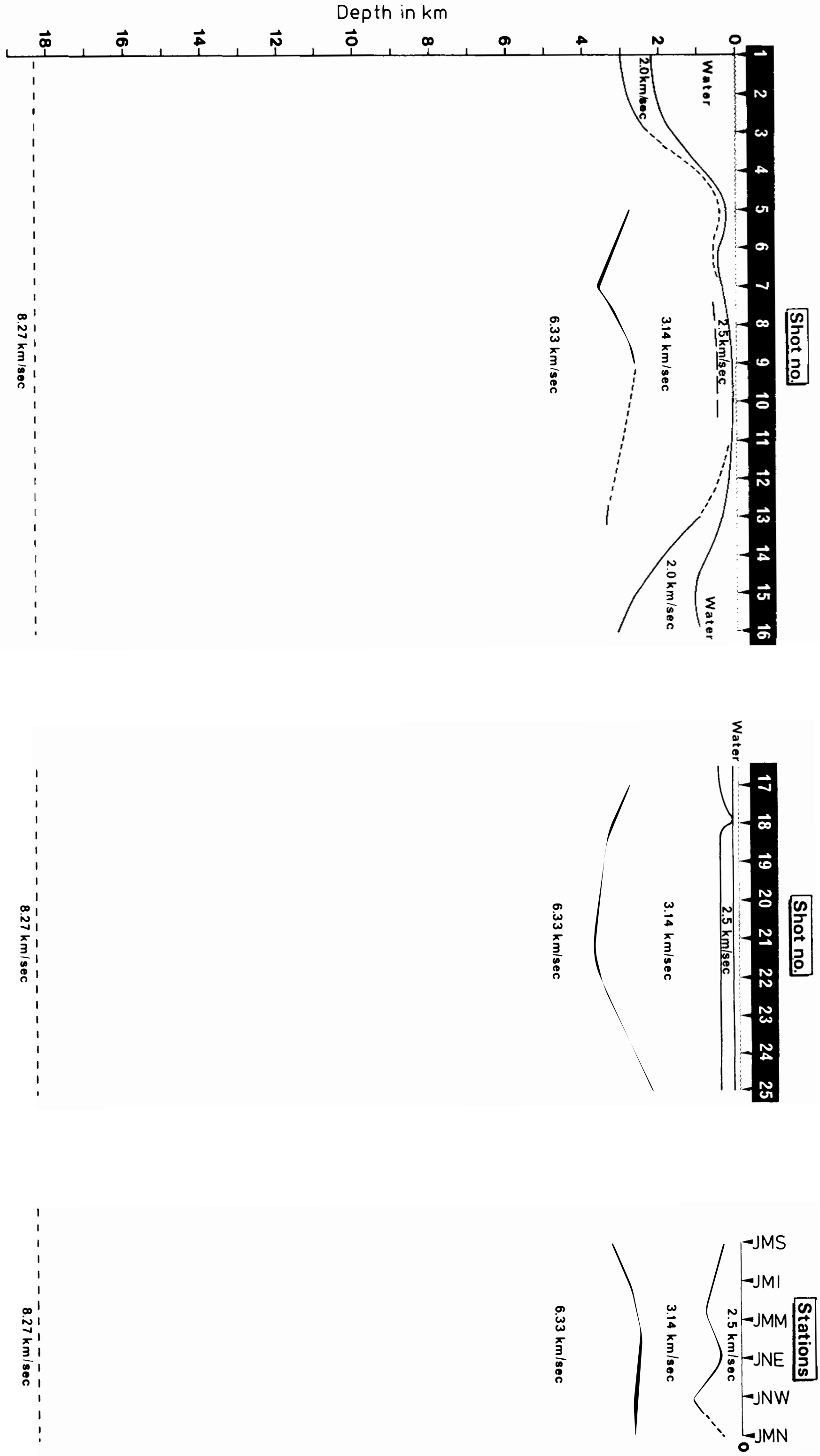

Fig. 4. *Graphic presentations of the results.*

arrivals lacks significant different travel times as can be seen for the longest distances in Figure 2. The same applies for the arrivals from shot 2, but the origin time for this shot is calculated. A slight difference between the two profile legs, if any, might be shorter travel times for shots 1 and 2.

The water depth at shot site 13 is 410 m, and at shot site 16 it is 1255 m. The upper sedimentary layer has already been corrected for as described in paragraph "Corrections". It must be noted that the corrected travel times for shots 13–16 thus depend on correction parameters not directly measured by the present survey.

The following 11 shot-station observations covering a distance range from 86–125 km were analysed by a straight line least squares program: 13–6, 14–1, 14–3, 14–4, 14–5, 14–6, 15–1, 15–3, 15–4, 15–6, 16–1. The resulting velocity is 8.27 ± 0.34 km/sec with an intercept of 4.9 ± 1.7 sec. Assuming that the top of layer 4 is horizontal and constant velocity in layer 3 this implies a depth of 18 km to layer 4.

Discussion

The justification for the resulting layered crustal model shown in Figure 4 is the clear breaks of the travel time curve in Figure 2. Some clear departures from such a simple model are also noted. The "early arrivals" for the shot range observation centered around Rekvedbukta might indicate the presence of a large dome of magma of low viscosity which has solidified.

Much of the lava on the northern half of the island is composed of alkali olivine basalt. The high proportion of TiO_2 and K_2O, the strong xenocrystic nature, and the high degree of differentiation of these lavas indicate that they are consistent with derivation from depths of 35–70 km by partial melting of a pyrolitic magma (HAWKINS and ROBERTS 1972, WEIGLAND 1972). Such a deep origin of the lava might also disturb the simple crustal model given in Figure 4. Farther south on the island, however, trachytes are found, sometimes as plugs, and these may have been derived by differentiation in shallow reservoirs from an ankaramitic-trachybasaltic parent from which clinopyroxene was removed (HAWKINS and ROBERTS 1972).

The isolines with the highest parameter value in Figure 3 enclose an area elongated parallel to the length of the island which trends northeast nearly perpendicular to the Jan Mayen fracture zone. It is interesting to note that recent eruptive activity typically occurs along fissure zones also trending northeast (FITCH 1964, SYLVESTER 1975). The area with the highest parameter value in Figure 3 lies mostly to the east of the island except for the south-eastern flank of the Beerenberg volcano. It is interesting to note that besides the summit crater, it is this flank which has had the most recent activity: the 1970 fissure vents, the steam eruptions from the satellite cone of Eggøya, and the recently discovered fumarolic activity a few kilometers northeast of Eggøya. The isolines with the highest parameter value in Figure 3 may indicate a rather narrow zone of weakness through which lava is prone to extrude. Such a zone may account for the observed low pass filtering effect on the seismic waves.

In this paper the upper sedimentary layer 1 is arbitrarily assigned a velocity of 2.5 km/sec at and close to the island. The exposed part of this layer is to some extent described in the literature (FITCH 1964, HAWKINS and ROBERTS 1972, SYLVESTER 1975). It is all volcanic in origin. The sediments at the sea bottom farther away from Jan Mayen, however, are mostly terrigenous in origin. At the Jan Mayen ridge south of the island TALWANI et al. (1975) found relative flat-lying beds of only a few hundred meter thickness on top of truncated eastward dipping older beds of much greater thickness. Deep-sea drilling data show that the sediments below the unconformity are almost completely terrigenous in origin. TALWANI et al. (1975) maintain that these sediments and the known absence of magnetic anomalies support the hypothesis that the Jan Mayen ridge was attached to Greenland initially as part of the continental shelf. The resulting seismic velocities, and especially that of layer 3 which reaches down to 18 km depth at the northern part of the Jan Mayen ridge, also support this hypothesis.

Acknowledgements

The Norwegian Defence Communication Administration arranged the field work for this study. Chief Engineer C. A. GLØERSEN and many other staff members of the above agency were also actively engaged in the field. Captains J. H. LILLEHEIM and A. BJØRNSTAD were in charge on board the participating Norwegian Navy frigates "Stavanger" and "Trondheim". Other people taking part in the field work included Engineer J. MATHISEN of Labteknikk, Moelv, and Professor A. G. SYLVESTER of the University of California, Santa Barbara. Professor SYLVESTER has also given much good advice throughout this study and has critically read the manuscript of this report and made several valuable suggestions. The above mentioned support and kind cooperation are greatly appreciated.

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Some rock and formation densities from Svalbard

By K. Howells[1], D. Masson Smith[2], and P. I. Maton[3]

Contents

Abstract

496 density determinations have been made on various Pre-Devonian, Devonian, Carboniferous, and Tertiary rocks from Svalbard. The resulting formation densities are as follows: Pre-Devonian, 2.76 g cm^{-3}; Devonian, 2.72 g cm^{-3}; Carboniferous, no value due to insufficient sample; Tertiary, 2.63 g cm^{-3}. These data are relevant to gravity surveys reported elsewhere.

Introduction

This paper presents the results of density measurements on rocks from Svalbard by three members of Cambridge Spitsbergen Expeditions. Three separate groups of measurements have been made, each in connection with other studies.

[1] Nova Scotia Research Foundation, 100, Fenwick Street, Box 790, Dartmouth, Nova Scotia B2Y 3Z7.

[2] Institute of Geological Sciences, 5, Princes Gate, London SW7 1QN, England.

[3] Hunting Surveys and Consultants Ltd., Elstree Way, Borehamwood, Hertfordshire, WD6 1SB, England.

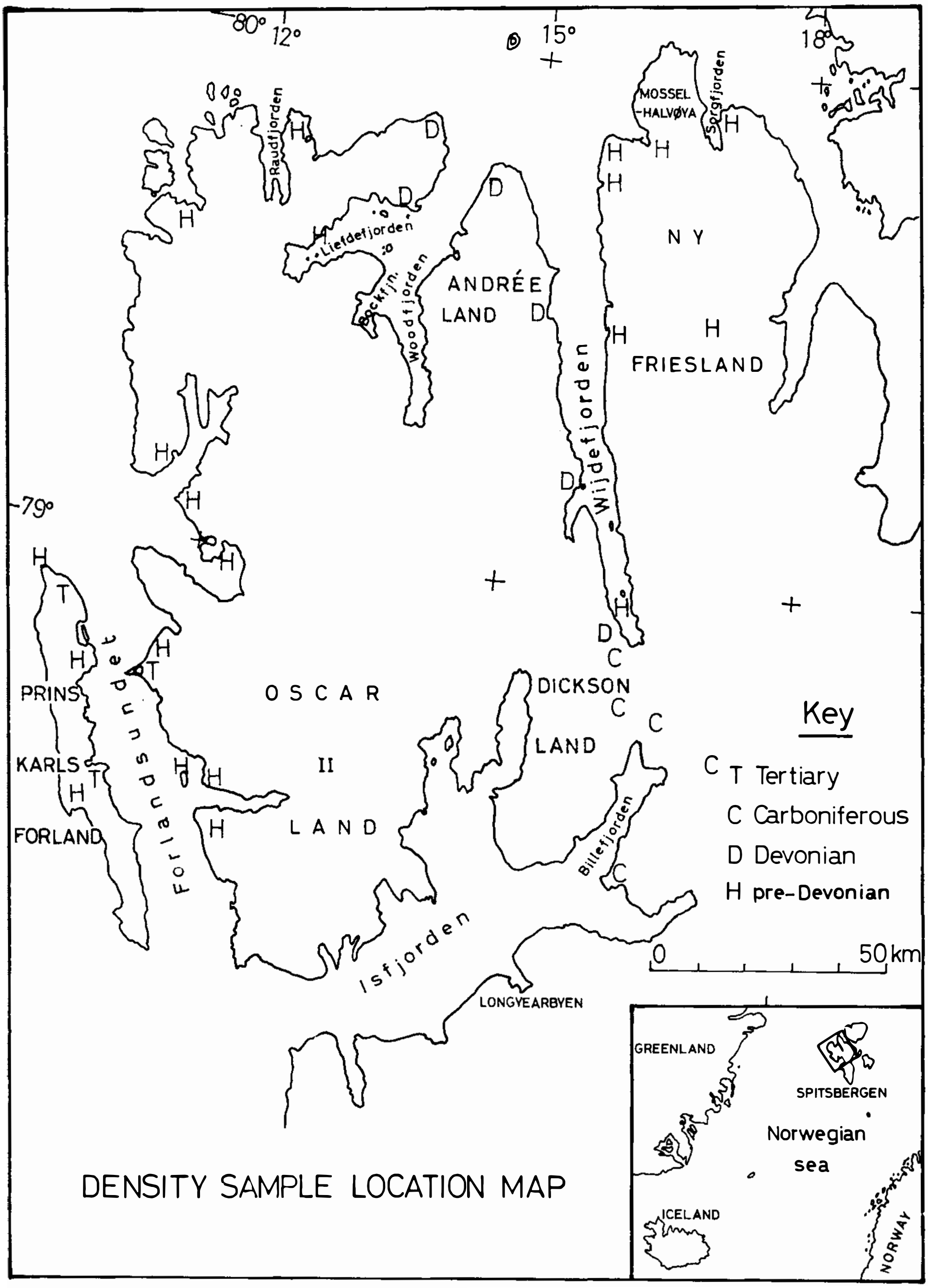

Fig. 1. *Location map of density samples.*

Firstly, in a comprehensive study of experimental techniques in rock density measurement MASSON SMITH between 1951 and 1955 determined 245 samples which had been collected for studies other than of density, from Hecla Hoek, Devonian and Carboniferous rocks in central north Spitsbergen. Secondly, HOWELLS between 1964 and 1967 measured the densities of 93 Pre-Devonian and Tertiary rocks from around Forlandsrevet, in connection with a gravity survey there. Thirdly, MATON between 1966 and 1970 measured 158 further Hecla Hoek and Devonian samples from north Spitsbergen, and more widespread Pre-Devonian and Tertiary samples from around Forlandsundet, in connection with gravity surveys of both areas. The greater part of this paper was written by MATON.

These measurements are by no means as comprehensive as, but rather are complementary to, those of KURININ (1965). Exact comparison with KURININ's results are prevented by lack of definition of which density he reported. However, in general, close agreement between his results and ours have been apparent.

Definitions

There are three significant measures of rock density. They are:

(1) Dry bulk density, ϱ_d, defined as the mass per unit volume of rock, this volume including pore space within the rock.
(2) Saturated bulk density, ϱ_w, is the mass per unit volume of the rock when pore space is saturated with water.
(3) Grain density, ϱ_g, is the mass per unit volume of the rock materials where the volume is exclusive of pores within the rock.

Porosity has been given two definitions. Firstly, HOLMES (1921) defined porosity P by the equation:

$$P(\%) = \frac{v}{v + V} \times 100 \qquad (1)$$

where v is the volume of pore space and V is the volume of rock material. This definition has been adopted both in the present study, and by SHERIFF (1973).

Hence if M is the mass of rock material, and m is the mass of water which fills v

$$\varrho_d = M/(V+v) \qquad (2)$$

$$\varrho_w = (M+m) / (V+v) \qquad (3)$$

$$\varrho_g = M/V \qquad (4)$$

Secondly, PARASNIS (1952) defined porosity by

$$P = 100\,\lambda / (1-\lambda) \qquad (5)$$

where

$$\lambda = \varrho_w - \varrho_d = m/(V+v) \qquad (6)$$

Equation 5, through its denominator, is dimensionally inhomogeneous. Further, since for water $m = v$, $\lambda = v/(V+v)$ and hence PARASNIS's definition of porosity is numerically, but not dimensionally, equivalent to

$$P = 100\ v/V$$

Since none of the rock grains are pore space, it seems illogical to define porosity in this way: porosity is better considered as the percentage of the volume of the rock specimen occupied by pore space.

Sampling considerations

The problem of obtaining a density value relevant to the total bulk of a rock formation has been discussed by many writers (e.g. DOBRIN 1960; GRANT and WEST 1965). The many indeterminate variables include facies variations, differing proportions of lithological components, weathering effects, water table level, and other factors.

MASSON SMITH made a thorough examination of the effects of weathering. His main conclusions may be summarised as follows:

(a) Weathering caused a reduction in bulk and grain densities, implying mineralogical alteration as well as physical degradation.

(b) The maximum reduction in bulk density caused by weathering was less than 0.5 g cm^{-3} for a wide range of lithologies.

(c) In fine grained sedimentary rocks, igneous rocks and metamorphic rocks the bulk density reduction was never greater than 0.03 g cm^{-3}, 2.5 cm below the weathered surface: for coarse sedimentary rocks this reduction was never found deeper than 15 cm below the surface.

The specimens collected from Svalbard have all been exposed by rapid frost shattering and are apparently little weathered. Latterly, they were also generally larger than 7–10 cm in each direction: each specimen commonly weighed more than 0.5 kg, and specimens were chosen for their typification of lithologies at their respective outcrop. In view of their size, and care of selection, it is considered that they are reasonably representative of their formation at outcrop.

Experimental methods

HOLMES (1921) described methods of determining bulk rock and grain densities. All these methods are subject to instrumental limitations: either chemical beam balances are used which limit specimen weights to a maximum of less than 200 g or less accurate beam and spring balances are used. HOWELLS and MASSON SMITH also used chemical balances, necessitating small specimens.

MASSON SMITH experimented extensively with saturating different lithologies under pressures of up to 800 kg cm^{-2}. The increase in water absorbed under pressure was found to be less than 10% of that absorbed at atmospheric pressure; pressure saturation had no advantages over the vacuum technique.

In the remainder of our determinations, saturation was effected by placing dry specimens in a chamber which was excavated to about 37.5 cm of mercury

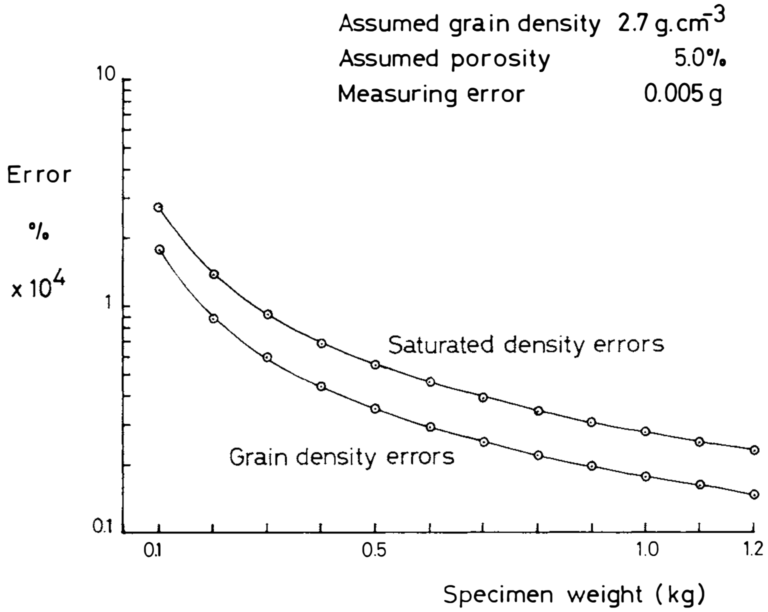

Fig. 2. *Errors in grain and saturated bulk densities caused by* ±0.005 *g weighing error.*

After about twenty minutes at this pressure, water was admitted until the specimens were totally immersed and pumping was continued for about a further thirty minutes. The available pump and chamber were incapable of giving a higher vacuum, and the low porosity values observed probably reflect this inadequacy.

Weighing of the larger (P.I.M.) specimens was done with a Mettler 1200N balance. This instrument can measure masses of up to 1200 g with an accuracy of ±0.005 g, thus weighing specimens twelve times heavier than could be weighed on most chemical balances without damaging them, and with similar accuracy.

Fig. 2 shows the percentage error in the grain and saturated bulk densities as a function of specimen weight for a specimen of density 2.7 g cm^{-3} and porosity 5%. It is evident that the errors in the two densities are very similar.

Errors in MATON's determination of the saturated bulk density also arise from incomplete saturation. Comparison of his porosity and saturated bulk density data with those obtained by MASSON SMITH suggest that in most metamorphic rocks this error is small. In rocks with porosities of more than c.5% there may be errors of 2% to 3% in the values determined by MATON.

Experimental results

NORTH SPITSBERGEN ROCKS

Table 1 summarises the densities of the main Hecla Hoek and Devonian rock types of north Spitsbergen. For each rock group the value obtained by MASSON SMITH is given first, followed by that of MATON, with the combined value last. Standard deviations are also given for each group.

Table 1(a)

Densities of Rocks from North Spitsbergen (in g $cm^{-3} \pm$ std. dev.)

Hecla Hoek	No. of Specimens	Finnlandveggen & Harkerbreen Groups		No. of Specimens	Planetfjella Group	
		Grain density	Saturated density		Grain density	Saturated density
Amphibolites	10	2.914 ± 0.144	2.897 ± 0.144			
	10	3.027 ± 0.059	3.004 ± 0.073			
	20	2.970 ± 0.124	2.950 ± 0.126			
Garnet semipelites	14	2.825 ± 0.067	2.795 ± 0.062			
	0					
Pelites, psammites, feldspathites, etc.	31	2.718 ± 0.088	2.701 ± 0.083	6	2.711 ± 0.030	2.687 ± 0.038
	28	2.717 ± 0.048	2.701 ± 0.046	5	2.804 ± 0.010	2.775 ± 0.012
	59	2.718 ± 0.072	2.701 ± 0.068	11	2.753 ± 0.052	2.727 ± 0.053
Marbles	11	2.724 ± 0.066	2.691 ± 0.060			
	5	2.759 ± 0.069	2.735 ± 0.077			
	16	2.753 ± 0.069	2.703 ± 0.068			
Metadolerites	1	3.012	2.936			
	14	3.094 ± 0.066	3.077 ± 0.063			
	15	3.088 ± 0.066	3.068 ± 0.068			

Table 1(b)

Devonian	No. of Data*	Grain Density	Saturated Density
Conglomerates	0		
	2	2.727±0.004	2.706±0.001
Sandstones (fine grained)	8	2.700±0.043	2.624±0.075
	18	2.711±0.026	2.687±0.032
	26	2.708±0.033	2.688±0.058
Sandstones (medium and coarse grained)	0		
	8	2.708±0.057	2.641±0.060
Siltstones	0		
	18	2.740±0.026	2.716±0.025
Shales	0		
	9	2.739±0.009	2.664±0.021

* The value quoted first is that determined by MASSON SMITH, the second was determined by MATON and the third is that of the first pair combined.

FORMATION BULK DENSITIES OF PRE-DEVONIAN ROCKS

Some preliminary calculations were made using the modal analyses of Harkerbreen Group rocks given by GAYER and WALLIS (1966, p. 31), and mineral densities given by BIRCH (1966), and DEER, HOWIE and ZUSSMAN (1965). These showed that the densities of all the lithological types of the scheme of petrographic nomenclature of WALLIS et al. (1968), except amphibolites, were largely a function of garnet content. The density of almandine is 4.318 g cm^{-3} (DEER et al. 1965).

It was therefore necessary to distinguish between amphibolites, the remaining lithologies with garnet, and the remaining lithologies without garnet, if not between each lithological type.

Finnlandveggen Group

Descriptions of Finlandveggen Group rocks (HARLAND et al. 1966) indicate that garnet is abundant in some mica pelites and semipelites as well as in amphibolites. Thus the Finnlandveggen Group rocks are considered to be a quarternary system whose proportions are listed in Table 2.

Table 2

Lithologic Proportions in the Finnlandveggen Group

Lithology	Thickness within formations (metres) Smutsbreen fm.	Eskolabreen fm.	Total	%
Marble	120	0	120	4
Garnetiferous Pelites and semi pelites	1100	200	1300	48
Amphibolite	0	600	600	22
Feldspathite	0	700	700	26

The formation bulk grain density so obtained is 2.825 g cm^{-3}.

Harkerbreen Group

The modal analyses of Harkerbreen Group rocks (GAYER and WALLIS 1966, p. 31) indicate that garnet comprises only 2% of one rock type, other than amphibolite. (This one rock was a quartzite of the Rittervatnet Formation). The Harkerbreen Group is therefore considered to be bimodal, comprising amphibolites and the remaining lithologies of WALLIS et al. (1968). Table 3 shows estimated proportions of rock types in the Harkerbreen Group. The authors are grateful to R. A. GAYER for these data.

Table 3

Lithologic Proportions in the Harkerbreen Group

Formation	Total	Thicknesses in Metres Amphibolites	Others
Sørbreen Fm.	265	53	212
Vassfaret Fm.	600	60	540
Bangenhuk Fm.	2000	300	1700
Rittervatnet Fm.	350	70	280
Polhem Fm.	900	225	675
Totals	4115	708	3407

Amphibolites = 17% Remainder = 83%

The resulting formation grain bulk density is 2.761 g cm^{-3}.

Planetfjella Group

Lithologies present in the Planetfjella Group include marbles and dolomites, quartzites, psammites, subpelites, and megacrystic feldspar psammites (WALLIS 1969). Proportions of these lithologies have been calculated from WALLIS's account of the northern type sector in Mosselhalvøya. The types were then grouped into:

(1) marbles and dolomites and

(2) the remainder.

Amphibolites are absent from the Planetfjella Group, but garnet does occur in some rocks (WALLIS 1969). The lithological proportions are shown in Table 4.

Table 4

Lithologic Proportions in the Planetfjella Group

Lithology	Thicknesses (metres)	Total (metres)	Percentage of Whole Group
Dolomite	130	360	9%
Marble	230		
Quartzites and quartz psammites	450		
Subpelite	1600	2860	91%
Psammite	810		

The bulk formation density weighted by these thicknesses is 2.719 g cm^{-3}.

Middle and Upper Hecla Hoek

The densities of rocks in these groups have not been studied since the gravity survey does not extend into areas where such rocks outcrop.

FORMATION BULK DENSITIES OF DEVONIAN ROCKS

Siktefjellet Group

GEE and MOODY-STUART (1966) did not give an overall ratio of sandstone to conglomerate within the Siktefjellet Group: the proportion used here is that of the thicknesses they observed in Siktefjellet (op. cit. p. 61) viz:

Sandstone	1400 m	93%
Conglomerate	100 m	7%

The bulk formation density thus obtained is 2.709 g cm^{-3}. It is based on six sandstone determinations and two conglomerate determinations and is probably not representative.

Red Bay Group

The group outcrops around Raudfjorden: samples have not been collected for density measurements (nor gravity measured) here, and the densities ascribed to sandstones and conglomerates are based on values obtained from specimens of the Wood Bay Formation. The sandstones of the two formations are not greatly dissimilar, while the clast content of the Red Bay Conglomerate generally comprises Hecla Hoek marbles, pelites, and psammites whose densities are similar to those of the sandstones (c. 2.72 g cm^{-3}). The proportions within the Red Bay Group given in Table 5 are based on FRIEND (1961).

Table 5

Lithologic Proportions in the Red Bay Group

Formation	Sandstone (metres)	Conglomerate (metres)
Red Bay Conglom.	0	600
Andréebreen Sst.	200	0
Fraenkelryggen Sst.	600	0
Ben Nevis Sst.	900	0
Total	1700	600
Percentage	73%	27%

Other Devonian Formations

The lithologic proportions and resulting formation densities of the Wood Bay, Grey Hoek and Wijde Bay Formations are tabulated below. The proportions in the Wood Bay Formation were calculated from the frequency distribution of grain sizes present in the rocks as given by FRIEND (1965, p. 42). The proportions in the Grey Hoek and Wijde Bay were estimated from field observations by the writer, and have been agreed by P. F. FRIEND (personal communication).

Table 6

Lithologic Proportions in the Wood Bay, Grey Hoek and Wijde Bay Formations

Formation	Conglomerate	Sandstone	Silt-Stone	Shale	Density g cm^{-3}
Wijde Bay		70%		30%	2.717
Grey Hoek		30%		70%	2.730
Wood Bay	2%	40%	58%		2.727

DISCUSSION

Compounding these formation densities and weighting them by their formations' respective thicknesses, bulk densities of 2.761 and 2.720 g cm^{-3} are obtained for Hecla Hoek and Devonian rocks respectively, with a contrast of 0.041 g cm^{-3}.

Throughout the foregoing computations the bulk grain densities have been used, for two reasons. Firstly, either the grain or the saturated bulk densities relate to the natural condition of the rocks. Of these the saturated density is probably more relevant to some depth below which the hydrostatic load of the rocks causes the pore space to be entirely closed. However, this depth is not known. Furthermore, it is known that the saturated densities have been less accurately measured than the grain densities, and that in any case there will not be a great discrepancy between the two for metamorphic and highly indurated sedimentary rocks such as those under study.

KURININ (1965) obtained mean densities of 2.72 g cm^{-3} and 2.69 g cm^{-3} for Hecla Hoek and Devonian rocks respectively, thus indicating a similar density contrast to that reported here. However, he did not indicate which density he had measured.

His Hecla Hoek samples were collected from Sorgfjorden and Nordaustlandet, beyond the gravity survey area, and from less highly metamorphosed rocks than those in western Ny Friesland. Thus, lower density values are to be expected. His Devonian samples came from Liefdefjorden, Bockfjorden and Billefjorden: 77 specimens from the former two localities had a mean density of 2.67 g cm^{-3}, which is closer to the saturated densities than to the grain densities measured by Cambridge investigators.

Further sampling in north-west Spitsbergen of Hecla Hoek, Siktefjellet and Red Bay rocks was prevented in 1968, but remains desirable. Nevertheless sufficient rock density data are now available to facilitate preliminary interpretation of the gravity anomalies in north Spitsbergen.

CARBONIFEROUS AND PERMIAN ROCKS

MASSON SMITH measured the densities and porosities of 38 Carboniferous and Permian rocks. Lithologically, these comprised mostly sandstones and limestones: they were collected during the 1949 Cambridge Spitsbergen Expedition from a limited number of localities around Billefjorden. The results are summarised in Table 7.

Table 7

Carboniferous Rock Densities and Porosities

	No. of Data	Grain Density g cm^{-3} ± std dev.	Saturated Density g cm^{-3} ± std dev.	Porosity %
(a) *Lithological Classification*				
Sandstone	10	2.64±0.02	2.47±0.03	9.9
Limestone	11	2.72±0.04	2.70±0.04	1.2
Shale	11	2.67±0.05	2.63±0.05	2.3
(b) *Stratigraphical Classification*[1]				
Gipshuken Formation	1	2.843	2.808	1.9
Nordenskiöldbreen Formation				
Cadellfjellet & Tyrrellfjellet Members	11	2,702±0.063	2.691±0.049	1.6±1.6
Minkinfjellet Member	3	2.665±0.043	2.559±0.115	6.5±4.6
Ebbadalen Formation	3	2.778±0.062	2.676±0.080	5.7±2.0
Billefjorden Group	4	2.627±0.013	2.485±0.089	9.8±5.3

[1] Stratigraphic nomenclature based on CUTBILL and CHALLINOR 1965.

The limited sample, and the wide diversity of facies within the Carboniferous and Permian rocks of Spitsbergen (CUTBILL and CHALLINOR 1965) preclude any attempt at evaluating formation bulk densities for the whole of the system from the data of Table 7: they are merely presented for completeness.

WEST SVALBARD ROCKS

Previous density determinations of Tertiary rocks from around Forlandsundet were made by KURININ (1965). HOWELL's data are summarised in Table 8: from these he obtained a density contrast of —0.144 g cm^{-3} for Tertiary rocks relative to Pre-Devonian rocks for his gravity interpretation.

KURININ's data are ambiguous: sandstone, siltstone and shale were not differentiated, and conglomerate not mentioned. Further, he did not state which density he was presenting. Nevertheless, he measured 149 specimens, all from around Selvågen. The maximum, minimum and mean values which he obtained were 2.78, 2.45 and 2.63 g cm^{-3} respectively.

In MATON's study Tertiary specimens were collected from around Selvågen and from Aberdeenflya, and Pre-Devonian specimens came from many localities around the survey area. In addition W. T. HORSFIELD provided some twenty Pre-Devonian specimens which typified formations that he was mapping in Oscar II land and Prins Karls Forland.

The results of the density measurements made in this study are summarised in Table 9.

Table 8

Densities of Rocks from Sarsøyra and Murraypynten (after HOWELLS) *in g* cm^{-3}

Rock	No. of Specimens	Saturated Bulk Density Max.	Min.	Mean	Std. dev.
Pre-Devonian brecciated limestones	25	2.923	2.668	2.703	0.047
Tertiary					
Conglomerates & grits	45			2.570	0.066
Sandstones	21			2.569	0.090
Siltstones	2			2.518	0.021
Overall Tertiary				2.574	± 0.071

ATKINSON (1963) estimated that the proportions of lithologies within the Tertiary McVitiepynten formation were the following: sandstone 50%, shale 30% and conglomerate 20%. Using these proportions for the whole of the Forlandsundet Tertiary and the densities reported in Table 9 the formation bulk density is 2.627 g cm^{-3}, which compares closely to KURININ's mean value of 2.63 g cm^{-3}.

ATKINSON, however, was considering only about 300 m of a ?4 km sequence.

Table 9

Densities of Rocks from Prins Karls Forland and Western Oscar II Land
(in g cm^{-3} ± std. dev.)

Rock	No. of Data	Grain Bulk Density	Saturated Bulk Density
Pre-Devonian			
Marbles	5	2.832±0.011	2.815±0.017
Pelites	14	2.762±0.122	2.686±0.088
Limestones	4	2.718±0.061	2.707±0.066
Conglomerates and Tillites	5	2.849±0.116	2.813±0.096
Igneous and meta-igneous	6	2.945±0.202	2.920±0.223
Tertiary			
Conglomerates	4	2.624±0.017	2.529±0.004
Sandstones and Siltstones	6	2.676±0.035	2.623±0.071
Shales	2	2.548±0.002	2.471±0.007

During the 1975 field-season (J. Odell of the CSE) measured the upper part of this section (around Aberdeenflya) in detail. It is also recorded by Livshits (1967, 1973, 1974). Estimates from the schematic section by Livshits (1974) for the Tertiary sequence around Aberdeenflya (Marchaislaguna Formation) give:

shale — 17%
siltstone/sandstone — 51%
conglomerate — 32%

which gives a formation bulk density of 2.64 g cm^{-3} in the north of Forlandsundet. If the percentages from the CSE investigation are employed (shale 3%, siltstone/sandstone 69%, conglomerate 28%) an even higher bulk density of 2.66 g cm^{-3} is obtained.

If, however, one considers the Tertiary sequence as a whole, relative percentages over all five formations as distinguished by Livshits (1974) are

shale — 22%
siltstone/sandstone — 51%
conglomerate — 27%

which gives a formation bulk density of 2.634 g cm^{-3}, again much in accord with the estimate of Kurinin.

Horsfield (personal communication) considered that the Pre-Devonian lithologies which have been sampled are roughly equally abundant in the field, with the exception of the basic igneous rocks and their derivatives. In the calculation of the formation bulk density the basic rocks were therefore omitted and the other types given equal weight. The resultant density for the Pre-Devonian around Forlandsundet is 2.793 g cm^{-3}, implying a general density contrast of 0.159 g cm^{-3} with the Tertiary.

It must be noted that the variability of the Tertiary lithologies between both north and south, east and west, will affect the density contrast from area to area. Thus in the north, taking an averaged Tertiary formation bulk density of 2.65 g cm^{-3} the density contrast to the Pre-Devonian rocks will be 0.143 g cm^{-3}. In the central western area (around Selvågen), it will be higher (0.159 g cm^{-3}), and to the east (Sarsøyra), where coarse lithologies dominate the sequence (say conglomerate 55%, shale 5%, sandstone/siltstone 40% giving a density of 2.641 g cm^{-3}) the contrast may be about 0.152 g cm^{-3} (intermediate).

The contrast obtained by HOWELLS was 0.144 g cm^{-3}, and thus the range 0.143 to 0.159 g cm^{-3} is available for subsequent gravity interpretation.

Conclusion

The contrast between the weighted Hecla Hoek and weighted Devonian formation grain densities is rather small (0.041 g cm^{-3}); smaller in fact than the mean standard deviation of all the Hecla Hoek lithology densities (0.077 g cm^{-3}), but larger than the corresponding statistic for the Devonian lithologies (0.030 g cm^{-3}). Nevertheless a 40 milligal Bouguer gravity anomaly exists along the eastern margin of the Devonian graben in Spitsbergen and the interpretation of this anomaly was discussed in HARLAND et al. (1974).

The density contrast between the Pre-Devonian and Tertiary rocks around Forlandsundet appears to be in the range 0.143 g cm^{-3} to 0.159 g cm^{-3}. A paper reporting the measurement and interpretation of the sizeable Bouguer anomaly over the Forlandsundet area is in preparation.

Acknowledgement

The authors gratefully acknowledge the use of research facilities at the Department of Geology, Sedgwick Museum, Cambridge. We thank Mr. W. B. HARLAND for his direction of our contributions to the Svalbard research at Cambridge. We also thank Mr. C. A. G. PICKTON for updating the calculation of the Tertiary formation densities in the light of the most recent stratigraphic data.

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Microfossils from the Janusfjellet Subgroup (Jurassic–Lower Cretaceous) at Agardhfjellet and Keilhaufjellet, Spitsbergen

– A preliminary report –

By MAGNE LØFALDLI[1] and BINDRA THUSU[1]

Contents

Abstract

Six foraminiferal assemblages are reported from the type section of the Janusfjellet Subgroup (Jurassic — Lower Cretaceous) at Agardhfjellet, east Spitsbergen. The foraminiferal faunas are characterized by simple arenaceous forms. These microfaunas, and associated dinoflagellate cysts, indicate a neritic environment for the Subgroup, except in the uppermost few meters, where coastal marine conditions prevailed. One of the assemblages is also recognized in Upper Jurassic rocks at Keilhaufjellet, south Spitsbergen. The dominance of simple arenaceous foraminifera in Spitsbergen is thought to be partly due to sediment substrate and climatic factors.

Introduction

Mesozoic sediments are exposed in the central and eastern parts of Spitsbergen and also on the islands of eastern Svalbard. These deposits are marine, marginal marine and partly continental consisting mainly of shales and sandstones with rare conglomerates and coals (HARLAND 1973; EDWARDS 1976). Biostratigraphical studies based on megafossils have been done by several workers. Newer data are published by PARKER (1967), TOZER and PARKER (1968), and NAGY (1970). KLUBOV (1965) has reported foraminifera from the Mesozoic sediments of Wilhelmøya.

[1] Institutt for Kontinentalsokkelundersøkelser (Continental Shelf Institute), Håkon Magnussons gt. 1B, 7000 Trondheim.

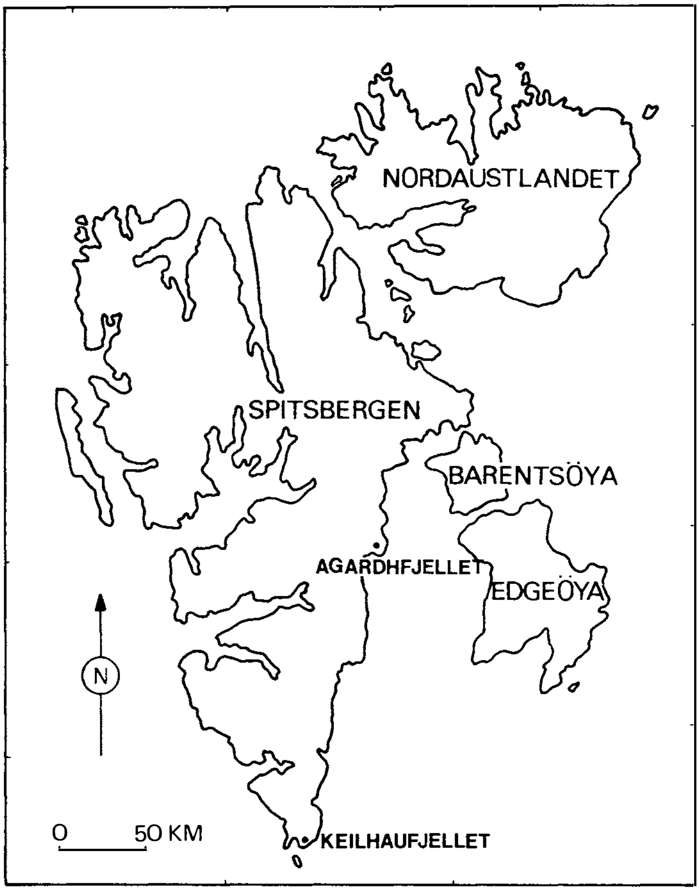

Fig. 1. *Location of Agardhfjellet and Keilhaufjellet, Svalbard.*

The Janusfjellet Subgroup at Agardhfjellet is predominantly shale, but siltstone and sandstone are also present especially at the top (Fig. 2). For details on the stratigraphy, lithology and paleontology, the reader is referred to Parker (1967) and Bjærke et al. (1976).

In the summers of 1973 and 1974 extensive sampling of Mesozoic rocks was carried out in Spitsbergen by Norsk Polarinstitutt and the Continental Shelf Institute. Micropaleontological study of this material has lead to the discovery of foraminifera in the Jurassic — Lower Cretaceous Janusfjellet Subgroup at its type section at Agardhfjellet and in the Jurassic rocks of Keilhaufjellet, Sørkapp Land (Fig. 1). Recently, Bjærke et al. (1976) reported the discovery of well-preserved dinoflagellates from the Janusfjellet Subgroup at Agardhfjellet.

The present report is concerned with the general features of the six foraminiferal assemblages recognized. These assemblages together with palynomorphs provide a basis for a preliminary interpretation of environments and paleobiogeography of the study area.

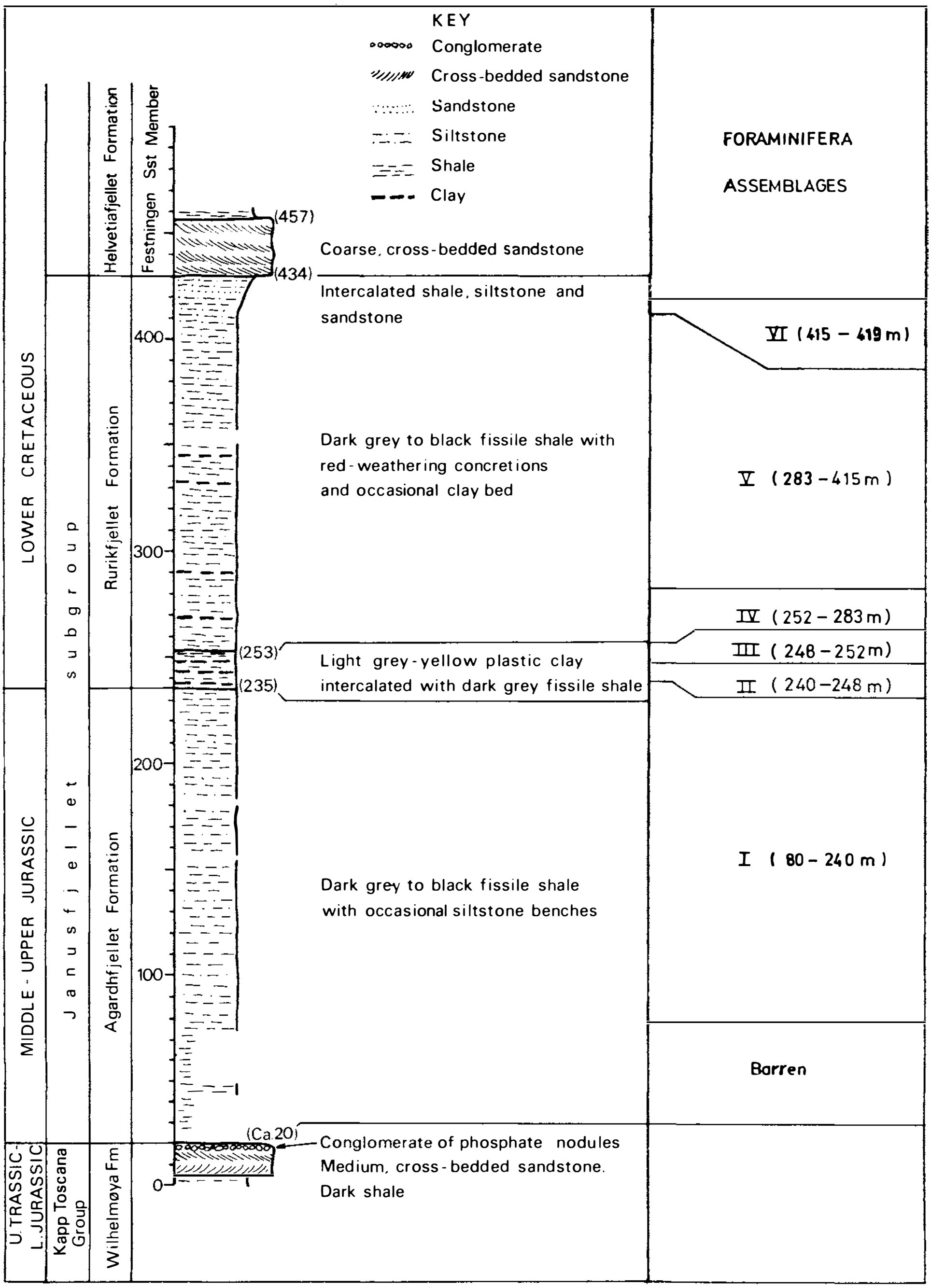

Fig. 2. *Section through the Jurassic–Cretaceous Janusfjellet Subgroup at Agardhfjellet (modified from* Bjærke *et al. 1976) with the stratigraphic distribution of microfossils.*

Sampling

Channel samples at two meter intervals were collected from the Janusfjellet Subgroup at Agardhfjellet (Fig. 2). Samples are nearly complete for most of the section apart from the basal 80 m which is poorly covered. Spot samples were obtained from Keilhaufjellet at intervals of up to several meters.

Microfossils

AGARDHFJELLET

A total of six foraminiferal assemblages are recognized at Agardhfjellet (Figs. 2, 3). Assemblage I belongs to the upper part of Agardhfjellet Formation and Assemblages II to VI are present in the Rurikfjellet Formation. The assemblages and their environmental interpretation are briefly summarized below.

Assemblage I (80–240 m)

This assemblage is made up exclusively of simple arenaceous foraminifera, some of which are distorted and poorly preserved. The lower part of the section (80–200 m) contains a poor fauna, whereas the upper part (200–240 m) is quite rich in specimens. This assemblage contains foraminifera of families Lituolidae and Ammodiscidae, represented by a few species of *Haplophragmoides* and *Ammodiscus.*

Dinoflagellate cysts are absent in this interval except for highly metamorphosed dark brown specimens observed in the uppermost part.

Species of *Haplophragmoides* and *Ammodiscus* are known to have wide environmental tolerances. However, the low diversity of the foraminifera suggests either a shallow neritic environment or somewhat deeper water, with reduced oxygen supply or lower temperature.

Assemblage II (240–248 m)

This assemblage is also made up exclusively of simple arenaceous foraminifera. The fauna is fairly well preserved and consists largely of members of the families Lituolidae and Ataxophragmiidae. The Lituolidae are dominated by *Recurvoides* and *Haplophragmoides*, and the Ataxophragmiidae are represented by the species of *Gaudryina* and *Verneuilina*. A few specimens of the families Ammodiscidae, Textulariidae and Trochamminidae occur. The Ammodiscidae are represented by species of *Ammodiscus* and *Glomospira*, the Textulariidae by *Textularia* and *Spiroplectammina*, and the Trochamminidae by *Trochammina.*

Dinoflagellate cysts, *Sirmiodinium grossi*, *Scriniodinium apatelum*, *Pareodinia* spp. are abundant in several samples. Species of *Gonyaulacysta, Cleistosphaeridium* and *Tenua* spp. are present in small numbers, but their preservation is poor. In general the dinoflagellate assemblages show low diversity (see also BJÆRKE et al. 1976).

The presence of a relatively varied foraminiferal assemblage together with dinoflagellate cysts suggests a neritic environment.

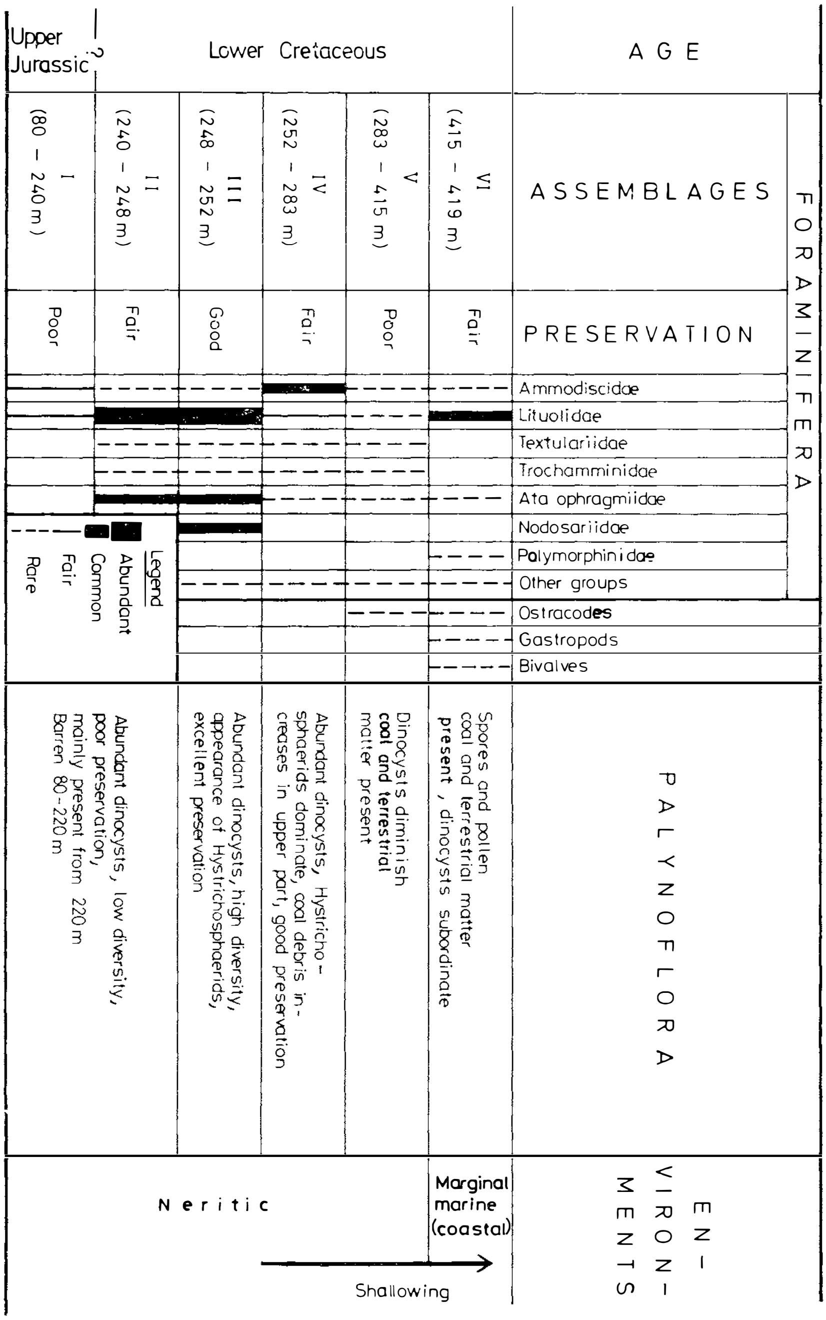

Fig. 3. *Distribution of microfossils and their environmental interpretations in the Janusfjellet Subgroup at Agardhfjellet.*

Assemblage III (248–252 m)

Arenaceous species of the families Lituolidae and Ataxophragmiidae continue to dominate in this assemblage. However, the assemblage shows the appearance of calcareous, benthonic species of the family Nodosariidae, including species of *Lenticulina, Marginulinopsis* and *Lagena.* This assemblage shows maximum diversity of species, when compared to the other assemblages.

The dinoflagellate cysts are well preserved in the interval 250–252 m and, like the foraminifera, show maximum diversity and abundance. Of note is the appearance of the *Hystrichosphaeridium- Oligosphaeridium*-group.

The presence of a mixed nodosariid – arenaceous assemblage indicates a neritic environment. This is supported by the presence of abundant and varied dinoflagellate cysts.

Assemblage IV (252–283 m)

This assemblage is dominated by species of the genera *Ammodiscus* and *Glomospira.* Species of *Haplophragmoides* are fairly well represented, but *Gaudryina, Trochammina* and *Textularia* are rare.

Certain dinoflagellates, e.g. *Scriniodinium apatelum* and *Imbatodinium villosum* which dominated Assemblages III are extremely rare, but *Sirmiodinium grossi* continues to be represented in fair numbers. However, the *Hystrichosphaeridium-Oligosphaeridium*-group shows increasing diversity. Above 260 m coaly matter dominates and several species of spores, and terrestrial debris appear.

The dominance of *Glomospira* and *Ammodiscus* indicates relatively deep water. Sliter and Baker (1972) concluded that these groups were most common in outer neritic and bathyal depths of Cretaceous seas. In the present study, the low diversity of the assemblage is more similar to assemblages found in shallow water. The coaly matter and terrestrial debris present in large quantities above 260 m also supports deposition in shallower marine waters.

Assemblage V (283–415 m)

This assemblage shows a marked decline in foraminifera. *Haplophragmoides, Trochammina, Gaudryina, Textularia, Ammodiscus* and *Glomospira* are present in small numbers. Rare specimens of polymorphinids and ostracodes also occur.

Dinoflagellate cysts diminish in number. Cavate pseudoceratian cysts, e.g. *Muderongia* sp., appear in this assemblage, as noted by Bjærke et al. (1976). Coal and some terrestrial debris increase notably. Spore species *Cicatricosisporites* and *Aequitriradites* and bisaccate pollen appear from 400 m.

The presence of a poor foraminiferal fauna represented by a few species suggests a neritic environment for this assemblage. This is consistent with the diminished number of dinoflagellate cysts, and the increase in terrestrial matter (coal and few spores).

Assemblage VI (415–419 m)

This assemblage shows an increase in foraminifera when compared to Assemblage V. The Lituolidae are again the most common group, represented by species of *Haplophragmoides* and *Ammobaculites*. A few specimens of the families Ataxophragmiidae, Ammodiscidae and Polymorphinidae occur. Shells of gastropods, bivalves and ostracodes also appear. This microfauna is fairly well-preserved.

Palynomorphs are similar to those in Assemblage V, but the progressive decline in number of dinoflagellate cysts and corresponding increase in terrestrial organic matter continues.

This assemblage is strongly indicative of a marginal marine environment conducive to the development of arenaceous foraminifera, ornamented ostracodes, and thick-shelled gastropods and bivalves. Furthermore, increased organic terrestrial debris and decreasing numbers of dinoflagellate cysts when compared to Assemblage IV and V support a marginal marine environment.

KEILHAUFJELLET

The Agardhfjellet Formation exposed at Keilhaufjellet, Sørkapp Land (Fig. 2) contains sparse and distorted tests of foraminifera. However, forms recognized include *Haplophragmoides* and *Ammodiscus*. This fauna is similar to Assemblage I at Agardhfjellet.

There is a general absence of palynomorphs in this area. The organic matter is highly metamorphosed, similar to Assemblage I at Agardhfjellet.

Discussion

Paleoecology and paleobiogeography

The paleontological interpretations presented here are based principally on the diversity of the microfossils and the relative abundance of dominant genera which have been compared with the bathymetric distribution of Cretaceous and Recent analogues found in the literature (BANDY and ARNAL 1960; PHLEGER 1960; WALTON 1964; SLITER and BAKER 1972).

Assemblage I is made up exclusively of simple arenaceous foraminifera of the families Lituolidae and Ammodiscidae, represented by a few species of *Haplophragmoides* and *Ammodiscus*. These groups are known to have wide environmental tolerances and occur in sediments representing a considerable depth variation. The low diversity of the foraminifera in this assemblage suggests a shallow neritic environment. However, this arenaceous fauna could also be the result of cool temperature or reduced oxygen supply in deeper water (BANDY and ARNAL 1960; MOORKENS 1976). Assemblage II is also made up exclusively of arenaceous foraminifera, but is richer in species and specimens. Here, members of the families Lituolidae and Ataxophragmiidae dominate the fauna, and the environment seems to be conducive to the development of diversified microfaunas in contrast to Assemblage I. Assemblage III has nodosariids along with arenaceous forms and this assemblage shows increased diversity of species suggesting a neritic condition. The presence of diversified dinoflagellate cysts supports such an environment. Assemblage IV notably lacks nodosariids, but arenaceous species, in particular the *Ammo-*

discus-Glomospira complex, might indicate somewhat deeper water. This is again supported by an increase in long-processed dinoflagellate cysts which are thought to be more characteristic of off-shore areas (VOZZHENNIKOVA 1967). However, some shallowing could have started from 260 m and up because of the influx of increased quantities of terrestrial organic debris, in particular coaly matter. Assemblage V is similar to Assemblage IV, but with a much poorer fauna. Shallowing of the sea could be responsible for such a reduction in numbers of species and specimens. The foraminiferal microfauna of Assemblage VI is largely made up of a few species of *Haplophragmoides* and *Ammobaculites*. Presence of *Ammobaculites* suggests coastal marine waters. The ornamented ostracodes and the thick-shelled bivalves and gastropods also indicate such an environment. This is independently supported by sedimentological studies (EDWARDS 1976, p. 44, 47). In summary, we consider Assemblage I to V to represent a neritic environment and Assemblage VI a marginal marine environment.

GORDON (1970, p. 1689) distinguished three principal types of shelf assemblages in the biogeographic distribution of Jurassic foraminifera: Nodosariid and nodosariid mixed assemblages, dominantly simple arenaceous assemblages, and calcareous benthonic assemblages other than nodosariids.

Jurassic assemblages from Agardhfjellet and Keilhaufjellet and also Lower Cretaceous assemblages from Agardhfjellet are characterized by the dominance of simple arenaceous foraminifera in contrast to the nodosariid-dominated assemblages in the Jurassic of Northern Europe north of the Alps and northern plains of North America. Such differences may be partly the results of sediment substrate as well as latitudinal or climatic factors (GORDON 1970, p. 1697, 1700).

According to LOEBLICH and TAPPAN (1953), Recent fine-grained mud bottoms often do not support a varied foraminiferal fauna. The few species present in this type of environment are mostly arenaceous, these may become numerous in individuals because of reduced competition. TAPPAN (1955) suggested that these features are characteristic of black shale faunas of all ages and areas. Presence of arenaceous assemblages with a low diversity in dark shale sequences of Spitsbergen suggests that the sediment substrate may have influenced the character of microfaunas in these areas.

Acknowledgements

The present study was carried out as a part of the Barents Sea Project, aimed at gathering scientific data about the Barents Sea and Shelf, and involving the participation of the Continental Shelf Institute and the Norsk Polarinstitutt, as well as other Norwegian research institutions.

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Permian conodonts from Spitsbergen and their stratigraphic significance; a preliminary note

By KRZYSZTOF MAŁKOWSKI[1] and HUBERT SZANIAWSKI[1]

Contents

Abstract

First conodonts from the Permian of Spitsbergen are described. They were found in the Spirifer Limestone of the Kapp Starostin Formation in Polakkfjellet (Torell Land) and the Hornsund region. They show strong affinities to those from the Leonardian (Artinskian) of North America which suggests a somewhat younger age of the Kapp Starostin Formation than previously supposed.

Stratigraphy

Permian rocks bearing rich and well-preserved brachiopod, coral, bryozoan and sponge faunas from Spitsbergen have been intensively studied by geologists and paleontologists from many countries. Nevertheless, their correlation with the Permian stratotype profiles from the Russian platform is still controversial.

Permian faunas from the areas of Hornsund and Polakkfjellet (Torell Land) were studied by expeditions of the Institute of Paleozoology (Zakład Paleozoologii) of the Polish Academy of Sciences to Spitsbergen in 1974 and 1975 (Fig. 1). The studies gave the first Permian conodonts and additional material of macrofauna and foraminifera. Conodonts are good guide fossils so it is expected that these finds will markedly contribute to the solving of some stratigraphic problems.

Several conodonts were found in the Spirifer Limestone at the base of the Brachiopod Cherts from Polakkfjellet (Fig. 2). The Spirifer Limestone comprises gray, grained limestone rich in brachiopod shells, occurring above

[1] Polska Akademia Nauk, Zakład Paleozoologii, Al. Zwirki i Wigury 93, 02–089 Warszawa.

gypsiferous marls and dolomites with gypsum (alabaster) intercalations. It presumably belongs to the Gipshuken Formation (Upper Gypsiferous Series), but the contact between these formations is obscured.

In the Hornsund area only single conodont, *Neogondolella* cf. *bisselli*, was found in a thin layer of an equivalent of the Spirifer Limestone, from the base of Brachiopod Cherty Limestone in the Hyrnefjellet. The Spirifer Limestone layer occurs here only in the area of that massif, wedging out to the south. At Treskelen peninsula there is a marked sedimentary gap and the Cherty Limestones directly overlay Coral Limestone of the Treskelodden Formation (Fig. 1) of the early Permian (BIRKENMAJER 1964, FEDOROWSKI 1964, 1965) or late Carboniferous (CZARNIECKI 1969) age. The Gipshuken Formation is assigned to the Artinskian (FORBES et al. 1958, CUTBILL and CHALLINOR 1965, SOSIPATROVA 1967) whereas the age of the Brachiopod Cherts is still the subject of controversy. In the past the latter were assigned to the Artinskian (TSCHERNYSCHEW 1902, FREBOLD 1937) or interpreted as an independent stage, Svalbardian, an equivalent of the Kungurian stage from the Russian

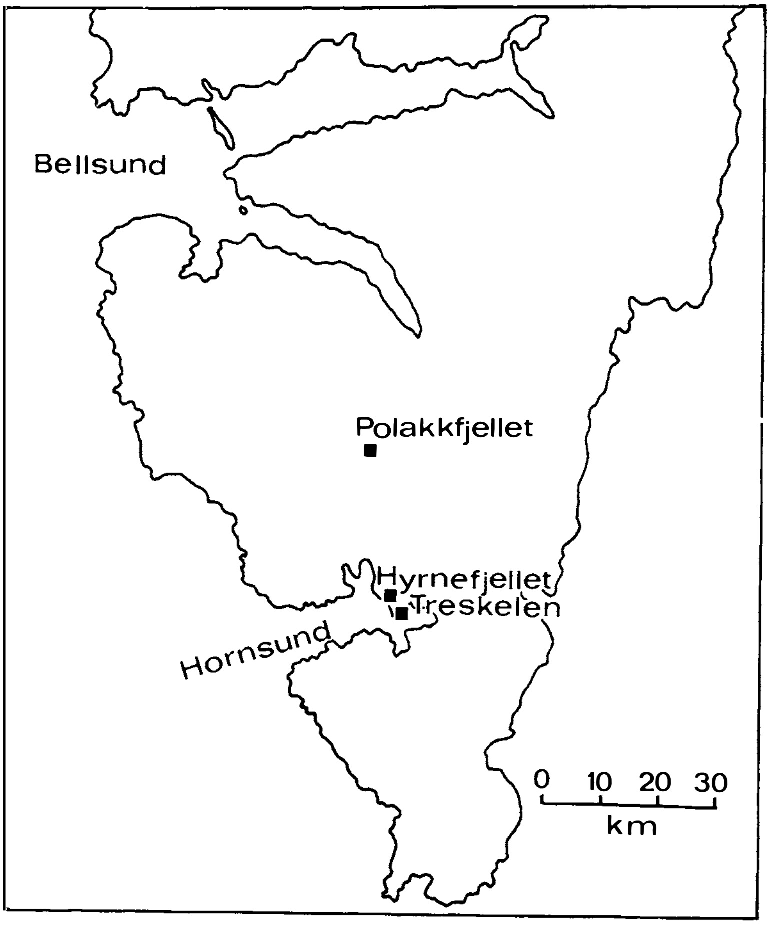

Fig. 1. *Sketch-map of southern Spitsbergen, showing the location of the studied profiles.*

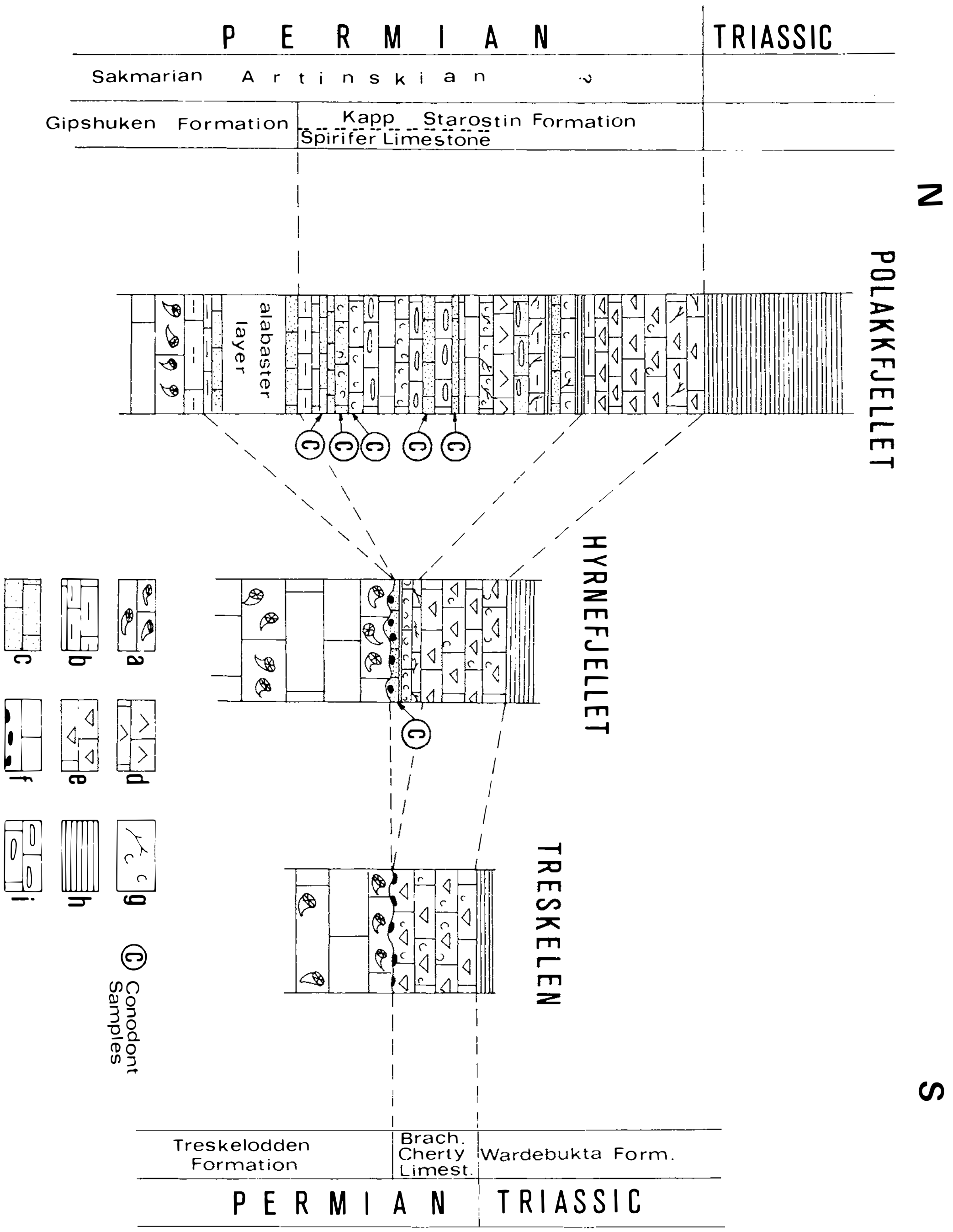

Fig. 2. *Scheme of the investigated profiles (thickness of stratigraphic units not to scale). a. coral bearing limestone; b. marly limestone; c. grained limestone; d. chalcedonite; e. cherty limestone; f. pebbles; g. bryozoans and brachiopods; h. shales; i. flints.*

Platform (STIEPANOV 1957). Recently they have been distinguished as a Kapp Starostin Formation, widely assumed to be of the Kungurian and early Late Permian age (CUTBILL and CHALLINOR, 1965, SOSIPATROVA 1967, STIEPANOV 1967) or Late Permian age (BUROV et al. 1965, USTRITSKY 1967). The Brachiopod Cherts yield no fusulinids so their datings were mainly based on brachiopods or small foraminifers. Taking into account differences in the foraminifer faunas, SOSIPATROVA (1967) proposed a separate horizon for the Spirifer Limestone, assuming that it is of the lower Kungurian age. Late Paleozoic faunas of Svalbard show strong Russian affinities (FORBES et al. 1958) but Permian conodonts are relatively well-known only from North America. Conodonts of the Spirifer Limestone appear to have close affinities with those from the lower Leonardian (Artinskian) of the United States.

The most important species from a stratigraphic point of view are conspecific or closely related to the species *Neogondotella bisselli* (CLARK and BEHNKEN) and *Neostreptognathodus pequopensis* BEHNKEN known to occur from the late Wolfcampian (Sakmarian) to middle Leonardian (BEHNKEN 1975a, b). These data suggest an Artinskian age of the lower part of the Brachiopod Cherts, i.e. the same as that suggested by earlier workers. Thus, it may be assumed that the Gipshuken Formation comprises the lower Artinskian at the most, and not the whole Artinskian as supposed by SOSIPATROVA (1967).

Systematic remarks (by H. SZANIAWSKI)

The material described is housed at the Institute of Palaeozoology of the Polish Academy of Sciences, Warsaw (abbreviated as ZPAL). Scanning microscope photographs were made at the Institute of Experimental Biology, Polish Academy of Sciences.

Neogondolella cf. *bisselii* (CLARK and BEHNKEN 1971)
(Pl. I, Fig. 1)

This species is represented by a single specimen from the Spirifer Limestone of the Hyrnefjellet massif. It differs from *N. bisselli* known from the U.S.A. in the narrower basal groove on the lower surface and the relatively larger posterior cusp. These features bring it somewhat close to *Neogondolella idahoensis* (YOUNGQUIST, HAWLEY and MILLER) from which it differs in the shape of the platform.

N. bisselli is known from the late Wolfcampian of North America. The generic name *Neogondolella*, BENDER and STOPPEL 1965, is regarded by KOZUR (1975) as a junior synonym of *Gondolella*, STAUFFER and PLUMMER 1932; but this problem is not within the scope of this paper.

Neostreptognathodus aff. *pequopensis*, BEHNKEN 1975
(Pl. I, Figs. 6–10)

This species quantitatively predominates in the Spirifer Limestone of the Polakkfjellet. About 40 specimens were extracted. The specimens differ from

Neostreptognathodus pequopensis BEHNKEN from the U.S.A. in the somewhat broader platform, in the presumably higher free blade (not illustrated by BEHNKEN 1975a) and in very small pustules marked on nodose denticles of the carinae. These features bring the specimens close to *Neostreptognathodus sulcoplicatus* (YOUNGQUIST, HAWLEY and MILLER) from which they differ in the lack of transversal ridges on the carinae and in that the juvenile forms (?) have a single carina. These juvenile forms (?) (Pl. I, Fig. 9) closely resemble *Sweetognathus whitei* (RHODES 1963).

Neostreptognathodus pequopensis is known to range from the uppermost Wolfcampian to early late Leonardian in North America.

Xaniognathus sp.
(Pl. I, Fig. 2)

Up to the present three specimens referable to the genus *Xaniognathus* SWEET 1971, were found in the Spirifer Limestone from Polakkfjellet. They presumably represent a new species of that genus but the material is insufficient for defining a new species.

This species is most close to *Xaniognathus abstractus* (CLARK and ETHINGTON 1962), from which it differs in its markedly broader basal cavity, more robust blade and shorter denticles.

Xaniognathus abstractus is known from the middle to late Leonardian of the North America.

Bar-like conodonts
(Pl. I, Figs. 3–5)

Besides the conodonts shown here (Pl. I, Figs. 3–5), the collection from the Spirifer Limestone of Polakkfjellet also comprises a number of fragments of bar-like conodonts.

SZANIAWSKI (1969) noted a similarity of conodont assemblage from the Permian of Poland to components of multielement natural assemblages known from the Carboniferous. Recently BEHNKEN (1975a) assigned Permian bar-like conodonts to the multielement genus *Ellisonia* SWEET 1970, and KOZUR (1975) proposed a new multielement genus *Stepanovites* KOZUR 1975, for them. Conodonts from Polakkfjellet, shown in Pl. I, Figs. 3–5, presumably belonged to one or two new multielement species. Unfortunately, the material is insufficient for reconstructing the apparatus or confirming the reliability of former reconstructions; therefore traditional form genera are used here.

Acknowledgement

We are grateful to prof. dr. KRZYSZTOF BIRKENMAJER for introducing us to the problems of the geology of the investigated area.

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PLATE

PLATE I

Fig. 1. *Neogondolella* cf. *bisselli* (CLARK and ETHINGTON). 1a, oblique-upper view of platform (×40). 1b, posterior part of the same specimen (×150). 1c, anterior part of the same specimen (×100). 1d, the same specimen, postero-lateral platform margin showing micro-ornamentation (×1000). ZPAL C.VII/1, Hyrnefjellet, Spirifer Limestone.

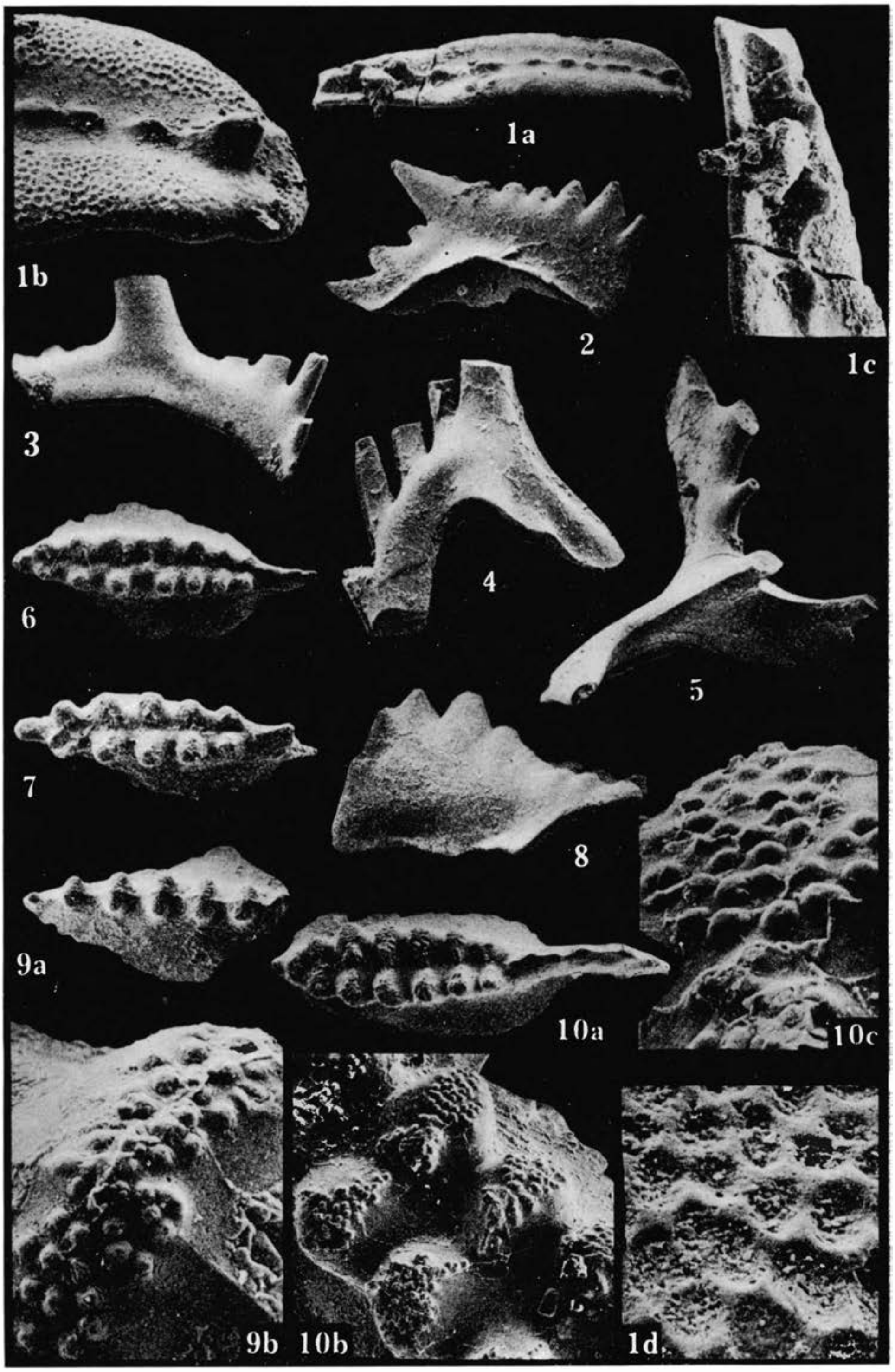
Fig. 2. *Xaniognathus* sp., lateral view (×100), ZPAL C.VII/201, Polakkfjellet, Spirifer Limestone.

Fig. 3. *Hindeodella* sp., lateral view of broken specimen (×50), ZPAL C.VII/211. Polakkfjellet, Spirifer Limestone.

Fig. 4. *Cypridodella* sp., posterior view of broken specimen (×150), ZPAL C.VII/212. Polakkfjellet, Spirifer Limestone.

Fig. 5. *Hibbardella* sp., oblique-upper view of broken specimen (×100), ZPAL C.VII/213. Polakkfjellet, Spirifer Limestone.

Figs. 6–10. *Neostreptognathodus* aff. *pequopensis* BEHNKEN. 6, upper view of specimen with the anterior part of blade broken off (×65), ZPAL C.VII/102. 7, oblique-upper view of platform (×100), ZPAL C.VII/103. 8, lateral view of free blade (×75), ZPAL C.VII/104. 9a, upper view of broken specimen of juvenile form? (×100). 9b, the same specimen showing micro-ornamentation (×1000), ZPAL C.VII/105. 10a, upper view (×75), 10b, the same specimen showing nodose denticles with micro-ornamentation (×220), 10c, the same specimen showing micro-ornamentation (×1000), ZPAL C.VII/101. All from Polakkfjellet, Spirifer Limestone.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Observations minéralogiques, pétrographiques et géochimiques sur des roches du Woodfjorden, Spitsbergen

Par GEORGES CALAS[1], MIREILLE MALOD-POLVÉ[2], YVES MOËLO[1] et CATHERINE VIAUX[3]

Contenu

Abstract

Some observations were made on rocks and minerals from Woodfjorden, Spitsbergen, with the French paleontological expedition of 1969. The nature and origin of volcanic rocks are discussed, based upon petrographical and geochemical studies: the material, alcaline basalts and trachydolerites, seems to have been contaminated with radiogenic strontium, mobilized from the continental basement of Spitsbergen. Related mineralizations within the underlying

[1] Laboratoire de Minéralogie-Cristallographie, associé au CNRS, Université Pierre et Marie Curie, 4 place Jussieu — 75230 Paris Cedex 05.

[2] Laboratoire de Géochimie et Cosmochimie, associé au CNRS, Université Paris VI et VII, 2 place Jussieu — 75221 Paris Cedex 05.

[3] Laboratoire de Géologie, Ecole Normale Supérieure, 46 rue d'Ulm — 75005 Paris.

Old Red Sandstones, with copper sulphides (chalcocite, covellite, bornite) and carbonates, are, on the other hand, studied. They are very different from those described in the other parts of Spitsbergen, by their original paragenesis and occurrence in devonian sediments.

Résumé

A la suite de la Mission paléontologique française organisée en 1969 par le Museum National d'Histoire Naturelle et le C.N.R.S., divers échantillons de roches et minerais ont été récoltés et étudiés. Il s'agit surtout de roches volcaniques récentes provenant du Nord de l'île, près du Woodfjorden, basaltes alcalins et trachydolérites sur lesquels ont été également effectuées des mesures de strontium radiogénique. Dans le même secteur, se trouvent dans les sédiments dévoniens de nombreux filons cuprifères (à sulfures de cuivre, parfois fortement oxydés) qui constituent un fait original dans la géologie du Spitsbergen, tant par leur paragénèse différente de celles déjà connues par ailleurs que par leur situation dans des roches sédimentaires.

Introduction

Le Museum National d'Histoire Naturelle et le Centre National de la Recherche Scientifique ont organisé pendant les mois de Juillet et Août 1969 une mission paléontologique dans les îles Spitsbergen et Edgeöya de l'archipel du Svalbard (Fig. 1). Cette mission a permis de récolter, en même temps, de nombreux échantillons pétrographiques et minéralogiques intéressants, surtout dans la partie Nord du Spitsbergen, dans la région du Woodfjorden.

Rappel géologique

Le Nord du Spitsbergen comprend essentiellement deux sortes de terrains (HARLAND 1961):

— le Complexe du Heckla Hoek constitué de terrains d'âge anté-ordovicien métamorphisés lors de l'orogénèse calédonienne (HARLAND et WILSON 1956)
— le Complexe des "Vieux Grès Rouges" d'âge Downtonien à Dévonien moyen, qui repose en discordance sur ce socle calédonien et dont l'épaisseur peut atteindre 9000 m.

Le reste de la série stratigraphique se rencontre plus au Sud. Dans le Nord de l'île, on n'observe au dessus des terrains dévoniens que des manifestations volcaniques récentes (mis à part quelques intrusions doléritiques qui se rencontrent vers l'Hinlopenstretet et le Storfjorden). Les plus anciennes coulées se rencontrent sur une pénéplaine datant certainement de la fin du Tertiaire et se trouvant actuellement à plusieurs centaines de mètres d'altitude, alors que les plus récentes reposent sur la surface d'érosion actuelle. Ces coulées, accompagnées de quelques appareils volcaniques et de rares sources thermales, se localisent sur les bords de l'Hinlopenstretet et surtout dans la partie nord-centrale du Spitsbergen: Andrée Land et partie orientale du Haakon VII

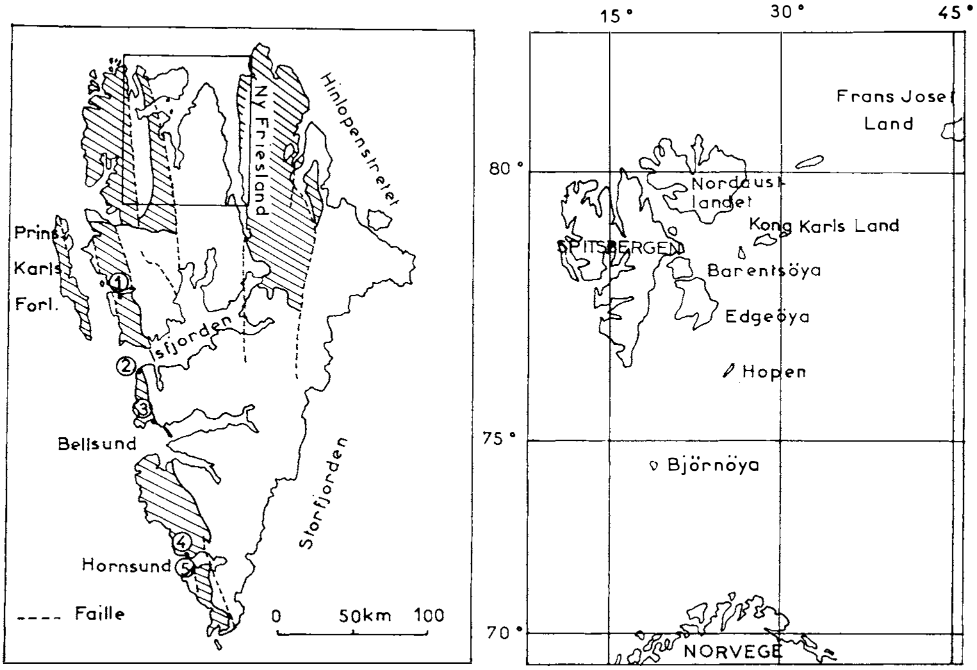

Fig. 1. *A droite : situation de l'archipel du Svalbard. A gauche : carte du Spitsbergen montrant le complexe de Heckla Hoek avec les principaux gisements métallifères : 1. St. Johnsfjorden ; 2. Kapp Mineral ; 3. Sinkholmen ; 4. Revdalen ; 5. Andvika (d'après* FLOOD *1969).*

On the right: localization of Svalbard archipelago. On the left: map of Spitsbergen showing the Hecla Hoek complex with mineralized localities: 1. St. Johnsfjorden; 2. Kapp Mineral; 3. Sinkholmen; 4. Revdalen; 5. Andvika (after FLOOD 1969).

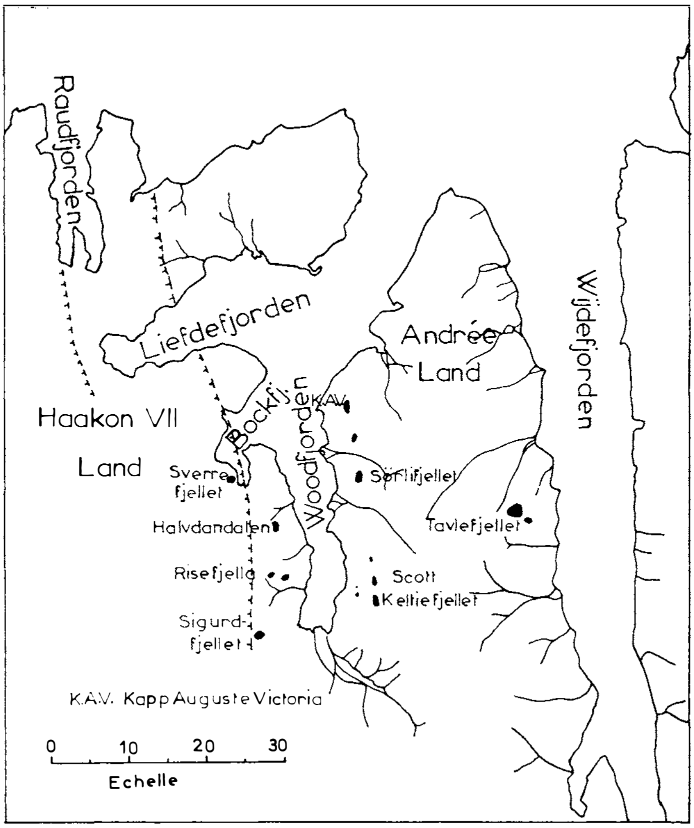

Fig. 2. *Carte de la région du Woodfjorden avec les principales manifestations volcaniques.*

Map of the Wood Bay area showing the main volcanic bodies.

Fig. 3. *Vue de Sörlifjellet depuis Halvdandalen; les coulées volcaniques sont nettement visibles au sommet (à droite se trouve la Stördalen).*

View on Sörlifjellet taken from Halvdandalen; volcanic flows are visible on the top (on the right is Stördalen).

Land, c'est à dire la région autour du Woodfjorden. Il s'agit probablement de manifestations récentes: 6500 à 4000 ans pour le volcan du Sverrefjellet (SEMEVSKIJ 1965). Ces âges ont cependant été controversés récemment par HALVORSEN (1972) pour lequel le neck de Halvdanpiggen serait d'âge permo-carbonifère d'après des données paléomagnétiques (voir plus loin).

Etude pétrographique et géochimique d'échantillons des coulées volcaniques de Halvdandalen et Sörlifjellet

Tout autour du Woodfjorden, les manifestations volcaniques sont nombreuses (Fig. 2): coulées de Kapp Auguste Victoria, Sörlifjellet (Fig. 3) et Scott Keltiefjellet (Fig. 4) à l'Est et de Risefjella, Halvdandalen (à proximité de Halvdanpiggen) et Sigurdfjellet (avec un appareil volcanique partiellement conservé dans ces deux cas) à l'Ouest, en relation avec la faille majeure qui sépare les terrains de l'Heckla Hoek du fossé central dévonien (voir Fig. 1). A proximité de cette faille se situe également le volcan de Sverrefjellet, au fond du Bockfjorden, associé à des sources thermales. Décrits par HOEL et HOLTEDAHL en 1911, ces affleurements n'ont, depuis, fait l'objet que d'études localisées (GJELSVIK 1963; BUROV 1965; SEMEVSKIJ 1965).

Les échantillons étudiés proviennent soit du Sörlifjellet (S3, S5, S7 et S9), coulée dont la base se situe vers 850 m au dessus de la rive orientale (Fig. 3) soit de Hvaldandalen (W6 et W15), pointement basaltique au sein des grès dévoniens.

Les résultats de cette étude ont été publiés par M. LUSSIAA–BERDOU–POLVÉ et al. (1973), aussi ne ferons-nous qu'en rappeler les points principaux:

Tableau 1

Analyses chimiques et normes des échantillons étudiés

Chemical analyses and norms of the samples studied

	S3	S5	S7	S9	W6	W15
SiO_2	43,47	42,49	43,11	46,60	48,89	54,50
TiO_2	2,22	2,64	2,62	1,45	1,33	1,49
Al_2O_3	14,35	14,22	14,51	15,68	15,70	16,98
Fe_2O_3	11,01	12,50	12,87	10,70	11,16	7,78
MnO	0,15	0,16	0,17	0,16	0,16	0,12
MgO	9,79	9,90	8,79	7,21	7,93	3,16
CaO	8,37	9,74	9,63	8,48	8,25	9,25
Na_2O	2,68	3,33	3,58	2,91	3,20	3,60
K_2O	1,76	1,45	1,59	0,73	0,79	0,55
H_2O	4,52	2,35	2,75	4,86	2,47	2,92
Total	98,32	98,78	99,62	98,96	99,88	100,35
Normes C.I.P.W.						
Q	0,00	0,00	0,00	0,3	0,00	8,43
or	10,41	8,58	9,40	4,45	4,67	3,25
ab	14,68	7,07	8,24	24,6	27,05	30,43
an	21,89	19,54	18,79	27,5	26,11	28,51
ne	4,32	11,42	11,93	0,00	0,00	0,00
di wo	8,20	12,02	12,11	6,03	6,20	7,26
di en	5,77	8,11	7,81	5,85	3,95	4,25
di fs	1,72	2,98	3,47	1,72	1,84	2,66
hy en	0,00	0,00	0,00	14,10	7,80	3,65
hy fs	0,00	0,00	0,00	6,47	3,63	2,29
ol fo	13,10	11,65	9,92	0,00	5,66	0,00
ol fa	4,32	4,73	4,87	0,00	2,91	0,00
ilm	4,69	5,57	5,53	2,74	2,81	3,15
mt	4,35	4,35	4,35	4,4	4,35	2,90

1. *Etude pétrographique de ces échantillons*

Les roches prélevées sont de deux types:

— cinq des six échantillons (S3, S5, S7, S9 et W6) sont des basaltes à olivine dont l'analyse chimique et la norme confirment qu'il s'agit de basaltes alcalins (tableau I). Ces résultats sont semblables à ceux de GOLDSCHMIDT concernant des roches de la même région (Fig. 5).

— le sixième échantillon, W15, est une trachydolérite à chimisme plus acide.

2. *Géochimie du strontium*

On observe une grande dispersion des résultats, entre 0.7044 et 0.7104 (Fig. 6), non reliable à une variation analogue en potassium, rubidium ou

Fig. 4. *Vue prise vers l'Est sur la partie Sud du Scott Keltiefjellet, pointement basaltique le plus méridional de la rive Est du Woodfjorden.*

View, to the east, on the southern part of Scott Keltiefjellet, the southernmost basaltic outcrop of the eastern coast of Woodfjorden.

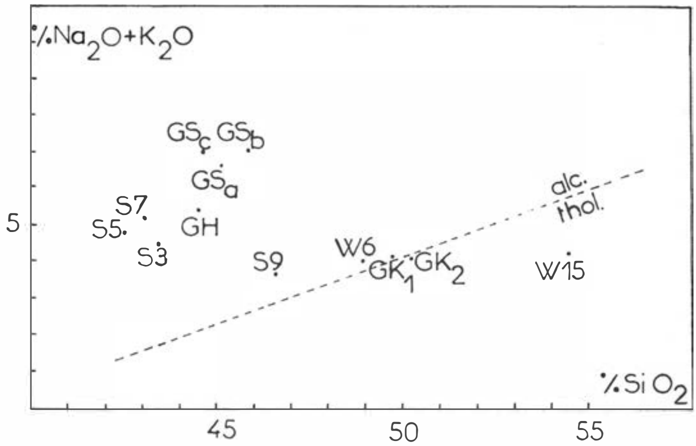

Fig. 5. *Diagramme alcali-silice des échantillons du Woodfjorden avec la séparation entre les champs alcalins et tholeiitiques (d'après les roches hawaïennes); on notera le caractère fortement alcalin de ce volcanisme. Echantillons analysés par* GOLDSCHMIDT*: GS_a, GS_b, GS_c: Sverrefjellet; GH: Halvdanpiggen; GK_1, GK_2: Kapp Auguste Viktoria.*

Alkali-silica diagram of samples from Woodfjorden, with separation between the alkali and tholeiitic fields (for Hawaiian rocks); note the alkalic character of this volcanism. Samples studied by GOLDSCHMIDT: GS_a, GS_b and GS_c: Sverrefjellet; GH: Halvdanpiggen; GK_1, GK_2: Kapp Auguste Viktoria.

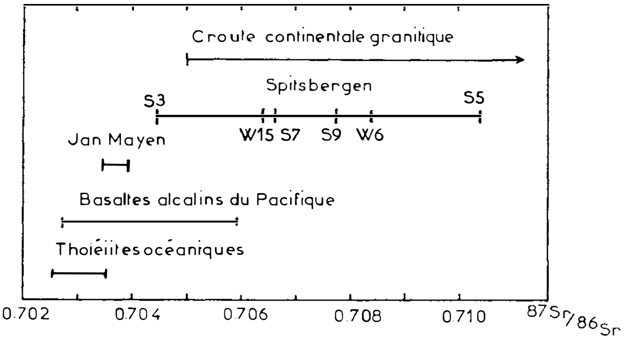

Fig. 6. *Valeur du rapport* $^{87}Sr/^{86}Sr$ *de quelques roches; Jan Mayen d'après* LUSSIAA BERDOU POLVÉ *et al.* (*1973*)*; basaltes alcalins du Pacifique, tholeiites océaniques d'après* HART (*1969*) *et* PETERMAN *et* HEDGE (*1970*).

$^{87}Sr/^{86}Sr$ values for some rocks; Jan Mayen after LUSSIAA BERDOU POLVÉ et al. (1973); alkali basalts from Pacific and oceanic tholeiites after HART (1969) and PETERMAN and HEDGE (1970).

strontium, ni à un paramètre quelconque de l'analyse chimique. Il faut donc exclure l'hypothèse d'une contamination crustale due à une assimilation du matériel mantellique, ce qui modifierait la composition chimique de celui-ci (enrichissement en éléments lithophiles). La faible distance entre les prélèvements excluant une trop grande différence quant à l'origine profonde de ces roches, il reste à faire intervenir l'hypothèse d'une contamination par déplacement du strontium 87 radiogénique seul — qui quitterait, sous l'effet de la température, les sites qu'il occupe dans les roches crustales traversées par un magma basaltique lors de sa montée.

Etude des filons cuprifères du Woodfjorden

Au cours de l'exploration de la division Kapp Kjeldsen, particulièrement riche en fossiles, nous avons rencontré, légèrement au nord de Halvdandalen un grand nombre de filonets de faible épaisseur (20 cm environ) qui recoupaient subverticalement la série, sans orientation préférentielle.

1. *Composition minéralogique des minéralisations sulfurées du Dévonien de Halvdandalen.*

Ces filons sont en général massifs. Nous avons cependant trouvé quelques géodes de calcite souvent transparente et bien cristallisée en rhomboèdres aplatis (forme équiaxe).

L'étude des minéralisations a été faite en sections polies (voir Fig. 7 et 8). Les minéraux opaques se présentent sous la forme de mouches millimétriques dispersées dans une gangue de quartz et de calcite. On y distingue:

a) de l'hématite en agrégats de lamelles (donnant ainsi un aspect de "gerbes" en section: Fig. 7), ou en cristaux dispersés dans le quartz,

b) divers sulfures de cuivre:

— la chalcocite (Cu_2S), dominante, parfois étroitement associée à de la digénite (Fig. 7),

— la covellite (CuS), soit en grandes plages indépendantes (Fig. 8), soit associée à la chalcocite,
— la bornite, en inclusions xénomorphes dans la chalcocite et la digénite (Fig. 7).

c) la malachite, principal minéral d'altération de ces sulfures, qui donne une couleur verte á la surface des filons.

2. *Aspect génétique*

Tous ces minéraux semblent appartenir à une même phase de dépôt, avec l'ordre de succession suivant:

a) dépôt initial de quartz, accompagné d'hématite en traces,

b) dans les géodes de quartz se déposent:
— de l'hématite
— de la bornite,
— de la chalcocite et de la digénite, qui remplacent la bornite,
— de la covellite en croissance indépendante, ou remplaçant la chalcocite et la digénite,

c) dépôt de calcite, essentiellement tardive.

Comme le contexte géologique semble indiquer un dépôt de basse température, il est possible d'utiliser les diagrammes d'équilibre de GARRELS. La paragénèse hématite — bornite — chalcocite — digénite — covellite indique ainsi un dépôt en milieu neutre à faiblement acide, faiblement réducteur.

3. *Etude minéralogique d'une azurite du Sigurdfjellet*

De nombreux échantillons d'azurite ont été récoltés par Y. CROCHET et Y. JÉHENNE à environ 1 km au Sud du Sigurdfjellet, en contrebas d'une coulée de basaltes alcalins à phénocristaux d'olivine. Il s'agit également de la formation Kapp Kjeldsen, comme dans le cas des filons sulfurés de Halvdandalen.

Cette azurite se présente sous forme massive, microcristalline, d'une très belle couleur bleu ciel. Le diagramme de rayons X correspondant est très semblable à celui donné par le fichier A.S.T.M.

La couleur remarquable de l'azurite est due à la présence d'ions Cu^{2+}: un spectre de réflectivité diffuse (voir Fig. 9) montre une absorption importante vers 700 nm, ainsi qu'en dessous de 450 nm, ce qui est causé par des ions cuivriques en sites octaédriques. Dans le proche infra-rouge, on note de nombreuses bandes d'absorption dues aux ions carbonates (à 2,05 et 2,28 μ) et aux ions hydroxyles (à 1,5 et 2,36 μ), ainsi que l'ont noté HUNT et SALISBURY (1971). Cependant, les bandes d'absorption caractéristiques des carbonates sont anormalement faibles dans les hydroxycarbonates de cuivre tels la malachite ($CuCO_3$, $Cu(OH)_2$) et l'azurite ($2CuCO_3$, $Cu(OH)_2$).

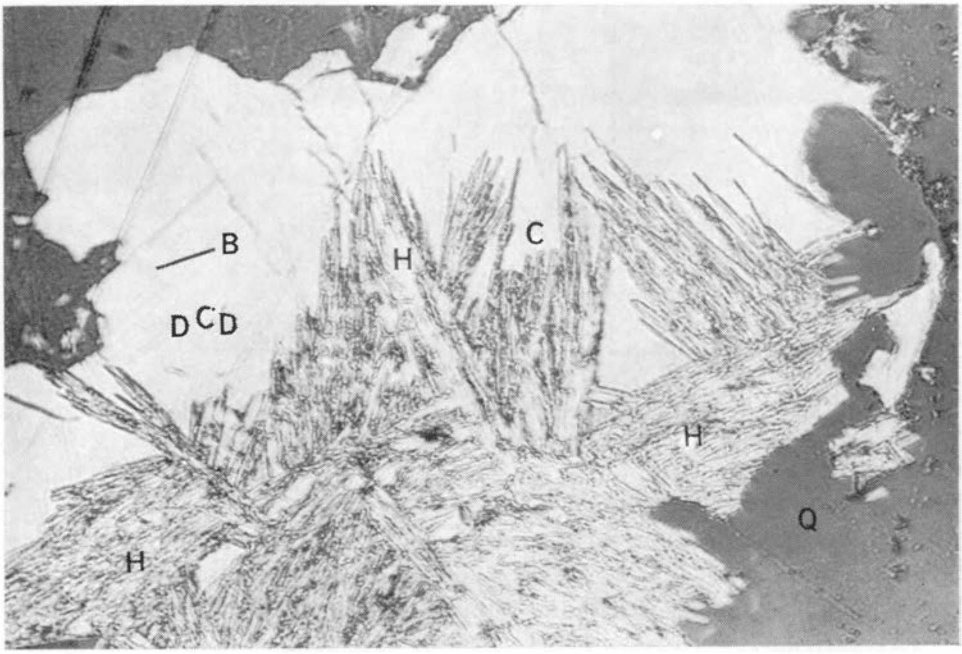

Fig. 7. *Section polie de minerai cuprifère de Halvdandalen: Hématite (H) en "gerbes" et association en lamelles parallèles de Chalcocite (C) et de Digénite (D), portant une inclusion xénomorphe de Bornite (B), × 200.*

Polished section of cupriferous minerals from Halvdandalen: "sheafed" Hematite (H) and association of parallel lamellas of Chalcocite (C) and Digenite (D) showing a xenomorphic inclusion of Bornite (B), ×200.

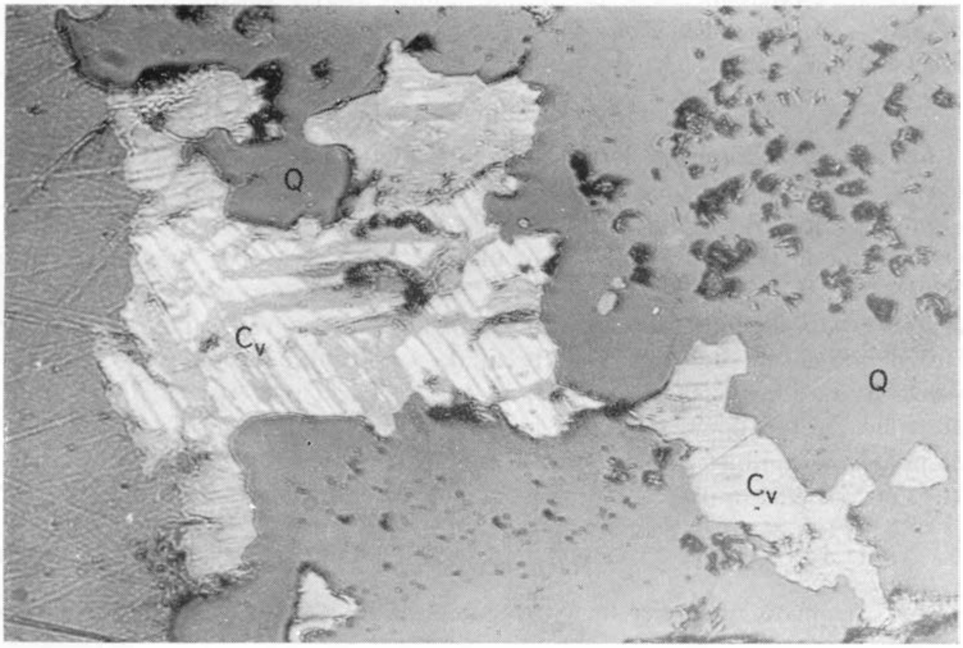

Fig. 8. *Section polie de Covellite (Cv) et Quartz (Q), × 200.*

Polished section of Covellite (Cv) and Quartz (Q), ×200.

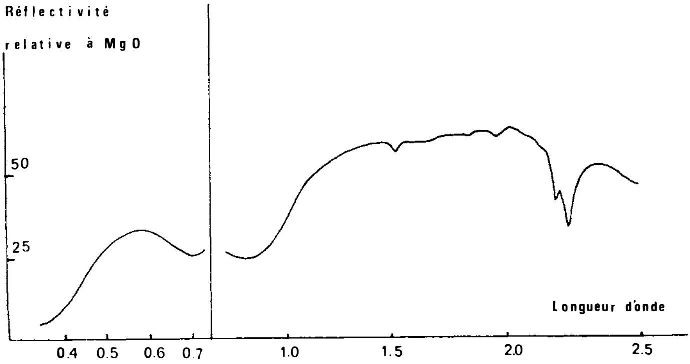

Fig. 9. *Spectre de réflectance diffuse d'azurite, pris par référence à MgO.*
Diffuse reflectance spectrum of azurite relatively to MgO.

4. *Comparaison avec les minéralisations connues dans le Spitsbergen*

Les minéralisations étudiées au Spitsbergen se rencontrent dans les formations Heckla Hoek et semblent être d'âge pré-dévonien, datant peut-être de la fin de l'orogénèse calédonienne (BIRKENMAJER et WOJCIECHOWSKI 1964; WOJCIECHOWSKI 1964; FLOOD 1969). De plus leur composition minéralogique est très différente: pyrite, chalcopyrite, galène et blende, dont les proportions relatives varient beaucoup entre les gisements.

La présence de filons sulfurés dans des terrains dévoniens constitue donc au Spitsbergen un fait original qui mérite d'être souligné. Il y a peut-être d'ailleurs une relation avec le volcanisme de la région nord-centrale de cette île, les deux phénomènes se produisant d'autre part à proximité d'une faille majeure qui sépare les Vieux Grès Rouges des terrains métamorphiques du Heckla Hoek.

Discussion

Les analyses chimiques des basaltes et trachy-dolérites des deux ensembles sont assez voisines (surtout celles des échantillons S9 et W6), mais il faut noter que les résultats des analyses des isotopes du strontium montre que les valeurs trouvées pour Halvdandalen sont comprises entre celles des échantillons du Sörlifjellet. Cette homogénéité des résultats est très intéressante et est à comparer aux données du paléomagnétisme, qui indiqueraient pour le neck de Halvdandalen un âge permo-carbonifère, très différent donc de celui des autres formations volcaniques de la région. Il serait par conséquent utile de posséder d'autres données géophysiques et géochimiques afin de voir combien de phases volcaniques se sont succédées dans le Woodfjorden, car les résultats que l'on possède, apparemment contradictoires, sont trop partiels.

Remerciements

Nous tenons à remercier les participants de la mission française au Spitsbergen dirigée par M. J. P. LEHMAN, qui ont permis à l'un d'entre nous (G.C.) de récolter les échantillons étudiés dans cet article.

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The age of Spitsbergen Dolerites

(From isotopic dating)

By Ju. P. Burov, A. A. Krasil'ščikov, L. V. Firsov, and B. A. Klubov

Abstract

New radiometric dates for Spitsbergen dolerites are presented. The data obtained are within the range of 198–93 m.y. There were two stages of the major intrusion corresponding to two age maximums of 144 ± 5 and 105 ± 5 m.y.

Basic magmatic activity was intense during the platform episode in the evolution of Svalbard. Dolerite sills and dykes are typical and widespread in the sedimentary sequence up to Upper Jurassic beds (Volgian stage).

Publications on Spitsbergen dolerites (Tyrrell and Sandford 1933, Burov and Livšic 1965, Firsov and Livšic 1967) and the geology of Svalbard usually speculate on the time of dolerite intrusion. Prior to recent studies, one group of investigators (Nathorst 1910, Tyrrell and Sandford 1933) suggested that the intrusions were Late Jurassic-Early Cretaceous in age, while another group (Burov and Livšic 1962, Orvin 1940, Harland 1961) dated them as Late Cretaceous or even Paleogene.

K-Ar dating of the dolerites (mainly from eastern Isfjorden) has been carried out recently both in our country and abroad (Gayer et al. 1966, Firsov and Livšic 1967). There is a significant discrepancy between the English and Soviet dates with an average difference of 30 m.y. even in samples of the same area.

Miller and Spall (Gayer et al. 1966, pp. 25–26) consider the dolerites in eastern Isfjorden to be Late Jurassic in age, 149–144 m.y., with alteration accounting for the differences between the five dates obtained. Firsov and Livšic consider the dolerites to be Middle Cretaceous (100 m.y.) with the fine variation in rock age "or some geological disturbance of K-Ar ratios" (Firsov and Livšic 1967, p. 183) accounting for differences in the determined ages.

This report deals with new age determinations of dolerites mainly from eastern Svalbard. The determinations were made in the Laboratory for Geochronology, Siberian Section of the U.S.S.R. Academy of Sciences, on material collected by the Spitsbergen Expedition of the Institute of the Geology of the Arctic in 1962–1964.

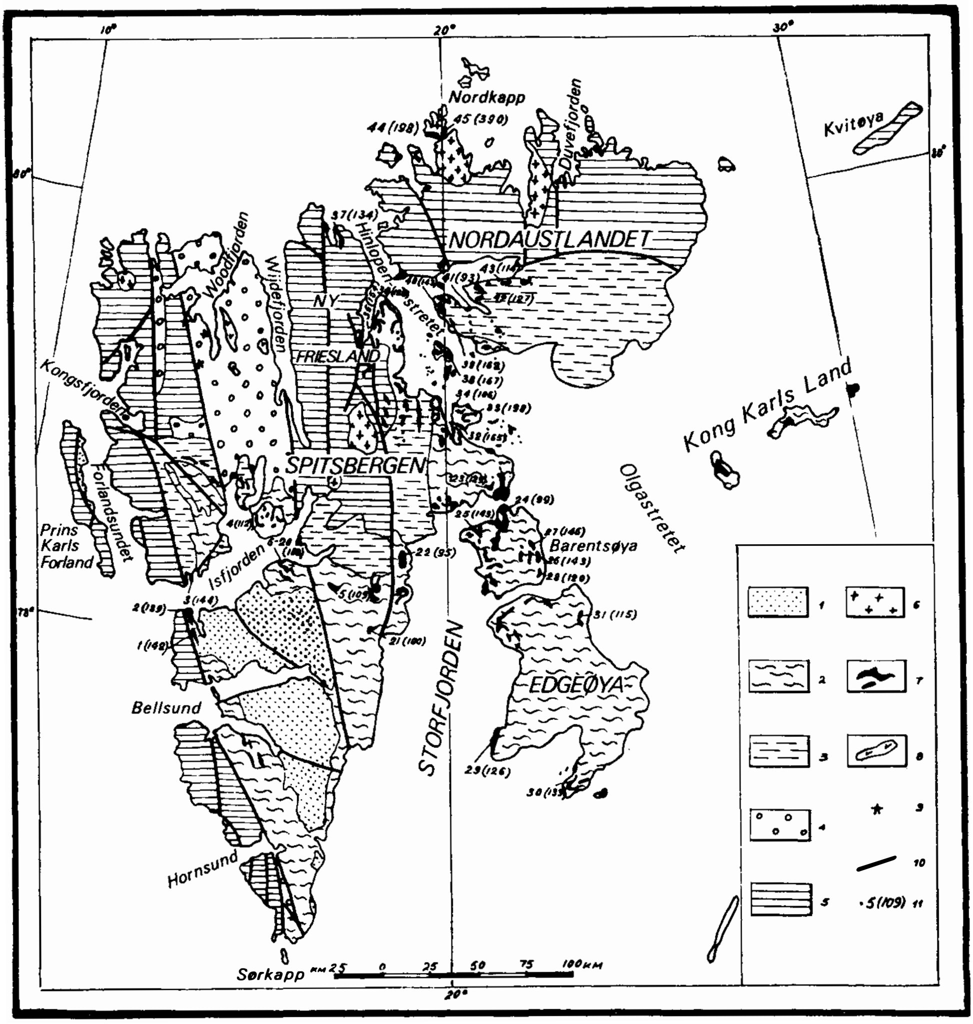

Fig. 1. *Sketch-map of dolerite intrusions in Spitsbergen (on geologic-tectonic base).*

Structural-formational complexes of the platform cover: 1. Paleogene complex; 2. Mesozoic complex; 3. Upper Paleozoic complex; 4. Devonian orogenic (postgeosynclinal) complex; 5. Caledonian and pre-Caledonian fold structures (Pre-Cambrian–Early-Paleozoic); 6. Caledonian granites; 7. Mesozoic dolerites; 8. (?) Late Mesozoic basalt flows; 9. Holocene volcanos; 10. Major faults; 11. Ordinal number of sample and its K-Ar date.

In the eastern part of the archipelago, generally being more tectonically stable, a large number of dolerite intrusions are exposed. No representative data on structural control of the igneous bodies is available, but it is noteworthy that swarms of dolerite intrusions are associated with junctions of major intersecting reactivated faults with submeridional and sublatitudinal trends.

The characteristics of the intrusions are often related to the country rock-type. Intrusions in Upper Palaeozoic carbonate deposits generally, have a steady strike, relatively planar contacts, and uniform thicknesses. Those in

Mesozoic clastic rocks sometimes diverge forming bodies with complex configurations and many apophyses. The total thicknesses of sills and dykes are 30 to 60 m and 10 to 15 m, respectively.

The most widespread rock type is a fine-grained ophitic quartz dolerite. Its mineral composition averages 45 to 50% plagioclase (AN50–80), 35 to 45% clinopyroxene (augite), 1 to 8% quartz and 4 to 10% opaque minerals (mainly ilmenite and titano-magnetite). Petrochemical differentiation of the intrustions is slight. Slightly differentiated intrusive bodies described from Barentsøya and eastern Isfjorden range petrologically from porphyritic olivine dolerites, with olivine content reaching 13%, to coarse-grained leucocratic gabbrodolerites. Fine-grained porphyries with non-crystalline glassy patches occur in the contact zones of the intrusions. Secondary alteration includes chlorite, iddingsite, carbonate and leucoxene, totalling 1 to 20%.

Determinations were made on 30 samples taken from localities shown in Fig. 1. K-Ar datings are given in Table 1 and plotted in Fig. 2 along with previous determinations (FIRSOV and LIVŠIC 1967).

The K-Ar dates range from 198 to 93 m.y.[1] The scattering of dates is due to both experimental (especially low K-Ar content) and geological factors. The dates are therefore of variable quality.

The oldest dates (390 to 198 m.y.) may be disregarded. The date 390 m.y. is from a sample (N3409) of the contact zone of a sill intruding Caledonian granites with K-Ar ages of 410 to 400 m.y. (KRASIL'ŠČIKOV, KRYLOV, and ALJAPYŠEV 1964). A sample (N 2863) from a similar geologic position is dated as 198 m.y. Both samples characterize the northernmost intrusions (Laponiahalvøya in Nordaustlandet), but petrologically they are similar to Mesozoic dolerites which occur elsewhere in Svalbard. The obviously exaggerated age may be due either to argon supplied by granites during dolerite emplacement, or a result of later tectonism.

Another sample (N 3398) from the upper sill on Wilhelmøya dated as 198 m.y., is also inconsistent with the true age. The sill occurs in fossiliferous Upper Jurassic strata and therefore must be from 150 to 135 m.y. in age. Two other sills in stratigraphically lower positions on Wilhelmøya are dated as 165 m.y. (sample N 3397, lower sill) and 106 m.y. (sample N 3399, middle sill).

The rest of the datings are relatively consistent with geological positions, allowing for the effects of alteration and experimental inaccuracies.

A comparison based on all available age determinations does not reveal any connection between dates and geological factors such as age and composition of country rock or the size, form and structural-petrological features of the intrusions. However, a relationship between geographical distribution and age is shown on the sketch-map (Fig. 1) and on the age-frequency distribution (Fig. 2).

Within Spitsbergen the samples were taken from three separate regions: western Isfjorden (NN 3376 to 3378), eastern Isfjorden (NN 3379 to 3380 and 2865 to 2879) and west side of Storfjorden (NN 3381 to 3382). In curve I

[1] Taking into consideration the dates obtained by L. V. FIRSOV and JU. JA. LIVŠIC (1967), the upper limit may reach 71 m.y.

Table 1

K-Ar dates of Spitsbergen dolerites

Ord N 1	Sample N 2	Geol. sp.N 3	Geographical sites 4	Stratigrafic age of country rock 5	Type of intrusions 6	Rock 7	Age (m.y.) 8
1	3377	8–1	*Isfjorden* Linnévatnet	C_3	Undifferentiated dyke	Quartzbearing dolerite	142
2	3376	1–12	Festningsodden	T_1	Undifferentiated sill	,,	139±8
3	3378	806	Selmaneset	T_1	,,	,,	146
4	3379	129–1	Kapp Tordsen	T	,,	,,	112
5	3380	143	Sassendalen Walenbergfjellet	P_2–T_1	Undifferentiated (?) sill	,,	109
6	2865	406–2,3	Sassenfjorden Grønsteinfjellet	T_3	,,	Leucocratic gabbro-dolerite	90±15
7	2869	406–4,5	,,	,,	,,	,,	71±15
8	2870	406–7,8	,,	,,	Slightly differentiated steep-dipping intrusion	Olivine dolerite	128±15
9	2876	407–10,11	,,	,,	,,	Leucocratic gabbro-dolerite	105±15
10	2877	407–15,16,18	,,	,,	,,	Olivine dolerite	85±15
11	2878	407–23	,,	,,	,,	,,	101±15
12	2874	1712–a,b	Lower De Geer dalen	T_3	Slightly differentiated sill	Fine-grained dolerite from inner contact	105±20
13	2871	1712–k,l	,,	,,	,,	,,	105±20
14	2875	1712–e,g	,,	,,	,,	Olivine dolerite	130±20
15	2868	403–i,o	Eastern side of De Geer dalen	T_3	,,	,, ,,	120±20
16	2872	1707–b	,,	,,	Slightly differentiated dyke	,,	99±20
17	2879	1707–d	,,	,,	,,	,,	105±20
18	2866	1707–e	,,	,,	,,	,,	112±30
19	2867	1707–g	,,	,,	,,	,,	89±20
20	2873	1706–r	,,	,,	Slightly differentiated sill	Olivine dolerite	111±30
21	3381	26	*Storfjorden* Agardhdalen Holmgardfjellet	J_3–K_1	Slightly differentiated sill	Olivine dolerite	100±4
22	3382	4	Wichebukta	T_3–J	,,	,,	95±2
23	3388	279–5	Ginevrabotnen Hellwaldfjellet	T_3	Undifferentiated sill	Quartzbearing dolerite	129

24	3389	299–2	*Barentsøya* Heleysundet	T_1	Slightly differentiated sill	Olivine dolerite	99
25	3390	371–1	Mistakodden	T_3	Undifferentiated sill	Quartzbearing dolerite	143
26	3391	18–82	Schweinfurtberget	,,	,,	,,	143
27	3392	50–1	Lomberget	,,	,,	,,	146
28	3393	75–1	*Edgeøya* Jeppeberget	,,		,,	120
29	3395	313–4	Kvalpynten	T_3	Undifferentiated (?) sill	Quartzitbearing dolerite	126±5
30	3396	28–2	Negerpynten	,,	Undifferentiated (?) dyke		133±2
31	3394	327–1	Kapp Heuglin	,,	Undifferentiated (?) sill	,,	115±5
32	3397	403–2	*Wilhelmøya*, southern coast	T_3	Undifferentiated sill	Quartzitbearing dolerite	165
33	3398	11–30	Tumlingfjellet	T_3	,,	,,	198
34	3399	412–1	northern coast	T_3	Undifferentiated (?) sill	Olivinebearing dolerite	106
35	3402	140–2	Lomfjorden, S.E. coast	C_3–P_1	Undifferentiated sill	Quartzbearing dolerite	154
36	3401	143–11	Lomfjorden, Kapp Fanshawe	C_3–P_1	Undifferentiated (?) sill	Olivine dolerite with micropegmatite	128
37	2864	15–2	Sorgfjorden, eastern coast	$PCam_3$	Undifferentiated sill	Quartzbearing dolerite	134±7
38	3400	155–1	*Nordaustlandet* Wahlbergøya	P_2–T_1	Undifferentiated sill	Quartzbearing dolerite	167
39	3403	92–3	Selanderneset	P_2	Undifferentiated dyke	,,	162
40	3404	331–1	,,	,,	Undifferentiated sill	,,	143
41	3405	76–1	Palanderbukta, Angelinberget	P_2	Slightly differentiated sill	Leucocratic gabbro-dolerite	93
42	3406	45–1	Zeipelodden	P_2–T_1	Undifferentiated sill	Quartzbearing dolerite	127
43	3407	33–2	Ismåsefjellet	P_2	,,	,,	114
44	2863	03–1	Depotodden	Caledonian granites	,,	,,	198±4
45	3409	138–1	Laponiahalvøya	,,	,,	,,	390

Samples NN 4,23–25,35–43 — Yu. P. Burov's coll., 1962; NN 2,26–34 — B. A. Klubov's coll, 1964; NN 1,44,45 — A. A. Krasil'ščicov's coll. 1962, 1964; NN3 ,22 — V. N. Sokolov's coll. 1963, 1965; NN 5,21 — A. I. Panov's coll. 1966; samples NN 6–20 — Firsov, Livsic, 1967.

these samples show a distinct peak at 105 m.y. A second peak at the right end of the curve is due to three samples dated 146 to 139 m.y. from western Isfjorden with tectonic conditions differing from those in central Spitsbergen. Excluding these samples, the average of 19 datings is 103 m.y. near the main peak.

Curve II based on 20 samples from eastern Svalbard (Edgeøya and Barentsøya, Hinlopenstretet area, Nordaustlandet), is more complex. In the age interval 167 to 93 m.y. it has three peaks at 165, 144 and 127 m.y. The average age for the 20 samples, 132 m.y., does not coincide with any peak. The average value from all 42 samples (120 m.y.) seems to lack any geological significance because of the wide date distribution. The combined distribution curve (Fig. 2, Curve III) has a distinctive peak at 144 m.y. resulting from the superposition of peaks.

The outlined pattern of the areal distribution of various dates becomes even more distinct when comparing slightly differentiated and undifferentiated intrusions. The great majority of "younger" ages in the interval from 70 to 130 m.y. belong to slightly differentiated intrusions, the "average age" from 19 samples being of 100 m.y. The ages of samples from undifferentiated intrusions lie in the interval 110 to 165 m.y. with maximum age and "average age" of 144 and 135 m.y., respectively. From the available sparse descriptions of samples studied by English geologists (GAYER et al. 1966), most samples were collected from undifferentiated intrusions, and this may account for the differences between English and Soviet results (FIRSOV and LIVŠIC 1967).

The data suggest that basic igneous activity occurred during a limited interval in the Mesozoic. Dolerite intrusion took place during most of the Jurrasic and half of the Lower Cretaceous. Following steady subsidence in the Triassic the Svalbard area began to emerge irregularly with total uplift in mid-Cretaceous time. The Jurrasic-Cretaceous sequence is relatively thin with a fragment of small and large-scale non-sequences.

The early dolerite intrusions known only in the Hinlopenstretet area were probably intruded at the Early-Middle Jurassic boundary.

The next intrusive phase was the most intense, and is dated at 144 ± 5 m.y. Dolerite bodies of this age are widespread in eastern Svalbard and include the intrusions in eastern Isfjorden. This date also coincides with the date peak obtained from undifferentiated intrusions.

A separate phase, corresponding to the peak at 127 m.y. is more difficult to explain. The samples have a random distribution and belong both to undifferentiated and to slightly differentiated intrusions. 127 m.y. may be considered as the beginning of basic magma differentiation, which lead to the slightly differentiated intrusions of the mid-Cretaceous.

Slightly differentiated intrusions are known from many localities on the archipelago, but only in central Spitsbergen does their volume exceed that of undifferentiated igneous bodies. It is therefore not surprising that the most probable age (100 ± 5 m.y.) of undifferentiated intrusions coincides with the maximum age and average age (103 m.y.) obtained on samples from this area.

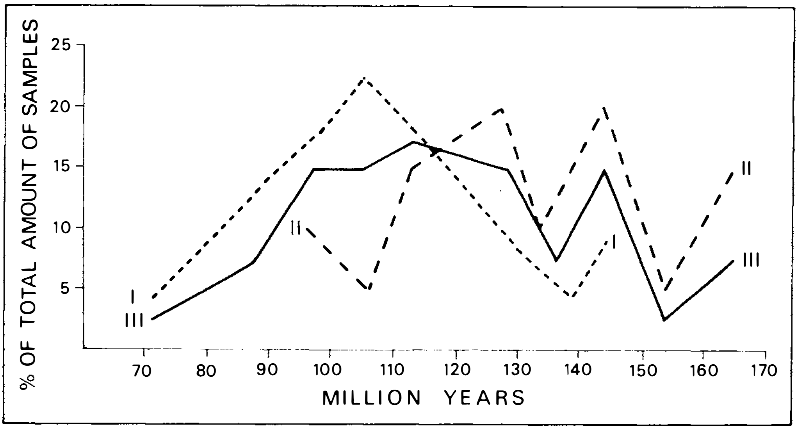

Fig. 2. *Plot of K-Ar date distribution for Spitsbergen dolerites: I. Curve for Spitsbergen; II. Curve for eastern Svalbard; III. Combined distribution curve.*

Thus, the intrusion of cratonic dolerites in Spitsbergen began at the Early-Middle Jurassic time boundary and was completed in the Upper half of the Cretaceous. The emplacement of most igneous bodies occurred in two phases with age maxima of 144±5 m.y. and 105±5 m.y. Undifferentiated bodies were intruded during the first phase while slightly differentiated intrusions were emplaced mainly in central Spitsbergen, during the second phase.

Basic igneous activity in Svalbard was not restricted to the emplacement of the Mesozoic dolerite.

Autometamorphozed gabbroic bodies are known to occur in Upper Pre-cambrian deposits along the western coast of Spitsbergen. Rocks of similar composition were recognized by KRASIL'ŠČIKOV on Storøya (near Nordaustlandet) in 1964 and K-Ar dated at 677±13 m.y. (sample N 3413).

In central Andrée Land in northern Spitsbergen olivine basalt flows rest on peneplained Devonian deposits. The recorded thickness of stratified basalts is 350 m. no overlying strata being exposed. The age of these Post-Devonian basalts is unknown because of their ill-defined geological position, and the absence of isotopic dates. They may represent an effusive phase of Mesozoic cratonic magmatism contemporaneous with dolerite intrusions and basalt extrusion in Franz Josef Land. However, it is more likely that they are younger, Late Cretaceous or even Paleogene, and associated with the modern trachy-basalt eruptions forming volcanos in northern Spitsbergen (Woodfjorden area). K-Ar dating of two basalt specimens from the Sverrefjellet volcano (samples NN 3383, 3384) shows values of less than 1 m.y. The dates are supported by study of marine terraces on the volcano flanks. SEMEVSKIJ calculated the age of formation of the volcano as 6.5 to 4 thousand years by comparing the terraces of the Sverrefjellet volcano with the equivalent terraces of Billefjorden dated by the radiocarbon method (SEMEVSKIJ 1965).

An important task for further investigation is to find a relationship between cratonic igneous activity and the tectonic history of Svalbard and the adjacent continental shelf.

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Nimbus-6 located automatic stations in the Svalbard waters in 1975

By TORGNY E. VINJE[1] and PER STEINBAKKE[2]

Contents

Abstract

A description is given of the experiment and results obtained with four Nimbus-6 located automatic stations in the Svalbard waters in 1975.

Introduction

Because of excess capability in the Random Access Measurement System (RAMS) on the Nimbus-6 satellite, guest investigators were invited by the U. S. National Aeronautics and Space Administration (NASA) to participate in experiments where the special positioning and data collecting system could be of particular advantage. The proposal, forwarded by Norsk Polarinstitutt (NP) and the Continental Shelf Institute (CSI), "Ice drift experiment in the Svalbard–Greenland area", was approved by NASA.

We got access to the first series of prototypes of Buoy Terminal Transmitters (BTT) built by the American Electronic Laboratories, and the necessary station numbers were allocated by NASA for the ice drift experiment.

Except for a test set financed by the CSI, expenditures have been divided on a 50–50% basis between the two Norwegian institutes involved.

[1] Norsk Polarinstitutt, Oslo.
[2] Continental Shelf Institute, Trondheim.

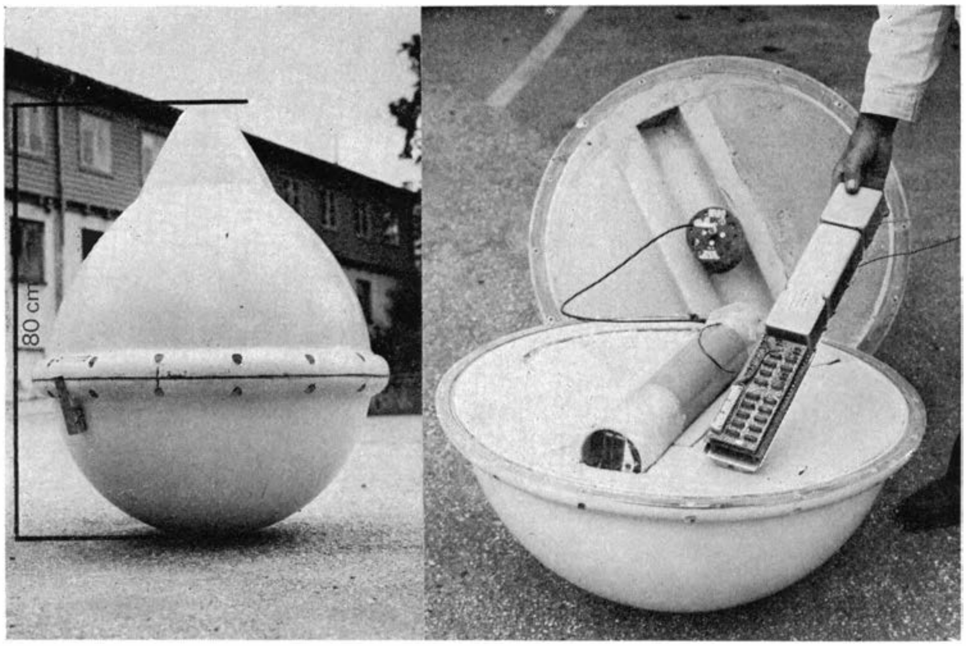

Fig. 1. *The buoy used in the ice drift experiment. Left: Shape and dimension. Note the magnetic switch. Right: The inside of the buoy showing antenna, transmitter, and battery package.*
Photo: CHR. MICHELSENS INSTITUTT

Design and mode of operation

The buoy should satisfy several demands. The hull should be strong enough to resist, and should also move upwards when exposed to severe pressure in the ice. It should be of such a construction that the very curious polar bear could do no harm, it should be easy to handle and small enough to pass through a narrow aircraft door. These demands resulted in the buoy shown in Fig. 1.

The transmitter, antenna, and batteries (lithium) are well insulated to avoid great temperature fluctuations. This is necessary to obtain a stable frequency during transmission. The weight of a station is about 55 kg.

When a station is activated, transmission takes place for one second every 62 seconds. When the Nimbus-6 passes within sight of the station, the signals are accepted with an allocated identification number. The data are recorded on tape in the satellite and tapped in the U. S. After computer processing the observations are sent from NASA to the users. We have received observations on a weekly basis both in line printer format and as punched cards. The most important parameter in the drift experiment is the position which in the NIMBUS-6/RAMS locating system is determined by the doppler-shift in frequency as the satellite passes by (see SISSALA 1975).

An automatic station can measure up to eight different parameters. For two of the stations the position only was observed, for the other two temperature at the bottom of the hull was observed as well. The inside temperature and the voltage of the battery package was measured successfully for only one of two stations.

The automatic stations were ordered from Chr. Michelsens Institute, which readily took up various kinds of challenges.

At very high latitudes the stations are seen by the satellite on every passage, in this case every 108th minute. The buoy is seen by the satellite for a maximum of 15 minutes per passage, and there will thus be a maximum of 14–15 transmissions received from a particular station per orbit. At least about five accepted transmissions seem to be necessary to obtain a position.

Positions are given with an accuracy of 5 km according to NASA. If, therefore, a station is placed on a certain place for a longer period of time, the position at this place may be estimated quite precisely. Station 0072 was blown on shore relatively soon after deployment and was found at the Nimbus-determined position after some time. Station 0044 also ended up on a beach in the northern part of the archipelago and was retrieved a year later at the estimated position. The position of Ny-Ålesund is determined with the aid of a geoceiver using the geodetic satellites. The Nimbus-determined position deviates from this position with 370 m for latitude and 111 m for longitude. The latter position is based on 84 so-called "two-pass position" determinations where observations have been omitted when temperature variations in the station have been critical for a stable frequency during the transmission. As much as 90% of the Nimbus positions are located within a distance of 1 km from the average position, the maximum deviation being 2.6 km. As the geoceiver-determined position is supposed to be correct, we may say that the maximum deviation for one Nimbus "two-pass position" is 3 km at Ny-Ålesund. This is well within the upper limit of position error which according to NASA is 5 km.

Deployment

The automatic stations had to be tested in the laboratory as well as in the field before deployment. The test set used here was built under a contract with NTNFR (Space Activity Division of the Royal Norwegian Council for Scientific and Industrial Research) by the Norwegian firm Eidsvoll Electronics, based on both American and Norwegian components. On a display the identification number as well as the figures of the other eight channels could be read. It was thus easy to check the function of the various stations.

Deployment was made by Norsk Polarinstitutt from an expedition ship at the end of July 1975. Originally the launching of Nimbus-6 was assumed to take place in 1974 and we had therefore planned to deploy the stations in April 1975 from a small airplane landing on the sea ice. The launching was, however, postponed until June 1975, and because of the partly melted or soft sea ice surface at that time, deployment of the stations had to be made from boat. Fig. 2 shows station 0072 on the ice.

Fig. 2. *The buoy on the ice at 80.5°N and 7°E.*
Photo: K. Z. LUNDQUIST

Observations

General

Fig. 3 shows the drift of the four buoys. Because of the novelty of this kind of experiment, a short description will be given of the drift of each station.

Station 0044 was deployed on 19 July at about 80.5°N and 7°E. It fell in the water within a week because of west southwesterly winds. Later it had a very complicated drift over large areas in open sea. It reached as far east as to 27° and as far north as to 81.9°. On 21 September it ended up in a deep fiord in a northerly gale. It was beset there for more than one month. The ice broke up on 31 October and the station was transported northwards. Transmissions disappeared on 5 December after having indicated a certain position in the northernmost area of the Svalbard archipelago. The area was visited in April 1976 but was at the time covered by hummocks and heavily screwed ice and a search for the station was fruitless. During a revisit in July, the station was found on the beach. Tests of the BTT show that the station is still in order.

All stations were built for an operation period of three months. Station 0044 was active for 139 days.

Station 0072 was equipped with one temperature sensor at the bottom of the hull and another one inside, in the centre of the capsule. The voltage of the battery package was also measured. This station, deployed on 19 July in the same area as 0044, was also affected by the disintegration of the ice and fell in the sea after a few days. Very interesting sea temperature observations were made when it passed from polar water through Atlantic water northwest of the islands. The station was blown on shore on 7 August and was squeezed

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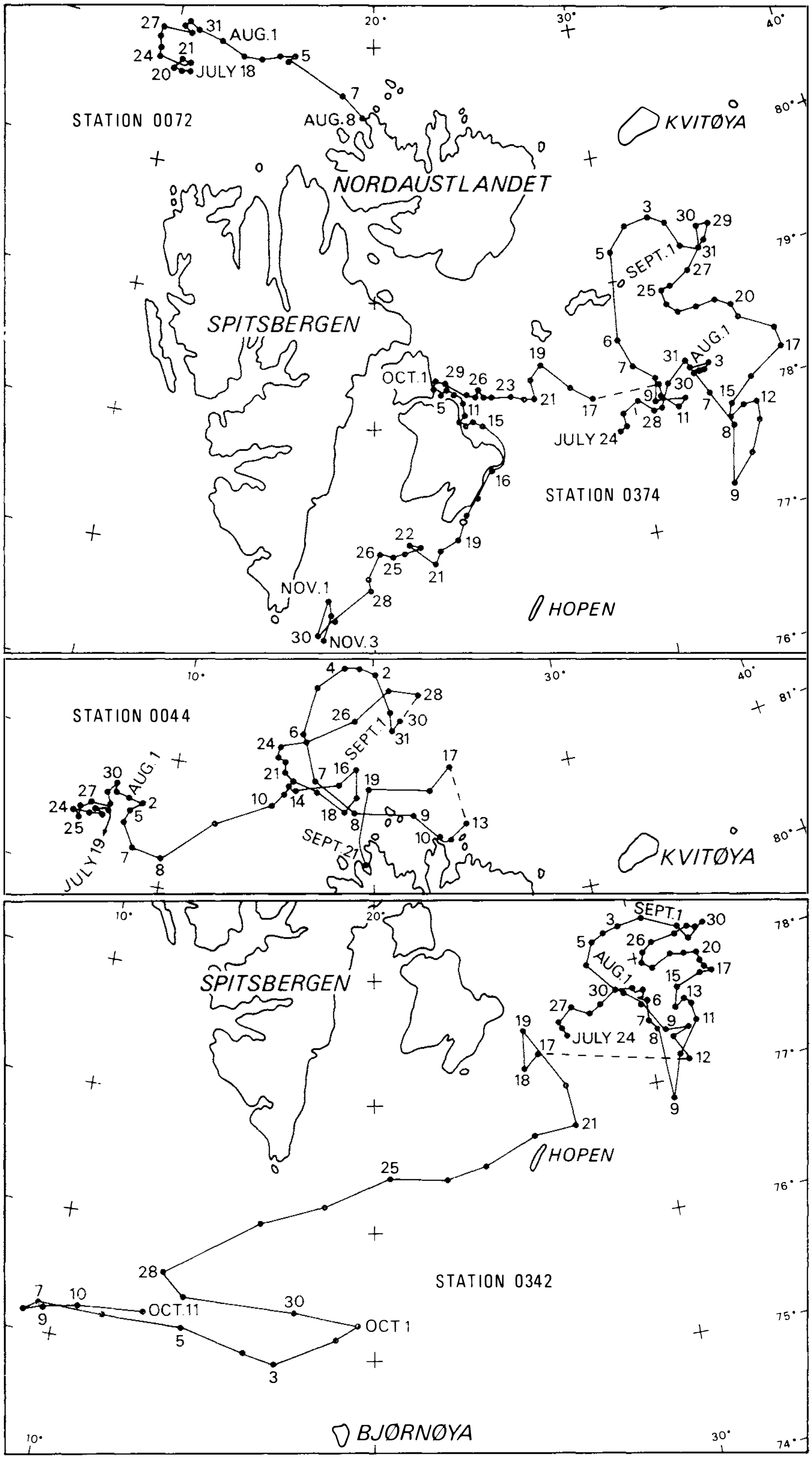
Fig. 3. *Drift of the stations. Each dot represents observation closest to noon. Dates are given at some of the points.*


STATION 0072
NORDAUSTLANDET
KVITØYA
SPITSBERGEN
STATION 0374
HOPEN
JULY 18
AUG.1
AUG.8
SEPT.1
AUG.1
JULY 24
OCT.1
NOV.1
NOV.3
STATION 0044
SEPT.1
AUG.1
JULY 19
SEPT.21
KVITØYA
SPITSBERGEN
SEPT.1
AUG.1
JULY 24
HOPEN
STATION 0342
OCT.11
OCT 1
BJØRNØYA

underneath the icefoot. The transmission was not interrupted, however, and later on, a boat in the area picked it up at the satellite determined position. The station was transported to Ny-Ålesund where it was used in further experiments and tests of the sensors. This station was active for a period of 133 days.

Station 0342 (position only) was deployed on 24 July. It circulated in the eastern part of the Svalbard archipelago for more than a month in partly ice-covered waters. In the middle of September it was blown west-south-westwards into open water. It was active for 81 days.

Station 0374 was equipped with a temperature sensor at the bottom. It gave very interesting temperature observations, which also indicated whether the capsule was on ice or not. The station circulated in the eastern part of the archipelago in partly ice-covered waters for about one and a half month. It was then driven westwards towards the islands and drifted southwards with the ice during October. This station was active for 102 days.

Fig. 3 indicates clearly that the drift of the buoy becomes markedly more affected by wind when passing into ice-free areas. Fig. 4 shows the wind observed at Hopen and Bjørnøya when the buoy drifted in ice-free waters relatively near these meteorological stations. A fair accordance between drift of the buoy and wind speed and direction is noticed. This suggests that wind information may be obtained relatively regularly and inexpensively from drifting buoys of this type.

Ice drift observations

There is only sparse ice drift information from the two northern buoys (0044 and 0072). During the first week, from 18 to 23 July, the buoys drifted so unsystematically that reliable drift figures cannot be calculated. This observation in itself, however, is of great interest both as a piece of information about the drift conditions which may be found in this area, and as valuable information for future experiments.

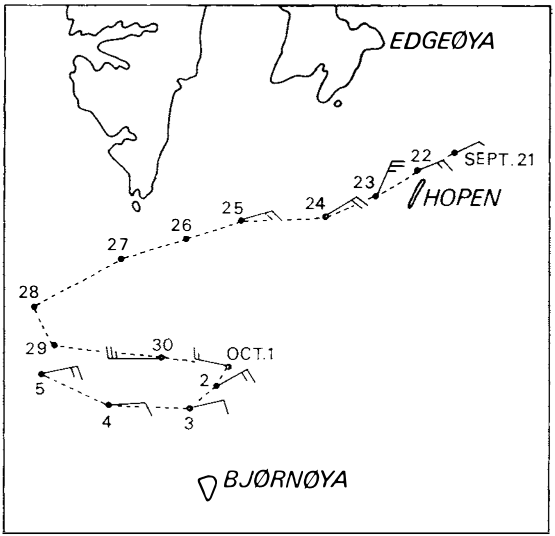


Fig. 4. *Drift of station 0342 in open sea plotted near noon positions near Hopen and Bjørnøya with observed wind at these two places.*

In the eastern part of the archipelago the stations 0342 and 0374 made relatively great circular movements until about mid-September. This corresponds with the fact that a relatively high concentration of drift ice was observed in the area during August and September this year (VINJE 1977). The circulation is seen to be anticlockwise. As this is the opposite direction of the sea currents in that area (*Atlas Murmanskoj Oblasti*), it is supposed that the circulation must have been wind-driven for the most part. A similar circulation is not observed north of Svalbard, which indicates different wind patterns for the two areas for the period in question.

From 25 July to 7 August the two buoys drifted east-north-east until 31 July and after that, south-south-eastwards. The average speed was 17 cm sec^{-1}. From deployment until mid-September the two stations are expected to have drifted in partly ice-covered areas, whereafter station 0342 was driven into open sea, while 0374 was beset off the coast. From the beginning of October to the 21st this station drifted southwards. The average speed was 12 cm sec^{-1} with a maximum 39 cm sec^{-1} between 15 and 18 October under conditions with moderate northerly winds. According to temperature registrations at the bottom of the hull the buoy was screwed up on ice and fell into water during this drift. This is evident from the temperature observations considered below.

Temperature observations

Fig. 5 gives observed temperatures. When the buoy is drifting in open sea the temperature is measured at depths not below about 35 cm.

The most striking contrast in sea temperatures was registered in the north when 0072 passed from the Trans-Polar Current with a minimum temperature of −1.9 °C into the Atlantic water masses of the Vest-Spitsbergen Current with a maximum temperature of +3.7 °C (see upper part of Fig. 5). This latter temperature is in fair accordance with other measurements. On 10 August, three days later, the sea surface temperature was thus measured to be 4.40 °C at 80°45′N and 15°55′E (Institute of Marine Research, Bergen). In addition, we know that the temperature sensor indicated 0.1–0.2 °C a few days earlier when the station was on melting ice. We note that the polar water shows a decrease in temperature when the Atlantic current is approached, and also that the maximum temperature in the latter current is found relatively close to the frontal zone.

As mentioned above, station 0072 was blown on shore on 7 August and squeezed underneath the icefoot. The temperature registered in this position may therefore be either that of air or water or a mixture of the two. Fig. 5 shows an average daily range of about 1 °C and a mean of about 3 °C for the period 7–30 August when the station was on shore. It is supposed that the daily range is caused by radiation influence.

The temperature registered by station 0374 indicates the existence of zones with marked temperature gradients also in this area. Such a front zone was passed on 16 August when the surface temperature dropped from +2.1 °C

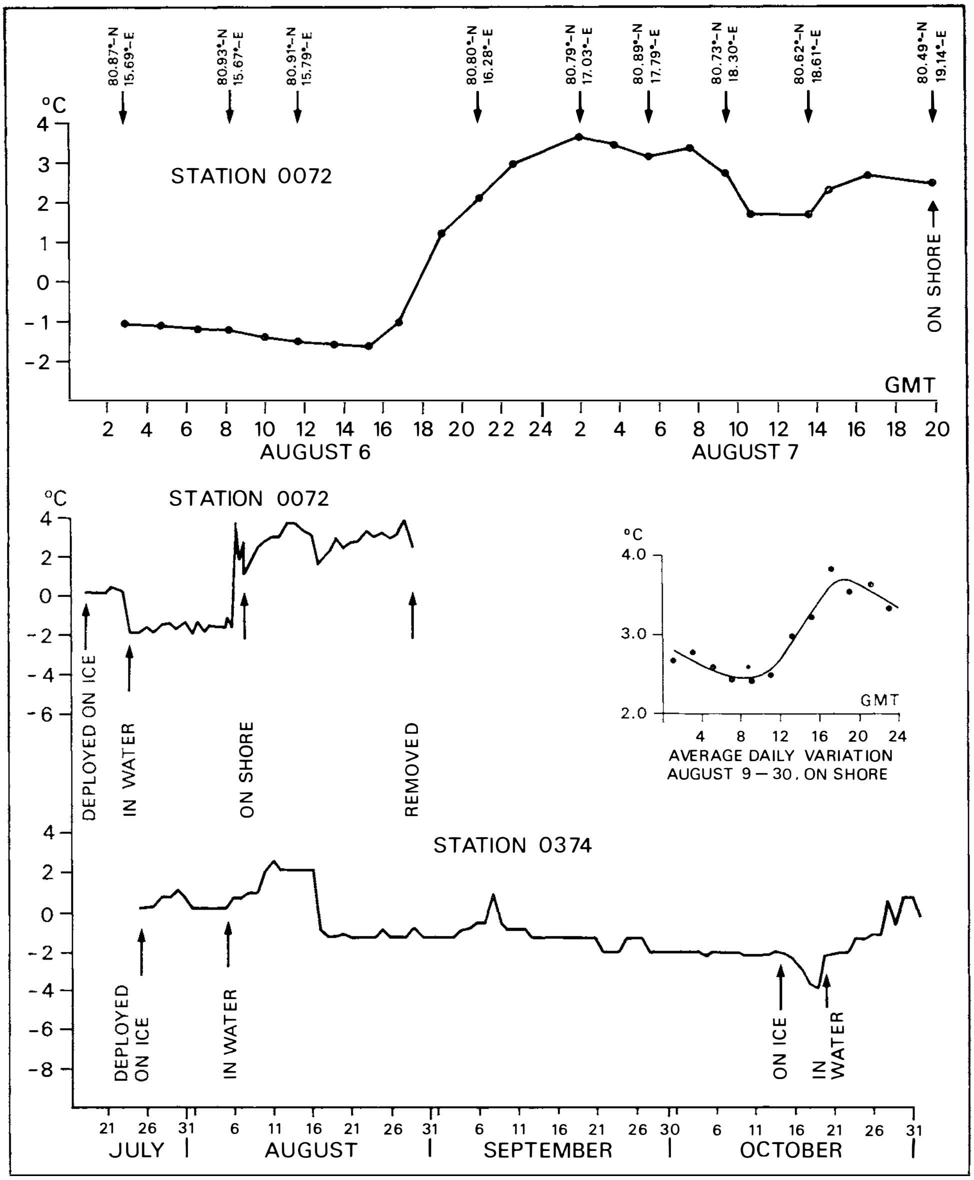


Fig. 5. *Temperature observations at the bottom of the hull for stations 0072 and 0374. Should be compared with Fig. 3.*

to −1.2 °C. Near Barentsøya and Edgeøya the sea temperature was registered at —2 °C to —2.1 °C during the freezing period. This is presumably too low. The present temperature observations may be considered correct to the nearest one or two tenths of one degree C only.

Housekeeping data

The stations were equipped with lithium organic electrolyte batteries. Fig. 6 shows the change in voltage during the period of operation. The general

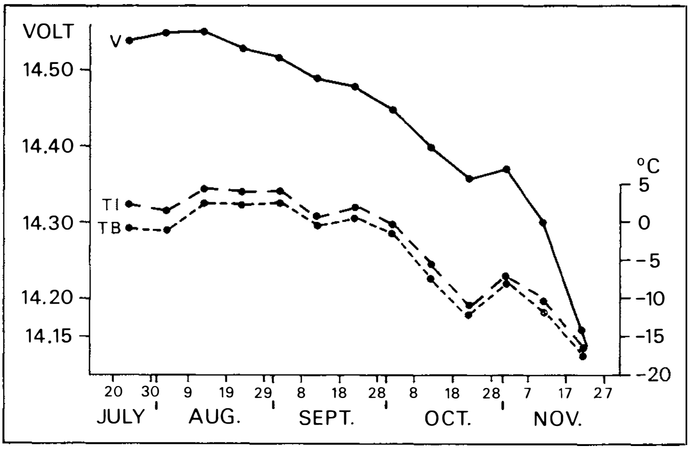


Fig. 6. *Housekeeping data for station 0072.*

abatement is to some extent due to a general fall in temperature which may be seen from the figure. At the end of the operation period the station was taken indoor for a while. The temperature increased from −18 °C to 14 °C, while the voltage increased from about 14.1 to 14.4 volts. This shows a decrease in voltage of about 0.01 volts per decreasing degree C. Fig. 6 shows that the effect of the insulation, averagely about 3 °C in the beginning, decreases somewhat during the period.

Concluding remarks

The experiment shows that both the positioning and the data collecting systems of Nimbus-6 are very reliable. It has opened up the possibilities for ice drift measurements and for data collection from remote and unaccessible areas. The prototype station used in this experiment seems to give reliable information from ice covered areas where ridging and disintegration take place as well as from the open sea where the orientation of the antenna may be very variable. When in open sea, the drift of the station may give good indication of wind speeds and directions.

Acknowledgements

We are very much obliged to NASA for making it possible for us to perform this experiment. The continuous flow of data has been impressive. Thanks are also extended to the Norwegian Meteorological Institute for its cooperation during the data processing.

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Barnacle Geese (*Branta leucopsis*) in the Arctic summer

– A reconnaissance trip to Svalbard –

By BARWOLT EBBINGE[1] and DOROTHEA EBBINGE-DALLMEIJER[1]

Contents

Abstract

Barnacle Geese (*Branta leucopsis*) were observed from late June until mid-August 1975 on Nordenskiöldkysten, a tundra area on the west coast of Spitsbergen, the main island of the Svalbard archipelago. Another party in the same area collected data on clutch size, and this combined with total counts of all families and other birds present in July and of the total number of nests occupied in the area, enables us to reconstruct breeding success and the composition of the July goose population. The 800 adult geese counted included 200 parents with young (mean family size 2.6 goslings), 160 failed breeders (45% of the clutches started were lost), and 440 non-breeders. Loss of goslings between hatching and departure from Svalbard was negligible. The egg phase is thus critical to reproductive success and invites further study.

Observations from a hide gave an impression of the daily time-budget of the geese both before and during the moult, and these data are compared with winter observations from the Netherlands. By moulting in the constant light of the far north the geese are able to detect predators in time to escape by swimming out to sea, and it is possible that the need to avoid the potentially dangerous dark periods is one of the factors causing northward moult migration in arctic geese.

[1] Biologisch Station "Schellingerland", Oosterend 71, Terschelling, Netherlands.

Introduction

After studying the daily routines of wintering Barnacle geese (*Branta leucopsis*) in the Netherlands (EBBINGE, CANTERS & DRENT 1975), we felt the need for studies in their arctic breeding and moulting grounds. In the future we hope to be able to measure the energy expenditure of the Barnacle goose throughout the year.

In summer 1975 we went to Spitsbergen, for a reconnaissance trip to Nordenskiöldkysten (78°N, 14°E). This is a coastal tundra area between Isfjorden and Bellsundet with sufficient rocks, skerries and small islands offshore to provide suitable nesting sites for Barnacle geese, Eider ducks (*Somateria mollissima*) and Glaucous gulls (*Larus hyperboreus*). In this area 15–20% of the total Barnacle goose population of Svalbard breeds and/or moults.

Methods

Data on clutch sizes were obtained from an American team (JOHN DITTAMI, SCOTT KENNEDY and CHARLIE THOMFORDE), studying the breeding biology of Barnacle geese on one of the islands offshore.

In cooperation with this group a careful count of the Barnacle goose population in the study area was carried out.

On 4 and 5 August all possible breeding islands along Nordenskiöldkysten were visited by boat together with AREND VAN DIJK and TOM VAN SPANJE, and all nests used by Barnacle geese this season were counted. By this time only a few Eider ducks were still breeding; the majority of the Eider ducks and all the geese had already left these islands, so we were sure not to cause any serious disturbance.

Though most nests had been abandoned about a month earlier, it was still feasible to distinguish between used and unused nests. All Barnacle goose nests were recognizable by a dike of droppings surrounding it, though in some cases there were fewer droppings surrounding the nest site, presumably indicating that this particular nest had been robbed and/or deserted before hatching.

Breeding success could be estimated by comparing the number of nests used to the number of successful families counted later, and by comparing the average clutch size before hatching with the mean brood size.

Survival of goslings, once hatched, was assessed by regular counting of the family sizes of at least ten families in a small area where 17 families raised their goslings.

Data on the daily time budget of flocks of Barnacle geese were collected by direct observation of the various activities performed. From a hide (1 m^3) placed near a pond we watched the geese by telescope (25 × 60). Every ten minutes we scored the activity of each goose in the group, covering the whole group several times until at least 100 scores were made. The following types of activity have been discerned: feeding, drinking, being alert, walking (without feeding or without apparently being alert), swimming (alert or not), flying, body care (preening, wing flapping, etc.), sleeping (legs covered, head mostly on back, but sometimes only with shortened neck) and social interactions (mostly one goose chasing the other).

At the end of June the activity was scored of a small flock of non-breeding birds that were not yet moulting.

In July, after hatching and when the adult birds had started to moult, the geese were very wary and immediately fled into a nearby pond as soon as a human being approached within a distance of 1 to 2 kilometres. When coming nearer than about 500 metres to such a flock swimming in a pond, they would leave the pond and run at a high speed to another pond or even more likely to the sea, staying there until the danger had disappeared.

In order not to be troubled by this wariness of the geese, we placed the hide on top of a hill about 300 metres away from a pond, enabling us to sneak into the hide without being seen by the geese expected to be feeding around this particular pond.

In a ten-day period in mid-July we were able to collect data about the activity of a flock of moulting geese with goslings (covering 20 hours of observation, spread over the entire 24-hour period of light). As the moulting birds cannot fly, they stay — if not disturbed too much — continuously in the same area. Thus, without individually recognizable birds at our disposal, we were sure to study the same flock (there was always a family with six goslings in the flock) at different times of the day. This made it possible to get a reliable picture of their daily time budget while moulting their primaries.

Goose droppings and two vegetation samples were collected and dried above a stove. The dry weight of the former and calorific value of both were determined using a ballistic bomb calorimeter. The number of droppings produced daily by a Barnacle goose was estimated roughly by extrapolation of a few data collected on defaecation rate.

Goose usage of the vegetation was assessed by counting the number of droppings left by the geese at two transects, consisting of 10 and 13 inconspicuously marked plots of 2×2 m each, where all droppings were counted and removed regularly.

Weather

According to the crew of the weather station at Kapp Linné (Isfjord Radio), thaw was about two weeks later than normal. Most observations described in this paper were made in July, when air temperatures ranged from 0°C to +11°C with a daily mean of +4.9°C.

The weather was usually calm and the sky overcast. Very often there was a light drizzle — about six days a week — and one day a week on the average the sun was shining.

Observations on Barnacle Geese

1. Arrival

The first Barnacle geese were seen on 18 May by the crew of the Isfjord Radio station near Kapp Linné. On 24 May two members of this crew went south by snow scooter and saw about 100 Barnacle geese near Van Muydenbukta and another 70 in Berzeliusdalen on snow-free places, the remainder of the tundra area still being snow covered.

According to LØVENSKIOLD (BAUER and GLUTZ VON BLOTZHEIM 1968) the Barnacle geese usually arrive in Svalbard during the last ten days of May. Although the season was late in Svalbard in 1975, the Barnacles arrived on schedule.

2. Breeding

In 1974 AREND VAN DIJK and TOM VAN SPANJE (pers. comm.) observed the first Barnacle egg hatch on 28 June on a small island off Nordenskiöldkysten. In 1975 hatching on this island did not occur until 5 July (DITTAMI et al. 1975). Apparently the breeding season had been delayed by the late thaw. In 1964 the spring was also unusually cold and this resulted in hatching between 4 and 11 July (NORDERHAUG, OGILVIE and TAYLOR 1965).

On the island already referred to, clutch sizes were determined at the end of the incubation period in 1974 (AREND VAN DIJK and TOM VAN SPANJE (pers. comm.)) and in 1975 (DITTAMI et al. 1975) (Table 1).

In 1975 the mean clutch size was smaller (almost significantly so, two-tailed t-test, $p<0.10$) than in 1974 on the same breeding island. That clutch size is smaller when thaw is late is a phenomenon already documented in the light-bellied Brent goose (*Branta bernicla hrota*) by BARRY (1962) and in Ross's goose (*Anser rossii*) by RYDER (1972). Geese are considered to be determinate layers, which means that at the start of laying the number of follicles stimulated by gonadotrophic hormones is definitively fixed, and equals the number of eggs laid (KLOMP 1970). In the Brent goose BARRY (1962) found that the later spring comes, the more follicles become atretic. By this "internal loss of eggs" clutch size becomes smaller, and when spring is very late no eggs are laid at all. As incubation in geese starts after the clutch has been completed, this phenomenon enables the geese to shorten the time of egg laying, by laying fewer eggs in years with late springs: a very useful adaptation to the short arctic summer.

3. Breeding success

A survey of all possible breeding islands along Nordenskiöldkysten (from Akselsundet up to Kapp Linné) on 4 and 5 August yielded a total of 182 Barnacle goose nests used in 1975 on five different islands (Table 2).

In July, when no adult Barnacle goose could fly, because they were all moulting, a careful count in the whole Nordenskiöldkyst-area yielded 800 adult Barnacles (adult $\geq$ 1 year old), including 100 successful families (parents with at least one gosling). This means that in 1975 only 55% (100: 182) of the breeding pairs were successful. As 1972 and 1973 both had good breeding seasons (CAMPBELL 1974), and as Barnacle geese start to breed when two or three years old, a high proportion of the breeding birds in 1975 must have been inexperienced. This may have contributed to this rather low breeding success.

Table 1
Mean clutch-size of Barnacle geese ($\pm$ 95% *conf. interv.*)

First egg hatched	Mean clutch-size	n	Year	
?	4.3 ± 0.52	16	?	NYHOLM 1965
				LØVENSKIOLD 1963
28 June	4.1 ± 0.52	19	1974	VAN DIJK and VAN SPANJE
6 July	3.3 ± 0.36	12	1975	DITTAMI c.s.

Table 2
Number of used nests on five breeding islands

No.	Barnacle geese	Eider duck	Glaucous gull
1	66	219	30
2	54	253	22
3	24	107	19
4	33	211	6
5	5	> 80	3
	—— +	—— +	—— +
	182	±900	80

Table 3
Brood size of Barnacle geese in Svalbard

Year	Hatching period	Brood size	
1964	4–11 July	2.6 (n = 59)	NORDERHAUG, OGILVIE, TAYLOR
1973	10–15 July	2.4 (n = 57)	JACKSON, OGILVIE, OWEN
1975	6–12 July	2.7 (n = 58)	this paper

On 20 July — one to two weeks after hatching — the mean brood size of 58 families on the tundra was 2.7 goslings. As neither the American team nor we observed any predation on goslings, not even when they left the breeding islands for the tundra, this figure may represent the average number of eggs hatched. Since mean clutch size was 3.3, this means that successful breeders had a hatching success of: $\frac{2.7}{3.3} = 82\%$.

In the Ross's goose RYDER (1972) gathered similar data in a rather late season with a large proportion of inexperienced breeders: in 67.6% of all the nests at least one egg hatched, and in these successful nests 86.1% of the eggs hatched.

In the Barnacle goose similar brood sizes were found by earlier research teams in Svalbard (Table 3).

4. Survival of the goslings

Regular counts near Kapp Martin where a maximum of 17 successful families raised their goslings, showed that the mean brood size remained virtually constant (Fig. 1), at least up to an age of five weeks. Brood sizes were determined three times covering a larger area (including Kapp Martin) (Figs. 1 and 2). Here too brood size proved to be virtually constant.

There is a difficulty in the interpretation of the brood-size data. Since the birds were not marked, there is a possibility that disappearance of whole broods might distort the results: on subsequent counts the parents would no longer be distinguished as such. However, total counts of the Kapp Martin population on five occasions show a stable proportion of adults accompanied by young and hence identified as parents, with approximately equal numbers of adults in the area throughout (see Fig. 1). This confirms that once hatched, gosling mortality was negligible.

From the average brood size from Fig. 2 (2.6), and knowing the total number of successful families in the area (100), we calculated that the fraction of juvenile birds along Nordenskiöldkysten was 25% $(\frac{260}{800+260})$. As ringing results show that the complete Barnacle goose population from Svalbard winters in Caerlaverock, Scotland (NORDERHAUG et al. 1965, JACKSON et al. 1974) its numbers are easily monitored by regular counts in this particular area.

Thus knowing the population size in 1974 and the normal annual mortality rate for adult Barnacles, and assuming that this Nordenskiöldkysten-population is representative for the whole Svalbard population, MYRFYN OWEN expected from this figure (25%) the total population to increase to 6,000 individuals. In fact, COLIN CAMPBELL counted in the autumn of 1975 in Caerlaverock 6,050 Barnacle geese. This suggests that even until reaching the wintering grounds mortality of goslings is negligible.

5. *Non-breeders*

The vegetation on the tundra itself is scanty. Around many small ponds on the tundra there is a narrow fringe of a richer grassy and mossy vegetation, but even this vegetation is very poor compared to the heavily fertilized grasslands frequented by Barnacle geese in the Netherlands. At the end of June, while the breeding birds were still on the islands offshore, small flocks of adult and subadult non-breeding Barnacle geese were seen feeding on the vegetation zone surrounding these ponds and pools. These birds were not yet moulting and flew across the tundra visiting several of the ponds as well as the offshore breeding islands.

In Table 4 the result of observations of these non-breeders are shown. They are based on five hours of observation of a flock varying in number from 15 to 29 individuals.

6. *Moulting*

Just after hatching, all families leave the breeding islands to feed on vegetation near the tundra ponds. Although most parents are still capable of flying in the first week after hatching, they do not fly, but walk and swim with their

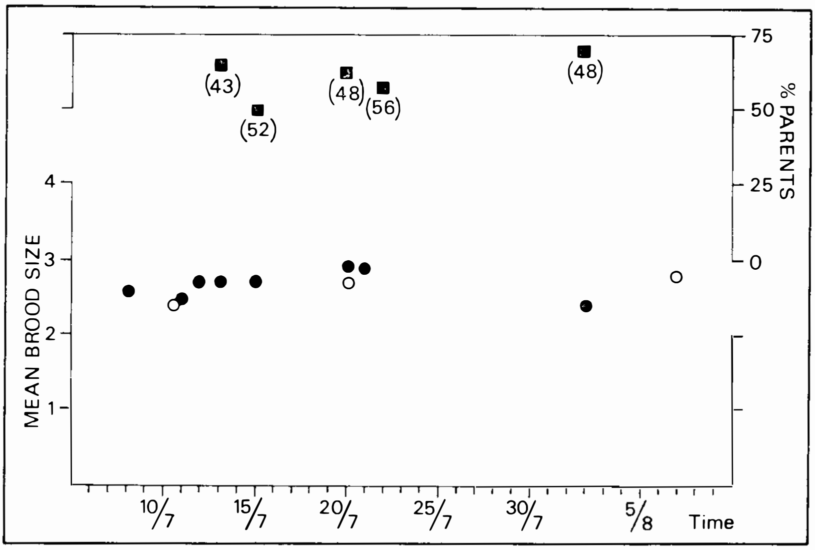

Fig. 1. *Mean brood size of Barnacle geese at Kapp Martin ($n \geq 10$; closed circles), and covering a larger area (open circles) in the course of time. Data from the three extensive surveys are given in full in Fig. 2. For the Kapp Martin counts with most complete coverage the percentage of adult geese classified as parents is also given (closed squares), with the total number of adults in the area in brackets.*

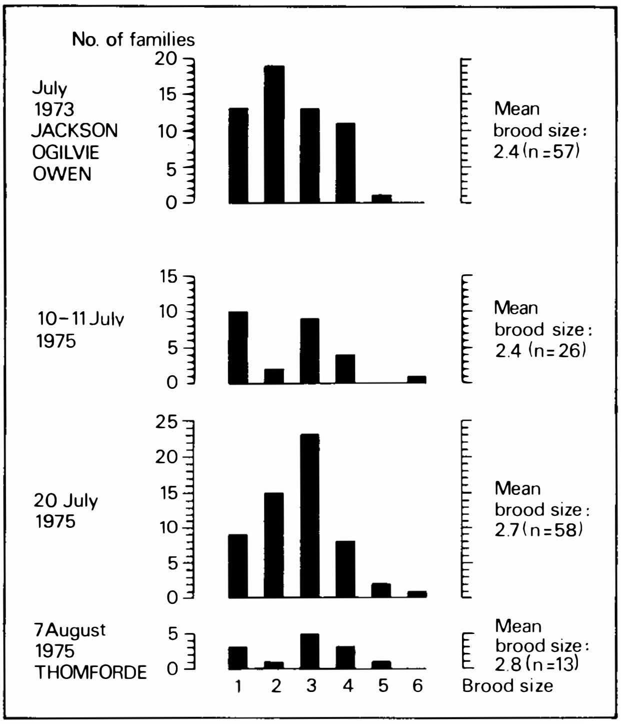

Fig. 2. *Frequency distribution of brood size in the Barnacle goose in Svalbard.*

Table 4
Time budget of non-breeding Barnacle geese before moulting

Per cent of time devoted to:								
feeding	drinking	alert	walking	swimming	flying	body care	sleep	soc. interactions
68	0.1	10	7	4	1	4	5	0.3

goslings. The characteristic barking sound of the Barnacle geese is only rarely heard in this period and during the next four to five weeks when the adult birds moult their primaries and as a consequence cannot fly at all. It was not until the second week of August that we again heard the Barnacles calling out aloud, as they flew across the tundra.

During the moulting period mixed flocks of non- or unsuccessful breeders and successful breeders with their goslings could be met with. The size of these flocks varied from 18 to 173 individuals, with a mean of 56 (n = 10).

In Figure 3 the mean % of feeding and sleeping adults is given for each 30 minutes in the course of the day. No clear cut daily rhythm is discernable in this figure, in agreement with our general impression that the birds regularly stopped feeding for short sleeping periods varying from 30 to 60 minutes.

In social birds like these geese a certain behaviour once started by one or a few individuals is very soon copied by the whole flock, hence the whole flock was often sleeping for some time. While active, much time is spent being alert, walking and swimming, and this is why the maximum level of feeding never rose above 60% in the adults. In the goslings this level was often 90%.

7. *Daily time budget*

From the average percentage of a certain activity in the group we calculated the number of hours per day an average adult Barnacle goose devotes to the different types of behaviour as listed in Table 5. In Fig. 4 this daily time

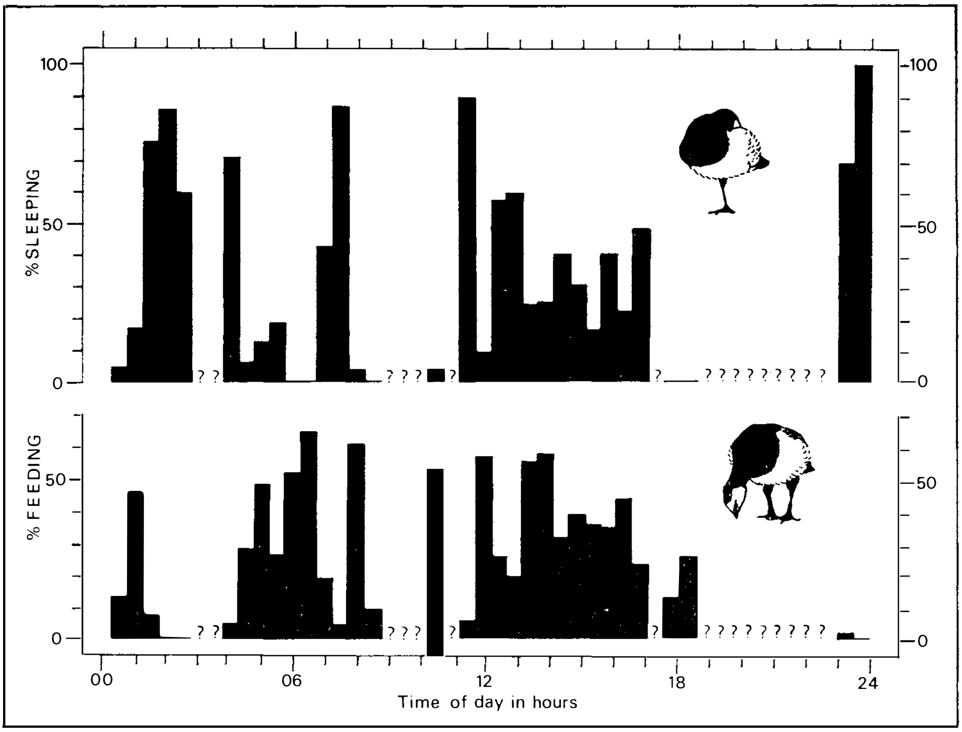

Fig. 3. *Daily rhythm of moulting adult Barnacle geese. ? = no observations.*

Table 5

Daily time budget of moulting adult Barnacle geese

Date	13–7	14–7	15–7	15–7	20–7	21–7	21/22–7	Mean
Time	4.05–8.35	10.30–11.30	10.35–14.10	14.10–18.30	10.40–12.20	22.20–23.00	23.05–2.45	
Number of activity counts	27	9	19	23	14	5	22	119
Per cent of time devoted to:								
Feeding	33	44	38	29	45	49	12	36
Drinking	0.1	0.2	0	0.1	0.1	1	0.1	0.2
Alert	19	15	14	15	14	12	25	16
Walking	7	3	2	3	4	4	2	4
Swimming	9	14	1	19	5	31	5	12
Body care	5	12	8	6	10	3	5	7
Sleeping	24	12	37	25	21	1	50	24
Soc. interactions	0.2	0.2	0.4	0.5	0.2	1	0	0.2
Number of non-parents	15	23	19	26	22	41	15	
Number of parents	28		10	26				
Number of goslings	36	16	> 15	> 32	+	+	+	

budget is compared to the daily time budget of wintering Barnacle geese in the Netherlands (Ebbinge, Canters and Drent 1975). While wintering, these Barnacle geese spend most of the light period on the feeding grounds — cultivated grasslands — and during this time of the day we could assess the activity of a group by scoring the activity of a random sample of 100–200 birds out of a flock varying in size from 200–4000 Barnacle geese.

The night-time is spent on the tidal mudflats and as no food is taken here we presume that nearly all of that time is spent sleeping, although some of the time spent here will be devoted to body care, swimming and social interactions. During the light phase of the moon a complete reversal of this daily rhythm often occurs, but the daily time budget in winter, as presented in Fig. 4 is based entirely on observations made during the dark phase of the moon.

During one session of 4½ hours on 13 July, we scored the activity of non-parents, parents and goslings separately. On 14 July, gosling activity was

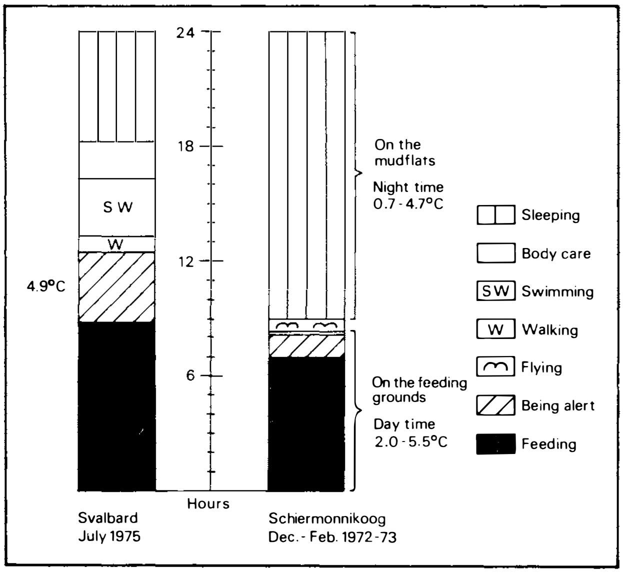

Fig. 4. *Daily time budget of fully grown Barnacle geese during summer moult and in winter.*

Table 6

Daily time budgets of non-parents, parents and goslings

	Per cent of time devoted to:							
	feeding	drinking	alert	walking	swimming	body care	sleep	soc. interactions
Non-parents (13/7)	39	0.3	14	13	17	7	10	0.2
Parents (13/7)	37	0.1	20	6	9	4	24	0.5
Goslings (13/7)	48	—	1	7	8	2	33	0.1
Goslings (14/7)	51	—	2	2	10	1	34	—

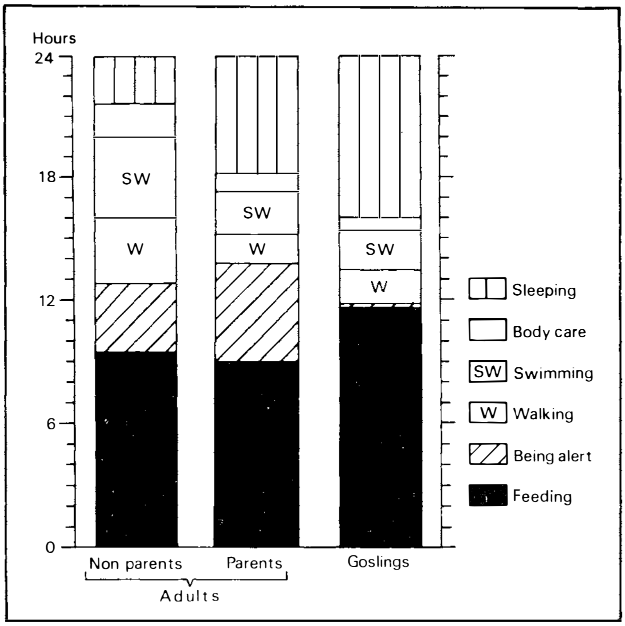

Fig. 5. *Average daily time budget of a flock of moulting Barnacle geese with goslings.*

once more scored (Table 6). The agreement between the mean time budget of the goslings on these two days is quite striking. The goslings spend 12 hours per day feeding and when not feeding clearly favour that type of behaviour in which the least amount of energy is lost: sleeping under mother's wing. They must follow their parents and from Table 6 and Fig. 5 it can be seen, as one would expect, that they spend the same amount of time walking and swimming as their parents do. As for the parents the average activity has been scored. The male however, spends much more time being alert than the female but less time sleeping and probably less time feeding, too. As the goslings always slept under the wings of a sleeping mother, it can be inferred that the female will spend at least as much time sleeping as the goslings (33%). Since the "average" parent devotes 24% of the time to sleeping, the male must in fact sleep less than 15% of his time.

In Fig. 5 the percentages from Table 6 are converted to hours per day. The most striking agreement between non-parents and parents is the amount of time spent feeding. But the former swim and walk much more, and spend less time sleeping and being alert.

8. Daily faecal output

Wintering Barnacle geese defecate at regular intervals of $3\frac{1}{2}$ minutes (OWEN 1975; EBBINGE, CANTERS and DRENT 1975), thus producing 160 droppings/24 hours.

During one of our sessions on Spitsbergen a flock of 43 adult Barnacle geese with goslings rested for about an hour and left soon after this resting period for another pond nearby. We were thus enabled to visit this place without disturbing the geese. As we observed in two tame Barnacle geese kept in a pen, on Schiermonnikoog, Netherlands, sleeping geese continue to defecate at regular time intervals, probably until their guts are emptied, but at least for

Table 7

Calorific values of food and faeces of Barnacle geese expressed in kilocalories/gram dry matter (kcal/gdm) or kcal/gram organic matter (kcal/gom)

Food plants	Calorific value		Site
	food	faeces	
Mosses (mainly *Bryum* spec.)	4.48 kcal/gdm		Nordenskiöldkysten, Svalbard, summer 1975
Grass (mainly *Dupontia*)	5.15 kcal/gdm		
Not determined	—	4.29 kcal/gdm	
Salicornia brachystachya	4.63 kcal/gdm	4.47 kcal/gdm	Lauwersmeer, Netherlands autumn 1974
Poa spec. & *Lolium perenne**	4.72 kcal/gom	4.38 kcal/gom	Schiermonnikoog, polder winter 1973–1974
Predominantly *Festuca rubra**	4.73 kcal/gom	4.55 kcal/gom	Schiermonnikoog, merse winter 1973–1974

* Data from PIET SWIERSTRA and GRETHA HOEKSTRA (1976)

about an hour, thus leaving a discrete pile of droppings behind. The first 43 discrete piles of droppings we found held a total of 175 droppings, but in fact we found 69 piles all looking equally fresh to us, holding a total of 288 droppings. Most probably the 26 (69–43) extra piles had already been produced during a previous sleeping pause at the same site, but by changing its position it is also possible for a goose to produce more than one pile of droppings during one sleeping pause. So these geese produced at least 175 droppings while resting, and certainly less than 288.

As part of the birds are alert while laying down, they add droppings to such a "resting pile", meanwhile being scored by us as being alert. For this reason we cannot reconstruct exactly from our data in how many goose-minutes these droppings were produced, but are left with 1695 goose-minutes as a minimum value and 2145 goose-minutes as a maximum. This yields a time interval of 5.9–12.3 minutes between two successive defecations.

On another occasion we were able to keep a continuous eye on a resting goose for 32 minutes, and three droppings were produced during this time (time intervals being 11′19″ and 8′35″).

For precise estimates, more data are clearly needed, but we may conclude that the defecation rate in Barnacle geese during the arctic summer is probably 3 times as low as in the winter when all feeding has to be done in the short period of daylight.

The mean dry weight of 255 adult Barnacle goose droppings, collected along Nordenskiöldkysten was 0.78 g.

Apart from this common fibrous type of dropping, geese produce now and then a rather bad smelling pasty type of faeces, an expulsion of the contents of the caeca, termed "splodge" (MATTOCKS 1971). Forming only a minor fraction of the excreta, we paid no attention to the "splodge", when estimating the daily food intake of Barnacle geese wintering in the Netherlands (EBBINGE, CANTERS and DRENT 1975). But one can imagine that when food is scarce, as in the arctic, "splodge" could play a more important role. In Table 8 the relative importance of splodge is expressed as the percentage "splodge" of the total number of excreta (n) as encountered on our regular dropping transects.

The two tame Barnacle geese that we kept in a pen on Schiermonnikoog, Netherlands, also fed at night, slept regularly for short periods in the daytime, and defecated at intervals of 5.4 minutes. Their feeding behaviour was more or less similar to that of wild Barnacles in the arctic summer. Table 8 shows that this similarity also holds for the relative caecal activity.

9. Goose usage of the vegetation

Because grazing geese defecate at regular time intervals, the density of their droppings on the feeding grounds can be used as a measure of goose usage of a vegetation. If geese leave an area — without being disturbed by predators or other factors, the most likely cause is shortage of food. Hence in that case cumulative dropping densities can be interpreted as a measure of maximum carrying capacity.

Table 8

Relative importance of the caeca in Barnacle geese

% "splodge"	n	
5.1%	2000	2 tame Barnacles Schiermonnikoog 1973
2.5%	454	wild Barnacles Schiermonnikoog, March 1975
5.7%	614	wild Barnacles Svalbard, summer 1975

Table 9

Barnacle goose dropping densities near tundra ponds, Svalbard 1975

Period	Cumulative number of goose droppings per m²		Number of permanent plots	Predominant vegetation
	mean	max.		
30 June—12 August	18.1	20.8	5	grass (*Dupontia*)
30 June—12 August	8.0	10.8	5	moss
10 July— 8 August	12.7	45.5	13	heterogenous (grass + mosses)

Table 10

Barnacle goose dropping densities cumulated over the whole winter period (October–March) in the Netherlands

	Cumulative number of goose droppings per m²		n	
	mean	max.		
1972–73 B	30.5	37.2	11	old pasture
— B	33.5	51.5	11	old pasture
— B	30.0	66.0	11	pasture newly sown previous summer
— S	38.0	51.3	11	old pasture
— S	45.1	63.8	11	salting (intensely grazed by cattle and treated with N-fertilizer)
— G	17.1	25.3	10	salting intensely grazed by sheep
— G	11.1	18.3	12	salting extensively grazed by sheep
— G	12.1	20.3	11	salting extensively grazed by sheep
— G	12.1	18.5	10	salting extensively grazed by sheep
1974–75 S	8.8	28.5	16	salting only grazed by rabbits and hare

n = number of permanent (2 × 2) m² plots S = Schiermonnikoog
B = Bantpolder area (NE-Friesland) G = salting along the coast of Groningen

As the Barnacle geese near Kapp Martin frequently moved from one pond to another — even without being disturbed — we may tentatively interpret the cumulative dropping densities (expressed as the number of droppings cumulated per square meter, see Table 9) as a measure of maximum carrying capacity of the vegetation around the ponds near Kapp Martin.

From Tables 9 and 10 we see that the Svalbard dropping densities are comparable to those of the Dutch natural saltings (unused or extensively used by farmers) with a predominant vegetation of *Festuca rubra*.

Discussion

The major factor reducing the production of fledged young in the Grey Lag goose (*Anser anser*) was the loss of complete clutches (NEWTON and KERBES 1973). Apparently this also applies to the Barnacle goose, as gosling mortality up to the wintering grounds proved to be negligible (Table 11). Direct observations of this regulatory mechanism in the Barnacle goose can only be made from hides that can be entered and left without disturbing the geese. Otherwise as a consequence of human visitation to these very small islands Barnacle geese and Eider ducks will suffer from egg predation by Glaucous gulls, Greater Black Backed gulls (*Larus marinus*) and Arctic skuas (*Stercorarius parasiticus*). This has already been stressed by NORDERHAUG (1968).

Neither MARSHALL (1938) nor CULLEN (1952) found evidence for the existence of a 24-hour rhythm in the activity of other arctic birds as Brünnich's Guillemots (*Uria lomvia*) and Kittiwakes (*Rissa tridactyla*) in the arctic summer. In the Fulmar (*Fulmarus glacialis*) on the other hand CULLEN (1952) demonstrated that distinct 24-hour rhythms do occur. The moulting Barnacle geese we observed in Svalbard did not demonstrate a clearcut 24-hour rhythm.

Sleep as well as the uptake of food is spread over the entire 24-hour period and the latter probably results in a defecation frequency three times as low as on their wintering grounds, where the dark compells the geese to rest on the safe mudflats for nearly $\frac{2}{3}$ of the 24-hour period. This defecation rate results in a daily production of about 150 droppings per goose, or roughly equal to the number of droppings produced daily in winter (160).

On their wintering grounds in Scotland (Caerlaverock) the average dry weight of a single dropping was 0.786 g (OWEN 1975), equalling the dry weight of a dropping produced in Svalbard (0.78 g). So even on a dry weight basis the total faecal output per day is about equal in summer and in winter.

A point yet to be clarified is whether the geese are able to utilize their food more efficiently in the arctic by slowing down the digestion rate (our data would indicate a retardation by a factor of about three). The calorific value of both food and faeces (Table 7) yields some information on the goose's capacity to digest its food, but as part of the food is retained completely we also need to know the percentage of food retained on a dry weight basis. Grasses are probably the main constituents of the Barnacle goose's summer diet (*Dupontia* being a common and heavily grazed grass species growing around the tundra ponds), but as is shown by DE KORTE (1972) mosses (*Bryum* sp.) can be taken too. However, as far as our present knowledge goes, it seems likely that the difference in calorific value of food and the corresponding droppings is slightly greater in the arctic (78°N) than on the wintering grounds (53°N). But this feature could very well be of minor significance when compared with the retention of food on a dry weight basis, as can be measured by using an indigestible constituent of the food as a marker (MOSS 1973).

The number of hours spent feeding per 24 hours is about 20% higher in the arctic summer than in the winter quarters. Since the total number of droppings produced per day and the mean dry weight of single droppings do

Table 11

Breeding success in three goose species. A nest is considered to be successful if at least one egg hatches

	% successful nests	Per cent eggs hatched in successful nests	
Anser anser	42–70	72–80	NEWTON & KERBES 1973
Anser rossii	67.6–88.3	86.1–89.6	RYDER 1972
Branta leucopsis	55	82	this paper

not differ much, the total amount of food taken in both on the wintering grounds and in the arctic summer may be about equal. The longer digestion time in the arctic could, however, result in a higher rate of food utilization, and this view is supported by the facts that in the arctic both the difference between calorific value of goose droppings and potential food, and the number of expulsions of the caecal contents are somewhat larger than in the wintering area. Further data on this subject are needed, especially concerning the Barnacle goose's summer diet and the amount of food retained on a dry weight basis.

The daily time budget of the goslings shows that in terms of energy expenditure they behave as economically as possible: feeding about 12 hours per day and most of the remaining 12 hours is spent sleeping under mother's wing, thus presumably reducing heat loss to a minimum. The activity of the male and female parent has not been recorded separately, yet from our general impression that the female feeds more often than the male it can be inferred that the male will be unable to devote sufficient time to feeding in order to maintain his body weight, because the "average" parent spends the same amount of time feeding as the non-parent. This would be consistent with BARRY's findings in the light-bellied Brant goose (*Branta bernicla hrota*). He found that body weight in the female reached a minimum value at hatching time and then started to increase again. In the male on the other hand, body weight decreased sharply while establishing and defending his territory in the period of egg-laying, then his body weight increased again during the less strenous incubation period, but decreased to an even lower level in the moulting period when he took over the dominant role in the care of the goslings.

In the Barnacle geese, too, we observed that the male spends considerably more time being alert than the female and often chases away other Barnacle geese and other goslings, thus ensuring enough space for the female and their own goslings to graze.

Which selection pressures made the Barnacle goose evolve as a species breeding in the high arctic (between 70° and 80° North) and wintering (between 51° and 58° North) in the temperate climatic zone? This question can possibly be answered if we are able to find certain advantages linked to its migratory behaviour.

Like all Anatidae, geese moult all their primaries simultaneously thus becoming flightless and much more vulnerable to terrestrial predators in particular for several weeks. Not relying on their wings for the gathering of food, Anatidae can afford a flightless period if enough food and safety are ensured. In diurnal birds, like geese, this safety is ensured in the arctic summer as darkness is absent, which makes it very hard for terrestrial predators, like the Arctic fox (*Alopex lagopus*), to catch a goose by surprise, as long as the geese stay near ponds or the sea.

The fear of — usually nocturnally active — terrestrial predators could also account for the fact that the Barnacle geese wintering in the northern part of the Netherlands in an area without foxes (*Vulpes vulpes*) do visit their feeding grounds at night during the light phase of the moon, while the Svalbard-Barnacles wintering in Caerlaverock, where foxes are abundant, never visit their feeding grounds at night (MYRFYN OWEN pers. comm.).

Apparently food conditions in the arctic are sufficient for the geese to perform their wingmoult, for their goslings to grow up, and for both to store enough fat deposits to perform their autumn migration. The temperatures in the arctic summer are strikingly similar to those encountered on the wintering areas in the Netherlands, although the dark nights may be somewhat colder in the winter (Table 12).

Apparently the Barnacle goose, insulated by high quality down feathers, is very well adapted to an average temperature of +5°C. Apart from the lack of food and the inhospitable climate in the arctic winter, which in themselves will be sufficient reasons for the geese to migrate south, the darkness of the arctic winter would provide the Arctic foxes with too many opportunities to catch geese by surprise.

Thus having developed the pattern of moulting all the primaries at once, it seems advantageous for geese to find a safe moulting place with sufficient food at hand. For the Barnacle goose such conditions were present in the high arctic. Body insulation with a thick layer of downy feathers can be regarded as a further adaptation to the arctic climate.

To test this Avoidance-of the-Dangerous-Dark-hypothesis, it would be interesting to know more about the mortality of moulting Pink-footed geese (*Anser brachyrhynchus*). This species breeds as far north as the Barnacles do, but also on Iceland (65°N), where during the moulting period a distinct period of darkness occurs, amounting up to six hours per day at the time moulting ends (Fig. 6).

Table 12

Mean temperatures of those periods when the daily time budgets mentioned in this paper have been estimated

Svalbard, July 1975		4.9° C	
Northern Netherlands, December 1972	day	2.0° C	
	night		0.7° C
Northern Netherlands, February 1973	day	5.5° C	
	night		4.7° C

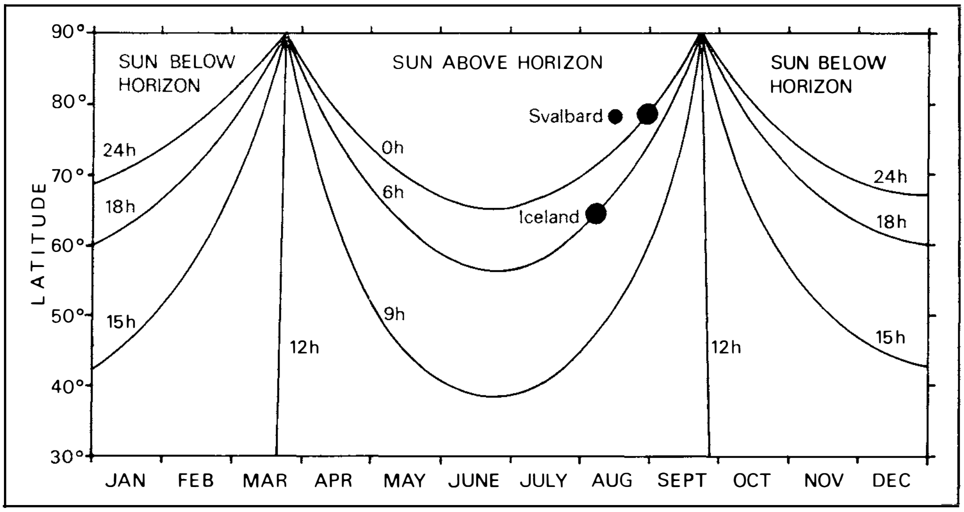

Fig. 6. *Goose phenology* (Bauer and Glutz von Blotzheim 1968) *in relation to duration of darkness* (McKay et al. 1969). *Large dots indicate end of moulting period in* Anser brachyrhynchus, *and smaller dots in* Branta leucopsis. *Duration of darkness is given as hours per day sun below horizon.*

In spite of the fact that moulting ends later in the season in Svalbard (end of August) than in Iceland (6–10 August), almost the whole moulting period in Svalbard is spent in continuous light conditions (first sunset on 23 August) (Fig. 6).

Being somewhat larger than a Barnacle goose, the Pinkfooted goose is able to defend its nest against the Arctic fox, and most Pinkfoot nests in Svalbard can be found on the tundra itself, within reach of the Arctic foxes. Two parent-Pinkfeet were even seen to chase an Arctic fox away from their goslings in Sassendalen, Svalbard (Arend van Dijk and Tom van Spanje pers. comm.). On the other hand, in Iceland many Pinkfeet were found dead, with their heads bitten off, apparently killed by Arctic foxes (John The Sailor pers. comm.).

In 1951 and 1953 the mortality of goslings out of the largest breeding colony in Iceland between hatching and arrival on the wintering grounds in the British Isles, was estimated at 60% (Bauer and Glutz von Blotzheim 1968). Gosling mortality was low during the first month after hatching (when the dark period is still short). As a consequence mortality must have been very high when the length of the dark period had increased. Part of these 60% however, was caused by human shooting during autumn migration.

Clearly more data on mortality of moulting adult Pinkfeet and their goslings in Iceland (65°N) and in Svalbard (78°N) are needed to make satisfactory comparisons, but it seems likely that the Icelandic Pinkfeet suffer from heavier losses due to Arctic fox predation than their Svalbard counterparts. If this is the case for the Pinkfoot, a goose able to defend its nest successfully against an Arctic fox in daylight, the losses for the smaller Barnacle goose, might have been even more severe, had it bred south of 70°N. Since 60–70% of the world population of Pinkfeet breed in Iceland, there must be some ecological advantages linked to their choice of breeding there. Clutch size of Icelandic Pinkfeet seems to be somewhat larger (4.5 eggs, n = 19) than in Svalbard (4.1 eggs, n = 55) (BAUER and GLUTZ VON BLOTZHEIM 1968), but as clutch size varies with climatic conditions these data are as yet inconclusive. Climatic conditions in Iceland will be less extreme than farther north, so probably non-breeding years, if occurring at all in Iceland, are presumably less frequent there.

Another adaptation of Icelandic Pinkfooted geese is the northward moult migration of non-breeders to Greenland (SALOMONSEN 1968). Svalbard non-breeders do not perform such moult migration. Reviewing the phenomenon of moult migration SALOMONSEN (1968) states the following: "Moult migration occurs in many goose species but is restricted to the non-breeders and the direction in all known cases is invariably north. It is probable that in many (or most) species the ultimate cause of the development of moult migration has been a potential shortage of food on the breeding ground, but it is difficult to understand why this moult migration in geese invariably moves in a northern direction, while all other moult migrations in wildfowl lead to regions with a milder climate". SALOMONSEN mentions two possible explanations:

"(1) It may have something to do with so-called 'prolongation of migration'. The immature birds are still in a migratory state when the time comes for them to leave the breeding grounds only a few weeks after arrival. Under such circumstances it is most likely that the choice of a flight direction will be the same as used during spring migration, i.e. northerly. If the northern direction is genetically fixed it will be kept provided that selective forces do not favour any other direction.

(2) The north direction may be the result of climatic influences. In arctic regions the length of time of snow-cover is of decisive significance for many ground-feeding birds and mammals. According to USPENSKI (1965) a snow-free period of three months is necessary for a successful accomplishment of the breeding cycle in most species of geese. Only the Snow Goose and the Brent Goose are able to manage the full breeding cycle in slightly over two months, owing to a particularly rapid development of the goslings and an accelerated wingmoult in the adults. Although the snow-free period in the high-arctic areas is too short to permit breeding in most species of geese, the food resources can be utilised by non-breeding birds when the snow-melt in the latter part of June has made the foodplants available to them. A high selective premium is granted to such populations in which the immature birds move north to the high-arctic region in June, leaving the food resources on the breeding places to the goslings and their parents, in this way enabling the breeding population to raise its productivity."

As all moult migration in geese, as listed by SALOMONSEN (1968), starts from the Arctic circle (66°N), or farther south, the Avoidance-of-the-Dangerous-Dark-hypothesis provides another explanation for the northern direction. Moreover, this hypothesis can possibly be tested by comparing the survival rate of different moulting groups within one species, i.e. the Pinkfooted goose.

Summary

To find out the possibilities of studying the behaviour of wild Barnacle geese (*Branta leucopsis*) on their breeding ground, as well as their impact on the vegetation, a reconnaissance trip (end of June until mid-August 1975) was made to Nordenskiöldkysten, a tundra area on the west coast of Spitsbergen, the main island of the Svalbard archipelago.

In the study area 800 adult Barnacle geese were counted, consisting of 100 families with a mean of 2.6 goslings and 80 unsuccessful breeding pairs and 440 non-breeding individuals. Although 80 nests must have been lost during the egg phase (45% of the clutch started) and clutch size was rather low (3.3), the production of young was reasonable (25% of total population), due to the fact that mortality of goslings was negligible.

Using a hide that could be entered without being noticed by the geese, a telescope (25×60), and a bit of luck, it proved feasible to study the activities of moulting Barnacle geese. Feeding of the moulting birds was spread out over the entire 24-hour period and alternated regularly by short sleeping periods. Thus 36% of the total time budget of the moulting adults is spent feeding, and 24% sleeping. The goslings on the other hand spend almost 50% of the 24-hour period feeding and 34% sleeping (Figs. 4 and 5). Dry weight of droppings of adult Barnacles was 0.78 g, equalling dropping weight on their wintering ground, Caerlaverock, in Scotland (0.786 g). Total number of droppings produced per day in the summer very probably equals the number produced in the winter (160/24 hrs).

Finally the hypothesis of "Avoidance-of-the-Dangerous-Dark" is proposed, which is based on the assumption that predation by Arctic foxes (*Alopex lagopus*) on flightless, moulting geese is very low in the daylight, but much higher in the dark. As a result the Barnacle goose may have developed in the course of its evolution into a species breeding and *moulting* north from 70°N, to be able to perform wingmoult under continuous light conditions. To test this hypothesis a suggestion is made to compare the mortality of Pinkfooted geese (*Anser brachyrhynchus*), breeding and moulting in Iceland (65°N) to the same species breeding and moulting in Svalbard (78°N).

This hypothesis also provides another explanation for the fact that moult migration of non-breeding geese in the northern hemisphere invariably moves in a northern direction.

Acknowledgements

We are very grateful to Dr. RUDI DRENT of the Zoological Laboratory, University of Groningen, Netherlands, for his kind help in supplying us with a hide and an inflatable rubber boat with a 15 HP Johnson outboard engine, as well as for his critical reading of the manuscript and improvements in the English text. We also wish to thank Mrs. H. LOCHORN-HULSEBOS, who typed the manuscript.

We wish to thank "Sysselmannen på Svalbard" for transporting our equipment from Longyearbyen to Kapp Linné, the crew of the Isfjord Radio station, Kapp Linné, for all their hospitality and help, Mr. PER JOHNSON for transporting part of our equipment from Kapp Linné to van Mijenfjorden, Norsk Polarinstitutt for letting us use their hut near Kapp Martin and for the help offered when we had to leave this hut, our two friends AREND VAN DIJK and TOM VAN SPANJE for all their information and help and for the many pleasant hours we spent together with them and LIV and FINN NYGÅRD, who worked for Norsk Polarinstitutt, Dr. MYRFYN OWEN of the Wildfowl Trust for his encouraging letters and critical reading of the manuscript, Dr. PIET OOSTERVELD for stimulating us to write this paper, and finally Dr. JOOST TINBERGEN and Dr. SERGE DAAN for their critical comments on the manuscript.

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Anatol Heintz

AV THORE S. WINSNES

Professor dr. philos. ANATOL HEINTZ, *fotografert i Ny-Ålesund sommeren 1964.*
Foto: THOR SIGGERUD

Professor dr.philos. ANATOL HEINTZ døde 23. februar 1975. Med ham har Norge mistet en stor geolog, polarforsker og pedagog, og Norsk Polarinstitutt en trofast venn. ANATOL HEINTZ ble født i St. Petersburg 9. februar 1898. Som ung flyktning kom han til Norge i 1919. Her begynte han å studere naturfag ved Oslo Universitet. Hans kunstneriske begavelse hjalp ham godt i denne første tiden, han kunne som kunstmaler underholde familien og bekoste sin videre utdannelse. Under professor JOHAN KJÆR begynte han sine paleontologiske studier, og etter hvert ble fossile fisk hans hovedinteresse.

I Norden var det i denne tiden en storstilet utforskning av de eldste fossile fisk, under ledelse av KJÆR i Norge og E. A. STENSJÖ i Sverige. I dette fruktbare miljø gjorde ANATOL HEINTZ seg snart gjeldende. Meget av fossilmaterialet som ble bearbeidet, var hentet på Spitsbergen av tidligere norske og svenske ekspedisjoner. Interessen for Svalbard ble derfor tidlig vakt hos HEINTZ. I 1925 deltok han som paleontolog i TH. VOGTS ekspedisjon, og i de følgende år kom en rekke publikasjoner om de fossilgrupper innen de fiskearter som hadde vekket hans særlige interesse, hailignende panserfisk, Acantaspider, og kjeveløse panserfisk, Ostracodermer, som han treffende kalte urfisk.

I begynnelsen av 30-årene ble det også samlet materiale fra devon på Øst-Grønland. HEINTZ bearbeidet dette og materiale fra andre områder. I 1939 ledet han den norske kontingent i en større engelsk-norsk-svensk ekspedisjon til Spitsbergens devonområder i nord. I 1949 arbeidet han i Hornsund og i 1959 og 1964 samlet han materiale i Isfjorden. Som et resultat av bearbeidelsen av dette materiale er det kommet en rekke avhandlinger som har vakt stor internasjonal interesse, og HEINTZ ble en autoritet innen sitt felt.

Imidlertid var ikke dette nok for en kapasitet som ANATOL HEINTZ. Hans interesser omfattet også andre felter, norske mammutfunn og menneskets avstamning. Han hadde en sjelden evne til å formidle sine kunnskaper i tale og skrift og skrev meget i leksika og lærebøker.

De som hadde den glede å studere under ham og arbeide sammen med ham, vil også huske hans vennlighet og store menneskelige forståelse. Han var en uredd forfekter av sine meninger og gikk ikke sjelden mot strømmen i samfunnsdebatten.

I *Norsk Geologisk Tidsskrift 55*, 203–211, er gitt en bibliografi over ANATOL HEINTZS publikasjoner. Her skal nevnes de av hans arbeider som er publisert av Norsk Polarinstitutt:

1929 Die downtonischen und devonischen Vertebraten von Spitzbergen. II. Acanthaspida. *Skrifter om Svalbard og Ishavet* Nr. 22. 81 pp. 24 pls.

— Die downtonischen und devonischen Vertebraten von Spitzbergen. III. Acanthaspida. Nachtrag. *Skrifter om Svalbard og Ishavet* Nr. 23. 20 pp. 3 pls.

1930 Oberdevonische Fischreste aus Ost-Grönland. *Skrifter om Svalbard og Ishavet* Nr. 30. 31–46. 4 pls.

1932 Beitrag zur Kenntnis der devonischen Fischfauna Ost-Grönlands. *Skrifter om Svalbard og Ishavet* Nr. 42. 27 pp. 6 pls.

— The Downtonian and Devonian vertebrates of Spitsbergen. IV. Suborder Cyathaspida. A preliminary report. By JOHAN KIÆR. Ed. by A. HEINTZ. *Skrifter om Svalbard og Ishavet* Nr. 52. 26 pp. 11 pls.

1935 Holonema-Reste aus dem Devon Spitzbergens. *Norges Svalbard og Ishavsundersøkelser Meddelelser* Nr. 31. 9 pp. 1 pl.

— The downtonian and Devonian vertebrates of Spitsbergen. V. Suborder Cyathaspida. Part 1. Tribe Poraspidei. Family Poraspidae Kiær. (J. KIÆR & A. HEINTZ). *Skrifter om Svalbard og Ishavet* Nr. 40. 138 pp. 40 pls.

1937 Die downtonischen und devonischen Vertebraten von Spitzbergen. VI. Lunaspis-Arten aus dem Devon Spitzbergens. *Skrifter om Svalbard og Ishavet* Nr. 72. 23 pp. 2 pls.

1943 The Downtonian and Devonian vertebrates of Spitsbergen. VIII. The English-Norwegian-Swedish expedition 1939. Geological results (S. FØYN & HEINTZ). *Norges Svalbard og Ishavsundersøkelser Skrifter* Nr. 85. 51 pp. 1 pl.

1953 Noen iakttagelser over isbreenes tilbakegang i Hornsund, Vestspitsbergen. *Norsk Polarinstitutt Meddelelser* Nr. 73. 36 pp.
1962 New investigation on the structure of Arctolepis from the Devonian of Spitsbergen (The Downtonian and Devonian vertebrates of Spitsbergen XII). *Norsk Polarinstitutt Årbok* 1961. 23–40. 1 pl.
— Aspects of the geology of Svalbard (T. S. WINSNES, A. HEINTZ & N. HEINTZ). *Norsk Polarinstitutt Meddelelser* Nr. 87. 35 pp.
1963 Professor dr. Thorolf Vogt som polarforsker. *Norsk Polarinstitutt Årbok* 1962. 153–156.
1964 Om rein og isbjørn på Svalbard. *Norsk Polarinstitutt Meddelelser* Nr. 92. 20 pp.
1965 A note on the stratigraphy of Goldschmidtfjella, Oscar II Land (A. HEINTZ & T. SIGGERUD). *Norsk Polarinstitutt Årbok* 1963. 251–253.
1966 Remarkable tracks from Vestspitsbergen. *Norsk Polarinstitutt Årbok* 1964. 241–242.
— Russian opinion about the discovery of Spitsbergen. *Norsk Polarinstitutt Årbok* 1964. 93–118.

Olav Holtedahl

AV THOR SIGGERUD

Professor dr. OLAF HOLTEDAHL døde 26. august 1975, vel to måneder etter at han fylte 90 år.

Holtedahls store innsats både for norsk geologisk forskning og som lærer og inspirator for to generasjoner norske geologer er omtalt annensteds i forbindelse med hans bortgang. For norsk Polarinstitutt er det naturlig å dvele ved hans polarinnsats og hans betydning for den geologiske utforskning i Arktis og Antarktis. Han var til sine siste dager sterkt opptatt av norske polarinteresser og en helhjertet venn av Norsk Polarinstitutt.

Holtedahl ble sterkt inspirert i unge år av Fridtjof Nansens Fram-ferd. Et varig minne om dette er et dikt til Frams ære publisert i Tidens Tegn.

Holtedahl deltok sommeren 1909 som nyutdannet cand. real. fra Det Kongelige Fredriks Universitet i Kristiania på Gunnar Isachsens Spitsbergenekspedisjon. Gunnar Isachsen kjente Holtedahl fra før, visstnok fra militærtjenesten, og det var under denne foregangsmann for den systematiske norske utforskning av Spitsbergen at Holtedahl fikk sin innføring i det høyarktiske ekspedisjonslivet. Holtedahl har blant annet fortalt om dramatiske roturer i drivisen.

Fra 1910 ble Holtedahl stipendiat ved Universitetet, men deltok på Isachsens Spitsbergenekspedisjon i 1910 og på Hoel og Staxruds ekspedisjon i 1911.

De tre vintrene deltok Holtedahl i bearbeidelsen av resultatene og ble regnet for å tilhøre staben ved Spitsbergenekspedisjonene.

Feltvirksomheten i Arktis ble det slutt på da han giftet seg og dro til USA. Til Spitsbergen kom Holtedahl kun en gang til, da han besøkte Bjørnøya i 1918. Han fortsatte imidlertid å publisere materiale derfra.

Holtedahl skulle isteden ta opp arbeidet i andre polaregner. I 1919 la han frem planer for en ekspedisjon til det da geologisk sett nesten ukjente Novaja Zemlja. Det ble vanskelig å skaffe penger til denne ekspedisjonen, men ikke minst takket være god støtte fra Fridtjof Nansen, gikk det i orden året etter, og en meget vellykket ekspedisjon ble gjennomført i 1921.

Karakteristisk for Holtedahl var at det ikke ble en rent geologisk ekspedisjon — han fikk også med seg en zoolog og en botaniker. I løpet av 20-årene kom resultatene av ekspedisjonen i tre store bind, foruten at Holtedahl skrev om en rekke forskjellige sider ved ekspedisjonen og om resultatene i mange organer. Til og med i en bok om «Practical Hints to Scientific Travellers» (HAGE 1925) har han en artikkel.

Som dosent og statsgeolog og fra 1920 som professor, arbeidet Holtedahl en rekke steder i Norge med geologiske undersøkelser. Men ukjente polartrakter hadde ennå stor interesse og da det ble en mulighet for å samle data i Antarktis ved hjelp av norske hvalfangstinteresser, var Holtedahl med.

På Lars Christensens «Norvegia»-ekspedisjon i 1927–28 gjorde Holtedahl omfattende geologiske iakttagelser fra Syd-Georgia, Syd-Shetland og Grahamland (Antarktiske halvøy). Rapporten som kom er utrolig omfattende og betydningsfull når man tenker på hvor kort tid han hadde på hvert sted. Det kom også et arbeid som har stor prinsipiell betydning for forståelsen av det landskapsmessige trekk som kalles «strandflaten». Holtedahl tolket sine iakttagelser fra det nedisete Antarktis i relasjon til hva man så i tidligere nedisete områder som f. eks. Norge, hvor nettopp «strandflaten» mange steder er et dominerende geomorfologisk trekk i landskapsbildet.

Holtedahl følte seg hele sitt liv tiltrukket av polaregnene som han lærte å kjenne som ung og av de geologiske problemer der. Hele 77 av de ca. 250

arbeider fra Holtedahls hånd som er tatt med i hans bibliografi omhandler polare områder i nord eller syd. I tid for publisering spenner de fra 1911 da det kom to arbeider: ett om karbonavsetninger på Spitsbergen og ett sammen med Hoel om lavadekker, etc. på det nordøstligste Spitsbergen, til det siste arbeidet fra arktiske egne som er trykket i 1970 hvor han skrev om det vestgrønlandske shelfområdet.

Holtedahl fikk etterhvert mange æresbevisninger, både norske og ikke minst i utenlandske vitenskapelige selskaper. Norsk Polarklubb kalte Holtedahl til æresmedlem ved sitt 40-årsjubileum. Holtedahl har også fått Det Norske Vitenskaps-Akademis Fridtjof Nansen belønning.

I polaregnene både i nord og syd har innsatsen fra norsk side vært blant den tidligste og den banebrytende. Dette har grunnfestet våre interesser i disse områder på mange måter, ikke minst i verdens omdømme.

Med Olaf Holtedahl gikk den siste pioner fra det norske geologiske arbeidet i Arktis og Antarktis bort, og et viktig avsnitt i norsk polarforskning er slutt.

Glaciological work in 1975

(Гляциологические работы в 1975 г.)

By Olav Liestøl

Contents

Abstract

In 1975 mass balance measurements were carried out on four glaciers in Norway. Storbreen showed a small negative balance of −15 g/cm² in contrast with Hardangerjøkulen, Supphellebreen, and Blomsterskardbreen with positive balances of 20 g/cm², 100 g/cm², and 170 g/cm², respectively. In Spitsbergen, Austre Brøggerbreen and Midre Lovénbreen had negative balances of −31 g/cm² and −20 g/cm², respectively.

Length fluctuations of sixteen glaciers were measured. All had retreated except Briksdalsbreen, an outlet glacier from Jostedalsbreen, which had an advance of 41 m, the largest since the measurements started 75 years ago.

Аннотация

В 1975 г. был измерен вещественный баланс четырех ледников в Норвегии, из которых один ледник, Storbreen, обнаружил незначительный отрицательный баланс в —15 г/см², тогда как баланс остальных трех ледников Hardangerjøkulen, Supphellebreen и Blomsterskardbreen оказался положнтельным, а именно равным соответственно 20 г/см², 100 г/см² и 170 г/см². На Шпицбергене ледники Austre Brøggerbreen и Midre Lovénbreen проявили отрицательный баланс соответственно в —31 г/см² и —20 г/см².

Измерены колебания длины десяти ледников, из которых отступили все за исключением вытекающего из ледяного щита Jostedalsbreen выходного ледника Briksdalsbreen, обнаружившего продвижение в 41 м, являющееся наибольшим за все 75 лет зарегистрированных ежегодных измерений.

Storbreen in Jotunheimen

The winter snow accumulation was above normal in all parts of the country this balance year and as in the previous two years, the steep gradient

Fig. 1. *Air photo taken 24 May 1975 showing Ny-Ålesund (lower left), Brøggerbreane (middle right), and Lovénbreane (middle left). In the background to the right Engelskbukta, with Comfortlessbreen and Uversbreen to the left.*

Аэрофотография, снятая 24 мая 1975 г., показывающая поселок Ny-Ålesund (внизу слева), ледники Brøggerbreane (посередине справа) и Lovénbreane (посередине слева). На фоне виднеются бухта Engelskbukta (справа), ледники Comfortlessbreen и Uversbreen (слева).

Photo: Jens Angard

across the watershed did not exist. The winter balance on Storbreen was therefore above normal, 155 g/cm², against 136 g/cm² in an average year.

A warm summer, especially in eastern Norway, caused an ablation of 170 g/cm². Therefore, in spite of the relatively large accummulation, the result was a negative balance of —15 g/cm².

Hardangerjøkulen

The measurement of this glacier was made at a reduced scale this balance year. All ablation stakes except three, were broken or snowed down before they could be replaced during the winter. Also, it was difficult to measure the accumulation as the last summer surface was difficult to locate by sounding. The accumulation was large, even larger than the high ablation caused by the warm summer. The result was a positive balance of 15 g/cm². The uncertainty

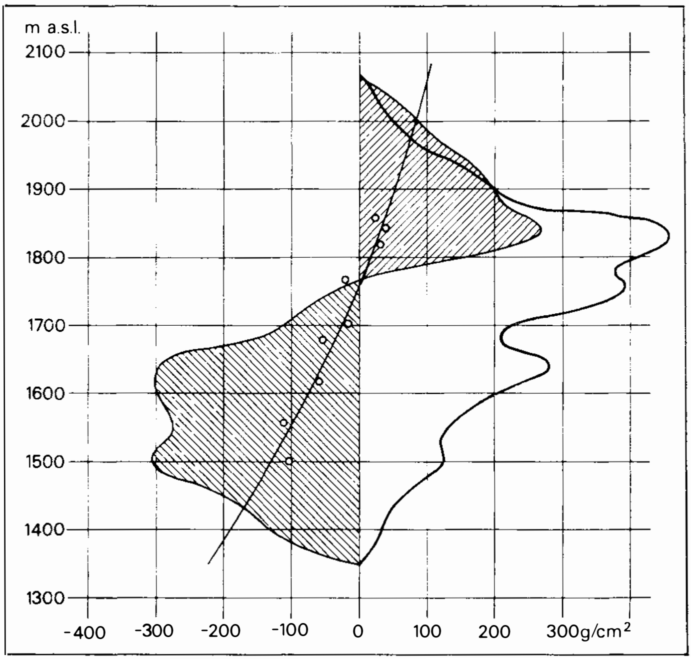


Fig. 2. *Mass balance variations on Storbreen 1974–75 in relation to height above sea level.*

Вариации вещественного баланса ледника Storbreen в 1974/75 г. в зависимости от высоты над уровнем моря.

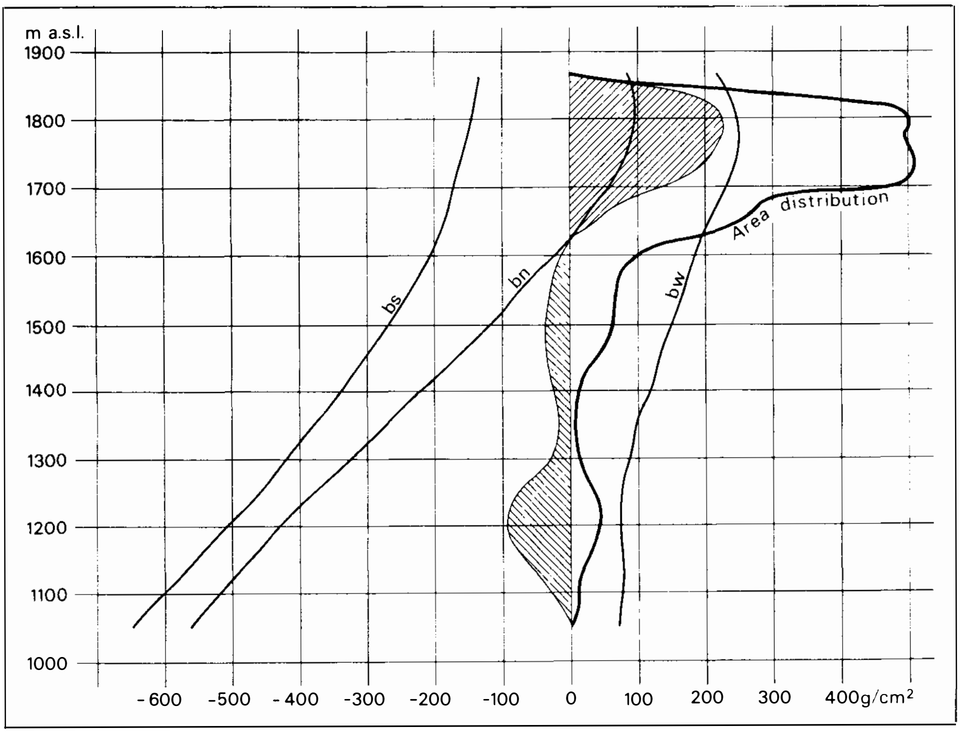


Fig. 3. *Mass balance variations on Hardangerjøkulen 1974—75 in relation to height above sea level.*

Вариации вещественного баланса ледника Hardangerjøkulen в 1974/75 г. в зависимости от высоты над уровнем моря.

is quite high owing to the above mentioned difficulties and is estimated to $\pm$ 20 g/cm² (Fig. 2 and Table 1).

Supphellebreen, Jostedalsbreen

This glacier was studied in detail by OLAV ORHEIM in the years 1963 to 1968. In 1975, the net balance was measured by a few stakes near the equilibrium line in the same way as in the previous year and was approximately 100 g/cm².

Blomsterskardbreen, Folgefonni

According to detailed studies by ARVE TVEDE in 1969—71, this glacier has one of the largest mass balance budgets in Norway. This was also theoretically computed by help of run-off measurement figures from the area, and the height of the equilibrium line. As mentioned in the last reports, the even and simple accumulation pattern registered in earlier detailed surveys, the measurements being based on three stakes near the firn line, gives a reliable basis for calculation of the glacier's mass balance. As no accumulation measurements have been made, only net balance figures are available. As in all previous years, measurements showed an increase in the glacier's volume, and the net balance was 150 g/cm².

Glaciers in Spitsbergen

In Spitsbergen glacier work was carried out on Austre Brøggerbreen and Midre Lovénbreen.

The work started with accumulation measurements at the end of May. The snow density was determined at three localities in the low, middle, and upper parts of both glaciers. There was good agreement between density figures at the same heights on the two glaciers. The same was the case with the amount of superimposed ice. As melting had not yet started, this ice had been formed during the autumn and early winter when rain and mild weather soaked the snow. Superimposed ice was not found higher than 300 m a.s.l., indicating that precipitation either fell as snow or did not soak the snow cover to the ice surface above this level. The superimposed ice was measured at 15 localities along the centre line of the glaciers and varied from about 12 g/cm² in the lower part to about 10 g/cm² at 200 m a.s.l. It then gradually diminished upwards and disappeared at 300 m a.s.l. as mentioned above. Superimposed ice formed during the summer was not measured, but estimated as in most previous years. Figs. 4, 5, 6, 7 show the snow depth, sounding grade, and the location of the ablation stakes.

As usual, ablation was regularly measured on stakes during the summer, the last measurement being made on 9 September. Some melting took place after this date and this ablation was measured when the accumulation work took place next spring before any melting had begun. The autumn superimposed ice had to be taken into account then.

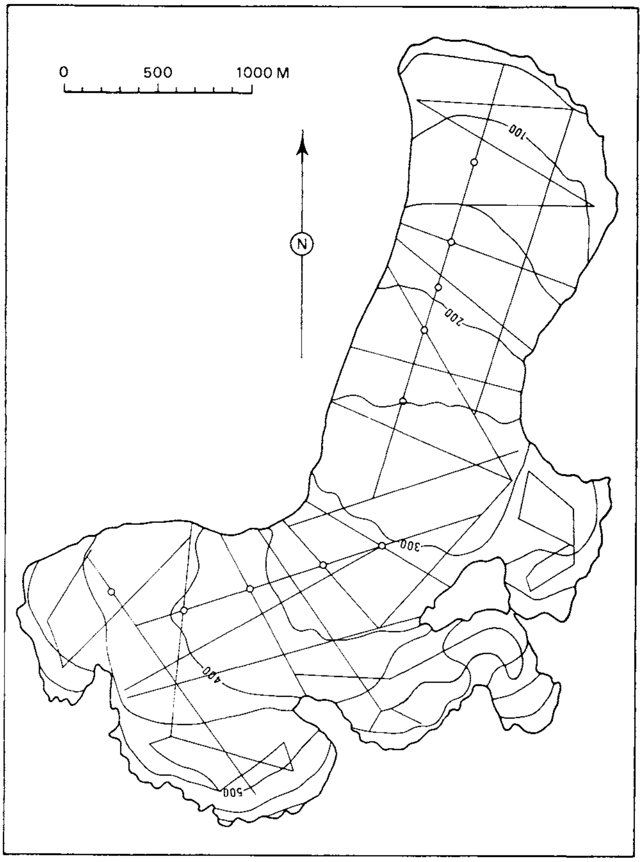


Fig. 4. *Sounding lines on Midre Lovénbreen along which snow depth measurements have been made. Trig-points and ablation stakes used for orientation of the lines are marked with triangles and circles.*

Линии на леднике Midre Lovénbreen, вдоль которых промерена глубина снега. Тригонометрические пункты и абляционные рейки, использованные для ориентировки линий, обозначены треугольниками и кругами.

Accumulation on both glaciers was above the average for the eight years of investigation and ablation about average. The result was a negative balance as in all the previous years. Mass balance figures for the years of investigation are listed in Table 1. There is good correlation between the variations in mass balance figures for the two glaciers. This is very reasonable as the two glaciers lie close to each other and are of nearly the same size. It may be seen from Fig. 8 A and B that the area distribution with height is not quite the same for the two glaciers. Brøggerbreen has a larger part of its area at a lower elevation than Midre Lovénbreen. This explains the higher ablation figure for Brøggerbreen throughout the years of investigation. As accumulation figures are also lower for Brøggerbreen, it is obvious that this glacier must have a greater loss in volume than Lovénbreen.

The negative balance registered this year is the ninth of a continuous number of years with negative balances. As stated in previous reports, it is

Table 1

Mass balance figures in g/cm² for Austre Brøggerbreen and Midre Lovénbreen 1967—75

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
1968—75	65	112	—47	66	106	—40

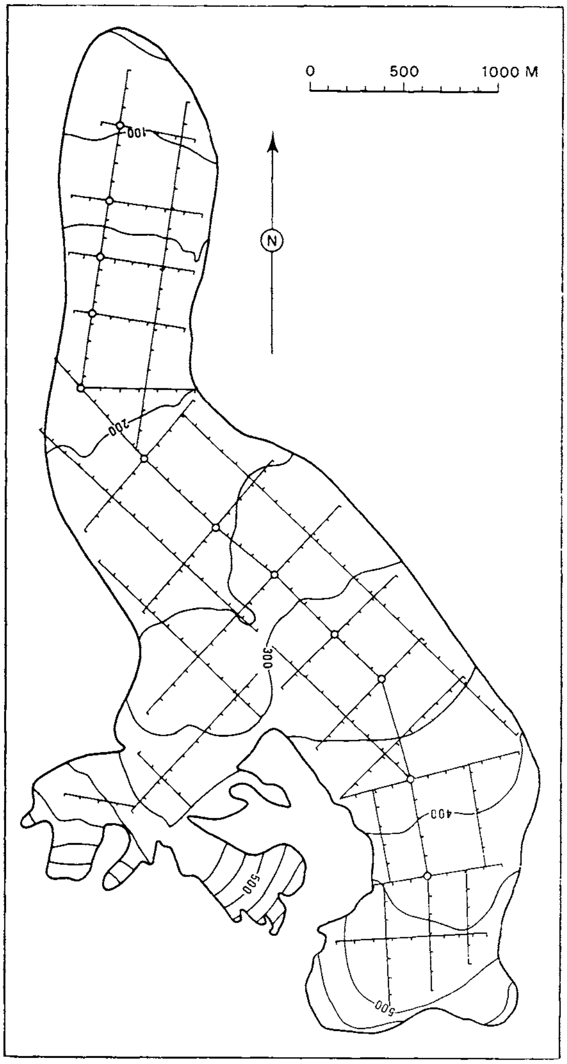


Fig. 5. *Snow depth sounding lines on Austre Brøggerbreen. Trig-points, compass and an odometer on a snow scooter have been used to fix the grid on the glacier.*

Линии вдоль которых промерена глубина снега на леднике Austre Brøggerbreen. Использованы тригонометрические пункты, буссоль и смонтированный на мотонартах одометр для определения сети на леднике.

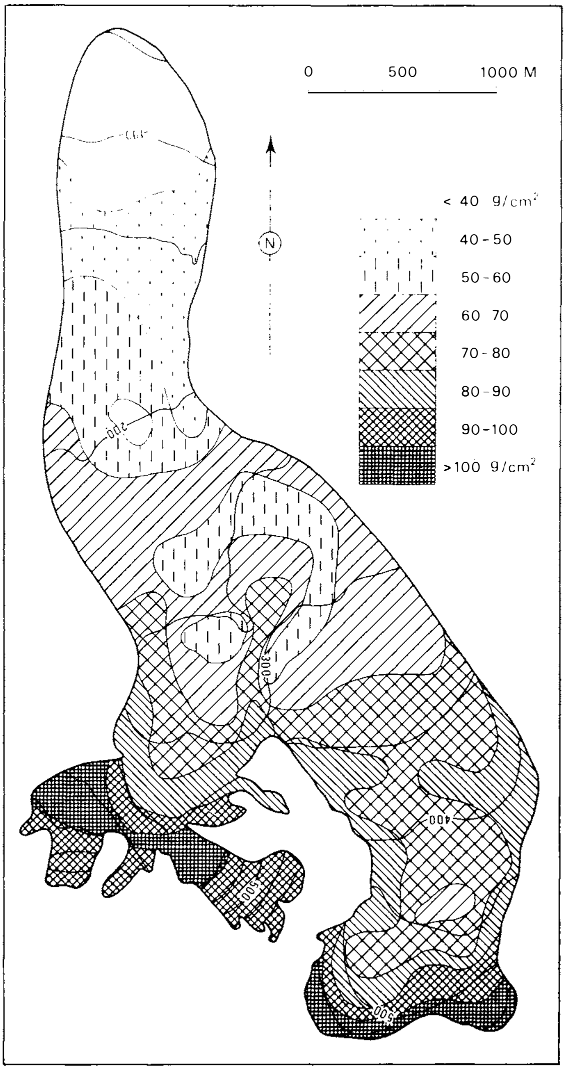


Fig. 6. *Distribution of snow accumulation on Austre Brøggerbreen 1974–75.*
Распределение снегонакопления на леднике Austre Brøggerbreen в 1974/75 г.

difficult to determine whether this fact is due to higher ablation or lower accumulation than normal. Normal is here the same as figures keeping the glaciers in a steady state or equilibrium condition. The ablation is dependent upon different meteorological factors. No glacimeteorological studies have been made on these glaciers, but radiation is supposed to be the most important factor. As there is normally a relatively good correlation between temperature and the main ablation factors, temperature figures available from meteorological stations are often alone used for a rough calculation of ablation.

In contrast to the mean winter temperatures which have shown large variations, the summer temperatures have been nearly constant during the sixty years of observations at Isfjord Radio, the meteorological station about 100 km further south on the coast. The correlation between measurements carried out at this station and the temperature measurements made over the

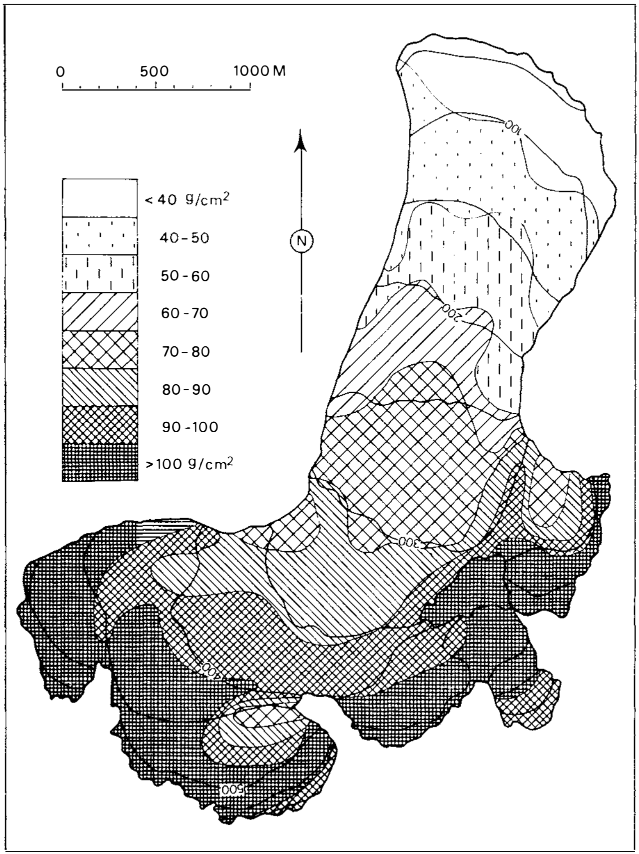


Fig. 7. *Distribution of snow accumulation on Midre Lovénbreen 1974–75.*

Распределение снегонакопления на леднике Midre Lovénbreen в 1974/75 г.

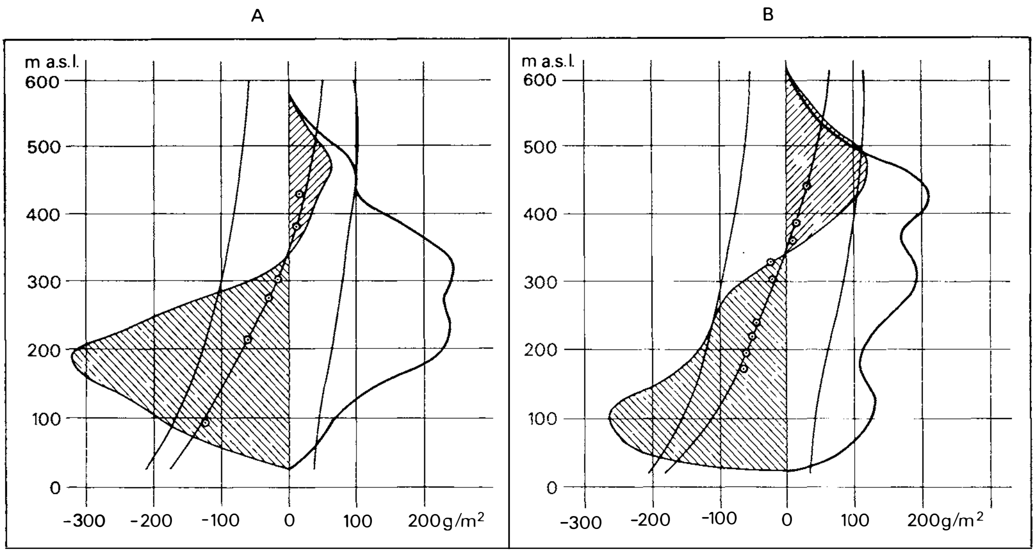


Fig. 8. *Mass balance variations in relation to height above sea level of Austre Brøggerbreen (A) and Midre Lovénbreen (B) 1974—75.*

Вариации вещественного баланса в зависимости от высоты над уровнем моря ледников Austre Brøggerbreen (A) и Midre Lovénbreen (B) в 1974/75 г.

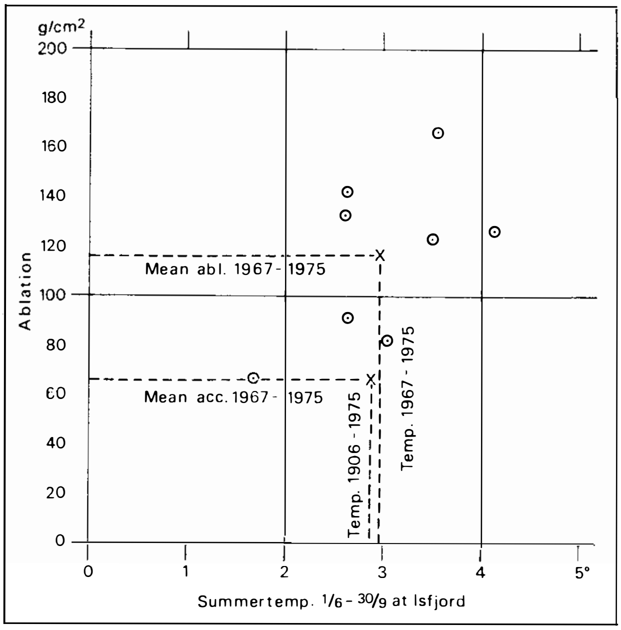
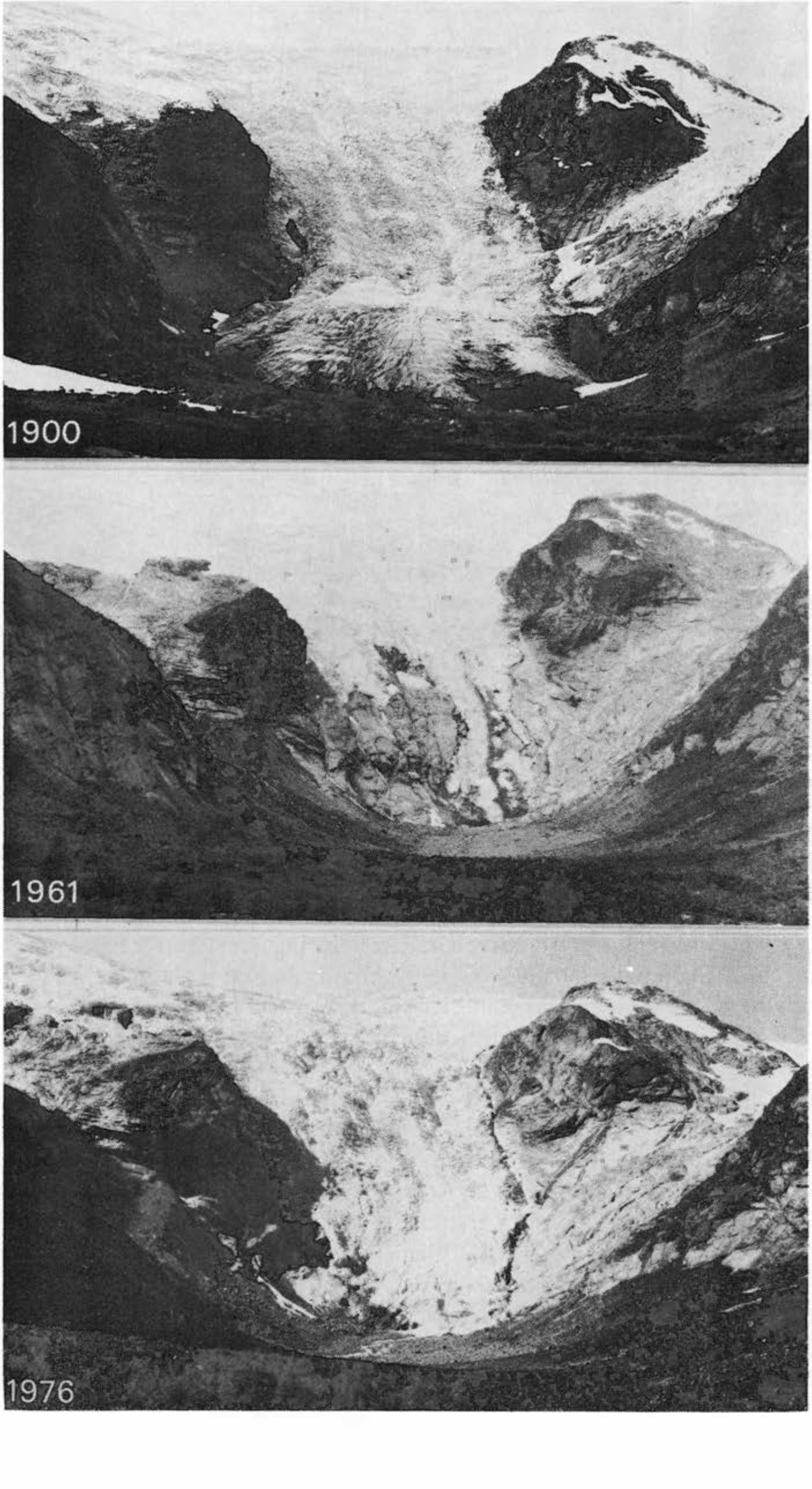


Fig. 9. *Ablation on Austre Brøggerbreen in relation to summer temperature at Isfjord Radio in the years 1967—75. Stippled lines show mean accumulation, ablation, and temperatures for the same years together with the mean for the period 1906—75.*

Абляция ледника Austre Brøggerbreen в зависимости от летней температуры воздуха на станции Isfjord Radio в 1967—75 гг. Пунктиром отмечены средние аккумуляция, абляция и температуры для тех же годов вместе с средними для периода 1906—75 гг.

last eight years at Ny-Ålesund close to the glacier, is quite good. There is reason to believe, therefore, that the ablation factors related to temperature should give good correlation with temperatures measured at Isfjord Radio. Fig. 9 shows that this correlation is not convincing, however. There could be different explanations for this. We know that radiation is the most important factor in ablation. Differences in cloudiness over the middle and higher part of the glacier and the regions near the coast where the meteorological stations are situated, are often registered.

Fig. 9 also shows that a much higher accumulation is needed to keep the glacier in a steady state condition. There is reason to believe, therefore, that low winter precipitation is responsible for all these years with negative balances. Photographs and maps show a continuous retreat on both Brøggerbreen and Lovénbreen during the last seventy years. This tendency is even more pronounced on the smaller glaciers in the area. Some of them have probably lost more than half their volume in the seventy-year period. The climate in the nineteenth century seems, therefore, to have been of a much more severe type than today.


1900
1961
1976

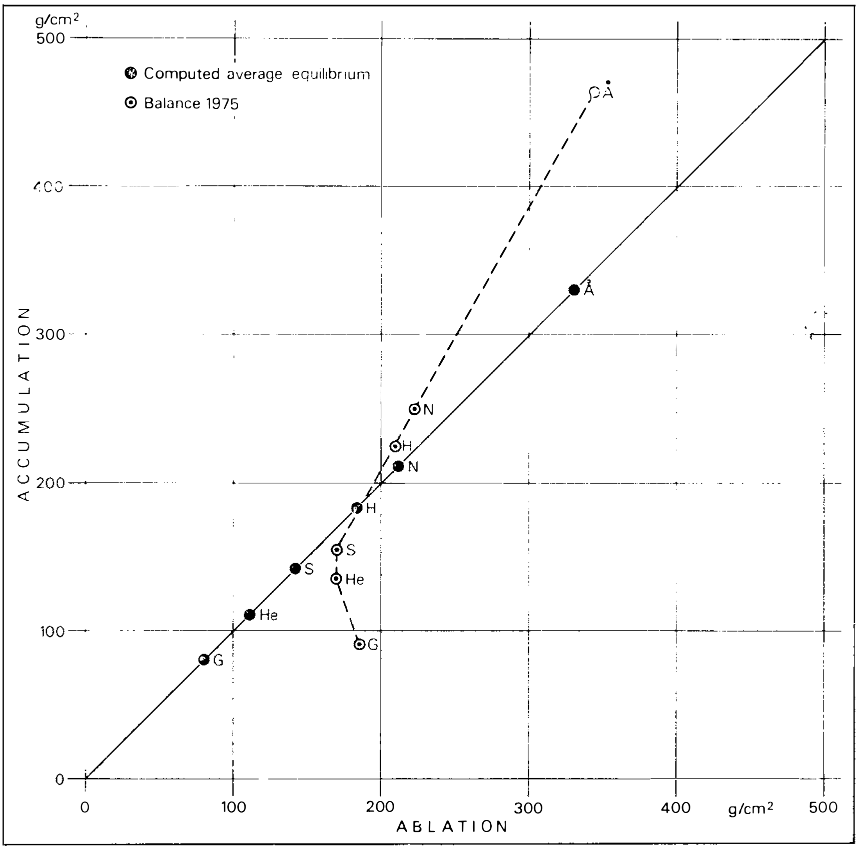


Fig. 11. *Relation between accumulation and ablation compared to the mean of a year with a computed balance budget and a "normal" mass exchange.*

G = Gråsubreen H = Hardangerjøkulen He = Hellstugubreen
N = Nigardsbreen S = Storbreen Å = Ålfotbreen

Взаимоотношения между аккумуляцией и абляцией в сравнении с средними значениями года с подсчитанным балансированным бюджетом и ,,нормальным" вещественным балансом.

Other investigations

The Norwegian Water Resources and Eletrcicity Board carried out measurements on eight glaciers in Norway, of which three, Engabreen, Trollbergdalsbreen, and Høgtuvbreen, are situated in northern Norway. The measurements and investigations dealt with in this paper are presented in Table 2. The mass balance figures for southern Norway are also presented graphically in Fig. 11.

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Fig. 10. *The fluctuation of Bergsetbreen, an outlet glacier from the Jostedalsbreen ice-cap. This is a fast reacting glacier with a time-lag of about three years. The height of the ice-fall is about 1000 m.*

Колебание вытекающего из ледяного щита Jostedalsbreen быстрореагирующего выходного ледника Bergsetbreen с запаздыванием примерно в три года. Высота ледопада около 1000 м.

Table 2

Mass balance measurements of different glaciers in Norway and Spitsbergen 1974—75

Name of glacier	Area km²	Winter balance g/cm²	Summer balance g/cm²	Net balance g/cm²
South Norway				
Blomsterskardbreen	—	—	—	170
Hardangerjøkulen	17.30	225	210	15
Ålfotbreen	4.79	464	343	121
Supphellebreen	11.98	—	—	100
Nigardsbreen	47.21	250	223	27
Storbreen	5.35	155	170	−15
Hellstugubreen	3.29	135	171	−36
Gråsubreen	2.52	91	186	−95
North Norway				
Høgtuvbreen	2.60	300	227	73
Engabreen	38.02	318	157	161
Spitsbergen				
Austre Brøggerbreen	6.12	78	109	−31
Midre Lovénbreen	5.80	83	104	−20

Measurements of the fluctuation of glacier tongues were carried out on sixteen glaciers, and the results are presented in Table 3.

Table 3

Fluctuations in length in metres of some glacier tongues

Jotunheimen			*Jostedalsbreen*	
Storbreen	— 8		Briksdalsbreen	+41
Styggedalsbreen	— 3		Fåbergstølbreen	−11
Memurubreen Ø	−52	(4 years)	Stegaholdbreen	+ 1
Veobreen	−17	»	Tunsbergdalsbreen	−10
Tverråbreen	−46	»	Austerdalsbreen	— 3
Styggbreen	0	»		
Hellstugubreen	−65	»	*Svartisen*	
Illåbreen N	−55	»	Engabreen	0
Illåbreen S	−42	»		
Leirbreen	−20	»		

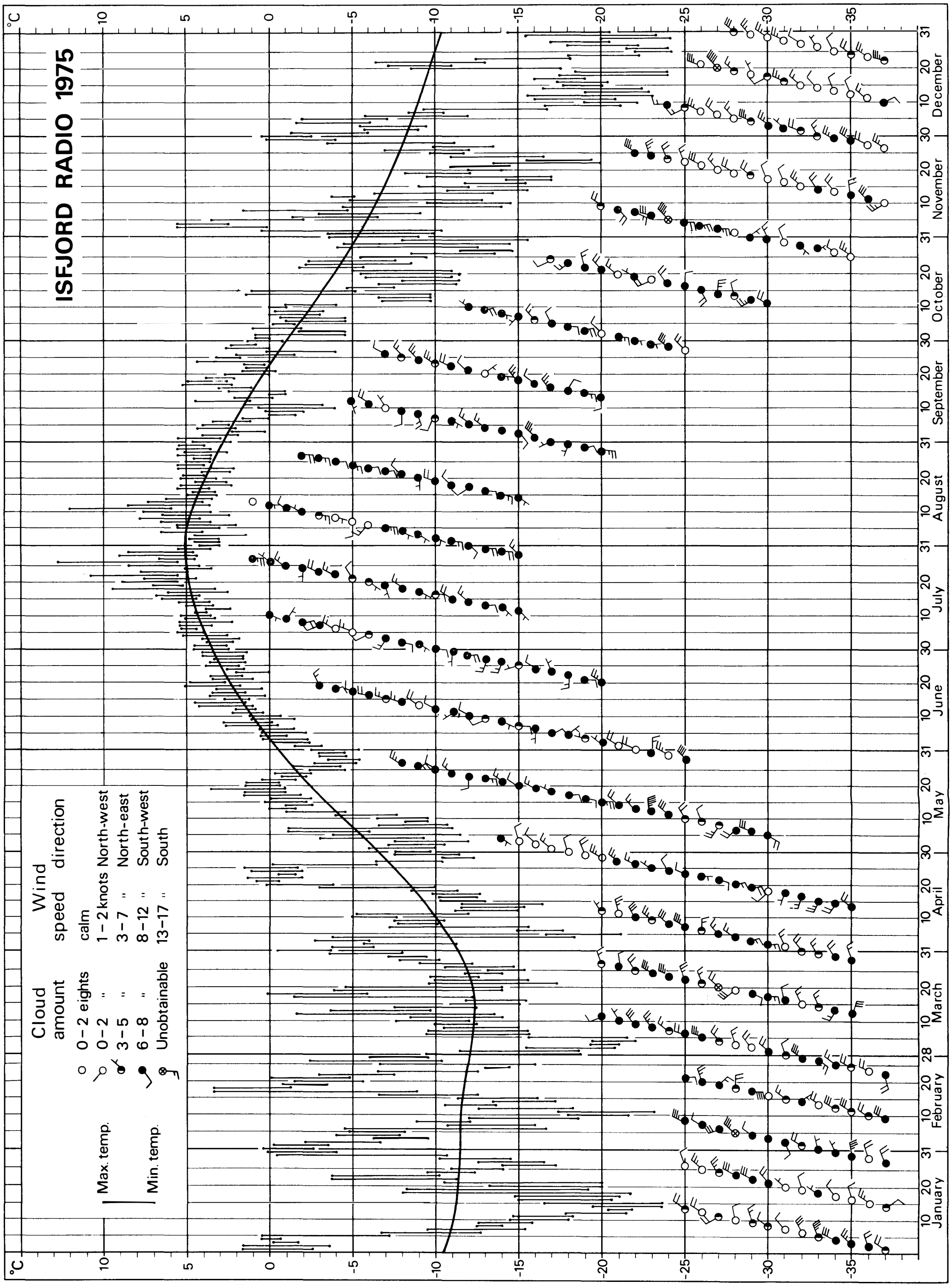
The weather in Svalbard in 1975

By Vidar Hisdal

The diagram presents some important meteorological elements observed at Isfjord Radio during 1975: 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 average annual temperature variation for the period 1947–74. The symbols used are explained by examples in the diagram.

The table contains the monthly mean temperatures for Isfjord Radio, Hopen, and Bjørnøya for 1975, as well as their deviations from the means based on the period 1947–74. The term "normal" used below refers to this latter period.

The weather during the first five days of the year was dominated by the passage of a well-developed low-pressure system. On four of these days the maximum temperature at Isfjord Radio exceeded 0°C. The winds were easterly or northeasterly. However, the air currents were not of polar origin, but formed the continuation of southerly currents in front of the depression. In the rear of the depression considerably colder air entered the region, between cyclonic centres passing farther to the south or east and a high-pressure ridge over Greenland. This air circulation was characteristic for most of January. During the last three days of the month and the first week of February several depressions passed the area, and the temperature was above normal. The second week of February was appreciably colder, due to invation of air from the Polar Basin, while the last half of the month again was dominated by a milder, cyclonic weather type. On 17 and 18 February the maximum temperatures observed at Isfjord Radio were as high as 3.3°C, and the precipitation fell as rain. Especially the first and last third of March were influenced by a cold, northeasterly flow of Arctic air, whereas cyclonic activity and milder spells were more predominant during the middlemost part and the last few days of the month. The larger part of April had northerly winds and temperatures about or below the average. The period 19 to 26 April formed the most pronounced exception from this general tendency, with transport of comparatively mild air from the south in connection with low-pressure passages. The start and end of May were cool, while particularly the days from the 12th to the 24th of the month had above normal temperatures, with


ISFJORD RADIO 1975
°C
10
5
0
-5
-10
-15
-20
-25
-30
-35
Max. temp.
Min. temp.
Cloud amount
0–2 eighths
0–2 "
3–5 "
6–8 "
Unobtainable
Wind speed direction
calm
1–2 knots North-west
3–7 " North-east
8–12 " South-west
13–17 " South
January
February
March
April
May
June
July
August
September
October
November
December

relatively moderate cyclonic activity and variable winds. Cyclonic activity influenced the weather during a few shorter periods in June as well. The typical air circulation during this month, however, was governed by an anticyclone over Greenland, or the Polar Basin, giving weak to moderate winds and temperatures about or somewhat below the normal for the season.

During July and August several depressions passed. The summer weather was thus cloudy, and southerly winds were frequent. At Isfjord Radio three days had maximum temperatures exceeding 10°C: 22 and 26 July, and 11 August. The maximum observed on 26 July, 12.8°C, was the highest temperature of the year. Apart from a cool spell from 7 to 11 September, this month had about normal or above normal temperatures, and the weather was considerably influenced by low-pressure centres travelling over or close to the Svalbard area. This mild, cyclonic weather type was not equally evident in October. Particularly during the three last weeks of this month, cold, Arctic air masses were predominant. During the first 12 days of November several vigorous cyclones passed, with mild, southerly winds in the front, and colder, northerly winds in the rear. It may be mentioned that both on the 3rd and the 4th of the month Isfjord Radio had maximum temperatures of 5.6°C. From the 12th on, however, a high-pressure over Greenland and adjacent regions took over, giving cold northeasterly winds. The last couple of days of the month were again influenced by depressions approaching from the southwest, and the temperature rose considerably, to maxima between 0° and 1°C. Except for two relatively mild spells, occasioned by the circulation around cyclonic centres moving farther south, the weather conditions in most of December was dominated by a cold, northerly air flow between high-pressure areas in the northwestern sector and low-pressure systems to the south or east of the archipelago. This circulation pattern is frequently associated with clear skies and, at this time of the year, radiational cooling of the ground, which implies that the air masses remain cold or grow still colder. The lowest temperatures of the year at Isfjord Radio occurred during the last half of December, the annual minimum, −24.2°C, being observed on the 25th of the month.

Monthly mean temperatures for 1975 (T) and their deviations (d) from the means of the period 1947–74.

		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Isfjord Radio	T	−11.3	− 9.5	−11.8	− 8.4	−3.9	1.4	4.8	4.4	1.3	−5.4	− 8.5	−15.8
	d	− 0.1	2.1	0.5	0.8	−0.5	−0.3	0.2	0.2	0.3	−2.2	− 1.5	− 6.4
Hopen	T	−12.0	−12.2	−15.3	−10.1	−5.0	−1.5	1.2	1.3	0.7	−5.4	−10.2	−17.1
	d	0.9	0.2	− 1.7	0.6	−0.3	−1.2	−0.8	−0.9	−0.1	−2.5	− 3.0	− 6.7
Bjørnøya	T	− 7.2	− 6.6	− 5.6	− 5.0	−1.1	0.3	3.2	4.0	2.5	−1.7	− 4.0	−11.6
	d	0.2	0.5	2.0	0.3	0.4	−1.7	−1.1	−0.4	−0.3	−1.6	− 1.0	− 6.0

The tabulated mean temperatures show that late winter and early spring were generally somewhat milder than normal. The only marked exception from this tendency is the cool month of March on Hopen. The average summer temperatures were close to normal at Isfjord Radio, while they were somewhat below normal at the two other stations. The end of the year was cold at all three stations, especially the month of December, with mean temperatures 6° to 7°C lower than the long-term average. Since regular observations started at these stations, a lower December mean has never been recorded at Bjørnøya (i.e. since 1920), only once at Isfjord Radio (since 1934), and twice at Hopen (since 1945). The annual amount of precipitation at Isfjord Radio, 332 mm, was somewhat below normal. Nearly 20% of this precipitation occurred during the above mentioned 12 "low-pressure days" in the beginning of November, a large part of it falling as rain. The month of December, on the other hand, was here not only the coldest, but also the driest one, with only 2 mm.

Sea ice conditions in the European sector of the marginal seas of the Arctic, 1966–1975

By Torgny E. Vinje

Contents

Abstract

Information on sea ice conditions from U.S. weather satellites has been reviewed for the period 1966–1975. Extreme distributions as well as drift patterns based on movements of giant floes, and sea ice conditions in 1975 compared to the ten year average are discussed.

Introduction

In the last ten years since 1966, U.S. weather satellites have effected information on sea ice distribution, thereby immensly increasing our previous relatively sparse knowledge on this subject. The survey below is mainly based on the satellite images recorded at the Norwegian Meteorological Institute from 1968 on, and on the ice charts published twice weekly by this institution since 1970. Information from the English Monthly Ice Charts has been used, as well as all other available data from aircraft, ships, and Arctic land stations. For the period 1968–70, the ice borders were depicted at Norsk Polarinstitutt.

General outline of the sea ice distribution

The main characteristic feature of the sea ice distribution in the European sector is caused by the prevailing warm and cold sea currents in the area. In west, the cold East-Greenland Current is passing southwards between Greenland and the northwards directed warm current from the Norwegian Sea. These two currents form the Jan Mayen Gyro which is more or less pronouncedly reflected in the sea ice distribution at these latitudes in the cold season. In the winter, the warm West Spitsbergen Current creates the northernmost area of open water in the Arctic.

In the eastern part of the Svalbard archipelago there is a predominant cold southwest-bound current, extending to Bjørnøya in the south, with a branch passing northwards along the western coast of Spitsbergen. At the southern border of the cold water passing over the relatively shallow shelf, the ice cover, during the cold season, is to a large extent governed by interaction with the warm current passing from the Norwegian Sea into the Barents Sea.

The distribution of concentrations higher than 3/8

In Fig. 1 the enveloping curves are given for maximum and minimum extension of sea ice concentrations higher than 3/8 for the first nine years of the ten-year period considered. Ice borders for 1975 are also given (for later discussion of this particular year), and the above mentioned envelopes including all ten years may be extended by the reader. All borders and envelopes refer to the end of each month.

Because of the large variations in the sea ice distribution observed from year to year, it is assumed that an ordinary mean ice edge may be somewhat artificial in many areas, and, moreover, difficult to define. We have therefore chosen to give the so-called median border which is defined as the line south of which sea ice concentrations higher than 3/8 are found in less than 50% of the observations made during the ten-year period considered.

The limiting concentration mentioned (3/8) is considered because comparisons between satellite imageries and surface observations have revealed that lesser concentrations are not always registered by weather satellites. This seems to depend upon the pattern of sea ice concentrations, whether it consists of long stripes, which may not be visible, or is more arbitrarily distributed, which may be observed in concentrations as small as 1/8.

However, for navigation through sea ice concentrations less than 3/8, ice-strengthened vessels are generally not necessary, and occurrence of smaller concentrations, therefore, is of little importance in this respect.

The main impression from Fig. 1 is the broad range within which the sea ice is observed during the ten-year period. This is assumed to be mainly due to changes in the atmospheric circulation combined with the variation of heat transported by the sea currents during the same period (DICKSON et al. (1975)). The improvement of the sea ice conditions north of Iceland since 1968, for instance, is accompanied by a change from a positive (7.3 mb in May 1968) to a negative (—7.2 mb in May 1971) deviation from the monthly mean air pressure at Reykjavik (*Die Grosswetterlagen Europas*). An intensification of the Icelandic Low will in turn set up stronger south-easterly winds in the area north of Iceland and influence the sea ice distribution as well as the sea currents.

Some marked features in the sea ice distribution may be observed from month to month. The Jan Mayen Gyro, for instance, is very clearly visualized in the cold season and most markedly at the end of March. The figures suggest a tendency of the Gyro to move towards south-south-west during the first months of the year. The special distribution of the sea ice north of Jan Mayen was first observed when sealing started, around 1850, and the names Odden and Nordbukta (Fig. 2) have been applied since then.

As early as at the end of March, there is a polynia south of Frans Josef Land. When the disintegration in the northern part of the Barents Sea occurs during the warmer season, this polynia gradually becomes more extensive and together with the disintegration going on at this longitude at the southern border of the ice, the area south of the archipelago is among the first to open up completely in the spring. It is also seen that the melting around the islands extends westwards and the melting north of Svalbard extends eastwards. In June, July, and August this may result in a large isolated sea ice area in the eastern part of the Svalbard archipelago. Moreover, this may indicate that the exchange of ice with the Arctic Ocean through the passage between Svalbard and Frans Josef Land is insignificant during the warmer season. The evolution of the disintegration in the eastern part of the Svalbard archipelago may also be governed by predominant surface drift patterns in this area. Measurements with self-positioning Nimbus-6 buoys revealed that they were circulating in this area for rather a long time in August 1975 (VINJE (1976)).

As seen above, satellite observations show that large-scale disintegration of ice may go on relatively far north of the most southern ice border. This suggests that previous ship observations may possibly have given a wrong impression of the sea ice distribution in areas with a complicated disintegration pattern, such as in the Svalbard and Frans Josef Land archipelagoes.

Extreme distribution of sea ice

Fig. 2 shows the distribution of sea ice for some extreme conditions. In April 1966 the amount of ice in the Barents Sea reached a maximum. Two years later, in April 1968, a maximum was observed around Iceland. It is noted that a maximum in the western region is not accompanied by a maximum in the eastern region or vice versa. This may have something to do with the predominant dimensions as well as the positions of the atmospheric circulation systems. If, therefore, the position of the ice edge is used as a climatic index, the conditions over a larger area should be considered.

Fig. 1 (on pages 162–165). *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 1966–74,*

— · — : *1975 ice border,*

—•— : *median border south of which sea ice (concentrations above 3/8) is observed in less than 50 per cent of the cases in the ten-year period 1966–75.*

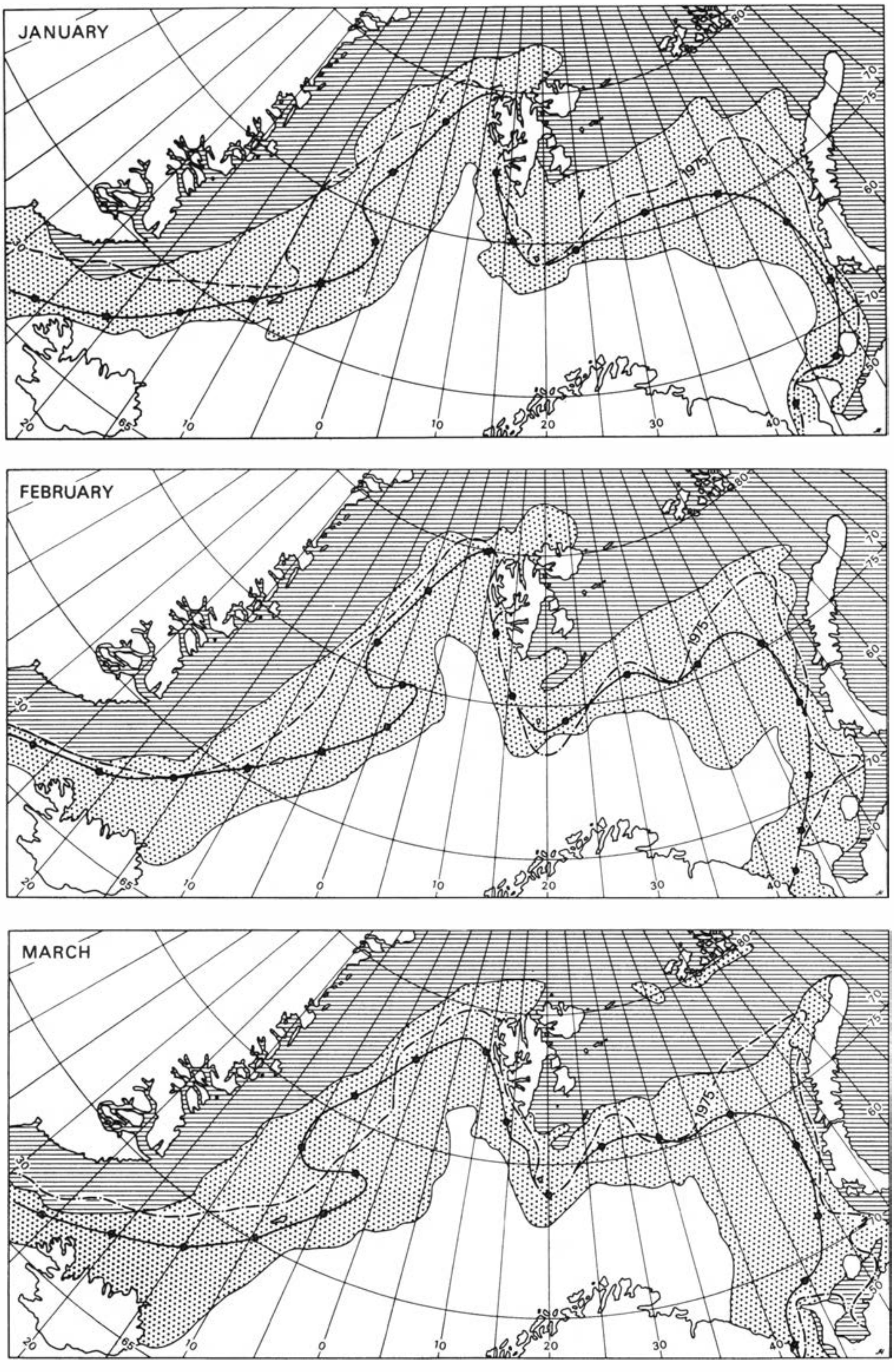


Fig. 1.

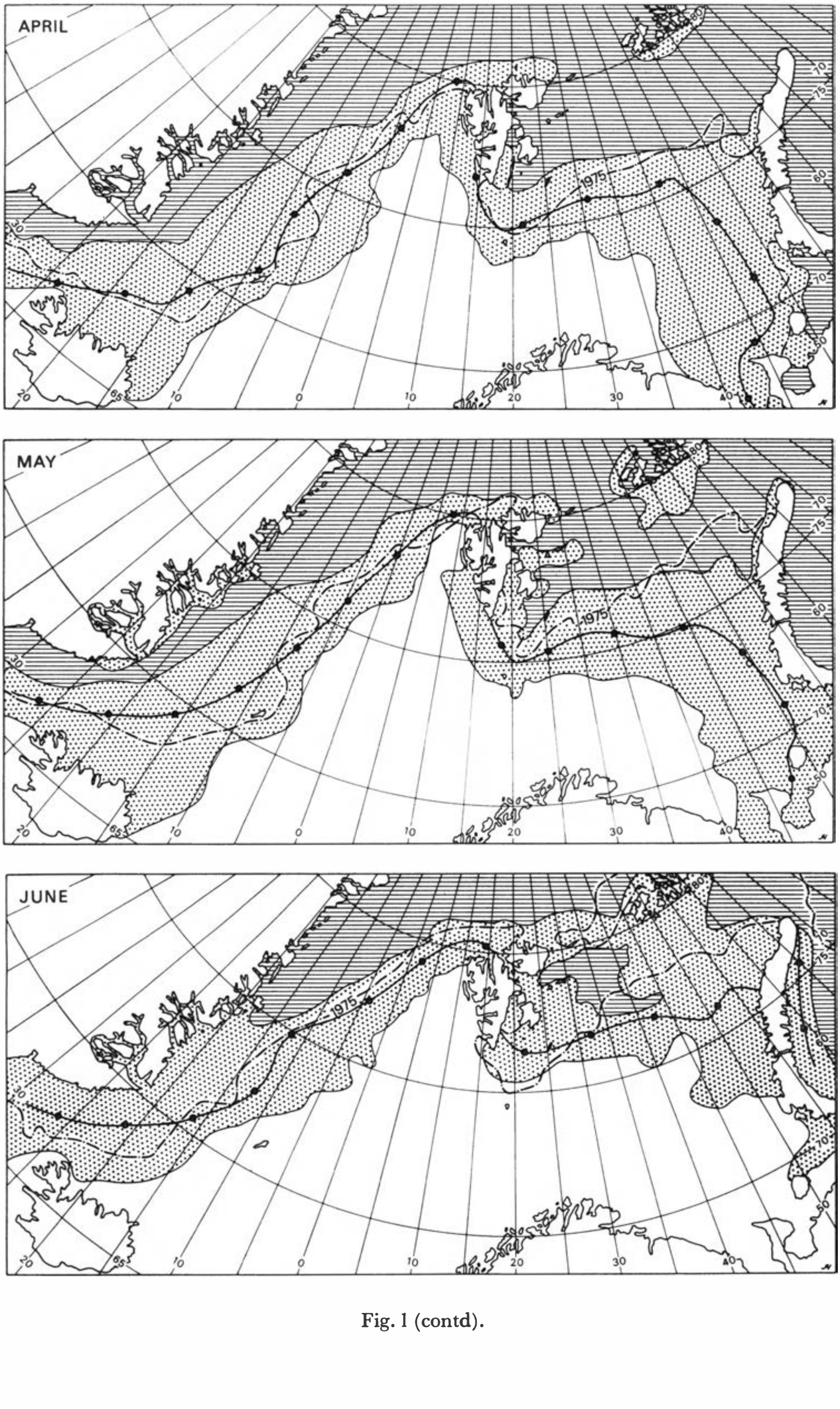


Fig. 1 (contd).

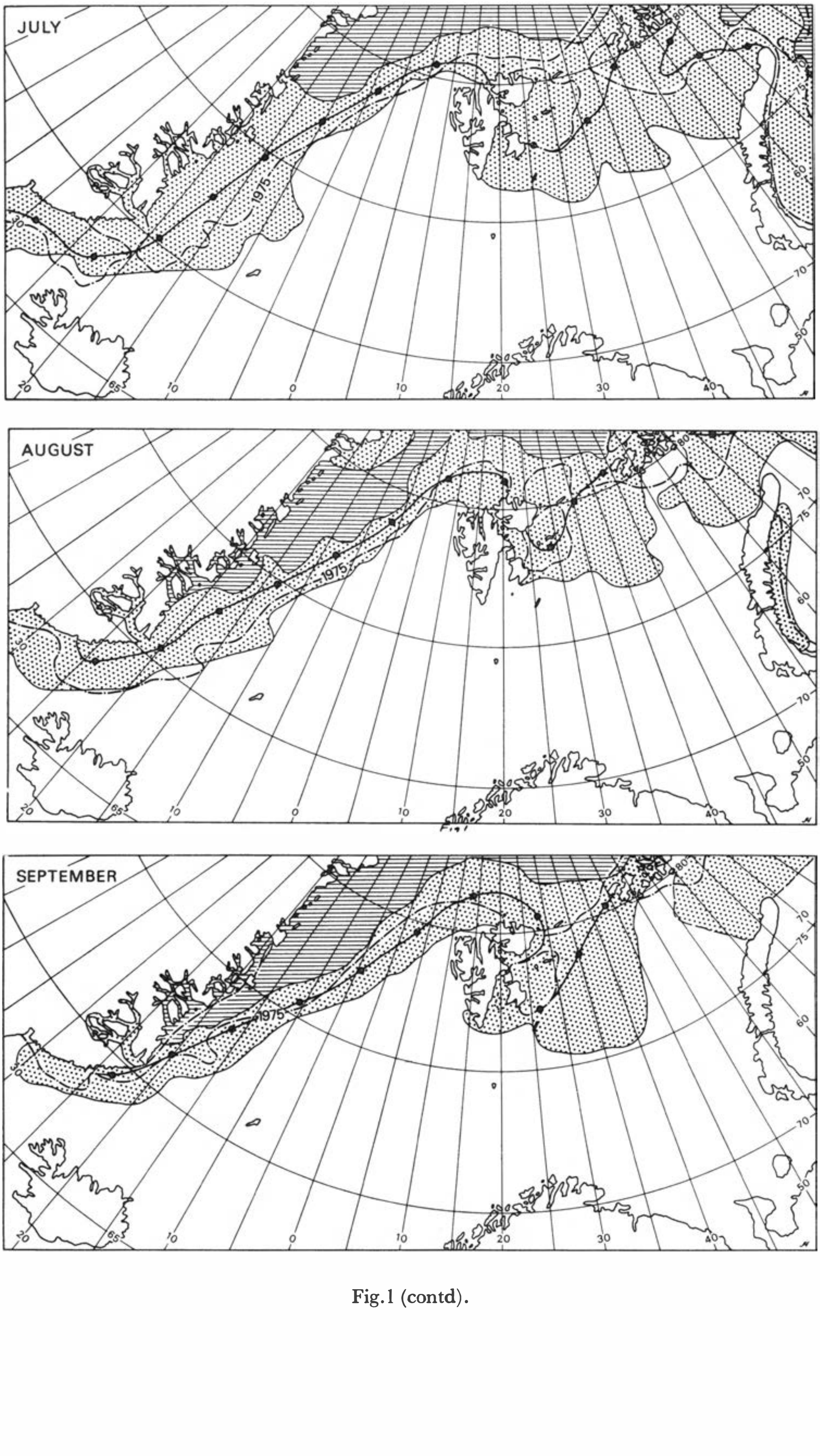

JULY
1975
AUGUST
1975
SEPTEMBER
1975
20
65
10
0
10
20
30
40
80
75
70
60
50

Fig.1 (contd).

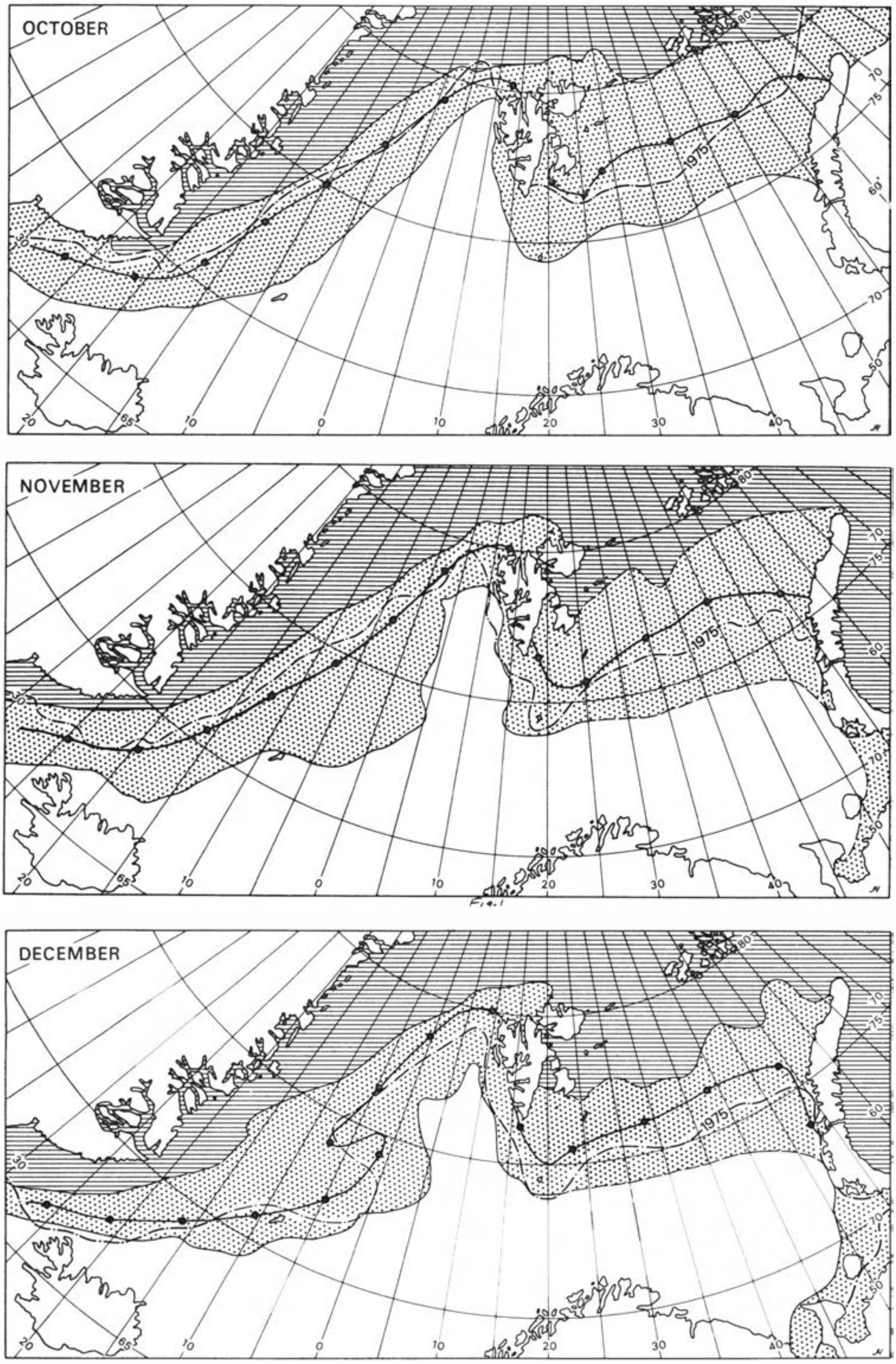

OCTOBER
1975
80
70
75
60
70
50
20
65
10
0
10
20
30
40
NOVEMBER
1975
DECEMBER
1975
30

Fig.1 (contd).

Odden and Nordbukta were extraordinarily well developed in the beginning of April 1970. Later in the year, Odden was parted from the rest of the ice and disintegrated as an isolated ice field. With the indicated circulation in the Jan Mayen area, the sea ice is found very close to the northern coast of Iceland. It is seen that Svalbardbukta and Bjørnøyodden at the same time are extremely well pronounced which is also the case with the northwards extending ice free area in the eastern Barents Sea. It may be noted that the positions of the ice border southwest and south of Svalbard are very near the same for the three extreme conditions referred to in Fig. 2.

In order to compare sea ice conditions in the Jan Mayen area with previous observations, copies of ship journals for April-May for the period 1853–1875 have been examined. Mr. N. Øritsland at Havforskningsinstituttet, Bergen, kindly provided information from the area for the years 1953 to 1965. Together with the satellite observations we are thus in possession of sea ice observations for two periods of equal lengths, a hundred years apart. Considering both periods, we find that the extreme eastward and westward extension of Odden was observed in April 1854 and 1957, respectively. It is noticed that the most westerly position during the first period was observed one year after the extreme eastward extension, in 1855. For the last period, we note the extreme development of the sea ice distribution in 1970. It is also remarked that the special indication of the Jan Mayen Gyro as observed in spring 1970, was not observed during the rest of any of the two periods and this special sea ice distribution, therefore, seems to be rather rare. It is noted that the main axis of Odden is oriented parallel to the Mid-Atlantic Ridge.

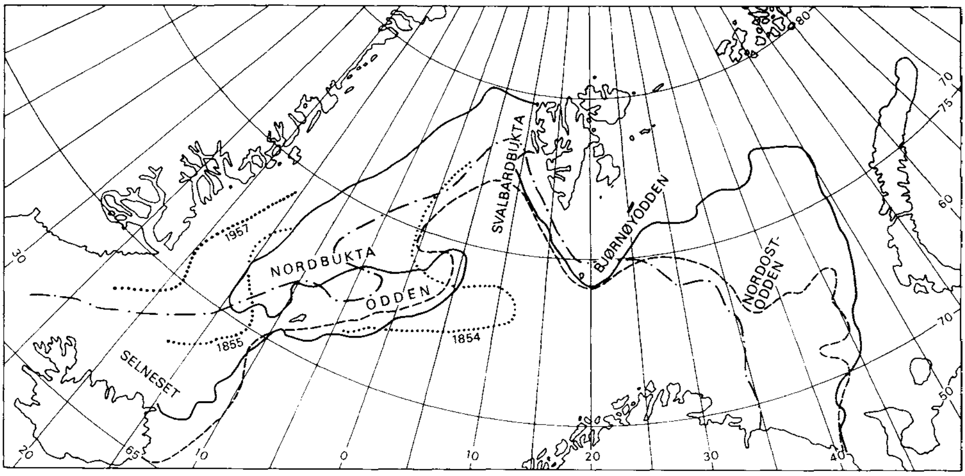


Fig. 2. *Extreme sea ice distributions.*

— · — : *10–20 April 1966,*

- - - - - : *10–20 April 1968,*

——— : *1–10 April 1970,*

. . . . : *ship observations made in April 1854, 1855, and 1957.*

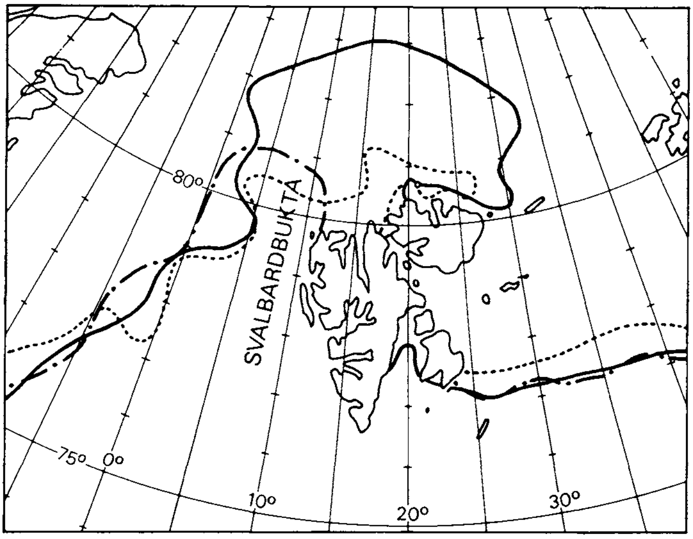


Fig. 3. *Observations showing sudden and extensive variations in sea ice conditions north of Svalbard.*

- - - - - : *21–23 November 1972,*

——— : *16 December 1972,*

— · — : *4 January 1973.*

In Fig. 3 is shown a variation in the northward extension of Svalbardbukta which seems to have occurred relatively suddenly in December 1972. The very extensive area of open water as illustrated on 16 December by the microwave image (ESMR) of Nimbus-5 (GLOERSEN et al. (1974)), was between 4 and 28 December indicated as open drift ice on the ordinary weather satellite images. The discrepancy in concentration is probably due to an assumed intense formation of frost smoke over the open water.

Due to the extraordinary high heat loss from an ice free ocean at high latitudes, an opening-up in the scale reported should totally change the heat budget and should be expected to have a pronounced effect over still larger areas. The considerable variation in the sea ice extension at this time of the year at these latitudes may indicate large-scale oceanographic variations and a possible change in the specific weight of the cold and warm water masses, causing the warm water to submerge at higher latitudes. In November 1974 fishing boats reached 82.5°N without encountering serious ice conditions (pers. comm. J. ANGARD). The formation of open water during the cold season may not be a rare phenomenon, therefore.

Ice drift observations

During April and May the minimal cloud cover enables us to trace giant floes over periods long enough to make fairly reliable estimates of the drift speed of the sea ice (VINJE (1968–1973)). In Fig. 4 these observations have been collected for a review. The figure indicates the well known increase in speed as the drift ice leaves the Polar Ocean, from 6–12 cm sec^{-1} at 80–81°N, with an average of about 8 cm sec^{-1}, to 6–37 cm sec^{-1} at 76–79°N, with an average of about 17 cm sec^{-1}. The highest velocities are observed near the continental slope with a maximum of 37 cm sec^{-1}. This spacial variation of observed drift velocities are in fair accordance with the dynamical calculations and observations of the sea current given by KIILERICH (1945). However, all current speeds given by KIILERICH are generally considerably higher than the ice drift speeds obtained from satellite images during the spring months.

Drift speed values for the area close to Jan Mayen given in Fig. 4, are based on observations from a sealer beset by drift ice for 22 days in April 1969. The great variations observed here were closely connected with variations in wind speed and direction (VINJE (1970)).

In the Svalbard area and in the Barents Sea the number of drift speed observations obtained is relatively small. This is assumedly due to the facts that there are fewer giant floes in this area and that the formation of leads are not generally observed to the same degree as in the East-Greenland Current where there is a prevailing meridional divergence in the ice field. (From observations in spring 1968, VINJE (1970) calculated a divergence of 10^{-7} sec^{-1} which might indicate an opening-up of as much as 20 per cent of a given area during one month.)

Numerous estimates have been given of the ice transport through the Fram Strait, see e.g. TIMOFEYEV (1958), nearly all close to 0.1 Sv. (1 Sverdrup = $10^6 m^3 s^{-1}$). For the ten-year period considered here it can be seen from Fig. 1 that the width of the ice flow, across the most narrow part of the strait, varies between 100 and 350 km in July and August. For the rest of the year this dis-

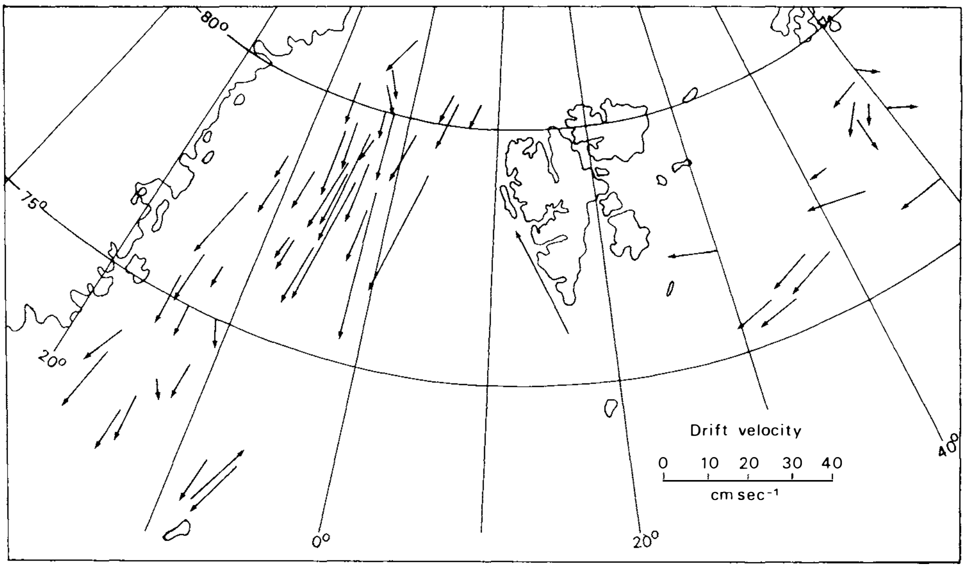


Fig. 4. *Ice drift observations collected in April and May, mainly from drift of giant floes as observed from weather satellites* (VINJE (1968–73)). *Length of arrow indicates velocity according to scale given to the right.*

tance varies between 250 and 500 km. If the ice drift speed in the Fram Strait is between 6 and 12 cm sec^{-1} as estimated from observations by weather satellites, and the average thickness of the ice is 3 m, the estimated export for July and August lies between 0.017 and 0.122 Sv. For the rest of the year it may vary between 0.044 and 0.140 Sv.

From automatic Nimbus-6 buoys placed on ice floes, the average drift speed between 81 and 80°N was measured to be as high as 24 cm sec^{-1} in the central area of the Fram Strait in April 1976. This indicates a 100 per cent increase of the maximum values given above and supports the impression that there may be considerable variation in the ice export from the Arctic Ocean. According to AAGAARD (1975) this export of ice represents the second highest term in the heat budget equation for the Arctic Ocean, if the estimate is 0.1 Sv as an annual average. The indicated variability, therefore, becomes of great importance in connection with heat budget calculations for shorter periods.

Sea ice conditions in 1975

The ice border at the end of each month is given in Fig. 1. The figure is self-explanatory as to the variation in ice conditions throughout the year and I will just mention below some of the most marked features.

At the end of January an effect of the Jan Mayen Gyro is indicated, this in spite of the relatively small amount of ice in the Greenland and Icelandic Seas. It is noted that the Odden and the Nordbukta are completely lacking at the end of February and March and that this coincides with an extremely northerly position of the ice border northwest of Iceland.

At the end of February the Bjørnøyodden has a maximum southerly extension, and from this time throughout May the ice border west of Novaja Zemlja is close to, or at its northern extreme position for the ten-year period considered. The Nordostodden (at 75°N and 37°E) is seen to be well marked at the end of February and March.

At the end of June there is an exceptionally large opening north-west of Frans Josef Land, in contrast to what is the usual position of this polynia, to the south of the archipelago. At the same time the Bjørnøyodden showsa maximum extension southwards. This indicates a relatively intense circulation in the Barents Sea Low which is in accordance with a deviation from the mean monthly air pressure in the central area of —2.7 mb. (*Die Grosswetterlagen Europas*). The relatively poor ice conditions south of Frans Josef Land is seen to exist from the end of July throughout September when the mentioned deviation became markedly positive, +3.2 mb. In the eastern part of the Svalbard archipelago there is an enclave of sea ice from the end of July to the end of September. As previously mentioned this may be due to a local circulation of the surface drift in this area (VINJE (1976)).

The refreezing during the first part of the cold season seems to proceed normally, but with a greater amount of ice in the Barents Sea and along the west coast of Spitsbergen than is usually found at the end of the year. The Bjørnøyodden is seen to be close to, or at its most southerly position in the ten-year period. In the East-Greenland Sea the effect of the Jan Mayen Gyro on the sea ice distribution at the end of December is relatively well indicated for that time of the year, and it is again noted that there is a maximum southerly position of the ice border in the Icelandic Sea.

Final remarks

The main impression when considering a series of sea ice observations is the great variability in the position of the ice edge which may occur even over very short periods. This indicates that long series of observations are necessary when changes in the ice border are to be used as index for climatic changes. The satellite observations also show that large-scale disintegration of the ice may go on relatively far north of the most southern border. This suggests that when considering small areas, care should be taken when ship observations from earlier days are compared with observations from satellites. This is particularly the case where the disintegration pattern is complicated, as in the Svalbard and Frans Josef Land archipelagoes.

There are several indications in the material considered here that a northerly (southerly) position of the sea ice border in the Icelandic Sea coincides with the absence (clear developement) of the features called Odden and Nordbukta. The absence of these features may be achieved if the Icelandic Low is relatively intense; the presence, however, is dependent upon a relatively weak air pressure gradient as well as a developed oceanic circulation. Together with the indication that a movement of the gyro towards south-south-west may take place during the first months of the year, this suggests that determination of the intensity and the change in position of the Jan Mayen Gyro could give prognostic indications for the ice conditions north of Iceland under conditions with a relatively weak air pressure gradient.

Acknowledgements

Thanks are extended to Mr. B. ARNESEN for drawing the figures and to Mr. E. THEISEN for critical reading of the manuscript.

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Radiation conditions in Spitsbergen in 1975

By Torgny E. Vinje

Contents

Abstract

Monthly sums of radiation components for land and open sea in Spitsbergen for 1975 are considered.

Introduction

Continuous radiation measurements were started in Ny-Ålesund (78°55′N, 11°56′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. Part of the ventilation system which very effectively keeps the domes clean, may be seen on Figs. 1 and 2. A description of the instruments and the calibration methods are given by Vinje (1976).

Results

The monthly sums of some of the radiation components are given in Table 1, together with the albedo of the tundra.

The annual sum of the global radiation (G) is seen to be about 54 000 ly. This is about 5.5% less than the quantity measured in 1974 and 1% higher than the ten-years average measured at the neighbouring station, Isfjord Radio, from 1951 to 1960 (Spinnangr (1968)). It is of interest to note that the annual sum of the global radiation measured at these northern latitudes amounts to only about 50 –60% of that measured at 70°S, e.g. Vinje (1964).

The low albedo (a) observed in February, March, and April 1975 is due to wind transport of a relatively sparse precipitation. The surface became totally snow-free on 17 June. The albedo then relatively suddenly decreased to 0.10. In the course of the summer it increased to 0.14 due to the effect of the changing of colours of the tundra vegetation.

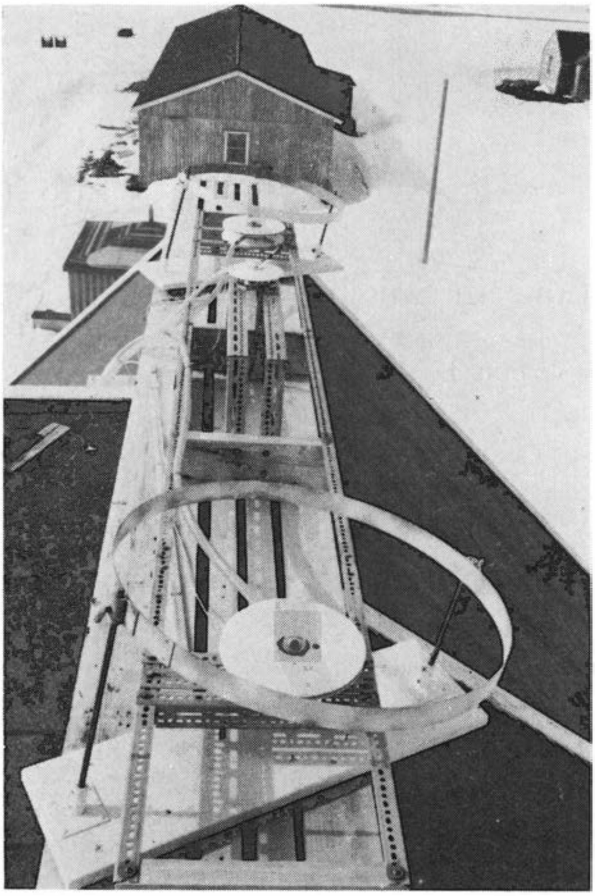


Fig. 3. *The diurnal variation of the global radiation (G), the radiation balance of the land surface (BL), and the radiative temperature of the surface (To) for the first ten-day period, 18—28 June, after snow melt in 1975.* →

Fig. 1. *Radiation instruments mounted on the roof of the research station in Ny-Ålesund. In the foreground a pyranometer for registration of diffuse sky radiation, then a pyranometer for registration of radiation from sun and sky (global radiation). In the background a shielded balance meter. The plastic tubes are part of the ventilation system.*

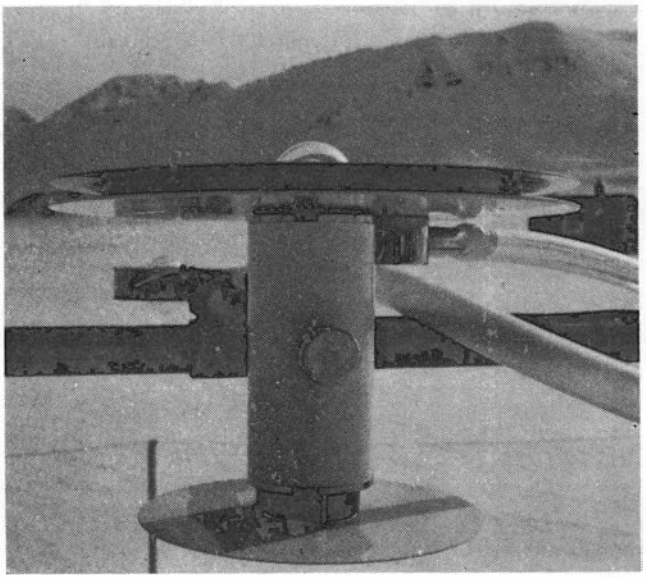
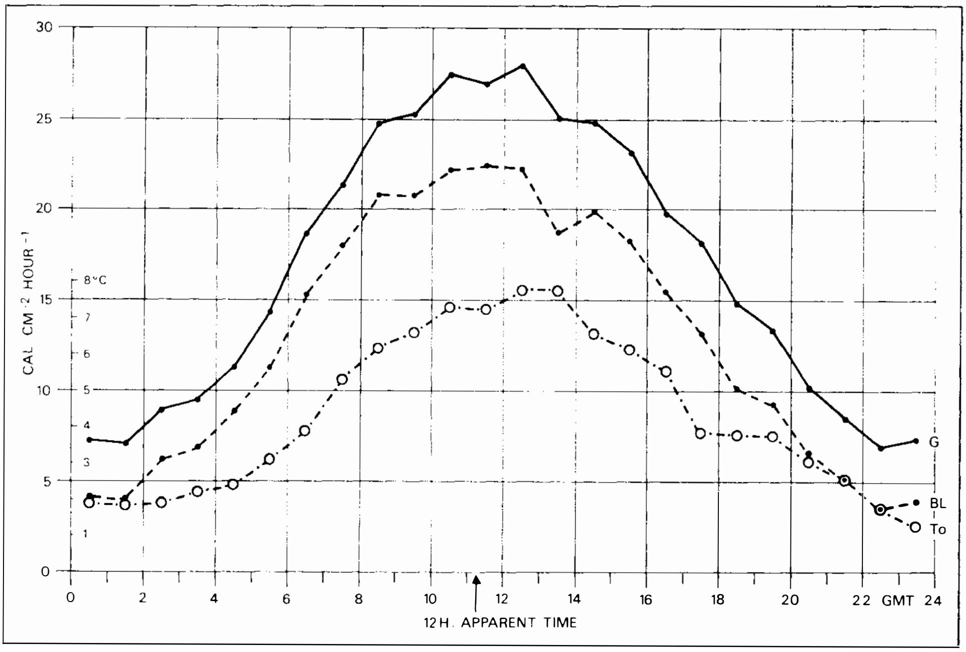


Fig. 2. *The albedometer and balance meter as mounted over the tundra. The plastic tubes are for ventilation.*



The atmospheric counter-radiation (A) in 1975 was 6.7% less than in 1974. This is mainly due to a deficit during the dark season.

The radiation balance of the land surface (BL) for 1975 amounts to only 45% of that observed in 1974. This great difference may mainly be due to a 2 700 ly higher global radiation in 1974. Table 1 shows that the net radiation of a land surface (BL), on an annual basis, is markedly higher than that of a sea surface of 0°C. A sea temperature increase of 5°C would cause an increase in the radiation loss which amounts to about 1500 ly month^{-1}. As a sea water temperature of 5°C is often measured in the area considered, at least in the summer and autumn months, it is seen that the actual annual net radiation of an open water area may well become negative at these latitudes. The values of this quantity given in Table 1 are therefore to be considered as maximum values.

In Fig. 3 are given the average hourly values of the global radiation, the net radiation, and the radiation temperature of the tundra for the period 18–28 June. As mentioned above, the snow had disappeared from the tundra on 17 June. The figure indicates that during the very short "spring" the average maximum surface temperature increases from 0°C to about 8°C over a period of a week or so.

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Table 1

Monthly sums, ly month^{-1}, of radiation components at Ny-Ålesund in 1975.

	Jan.	Febr.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
G		45	1 815	6 484	12 840	14 559	9 349	6 344	2 418	300			54 154
a		0.677	0.407	0.706	0.803	0.421	0.121	0.137	0.380	0.762			
A	13 865	13 638	13 722	15 288	17 522	18 129	20 960	18 595	18 079	16 134	14 211	13 992	194 135
BL	−2 524	−1 721	−1 273	270	1 056	6 549	6 568	3 568	146	−1 773	−2 327	−2 234	6 305
BS	−6 634	−4 844	−5 146	1 290	8 587	11 400	8 897	3 813	420	−4 092	−5 610	−6 510	1 571

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*

Observations of animal life in Svalbard in 1975

(Наблюдения над фауной Свальбарда в 1975 г.)

By Thor Larsen

Contents

Abstract

Observations of birds and mammals in Svalbard were collected from 25 expeditions and persons during 1975. Efforts were made to obtain quantitative information on some common species, as muskox (*Ovibos moschatus*), long-tailed duck (*Clangula hyemalis*), eider (*Somateria mollissima*), king eider (*Somateria spectabilis*), pink-footed goose (*Anser fabalis brachyrhynchus*), and barnacle goose (*Branta leucopsis*). Most observations are from the west coast of Spitsbergen, but some are from the northern part of Spitsbergen, Hopen, and Tusenøyane. The majority of observations were made between June and August.

Аннотация

Получены материалы наблюдений над птицами и млекопитающими, проведенных на Свальбарде 25 экспедициями и лицами в 1975 г., главным образом в период июнь — август. Постарались достать количественные сведения по некоторым общим видам, как овцебыкам (*Ovibos moschatus*), морянкам (*Clangula hyemalis*), обыкновенным гагам (*Somateria mollissima*), гагам-гребенушкам (*Somateria spectabilis*), короткоклювым гуменникам (*Anser fabalis brachyrhynchus*) и белощеким казаркам (*Branta leucopsis*). Большинство наблюдений провелось на западном берегу Шпицбергена, но некоторые из них — в северной части Шпицбергена, на о-ве *Hopen* (Надежды) и архипелаге *Tusenøyane* (Тысяча островов).

Introduction

Norsk Polarinstitutt's questionnaire on the fauna of Svalbard was distributed to most Norwegian and foreign expeditions visiting the archipelago in 1975. Observations were made mainly along the west coast of Spitsbergen, particularly in the Isfjorden area and in Nordenskiöld Land. Other observations are from Tusenøyane, Hopen, and the northern part of Spitsbergen. Quantitative data have been obtained on some species. Observations on reindeer (*Rangifer tarandus platyrhynchus*) are not published here, since quantitative information on this species is obtained through the MAB programme, and will be published separately. I am grateful to the following persons and groups for their contribution of data and information: F. Berntsen (FB) from Wijdefjorden, S. A. Backstrøm (SAB) from Krossfjorden, L. Christiansen (LC) from the Isfjorden area, A. M. van Dijk, T. M. van Spanje, B. Ebbinge, and D. Ebbinge (D/S/E) from all islands between Reiniusøyana and St. Hansholmane, J. P. Dittami (JPD) from the west coast of Nordenskiöld Land, B. Ebbinge and D. Ebbinge (B&DE) from the coast of Nordenskiöld Land between Kapp Linné and Kaldbukta, H. J. Edel (HJE) from Bjørnøya, D. Elgvin (DE) from northwest Spitsbergen, S. Halvorsen (SH) from Nordenskiöld Land, J. Halvorsrud (JH) from northwest Spitsbergen, Hopen Radio (Hop.rad) from Hopen, L. H. Jenneborg (LHJ) from Liefdefjorden, K. Kastnes (KK) from Adventdalen, Reinsdyrflya, and Berzeliusdalen, I. Kristensen (IK) from the Isfjorden area, F. Müller and J. Thomassen (M/T) from the west coast of Spitsbergen and Daudmannsodden, F. Nygård and L. Nygard (F&LN) from the Kapp Martin area, C.A.G. Pickton (CAGP) from the west coast of Spitsbergen, P. Prestrud (PP) from Prins Karls Forland, the Ny-Ålesund area, and northwest Spitsbergen, O. Salvigsen (OS) from the inner part of van Mijenfjorden, E. Sendstad (ES) from the Ny-Ålesund area, Sevmorgeo, Leningrad (SEV), from northern Spitsbergen, H. Stormyr (HS) from Adventdalen and Grumantbyen, G. Ytreland (GY) from Tusenøyane, and R. Aabakken (RAA) from Nordenskiöld Land, Prins Karls Forland, Moffen, and Wijdefjorden.

Most information has been given on the questionnaires, but data have also been obtained from typewritten reports (Dittami 1975, Prestrud 1975, and Thomassen 1975). Most observations were made in June, July, and August.

Mammals

Muskox (*Ovibos moschatus*): See Table 1.

Polar bear (*Ursus maritimus*): One adult was seen at Bangenhuken 3 June (RAA) and four individuals at Øyrlandet in early July (CAGP). Polar bears were frequenting the west coast of Spitsbergen during winter, but quantitative information has not been obtained.

Common seal (*Phoca vitulina*): One animal was seen at Kaldneset 19 July (PP). 50 to 60 animals were seen on the shore at Horneflya 3 August (PP).

Walrus (*Odobenus rosmarus*): One animal was seen in Forlandssundet 10 June (RAA). At least 53 adult animals were counted on Moffen 12 July (RAA). One animal was seen off Kapp Gurnerd 19 August.

Birds

Great northern diver (*Gavia immer*): At least three adults were seen in Gravsjøen throughout June, July and August (JPD). One adult was seen at Store Andøya 3 August (JH).

Table 1

Observations of muskox (Ovibos moschatus) *in Svalbard in 1975*

Наблюдения овцебыков (*Ovibos moschatus*) на Свальбарде в 1975 г.

Locality/date Местность/дата	Number Число	Observer/remarks Наблюдатель/примечания
Nordenskiölddalen, 6/7	6 ad., 1 juv.	OS
Damesmorena, 6/7	1 ad.	OS
Adventdalen, 13/7	5 ad.	HS
Grumantbyen, 15/7	4 ad., 1 juv.	HS
Blåhuken, medio July	4 ad.	M/T
Adventdalen/Mälardalen, 19/7	8 ad.	HS
Reindalen, at "Pluto-hytta", 28/7	5 ad., 1 juv.	B & DE
De Geerdalen, 13/8	5 ad., 2 juv.	SH
Fuglefjella, late September	8 ind.	RAA. Animals found dead under cliff, four taken by avalanche.
Pilarberget, 16/8.	9 ad.	B & DE

Table 2

Observations of long-tailed duck (Clangula hyemalis) *in Svalbard in 1975*

Наблюдения морянок (*Clangula hyemalis*) на Свальбарде в 1975 г.

Locality/date Местность/дата	Number Число	Observer/remarks Наблюдатель/примечания
Kapp Martin/Diabaspt. 10–11/7	19 ad.	B & DE
Sveagruva, 18/7	1 ad.	M/T
Aitkenodden, 18/7	5 ad.	PP
Kaldneset, 19/7	2 ad.	PP
Flosjøen, 21/7	58 ad.	B & DE
Daudmannsodden, July/August	40–50 ad.	M/T. Observed daily
West coast of Nordenskiöld Land, June, July & August	—	JPD. Common. 140 birds observed at Osodden.
Daudmannsodden, 24/8 and 27/8	80 ad.	M/T

M a l l a r d (*Anas platyrhynchos*): One adult female was seen in Oddvatnet several times in late July (JPD).

T e a l (*Anas crecca*): Three adult birds were seen in Fyrsjøen 27 June (B&DE).

L o n g - t a i l e d d u c k (*Clangula hyemalis*): See Table 2.

C o m m o n s c o t e r (*Melanitta nigra*): Four birds were seen at Camp Morton in Berzeliusdalen 7 October (KK).

E i d e r (*Somateria mollissima*): See Table 3.

K i n g e i d e r (*Somateria spectabilis*): See Table 4.

Table 3

Observations of large flocks of eiders (Somateria mollissima) *in Svalbard in 1975. Flocks of less than 50 birds not listed.*

Наблюдения крупных стай гаг (*Somateria mollissima*) на Свальбарде в 1975 г. Не включены в список стаи, насчитывающие меньше 50 особей.

Locality/date Местность/дата	Number Число	Observer/remarks Наблюдатель/примечания
Ny-Ålesund — Kongsvegen, 22/7	146 ad., 136 pull.	ES
Lernerøyane, 24/7	30 ad., 60 pull.	JH
Liefdefjorden west, 23/7–11/8	120 ad., 100 pull.	JH
Inner Bockfjorden, 30/7	60 ad., 17 pull.	JH
Lomfjorden, 30/7–10/8	14 ad., 42 pull.	SEV
Reinsdyrflya southwest, 3/8	50 ad., 100 pull.	JH
Kapp Martin, 4/8	188 ad., 34 pull.	B & DE
All islands between Reiniusøyane and St. Hansholmane, 4–5/8	791 nests	D/S/E
Reinsdyrflya north, 20/8	100 ad., 160 juv.	KK
Daudmannsøyra, July/August	—	M/T. Several thousand along the coast

Table 4

Observations of king eiders (Somateria spectabilis) *in Svalbard in 1975*

Наблюдения гаг-гребенушек (*Somateria spectabilis*) на Свальбарде в 1975 г.

Locality/date Местность/дата	Number Число	Observer/remarks Наблюдатель/примечания
Kapp Martin-Diabaspt., 10–11/7	28 ad.	B & DE
Slettenesvatnet, 12/7	11 ad.	B & DE
Kapp Martin, 16/7	300 ad.	M/T
Pricepynten, 16/7	7 ad.	PP. 5 males and 2 females
Kapp Martin, 22/7	20 ad.	B & DE
West coast of Nordenskiöld Land, 17–29 July	6 nests	JPD
Båtodden, 8/8	250 ad.	JPD

Pink-footed goose (*Anser fabalis brachyrhynchus*): See Table 5.

Brent goose (*Branta bernicla hrota*): Two adults were seen on Forlandssletta 19 July (PP) and eight adults and two young on Daudmannsøyra 17 August (M/T).

Barnacle goose (*Branta leucopsis*): See Table 6.

Bewick's swan (*Cygnus bewickii*): One adult was seen at Gaffelbekkane 31 July. Photo was taken (JPD).

Ringed plover (*Charadrius hiaticula*): One nesting pair was seen on Gravodden, Bjørnøya 23 July (HJE). Probably six different birds were seen in Adventdalen between 26 July and 2 August (KK). Six birds were seen in Ny-Ålesund 13 July and four on Kaldneset 19 July (KK). One pair was

Table 5

Observations of pink-footed goose (Anser fabalis brachyrhynchus) *in Svalbard in 1975*

Наблюдения короткоклювых гуменников (*Anser fabalis brachyrhynchus*) на Свальбарде в 1975 г.

Locality/date Местность/дата	Number Число	Observer/remarks Наблюдатель/примечания
Båtodden, 28/6–4/7	14 ad.	B & DE
Kapp Martin, 8/7	14 ad.	B & DE
Fuglehuken, 15/7	15 ad.	M/T. 15 were moulting
Kapp Martin–Diabaspt., 10–11/7	31 ad.	B & DE
Kapp Martin, 17/7	3 ad.	B & DE
Kaldneset, 19/7	27 ad. 26 juv.	PP
West Forlandssletta, 19/7	40–60 ad.	PP
Kapp Martin-van Muydenbukta, 20–21/7	80 ad. 7 pull.	B & DE
Fuglehuken, 24/7	32–37 ad., 10 juv.	PP
Barentsfjellet, 24/7	50–60 ad., 40–50 juv.	PP
Roosneset, 30/7	45 ad.	JH. Birds were moulting
Sjøvernbukta, 8/8	15 ad.	JH
Sørdalsbukta, 8/8	150 ad.	DE
West coast of Nordenskiöld Land, mid-August	32 nests	JPD
North Reinsdyrflya, 20/8	128 ind.	KK
Daudmannsøyra, 21/8	110 ad.	M/T
South Reinsdyrflya, 21/8	38 ind.	KK
Reinsdyrflya, crossing, 24/8	ca. 530 ind.	KK
Berzeliusdalen, "Camp Morton", 4/9	69 ind.	KK
Berzeliusdalen, bottom, 5/9	310 ind. +	KK
Reindalen and Berzeliusdalen, 26/9	70 ind.	RAA. Observed from plane

seen at Oddvatnet 3 to 19 August (JPD). Single observations were made in Longyearbyen 12 July and 29 July, on Sarstangen 15 July and on Daudmannsøyra 24 August (M/T).

Turnstone (*Arenaria interpres*): See Table 7.

Whimbrel (*Numenius phaeopus*): One bird was seen at Longyearbyen 11 July (M/T).

Bar-tailed godwit (*Limosa lapponica*): One juvenile was seen on Daudmannsøyra between 23 and 28 August (M/T).

Knot (*Calidris canutus*): The species was observed daily on Daudmannsøyra from 19 August until 28 August. On 24 August, 22 migrating birds were seen (M/T).

Little stint (*Calidris minuta*): Three birds were seen at Longyearbyen 29 July (M/T).

Table 6

Observations of Barnacle goose (Branta leucopsis) *in Svalbard in 1975*

Наблюдения белощеких казарок (*Branta leucopsis*) на Свальбарде в 1975 г.

Locality/date Местность/дата	Number Число	Observer/remarks Наблюдатель/примечания
Båtodden, 28/6–4/7	30 ad.	B & DE
Sveagruva, 1/7	10 ad.	OS
Kapp Martin, 16/7	30 ad.	M/T
Forlandssletta, 19/7	15–20 ind.	PP
Vårsolbukta–Kapp Martin, 20–21/7	385 ad., 156 pull.	B & DE. Average 2.6 goslings per pair
Reindalen, "Plutohytta", 28/7	8 ad., 6 pull.	B & DE
West coast of Nordenskiöld Land, 31/7	764 ad.	JPD. Av. egg clutch size 3.3 (12 nests), av. family size 2.8 goslings (14 families)
Kapp Martin–Kapp Bjørset, 19/7–27/8	300–400 ind.	F & LN. Also 2 albino juv.
All islands between Reiniusøyane and St. Hansholmane, 4–5/8	182 nests	D/S/E
Daudmannsøyra, 8–13/8	about 100 ind.	M/T
Båtodden, 10/8	5 nests	B & DE
Smeerenburg, 11/8	17 ad.	PP
Kobbefjorden, 18/8	16–21 ad., 7 juv.	PP
West Danskøya, 18/8	16 ad.	PP
Worsleyhamna, 22/8	2 ad.	KK
Tordenskioldbukta, 28/8	about 250 ind.	M/T

Table 7

Observations of turnstone (Arenaria interpres) *in Svalbard in 1975*

Наблюдения камнешарок (*Arenaria interpres*) на Свальбарде в 1975 г.

Locality/date Местность/дата	Number Число	Observer/remarks Наблюдатель/примечания
Avtjørna, Bjørnøya, 21/7	2 ad.	HJE
Gravsjøen, June–July	—	JPD. Seen occasionally
Kapp Martin, 3/8	2 ad.	B & DE
Smeerenburg, 9/8	3 ad.	PP
Daudmannsøyra, 11–28/8	—	M/T. Three or more ind. seen daily. 32 ind. on 25/8.
Ny-Ålesund, 16/8	2 ad.	PP
Reinsdyrflya, 20/8	3 ad.	KK

D u n l i n (*Calidris alpina*): One bird was seen at Kapp Martin 16 July and four on Daudmannsøyra 25 July (M/T). Probably four different birds were seen in Adventdalen between 26 July and 2 August (KK).

S a n d e r l i n g (*Crocethia alba*): One adult bird was seen at Båtodden 2 July and one at Kapp Linné 13 August (B&DE). One adult was seen at

Fig. 1. *The great skua* (Catharacta skua) *is occasionally observed in Svalbard.*
Большой поморник (Catharacta skua) изредка наблюдается на Свальбарде.
Photo: HELGE JACOBSEN

Orustosen between 18 and 20 July (JPD), and another on Daudmannsøyra 23 July (M/T).

Red-necked phalarope (*Phalaropus lobatus*): One bird was seen at Ny-Ålesund 15 July (M/T).

Long-tailed skua (*Stercorarius longicaudatus*): Two birds were seen at Daudmannsøyra 18 August (M/T).

Great skua (*Catharcta skua*): Two adults were seen at Båtodden 28 June (B&DE). Two adults were seen on Aberdeenflya 24 and 25 July, and three at Richardlaguna 3 August (PP). At Gravsjøen, up to three individual birds were seen occasionally throughout June, July and August (JPD). Two birds were seen on Daudmannsøyra 24 July. Another six single observations were made in late July and early August (M/T).

Sabine's gull (*Xema sabini*): One adult bird was seen on Daudmannsøyra 23 July and 1 August (M/T). One bird was seen in Liefdefjorden 26 July (LHJ), and one in Kongsfjorden 24 August (PP).

Short-eared owl (*Asio flammeus*): Feathers from a dead bird were found in Marvågen 3 August (SH).

Swift (*Apus apus*): One adult was seen at Fuglehuken 29 July (PP).

Swallow (*Hirundo rustica*): Three adult birds were seen at Hopen Radio 12 May (Hop.rad).

Hooded crow (*Corvus cornix*): Two adults were seen at Hopen Radio 25 April (Hop.rad).

Blackbird (*Turdus merula*): A dead female bird was found by Mr. BYE from Isfjord Radio (JPD).

References

DITTAMI, J. P., 1975: *The preliminary report of an expedition to Svalbard for the study of Barnacle geese* Branta leucopsis. Typewritten, 3 pp.

PRESTRUD, P., 1975: *En del observasjoner av fugl og pattedyr fra Svalbard sommeren 1975.* Typewritten, 7 pp.

THOMASSEN, J., 1975: *Rapport — sommeren 1975.* Typewritten, 13 pp.

Norsk Polarinstitutts virksomhet i 1975

AV KAARE Z. LUNDQUIST

Organisasjon og administrasjon

PERSONALE

Norsk Polarinstitutt hadde 34 faste stillinger i 1975, det samme som foregående år. ØRNULF LAURITZEN ble ansatt som forsker III (geolog) fra 1/1. MAGNE GALÅEN fratrådte sin stilling som karttegner II den 28/2. KIRSTEN DANIELSEN fratrådte sin stilling som kontorfullmektig II den 30/4. PER JOHANSEN fratrådte sin stilling som kontorassistent fra 15/9. ØIVIND MEHLUM ble ansatt som karttegner II fra 1/11. Direktør TORE GJELSVIK er innvilget ett års permisjon (forskningsfriår) fordelt over tidsrommet 1975/77. I 1975 ble 5 ½ måneder av permisjonen tatt i tiden 1/3 —31/5 og 15/10 —31/12. Under permisjonsfraværet har underdirektør KAARE Z. LUNDQUIST fungert som direktør. Laborant i særklasse KNUT VABRÅTEN er innvilget permisjon uten lønn 1/1 —31/12. Pr. 31/12 var en stilling som kontorassistent ubesatt.

Midlertidig engasjerte:

BREKKE, ANNEMOR,	redaksjonssekretær
EDWARDS, MARC B.,	Ph.D. (lønnet av NTNF på Barentshavprosjektet til 1/7)
HUSETH, ROLF EGIL,	assistent
JØRGENSEN, MARIT,	kontorassistent (deltidsstilling) — fra 15/11
KNUDSEN, ELSA,	kontorassistent
LIEN, MAI-BRITT,	tegner II — til 15/7
MØLLER, JON ERIK,	laborant I — fra 10/2

Stipend og forskningsbidrag er gitt til:

Cand. mag. KARI PEDERSEN, stipend til dekning av utgifter til feltarbeid i forbindelse med hovedfagsoppgave i glasiologi.

Cand. mag. KJELL REPP, stipend til dekning av utgifter i forbindelse med breundersøkelser ved Ny-Ålesund.

Førstekonservator DAVID WORSLEY, stipend til dekning av reiseutgifter til Bjørnøya for ham selv og en assistent. De foretok geologiske undersøkelser etter et program utarbeidet i samråd med Norsk Polarinstitutt.

Cand. mag. ØYSTEIN HAGA, stipend til dekning av reiseutgifter til Svalbard for ham selv og en assistent. De foretok kvartærgeologiske undersøkelser ved Sveagruva i forbindelse med hovedfagsoppgave i kvartærgeologi.

Cand. real. A. DALLAND og hovedfagstudentene T. GJELLBERG, E. KALGRAFF og D. TØNSETH, stipend til dekning av utgifter i forbindelse med spesielle sedimentologiske undersøkelser mellom Isfjorden og Van Mijenfjorden.

Cand. mag. NILS A. ØRITSLAND, stipend til dekning av lønnsutgifter til teknisk hjelp i forbindelse med et forskningsprosjekt om oljens virkning på pelsdyr, særlig sel.

Cand. mag. TORE ROLF LUND, stipend til dekning av utgifter til feltarbeid i forbindelse med hovedfagsoppgave i limnologi.

Oppnevnelser og tillitsverv

STEINE oppnevnt som medlem i Gruppe for geodesi i Den nasjonale komité for geodesi og geofysikk.

VINJE oppnevnt som medlem i NTNF's faggruppe for datainnsamling.

REGNSKAP FOR 1975

Kap. 950. Poster:	*Bevilget:*	*Medgått:*
1. Lønninger	kr. 3.197.000	kr. 3.321.100
9. Deltagelse i Antarktisekspedisjon	« 130.000	« 154.700
10. Kjøp av utstyr	« 40.000	« 38.400
15. Vedlikehold	« 4.000	« 3.300
20. Ekspedisjoner til Svalbard og Jan Mayen	« 1.876.000	« 1.966.000
21. Forskningsstasjonen på Svalbard	« 1.100.000	« 929.400
29. Andre driftsutgifter	« 1.200.000	« 1.195.700
70. Stipend	« 50.000	« 49.000
	kr. 7.597.000	kr. 7.657.600
Kap. 31. Fyr og radiofyr på Svalbard	kr. 40.000	kr. 72.300

Kap. 3950. Inntekter:	*Budsjettert:*	*Regnskap:*
1. Salgsinntekter	kr. 70.000	kr. 62.900
2. Refusjon fra Svalbardbudsjettet	« 825.000	« 825.000
3. Andre inntekter	« 10.000	« 0
	kr. 905.000	kr. 887.900
Kap. 4905. Tilfeldige inntekter	kr. 0	kr. 790

Feltarbeid

NORGE

Glasiologi

Breundersøkelsene i Norge ble ledet av O. LIESTØL. De rutinemessige målinger av breenes massebalanse på Storbreen og Hardangerjøkulen ble utført av LIESTØL og KJELL REPP. O. ORHEIM og BJØRN WOLD foretok målinger i mindre målestokk på henholdsvis Suphellebreen og Blomsterskardbreen. Storbreen viste et underskudd, mens de øvrige hadde positiv balanse. Målinger av breenes lengdevariasjoner ble foretatt ved åtte breer. Av de to breene som økte, gikk Briksdalsbreen frem 41 m. Dette er den største økning på ett år som er registrert siden målingene begynte i 1900. De andre breene var i stillstand eller gikk tilbake.

SVALBARD

Instituttets sommerekspedisjon til Svalbard ble organisert og ledet av operasjonssjef T. SIGGERUD og omfattet, foruten besetningene på fartøyer og helikoptre, i alt 37 personer. Av disse deltok tre i halve sesongen og en for kortere tid. Av deltakerne var 16 instituttets faste medarbeidere, fem engasjerte fagmedarbeidere og 17 engasjerte assistenter. Ekspedisjonen ble gjennomført etter programmet og uten ulykker eller uhell.

Hovedekspedisjonen arbeidet i 1975 i Svalbards nordvestlige område, med hovedbase inkludert to helikoptre i Ny-Ålesund. I dette området ble det arbeidet med geologiske undersøkelser av det faste fjell og kvartæravsetninger. Partiene ble sendt ut i felten, flyttet og trukket inn ved hjelp av helikoptrene.

I Ny-Ålesundområdet var flere grupper biologer i arbeid ved forskningsstasjonen. Når det passet i flyopplegget, ble også disse transportert med helikoptrene.

Geofysikerne reiste til Ny-Ålesund i april—mai og arbeidet der uavhengig av ekspedisjonen for øvrig.

Hydrograferingsarbeidene foregikk med M/S «Olaf Scheel» utenfor vestkysten av Svalbard med landstasjoner for HI-FIX-systemet på Kapp Martin og Daudmannsøyra. Inne i de nordlige armer av Isfjorden foregikk opploddingen (hydrograferingen) på to skift med hydrograferingsbåten «Svalis».

På Jan Mayen var det en kortere glasiologisk undersøkelse.

Se forøvrig de enkeltes rapporter.

Hydrograferingsfartøyet «Olaf Scheel» lastet utstyret i Bodø 7/7. Alt hydrograferingspersonell reiste med denne. Fartøyet returnerte til Bodø 4/9.

Sommeren 1975 var det intet eget ekspedisjonsfartøy, men M/S «Signalhorn» under ledelse av LUNDQUIST, lastet utstyr for ekspedisjonen i Bodø 10/7 og fraktet det og en del av ekspedisjonsdeltagerne til Ny-Ålesund. Det ble også satt ut depoter på nordsiden for årets flyvninger og for en biologisk vårekspedisjon i 1976. Både i nordvestlige og østlige farvann ble det satt ut bøyer for isdriftmålinger. Fartøyet returnerte til Bodø 24/7. 26/8 ankom M/S «Signalhorn» til Ny-Ålesund og hentet ekspedisjonen, som ble avsluttet i Bodø 29/8.

To Bell Jet Ranger helikoptre var leiet for sommeren og ble sendt til Svalbard og senere tilbake til Norge med kullbåt via Longyearbyen. Helikoptrene fløy til Ny-Ålesund.

En ekstraordinær begivenhet fant sted 14/8, da ekspedisjonen feiret 50-årsjubileet for Svalbard som norsk land ved en stilfull fest i Ny-Ålesund. Senere disponerte statsministeren med følge helikoptrene i to dager for offisielle besøk bl.a. i Barentsburg.

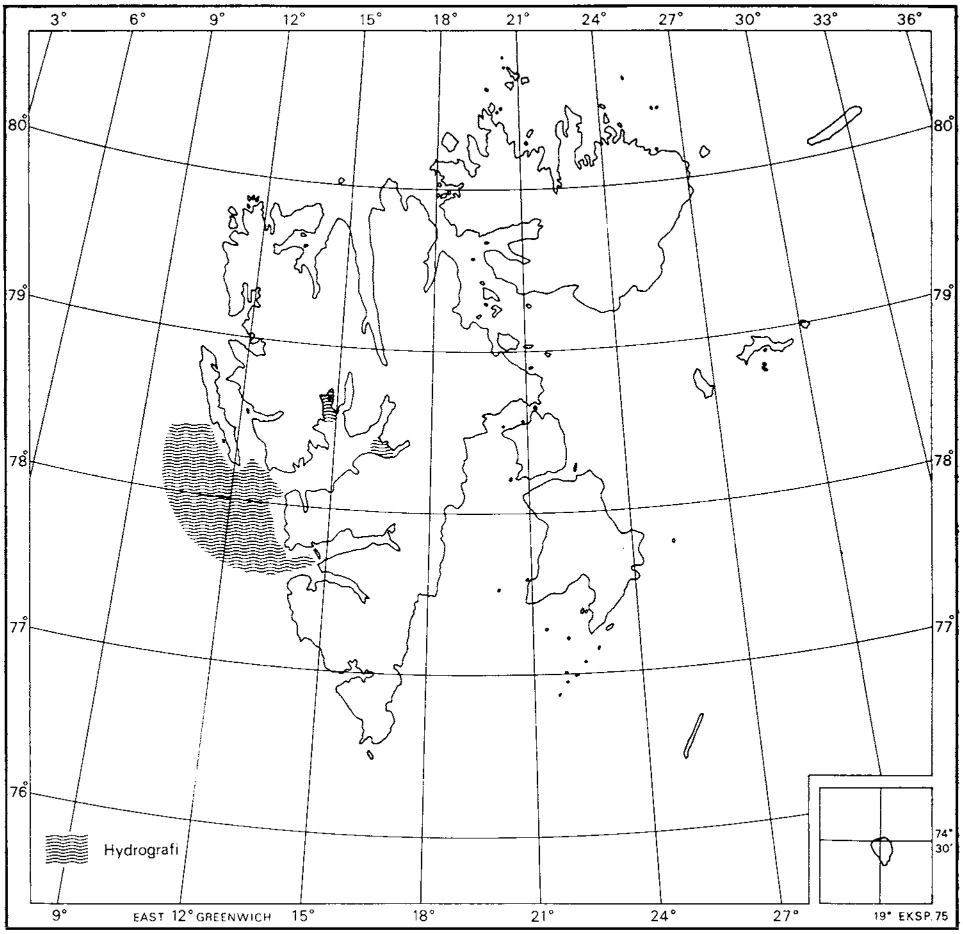

Fig. 1. *Hydrografiske arbeidsområder i 1975.*

Hydrografi

I feltsesongen (7/7 –15/9) ble det med hydrograferingsbåten «Svalis» foretatt opplodding i målestokken 1:50 000 i Sassenfjorden og Ekmanfjorden. Arbeidet ble ledet av H. HORNBÆK, assistert av engasjert hydrograf BJØRN S. JAKOBSEN samt R. MANDT, SIVERT UTHEIM, LARS KRISTIANSEN, IVAR R. KRISTENSEN og SIEGFRIED STEINMETZ. I siste del av sesongen ble det foretatt opplodding i målestokken 1:10 000 og strømmåling i Akselsundet samt kontrollodding i målestokken 1:5000 og strømmåling i Sveasundet.

Hydrograferingstoktet med M/S «Olaf Scheel» ble ledet av J. H. CHRISTIANSEN. E. NETELAND hadde tilsyn og vedlikehold av HI-FIX-systemet og annet elektronisk utstyr. Som assisterende hydrograf var LARS BAKSTAD engasjert frem til 2/8 og BJØRN FRETHEIM for resten av sesongen.

JENS ORNING var engasjert som assistent om bord i hydrograferingsfartøyet og assistentene JØRN THOMASSEN, FRODE MÜLLER, LIV BØRRESEN og FINN NYGÅRD betjente slavestasjonene på Daudmannsodden og Kapp Martin.

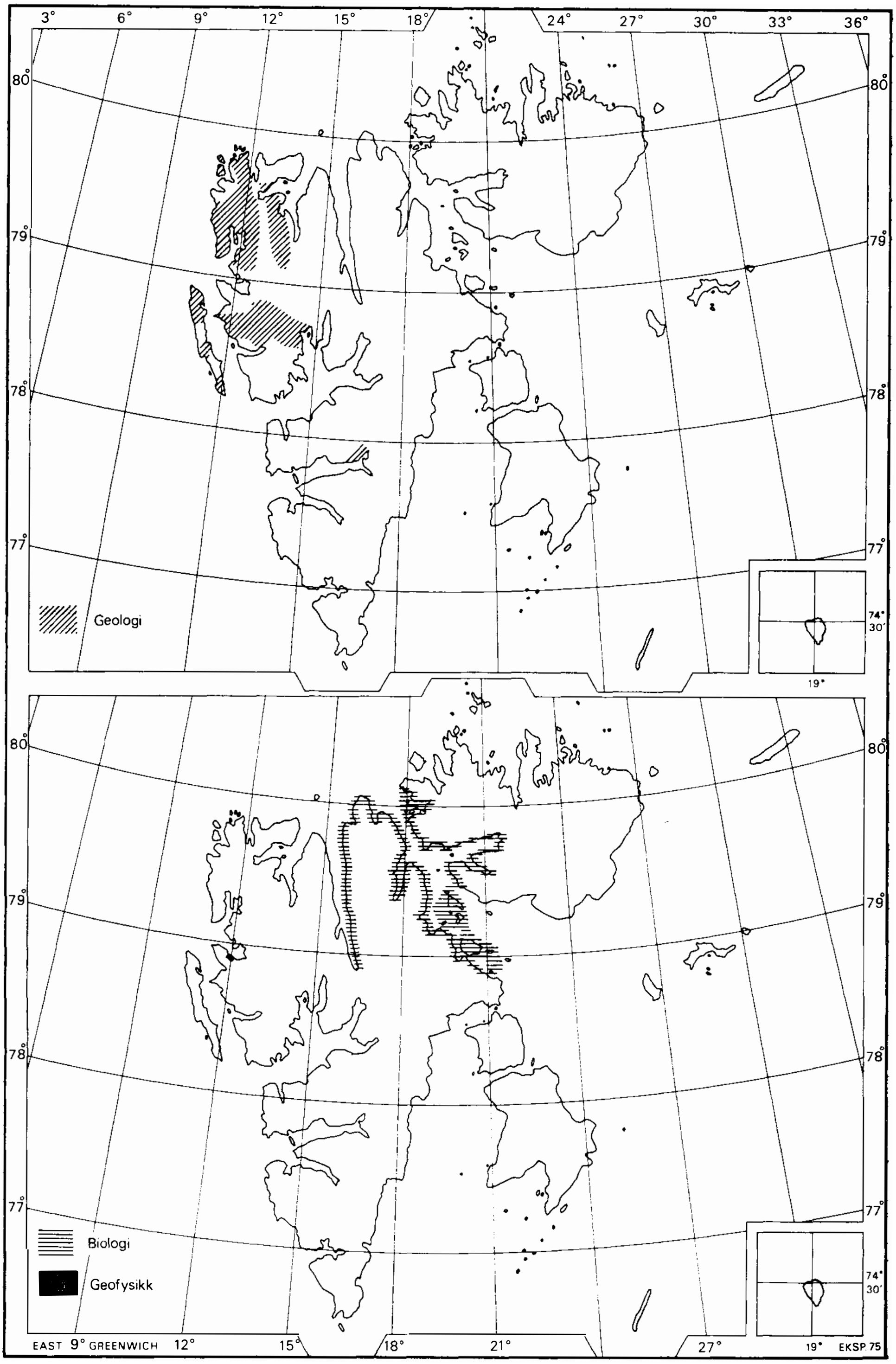

Fig. 2. *Geologiske, biologiske og geofysiske arbeidsområder i 1975.*

På grunn av vanskelige isforhold på østsiden av Svalbard valgte man, etter at fyrettersynet var utført, å utføre opplodding på vestkysten i direkte tilknytning til tidligere målinger. I alt ble det loddet opp ca. 4 930 n mil.

Geologi

Feltarbeidet besto i en konsentrert innsats i den nordvestre del av Spitsbergen. Hensikten var å undersøke og kartlegge blant annet de indre og mest utilgjengelige områdene der. Ved hjelp av to helikoptre av typen Jet Ranger klarte man å flytte leirer inn i de indre områdene og rekke over hele arbeidsområdet. Basen for operasjonen var Ny-Ålesund, og operasjonen varte i seks uker.

Tre feltpartier arbeidet nord for Kongsfjorden: GJELSVIK med to assistenter, A. HJELLE med to assistenter og OHTA med to assistenter. Syd og øst for Kongsfjorden arbeidet Ø. LAURITZEN med to assistenter og T. WINSNES med en assistent.

SALVIGSEN med en assistent foretok kvartærgeologiske undersøkelser ved Sveagruva i begynnelsen av juli. Senere sluttet partiet seg til helikopteroperasjonen og foretok undersøkelser på Prins Karls Forland og på øyene lengst i nordvest.

I to dager i begynnelsen av august ble det foretatt ekskursjoner til enkelte geologiske nøkkelområder sammen med en engelsk og tre sovjetiske geologer.

Geofysikk

LIESTØL oppholdt seg i Ny-Ålesund 24/5—18/6. Med assistanse av REPP foretok han målinger av akkumulasjonen på Lovénbreen og Brøggerbreen. Dessuten ble det foretatt en del triangulering og bestemmelse av den påfrosne is på breene. Videre ble en rekke forekomster av grunnvann undersøkt.

V. HISDAL oppholdt seg ved Forskningsstasjonen i Ny-Ålesund i tiden 21/5—18/6 og utførte en rekke målinger av den direkte solstråling innenfor seks forskjellige bølgebånd ved hjelp av to «Volz sun photometers». Videre ble belysningen i lux målt under forskjellige solhøyder og atmosfæriske forhold, samtidig som energien av den totale solstråling og den diffuse himmelstråling ble avlest. Observasjonene skal brukes til en vurdering av sammenhengen mellom disse forskjellige sider ved strålingsmiljøet på Svalbard.

T. VINJE oppholdt seg på samme sted 22/4—28/5 for å kalibrere instrumentene i kort- og langbølgeområdet. Ventileringen ble utbygget for å holde borte snø og regn. Strålingsinstrumentene ble ettersett og registreringssystemene kontrollert.

Biologi

T. LARSEN oppholdt seg på Svalbard i april for å foreta registreringer av isbjørn og isbjørnhi i området NØ Spitsbergen—Hinlopen—Nordaustlandets østkyst. Registreringene ble foretatt på vegne av Miljøverndepartementet og Sysselmannen som ledd i arbeidet med å vurdere en scootertrasé til NØ Spitsbergen og Lomfjorden.

Det var ingen egen biologisk feltaktivitet under Norsk Polarinstitutts hovedekspedisjon, men MAB-programmet, som instituttet har det koordinerende og administrative ansvar for, ble igangsatt. Faunistiske observasjoner ble gjort av Norsk Polarinstitutts øvrige feltpartier og av andre grupper og enkeltpersoner.

Fyr og radiofyr

Ettersynet av fyr og radiofyr ble utført med M/S «Olaf Scheel» av NETELAND og HI-FIX-assistenter i tiden 14/7 – 20/7.

Batterikapasiteten på de elektrifiserte lysfyr ble målt og lampene ettersett, uten at noen utskifting ble foretatt. Gassflasker ble skiftet på Kapp Ekholm, Akseløya, Brandalpynten og Kapp Amsterdam.

På Fuglehuken, Rundodden og Bellsund ble det montert nye radiofyr.

I 1976 tas det sikte på elektrifisering av lyktene på Brandalpynten, Kapp Ekholm og Akseløya.

JAN MAYEN

ORHEIM, assistert av JAN MANGERUD, utførte massebalansemålinger på Sørbreen i tiden 12/6 – 19/6. Alle stakeposisjoner ble besøkt og en rekke nye staker ble satt ut. MANGERUD utførte også en del kvartærgeologisk arbeid, inkludert innsamling av drivved med henblikk på C-14 datering.

Flyfotografering

For midler stilt til disposisjon fra NATO Research Grants Programme, inngikk Norsk Polarinstitutt kontrakt med Landmælingar Islands, Reykjavik, om flyfotografering av Jan Mayen. Fotograferingen ble foretatt med vidvinkelkamera fra ca. 7 600 og ca. 3 800 m-høyder. En del fotograferinger ble også foretatt fra lavere flyhøyder. De tre foregående år har dårlig vær forhindret denne fotograferingen.

ANTARKTIS

Med logistisk støtte fra National Science Foundation var HJELLE, Y. OHTA, WINSNES og REPP i Antarktis fra november 1974 til februar 1975. Hovedarbeidet var en stratigrafisk tektonisk undersøkelse i den sydlige del av Ellsworthfjellene. Gruppen returnerte til Norge 14/2 1975.

Arbeid ved avdelingene

(Se også under publikasjoner)

Hydrografi

HORNBÆK utførte redaksjonelt arbeid i forbindelse med trykking av nye utgaver av sjøkartene 502, 503 og 507 og forberedte nye utgaver av sjøkartene 504 og 513. Videre planla og tilrettela han utgivelsen av nytt sjøkart 523.

CHRISTIANSEN bearbeidet hydrografisk materiale fra 1973 og 1974 og bisto i det rutinemessige arbeid ved avdelingen.

Geodesi — topografi

Det ble i 1975 laget programmer for trigonometriske beregninger på Diehl Alftronic regnemaskin og utført beregninger i forbindelse med det topografiske kartverket Svalbard 1:100 000.

Kartbladene G7 Svenskøya og H4 Kongsøya ble konstruert i serien Svalbard 1:100 000. En fullstendig ny, foreløpig utgave av C9 Adventdalen i samme serie ble utgitt. Utgaven bygger imidlertid på den samme kartkonstruksjon som det tidligere kartet fra 1950. Kystkontur i Dicksonfjorden i målestokk 1:100 000 og i Akselsundet i målestokk 1:10 000 ble konstruert for hydrografisk avdeling. En pingo i Dunderdalen, Spitsbergen, i målestokk 1:2 000 ble konstruert for geologisk avdeling, og Trollkjeldene på Spitsbergen i samme målestokk for biologiske undersøkelser. Barentsøya ble aerotriangulert.

Et område på Sør-Jan, Jan Mayen, som ikke kunne kartlegges med det tidligere materialet, ble konstruert på grunnlag av nyfotograferingen om sommeren.

Ved hjelp av resultater fra engelsk markarbeid, ble kart over Heimefrontfjella og Mannefallknausane konstruert i målestokk 1:100 000 etter skråbilder, for senere utgivelse i serien Dronning Maud Land 1:250 000. I denne serien utkom to kartblad: N5 Forposten og N6 Sarkofagen.

Geologi

I tiden 2.—6. juni 1975 arrangerte Norsk Polarinstitutt et symposium om Svalbards geologi — «The geological development of Svalbard during Pre-Cambrian and Lower Paleozoic, including Devonian». 26 deltagere fra Sovjet Danmark, England, USA, Canada og Norge presenterte atten arbeider som senere vil bli utgitt i et eget nummer av Norsk Polarinstitutts serie «Skrifter»

H. MAJOR utførte kullpetrografiske undersøkelser av kull fra gruve 4 og 7 i Longyearbyen, avga uttalelser til ID og andre om Svalbardkull og foretok i tiden 11—25/8 undersøkelser i gruven i Longyearbyen og den nye Svea gruve i øst.

WINSNES utarbeidet etter sin hjemkomst fra Antarktis en rapport om ekspedisjonen, forberedte og ledet et symposium om Svalbards geologi og tilrettela sommerens ekspedisjon til Spitsbergen. Han har holdt flere foredrag om Arktis og har administrert den geologiske avdelingen.

HJELLE deltok i Antarktisekspedisjonen, og begynte etter hjemkomsten å bearbeide det innsamlede materiale. Han deltok i Svalbardsymposiet med et foredrag og gjorde klart et materiale for publikasjon. Han har fortsatt bearbeidelsen av materiale fra Dronning Maud Land.

OHTA deltok i Antarktisekspedisjonen. Etter hjemkomsten utarbeidet han to artikler til Svalbardsymposiet og en feltrapport fra Antarktis. Antarktismaterialet ble bearbeidet og analysert. To geologiske artikler er publisert.

LAURITZEN begynte ved Norsk Polarinstitutt 1. januar. Han har satt seg inn i arbeidet og deltatt i organiseringen av Svalbardsymposiet. Etter sommerens ekspedisjon er innsamlet materiale blitt bearbeidet.

O. SALVIGSEN bearbeidet feltobservasjoner fra 1974 og studerte flybilder fra Spitsbergen som forberedelse til feltsesongen. Etter ekspedisjonen er innsamlet materiale blitt bearbeidet.

EDWARDS (Barentshavprosjektet) bearbeidet materiale samlet inn i 1974.

Geofysikk

HISDAL fortsatte bearbeidelsen av strålingsobservasjoner fra Ny-Ålesund. De endelige beregninger i forbindelse med de målte spektralfordelinger av sol- og himmelstrålingen ble stort sett fullført. Han tok videre opp arbeidet med en kortfattet beskrivelse av Svalbards geografi.

LIESTØL bearbeidet glasiologisk og annet feltmateriale for Norge og Svalbard. Han var veileder for hovedfagstudenter, holdt en forelesningsrekke i glasiologi og var sensor i limnologi og fysisk geografi ved Universitetet i Oslo. Han deltok også som veileder ved Geografisk Instituttets feltkurs på Finse.

ORHEIM foretok utredningsarbeid i forbindelse med 1976/77-ekspedisjonen til Antarktis. Glasiologiske data fra Jan Mayen, Supphellebreen og Syd-Shetlandsøyene ble bearbeidet. Han har forsøkt å etablere prinsipper for tolkning av mikrobølgebilder fra Antarktis tatt med NIMBUS satellitt, og har arbeidet med LANDSAT-2 bilder fra Dronning Maud Land. Han var også veileder for en hovedfagstudent.

VINJE utarbeidet isoversikt for 1974 og gjennomgikk de siste 10 års satellittdata for å få en bredere oversikt. Han var «principal investigator» i en avtale med NASA om bruk av automatiske satellittstasjoner som ble satt ut på isflak ved Svalbard i juli. Det samme gjelder for en annen samarbeidsavtale med NASA om mottagelse og bearbeidelse av LANDSAT-bilder fra Svalbard — Grønlandområdet. Omkring 50 bilder med oppløsning på 80 meter ble mottatt i løpet av året. Han deltok meget i komitéarbeid.

Biologi

LARSEN fortsatte bearbeidelsen av det vitenskapelige materiale som er innsamlet gjennom flere år. Han har innenfor sitt fagområde drevet en utstrakt konsulentvirksomhet vis-à-vis myndighetene, institusjoner og enkeltpersoner. I begynnelsen av året fungerte han som sekretær i MAB styringsgruppe, og høstsemesteret 1975 var han veileder ved Universitetet i Oslo, Rådet for Natur- og Miljøfag.

Biblioteket

I 1975 ble det registrert 470 titler, herav bl.a. 70 innkjøpte bøker, 32 av gammel bestand, 156 særtrykk og småskrifter, 67 fra bytteforbindelser og 6 som gaver.

Særtrykksamlingen er på 6050 stk. Det er etablert fire nye bytteforbindelser og tegnet tre nye abonnementer.

Registrerte utlån var i alt 479, derav 335 til instituttets personale, 108 til personer utenfra og 36 til andre biblioteker. Registrerte utlån fra andre biblioteker var 42.

Konsulent- og informasjonsvirksomhet

Instituttet har i likhet med tidligere år vært konsultert om polare spørsmål av norske myndigheter og av personer i inn- og utland.

GJELSVIK deltok i februar i møte i Utenriksdepartementet i forbindelse med forberedelsen av Det 8. konsultative møte under Antarktistraktaten. I august/september hadde han besøk av representanter for PRB, National Academy of Science, USA, som var i ferd med å utarbeide et program for en påtenkt drivende stasjon i den eurasiske del av Polhavet, The Fridtjof Nansen Drift Station (FNDS). Han ble bedt om å være norsk kontaktledd for planene og hadde i den anledning drøftelser med en rekke norske vitenskapelige institusjoner som kunne være interessert i planene.

LUNDQUIST og forskerne besvarte, innenfor sine respektive fagområder, henvendelser fra massemedia vedrørende instituttets arbeidsoppgaver og virksomhet i polarstrøkene.

Reiser, møter og kursvirksomhet

J. BJØRKE, HORNBÆK, LUNDQUIST og MANDT deltok i mars i «Kartdagene 1975» som ble arrangert i Skien av Norges Karttekniske Forbund.

GJELSVIK deltok i januar, i egenskap av president for SCAR, i en tur til Antarktis for å være til stede ved åpningen av den nye amerikanske forskningsstasjonen på Sydpolen. På tilbakereisen hadde han drøftelser i Boulder, Colorado, og i Washington D.C. med representanter for National Oceanographic and Atmospheric Administration og National Science Foundation om polarforskning av felles interesse for Norge og USA. I juni ledet han det årlige møte i eksekutivkomiteen for SCAR i Cambridge, og i november deltok han i et møte i Washington D.C. om planlegging av prosjektet The Fridtjof Nansen Drift Station (FNDS). På reisen besøkte han Ottawa for drøftelser med dr. E. F. ROOTS i planleggingsavdelingen for Department of the Environment. Under oppholdet i Washington drøftet han spørsmålet om samarbeid mellom USA og Norge i Antarktis med representanter for OPP og NSF, i forbindelse med Norsk Polarinstitutts kommende Antarktisekspedisjon.

I Norge deltok GJELSVIK i en rekke møter i en komité, sammensatt av representanter for Luftforsvaret, Norsk Aeroklubb, SAS og Norsk Polarinstitutt, som forberedte feiringen den 15. juni av 50-årsjubileet for Roald Amundsens flytokt mot Nordpolen med flyvemaskinene N 24 og N 25. I juni møtte han som norsk delegat på Det 8. konsultative møte under Antarktistraktaten, som ble arrangert i Oslo av Utenriksdepartementet. Videre deltok han i september i åpningen av flyruten til Svalbard og innvielsen av Svalbard flyplass.

HISDAL, ORHEIM, LIESTØL og VINJE deltok i august/september i International Union of Geodesy and Geophysic's symposium i Grenoble.

LARSEN deltok i september i The Circumpolar Conference on Northern Ecology i Ottawa og i arbeidsmøter arrangert samme sted for medlemmer av The IUCN Polar Bear Specialist Group. I oktober deltok han i World Wildlife Fund's årlige kongress og komitémøter.

LIESTØL deltok som guide i Geografisk Instituts ekskursjon til Finseområdet i juni.

ORHEIM deltok i mai på årsmøte og i to rådsmøter i International Glaciological Society (IGS), Cambridge. I august deltok han i SCAR's arbeidsgruppe og i rådsmøte i IGS, avholdt i Grenoble.

LUNDQUIST deltok som medlem av den norske delegasjon, i forhandlingsmøte med Sovjet om grensespørsmål i Barentshavet. Møtet ble holdt i Oslo i november.

SALVIGSEN deltok i oktober i et symposium om klimaforandringer, arrangert av Universitetet i Lund.

VINJE deltok i juni i Skandinavisk havismøte i Oslo.

WINSNES deltok i februar i et orienteringsmøte i Stavanger om aktiviteter på kontinentalsokkelen og i desember i et orienteringsmøte avholdt av Oljedirektoratet om IPOD/JOIDES.

Forelesnings- og foredragsvirksomhet

Instituttets medarbeidere har i 1975 holdt følgende foredrag:

GJELSVIK: «The Hecla Hoek ridge of the Devonian Graben between Liefdefjorden and Holtedahlfonna, Northern Norway». Det geologiske Svalbardsymposium, Oslo, i juni.

— «Utforskningen av kontinentalsokkelen i Barentshavet — fra Fridtjof Nansens tid til i dag.» Det Norske Videnskaps-Akademi, Oslo, i oktober. Forelesning over samme emne ble holdt i Trondheim Geologklubb og ved Universitetet i Tromsø i november og i Polarklubben, Oslo, i desember.

LARSEN: «Isbjørnundersøkelsene på Svalbard.» Foredrag om dette emne ble holdt i Polarklubben, Oslo, i januar, i Ås Zoologisk Forening og i Zoologisk Fagutvalg, Oslo, i februar, ved et seminar ved Universitetet i Trondheim i mars og i Longyearbyen i april.

LAURITZEN: «Den historisk-geologiske utvikling av Europa.» Forelesningsserie på 14 timer ved Universitetet i Oslo høsten 1975.

LIESTØL: «Om snø og is.» Kåseri i NRK i mars.

— «Brefluktuasjoner på Svalbard.» Bergens geofysiske forening i mars.

LUNDQUIST: «Kartlegging av polarområder.» Rogaland Kartteknisk Forening, Stavanger, i januar.

MAJOR: «Hva er egentlig kull? Hva har vi av kull i Norge?» Metallurgisk Forening, NTH, Trondheim i november.

OTHA: «Lithostratigraphy, structure and metamorphism of Prince Karls Forland and St. Jonsfjorden» og «Blue schist metamorphism in West-Spitsbergen». Begge foredrag holdt under det geologiske Svalbard-symposium, Oslo, i juni.

ORHIEM: «Redegjørelse for planer for ny norsk ekspedisjon til Antarktis.» Geofysisk institutt, Universitetet i Bergen, i mars.

ORHIEM: «Breer og vulkaner i Antarktis.» Geografistudentenes forening, Norges Handelshøyskole, i mars.

— «Norsk forskning i Antarktis i de nærmeste år.» Geologisk institutt, Universitetet i Bergen, i mars.

— «Moderne geofysisk forskning i Antarktis.» Bergens geofysikerforening, i mars.

— «Glaciological significance of microwave images of Antarctica.» International Glaciological Society (IGS), Cambridge, England, i mai.

— Foreleste i glasiologi ved Universitetet i Bergen, høstsemesteret 1975.

— «Norges innsats i Antarktis — hva vi har gjort og hva vi vil gjøre.» Norsk Geografisk Selskap i november.

SIGGERUD: «Svalbard og Svalbards utforskning.» I alt 21 foredrag om dette emne i Folkeakademier, industriforeninger, Universitetet i Bergen, Geologisk Forening i Bergen, etc.

VINJE: «Variabiliteter av isforholdene i Arktis.» NIF's symposium om oljeboring på arktiske sokler, avholdt i Stavanger i oktober.

WINSNES: «Miljødatainnsamling — Barentshavet.» Foredrag på etterutdanningskurs, arrangert i Stavanger av Norske Sivilingeniørers Forening i oktober.

Publikasjoner

Skrifter:

Nr. 162 — R. A. FORTEY: The Ordovician Tribolites of Spitsbergen. II. Asaphidae, Nileidae, Raphiophoridae and Telephinidae of the Vallhallafonna Formation.

Årbok 1973:

HISDAL, VIDAR: Some features of the distribution of cloudiness and duration of sunshine at Norwegian Arctic stations. 7—26.

VINJE, TORGNY E.: On the small scale features of temperature and wind profiles near a snow surface. 27—39.

LAURITZEN, ØRNULF and DAVID WORSLEY: Observations on the Upper Palaeozoic stratigraphy of the Ny Friesland area. 41—51.

SIEDLECKA, ANNA: The petrology of some Caıboniferous and Permian rocks from Bjørnøya, Svalbard. 53—71.

HALVORSEN, ERIK: Secondary Fe-spinel formation in red beds from the Wood Bay Formation, Svalbard. 73—85.

ÅM, KNUT: Magnetic profiling over Svalbard and surrounding shelf areas. 87—99.

LARSEN, THOR: Polar bear den surveys in Svalbard in 1973. 101—111.

HJELJORD, OLAV: Studies of the Svalbard reindeer. 113—123.

GULLESTAD, NILS: On the biology of char in Svalbard. 125—140.

HAGELUND, KARL and MAGNAR NORDERHAUG: Studies of population changes and breeding processes in a colony of Eiders in Svalbard. 141—161.

— Studies of the productivity of the Svalbard Eider under optimal conditions. 163—174.

BENGTSON, SVEN-AXEL: Tetthet av hekkende vadere på tundraen omkring Ny-Ålesund, Svalbard. 175—178.

LIESTØL, OLAV: Hans W:son Ahlman. 179—180.

— Glaciological work in 1973. 181—192.

HISDAL, VIDAR: The weather in Svalbard in 1973. 193—195.

VINJE, TORGNY E.: Sea ice and drift speed observations in 1973. 197—202.

LARSEN, THOR: Iakttagelser over dyrelivet på Svalbard i 1973. 203–210.
GJELSVIK, TORE: Norsk Polarinstitutts virksomhet i 1973. 211–224.
SIGGERUD, THOR: Forskningsstasjonen på Svalbard. 225–226.
GJELSVIK, TORE: The activities of Norsk Polarinstitutt in 1973. 227–232.
— Main field work of scientific and economic interest carried out in Svalbard in 1973. 234–235.
CROOT, DAVID G.: The morphology and evolution of an esker in Spitsbergen. 237–239.
MØHL, ULRIK: Dating of the Bison find from Siberia. 240–241.

Sjøkart:

502 Bjørnøyfarvannet 1:350 000 (ny utgave).
502C Bjørnøyfarvannet 1:350 000 (CONSOL).
503 Fra Bellsund til Forlandsrevet med Isfjorden 1:200 000 (ny utgave).
507 Nordsvalbard 1:600 000 (ny utgave).

Landkart:

Svalbard 1:100 000:
C9 Adventdalen (foreløpig utgave).

Dronning Maud Land 1:250 000:
N5 Forposten.
N6 Sarkofagen.

Annen publisering:

Instituttets medarbeidere har utenom instituttets serier publisert:

THOR LARSEN sammen med T. SCHMIDT og E. NORDLING: *Økologimiljølære.* Scandinavian Video Casette Group. 112 pp.
THOR LARSEN: Progress in polar bear research and conservation in the five Arctic nations. *Environmental Affairs* **4**(2):295–308.
— Problems in management oriented studies of birds and mammals in European High Arctic. Proceedings Circumpolar Conference on Northern Ecology, Ottawa 1975 (in print).
— Miljøleksikon v/Norges Naturvernforbund/Stiftelsen NKI. 121 pp. (medarbeider).
ØRNULF LAURITZEN: Methods for the study of microfacies with an example from the Oslo Region. The Middle Ordovician of the Oslo Region, Norway, 25. *Norsk Geologisk Tidsskrift* **55**. pp. 91–96, 1975.
OLAV LIESTØL har levert bidrag til *Breundersøkelser i Norge i 1974.* Rapport fra NVE.
YOSHIHIDE OHTA: Intergranular co-ordination of plagioclase in a porphyroblastic domain (with S. G. HOE). *Japanese Geol. Soc. Jour.*, Nov. 1975.
OLAV ORHEIM: Post and present mass balance variations and climate at Deception Island, South Shetland Island, Antarctica. *IASH-AISH Publ.* No. 104. pp. 161–180.
— Antarktis i fokus – hva gjør norsk forskning? *Forskningsnytt* nr. 3 1975, pp. 10–14.
TORGNY VINJE: Om formen på temperatur- og vindprofiler nær en snøflate. *SMS Bulletin*, Stockholm.

Forskningsstasjonen på Svalbard

Det leieforholdet som ble etablert i 1974 mellom Norsk Polarinstitutt og Kings Bay Kull Comp. A/S, fortsatte også i 1975. KBKC har stått for den generelle drift av anlegget i Ny-Ålesund (kraftstasjon, vannanlegg, messe etc.). For disse ytelser har Norsk Polarinstitutt betalt en fast avgift på kr. 600 000,–.

Bemanningen av Forskningsstasjonen i 1975 har vært:

Ingeniør JENS ANGARD	1/1 –31/12	
Vit.ass. DAG BJØRKEDAL	1/1 –31/8	
Stasjonssjef JAN E. HAUGLAND	1/9 –31/12	(felles for NP og KBKC)
Vit.ass. ARVID HEGSTAD	1/9 –31/12	
Ingeniør JAN A. JENSEN	23/6 –23/8	
Assistent FINN PETTERSEN	27/6 –22/8	

I tillegg har KBKC hatt en leirbesetning på fire mann.

Kapasiteten ved stasjonen er foreløpig så liten at man etter samråd med myndighetene har begrenset adgangen til stasjonen til norske forskere eller utenlandske forskere som deltar i norske prosjekter. Det arbeides med planer om fremtidige utvidelser.

Stasjonen ble sommeren 1975 benyttet som base for Norsk Polarinstitutts Svalbardekspedisjon. 5–6 mann var fast stasjonert i Ny-Ålesund, mens 16 mann var forlagt ute i felten. Transport til og fra felten ble foretatt med to helikoptre.

I 1975 hadde stasjonen en rekke offisielle besøk, bl.a. av statsminister BRATTELI og frue, statssekretær FUGLERUD, ministerråd BUCHER-JOHANNESSEN, stortingsmann HELLEM, sysselmann ELDRING og bergmester JOHNSEN. Ledelsen ved Norsk Polarinstitutt besøkte også stasjonen i løpet av sommeren.

En rekke forskere arbeidet ved stasjonen i løpet av våren og sommeren, blant andre: O. LIESTØL, V. HISDAL, T. VINJE og K. REPP fra Norsk Polarinstitutt, L. H. JENNEBORG fra Gøteborg Universitet, G. KNABEN, A. EMANUELSSON og B. A. ROSSELAND fra Universitetet i Oslo, Y. GJESSING fra Universitetet i Bergen, O. BRATTENG, E. MIKALSEN, T. BRATTLI, K. M. JOHANSEN, O. HARANG, K. HENRIKSEN, D. MCARTHUR og T. BERKEY fra Universitetet i Tromsø, N. GULLESTAD fra Nordland Distriktshøgskole, Bodø, og distriktveterinær OLAV SCHØLAAS.

To forskergrupper fra Universitetet i Trondheim (I. BRATTBAKK, J. HERMANSEN, A. ELVEBAKK, T. KLOKK, O. RØNNING og T. BERGVIK, A. HEGGSTAD og E. SENSTAD) drev vegetasjonskartlegging og evertebratikologiske undersøkelser på Brøggerhalvøya i forbindelse med MAB-programmets (Man and the Biosphere) arbeid på Svalbard.

Et reportasjeteam fra NRK og representanter fra en rekke presseorganer besøkte Forskningsstasjonen i løpet av sommeren.

Oversikt over kontinuerlige forskningsprosjekter ved Forskningsstasjonen i 1975

1. *Fotometer:*
   Oppdragsgiver: Nordlysobservatoriet, Tromsø.
   4 kanaler senit fotometer med digital/analog utlesning har periodisk vært i drift.

2. *Magnetometer:*
Oppdragsgiver: Universitetet i Tromsø.
Registreringene har gått som normalt hele perioden.

3. *Riometre:*
Oppdragsgiver: Nordlysobservatoriet, Tromsø.
Tre på 20, 27 og 30 Mhz i drift. Utstyret har etter nedleggelsen av ESRO-sambandet fungert tilfredsstillende.

4. *All-sky-camera:*
Oppdragsgiver: Nordlysobservatoriet, Tromsø.
Problem med ny, automatisk tidsmarkering som periodevis ødela registreringene. Kameraet har vært i Norge for ombygging.

5. *Seismisk stasjon:*
Oppdragsgiver: Jordskjelvstasjonen, Univ. i Bergen.
Har gått som normalt, bortsett fra en ukes stans i sommer på grunn av teknisk overhaling av instrumentene.

6. *Luftforurensingsmålinger:*
Oppdragsgiver: Norsk Institutt for Luftforskning.
Prøvetagningen har blitt forstyrret av lokale forurensingskilder. Sektorsampler for eliminering av lokale kilder har ikke fungert tilfredsstillende.

7. *Oseanografi:*
Oppdragsgiver: Havforskningsinstituttet, Bergen.
6 målinger er tatt i stasjon A og 6 i stasjon B. Det er vanskelig å få tatt prøvene. Slik is- og værforholdene har vært, ble utsetning av båten problematisk. I mørketiden er det ikke forsvarlig å ta prøvene.

8. *Meteorologi:*
Oppdragsgiver: Meteorologisk Institutt, Oslo.
Meteorologiske observasjoner er blitt tatt tre ganger daglig, kl. 0630, 1230 og 1830, og sendt til Isfjord radio for videresending.

9. *Strålingsmålinger:*
Oppdragsgiver: Norsk Polarinstitutt.
De fem viktigste strålingskomponenter for klimatiske undersøkelser har vært registrert hele året.

10. *Tidevannsmåler:*
Oppdragsgiver: Norsk Polarinstitutt.
Har gått normalt i perioden.

11. *Glasiologi:*
Oppdragsgiver: Norsk Polarinstitutt.
Avlesning på akkumulasjonsstaker.

12. *Biologi:*
Oppdragsgiver: Norsk Polarinstitutt.
Registrering av generelle biologiske observasjoner hele året.

The activities of Norsk Polarinstitutt in 1975 — Extract of the annual report —

By KAARE Z. LUNDQUIST

Norsk Polarinstitutt had, as before, 34 permanent positions in 1975. In addition seven employees were engaged on limited-term contracts.

Field work

NORWAY

Glaciology

The studies were led by O. LIESTØL who, together with K. REPP conducted routine glacier mass balance measurements at Storbreen and Hardangerjøkulen. O. ORHEIM and B. WOLD conducted simplified mass balance measurements respectively at Supphellebreen and at Blomsterskardbreen. Storbreen showed a deficit whereas the other glaciers showed positive balances.

Frontal positions of eight glaciers were measured. Two were advancing, including Briksdalsbreen which advanced 41 m. This is the largest annual advance registered since the measurements began in 1900.

SVALBARD

The summer expedition was organized and led by T. SIGGERUD. Altogether 37 persons participated, not counting crews on ships and helicopters. The programme was carried out as planned without mishaps.

The main expedition conducted geological work in the northwestern part of Svalbard, using two helicopters based in Ny-Ålesund. Groups making biological studies in this area were also transported by the helicopters.

The geophysicists worked in Ny-Ålesund in April–May.

Brief glaciological work was done at Jan Mayen.

The hydrography was carried out using M/S "Olaf Scheel" outside Isfjorden, with land bases for the Hi-Fix positioning system at Kapp Martin and Daudmannsøyra. Further hydrography was done in the northern branches of Isfjorden using the motor boat "Svalis". "Olaf Scheel" left Bodø on 7 July and returned there at 4 September.

There was no separate expedition vessel in the 1975 summer, but M/S "Signalhorn", led by K. Z. LUNDQUIST, loaded equipment in Bodø on 10 July and carried this and some expedition members to Ny-Ålesund. Depots for the helicopters and for a spring 1976 expedition were also established in the northern areas, and buoys for ice drift movements were emplaced in the northwestern and eastern waters. The ship returned to Bodø on 24 July. She returned to Ny-Ålesund on 26 August and carried the expedition to Bodø, arriving on 29 August.

Two Bell Jetranger helicopters with crew were rented for the summer and were shipped between Norway and Longyearbyen. They flew to Ny-Ålesund, which was the base for the main expedition.

An extraordinary event took place on 14 August when the expedition celebrated the fiftieth anniversary of Svalbard becoming Norwegian territory. Later the Prime Minister and his party used the helicopters for two days making official visits.

Hydrography

H. HORNBÆK, assisted by B. JAKOBSEN, R. MANDT, S. UTHEIM, L. KRISTIANSEN, I. R. KRISTENSEN, and S. STEINMETZ used the sounding boat "Svalis" from 7 July to 15 September in Sassenfjorden and Ekmanfjorden. Detailed soundings and current measurements were done in Akselsundet and Sveabukta.

The other hydrographic survey with M/S "Olaf Scheel" was led by J. H. CHRISTIANSEN. E. NETELAND looked after the Hi-Fix system and other electronic equipment. L. BLAKSTAD and B. FRETHEIM were engaged each for half the season as assistant hydrographers.

Due to the difficult ice conditions in the east, it was decided to conduct soundings in the western areas. Altogether 4930 n. miles were sounded.

Geology

The field work was a concentrated effort with the helicopters in areas of difficult access in the northwestern part of Svalbard.

T. GJELSVIK, A. HJELLE, and Y. OHTA, each with two assistants, worked north of Kongsfjorden.

Ø. LAURITZEN with two assistants and T. WINSNES with one assistant worked south and east of Kongsfjorden.

O. SALVIGSEN with one assistant studied the Quaternary geology around Sveagruva in early July. Later they joined the other geologists and worked on Prins Karls Forland and on the island in the far northwest.

Geophysics

O. LIESTØL assisted by K. REPP, measured the snow accumulation on Lovénbreen and Brøggerbreen. Triangulation work and measurements of the superimposed ice were also carried out and ground water springs were investigated.

V. HISDAL worked at the Research Station in Ny-Ålesund from 21 May to

18 June measuring intensity distribution and energies of direct and diffuse sun radiation.

T. VINJE also worked in Ny-Ålesund, from 22 April to 28 May calibrating and servicing the radiation instruments both in the short- and long-wave region. The ventilation of various instruments was improved.

Biology

T. LARSEN registered polar bears and their dens during April, covering the area northeast Spitsbergen — Hinlopenstretet — east coast of Nordaustlandet. The registrations were conducted on behalf of the Department of the Environment and Sysselmannen as part of the evaluation of a scooter path to northeast Spitsbergen.

The other biological field activity was the start of the MAB programme which is an independent project for which Norsk Polarinstitutt has the coordinating and administrative responsibility.

JAN MAYEN

O. ORHEIM assisted by J. MANGERUD conducted mass balance studies at Sørbreen in June. MANGERUD also carried out glacial geological studies, including collection of samples to be dated by C-14.

Aerial photography

Landmælingen islands, Reykjavik, was contracted by Norsk Polarinstitutt to do aerial photography which was done by wide-angle cameras, mostly from elevations of 7600 and 3800 m. Funds for this has been provided by the NATO Research Programme. Poor weather made accomplishment of this work impossible in the three previous years.

ANTARCTICA

The geologists A. HJELLE, Y. OHTA, T. S. WINSNES and K. REPP worked in the southern part of the Ellsworth Mountains from November 1974 to January 1975, conducting mostly stratigraphic/tectonic studies. Logistic support was provided by the U.S. National Science Foundation.

Preparation of data

Hydrography

H. HORNBÆK did editing work on charts 502, 503 and 507 and prepared new editions of charts 504 and 513. He planned and prepared the publishing of new chart 523.

J. H. CHRISTIANSEN worked on the 1973 and 1974 soundings and took part in the routine work of the section.

Geodesy — topography

Programmes were made for trigonometric computations on a Diehl Alftronic computer, and these were used in connection with the 1:100 000 topographic maps. Maps G7 Svenskøya and H4 Kongsøya have been constructed. A new edition of C9 Adventdalen has been published. The coastline of Dicksonfjorden at scale 1:100 000 and of Akselsundet at 1:10 000 were constructed for the hydrographic section. A map of a pingo in Dunderdalen at scale 1:2000 was constructed for the geologists and one at the same scale was made of Trollkjeldene for the biologists. Barentsøya was aero triangulated.

New constructions were made of an area of Sør-Jan, Jan Mayen, that could not be constructed from the old photographs.

Maps of Heimefrontfjella and Mannefallknausane were constructed at scale 1:100 000 by use of data from British field work. These will later be printed in the series Dronning Maud Land 1:250 000. The maps N5 Forposten and N6 Sarkofagen were published in the same series.

Geology

A symposium on the geology of Svalbard — "The geological development of Svalbard during Pre-Cambrian and Lower Paleozoic, including Devonian" — was arranged in Oslo 2–6 June 1975. 26 participants from the Soviet Union, Denmark, England, the United States, Canada, and Norway contributed with eighteen papers, later to be published in a special issue of the Norsk Polarinstitutt *Skrifter* series.

H. Major continued coal petrographic studies of samples from mines 4 and 7 in Longyearbyen. He provided statements for the Department of Industry and others and studied the mines in Longyearbyen and Svea in August.

T. S. Winsnes prepared a report on the Antarctic expedition, prepared and led a symposium on the geology of Svalbard, and laid the plans for the Svalbard Expedition. He gave many lectures on the Arctic, and he administered the geologic section.

A. Hjelle took part in the Antarctic expedition and, upon returning, started analysis of samples. He gave a paper at the Svalbard Symposium and prepared data for publication. He has continued analysis of the Dronning Maud Land material.

Y. Ohta also took part in the Antarctic Expedition. He prepared two papers for the Svalbard Symposium and a field report from the Antarctic work. The Antarctic data has been analyzed, and two geologic papers have been published.

Ø. Lauritzen began at Norsk Polarinstitutt on 1 January. He took part in the organization of the Svalbard Symposium and has worked on the material collected during the 1975 summer field work.

O. Salvigsen worked on data from the 1974 and 1975 summers' field work and studied aerial photography preparing for the 1975 season.

M. B. Edwards analyzed material collected during 1974.

Geophysics

V. Hisdal has continued analysis of the radiation observation from Ny-Ålesund. Final analysis of the measured spectral distribution is mostly completed. He started work on a brief description of the geography of Svalbard, to be published as Polarhåndbok Nr. 2 in 1976.

O. LIESTØL prepared glaciologic, meteorologic and other field data from Svalbard and Norway. He was also adviser for graduate students and held a lecture series in glaciology at the University of Oslo.

O. ORHEIM made preparations for the 1976/77 Antarctic Expedition. Glaciological data from Jan Mayen, Supphellebreen, and the South Shetland Islands were analyzed. He has analyzed Nimbus microwave imagery of Antarctica, and Landsat-2 satellite imagery from Dronning Maud Land. He was adviser for one graduate student.

T. VINJE prepared sea ice charts for 1974 and analyzed ten years of satellite data. He was principal investigator for a project with NASA using automatic satellite stations placed on sea ice off Svalbard in July, and for a project using Landsat-2 images of the Svalbard–Greenland area. About 50 images with 80 m resolutions were received during the year. He took part in much committee work.

Biology

T. LARSEN continued analyzing material collected over many years. He has done extensive consultation work for the government, institutions, and individuals. He functioned as secretary for the MAB steering group in the early part of the year.

The Research Station at Ny-Ålesund

Kings Bay Kull Comp. A/S have supplied the logistic needs for the research station for 1974/75 for a payment of kr. 600,000.— from Norsk Polarinstitutt. During the 1974/75 winter, five support personnel from Kings Bay Kull Comp. A/S have worked in Ny-Ålesund in addition to the two scientists/technicians, and one station chief. The capacity of the station is still so limited that its use has been confined to Norwegian scientists or foreign scientists participating in Norwegian projects. Plans for future expansion are being made.

The main continuous registration studies in 1975 have covered the following fields:

4-channel photometer — Earth magnetism — HF absorbtion measurements by rhiometers — Night sky photography by "all-sky-camera" — Seismic registrations — Air pollution studies — Oceanographic studies — Meteorological observations — The five main radiation components — Tidal registrations — Measurements of mass balances of glaciers — Biologic observations were made throughout the year —

The station was used as base for the Norsk Polarinstitutt 1975 expedition. Of this, about six persons were permanently stational at the base, and sixteen lived in the field with transport provided by the two helicopters.

Main field work of scientific and economic interest carried out in Svalbard in 1975

By Kaare Z. Lundquist

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 37 (+ transport crew, two ships, one boat, two helicopters)	NW area of Spitsbergen July–August	Hydrography, topography, geology, geophysics, and biology. See pp. 189–193.
	Norsk Polarinstitutt/MAB	Ingvar Brattbakk Erling Sendstad Nils A. Øritsland 15	Western Spitsbergen June–December	Vegetation mapping, evertebrate zoology, reindeer biology
	Arctic Exploration a/s	Jan Hatle 4	Gipsdalen July–August	Coal investigations
	Paleontologisk Museum, Universitetet i Oslo	David Worsley 2	Bjørnøya July–August	Geology
	Miljøverndepartementet	Nils Gullestad 2	Mitrahalvøya July–August	Biology
	Geologisk institutt, Universitetet i Bergen	Ron Steel 5	Bjørnøya July	Geology
Austrian	Österreichische Akademie der Wissenschaften	John Dittami 3	Nordenskiöld coast June–August	Ornithology
British/ German	Cambridge–Hamburg Spitsbergen Expedition 1975	W. B. Harland and U. Lehman 17	Area around Forlandsundet June–September	Geology

Nationality	Institution or company (residence) Name of expedition	Name(s) of leader(s) Number of participants	Area of investigation Period	Work
Dutch	Netherlands Foundation for Arctic Biological Research	BART EBBINGE 2	Coast of Nordenskiöldlandet June–August	Ornithology
		JAN v. DIJK 2	Coast of Nordenskiöldlandet June–September	Ornithology
German	Max-Planck Institutes für Limniologie	M. P. D. MEIJERING 4	Bjørnøya, areas around Longyearbyen and Ny-Ålesund July–August	Limnology
German	Botanische Staatssammlung, Munich	HANNES HERTEL 4	Areas around Ny-Ålesund and July–August Longyearbyen	Botany
Polish	Wroclaw University Svalbard Expedition 1975	RYSZARD CZAJKOWSKI 15–20	Hornsund area June–September	Glaciology, geology, etc.
	Institute of Geography of the Polish Academy of Sciences & Geographical Institute of Nicolas Copernicus University of Torén	JAN SZUPRYCZYŃSKI 12	Oscar II Land June–August	Glaciology, geology, etc.
Soviet	Arktikugol	GUSEV & KUZNETZKOV Abt. 100 with ice breaker «Krassin» as base	Colesbukta Throughout the year	Oil drilling
	Institute of Geography, Moscow	EVGENIJ ZINGER 4	Area around Longyearbyen June–July	Glaciology

Notiser

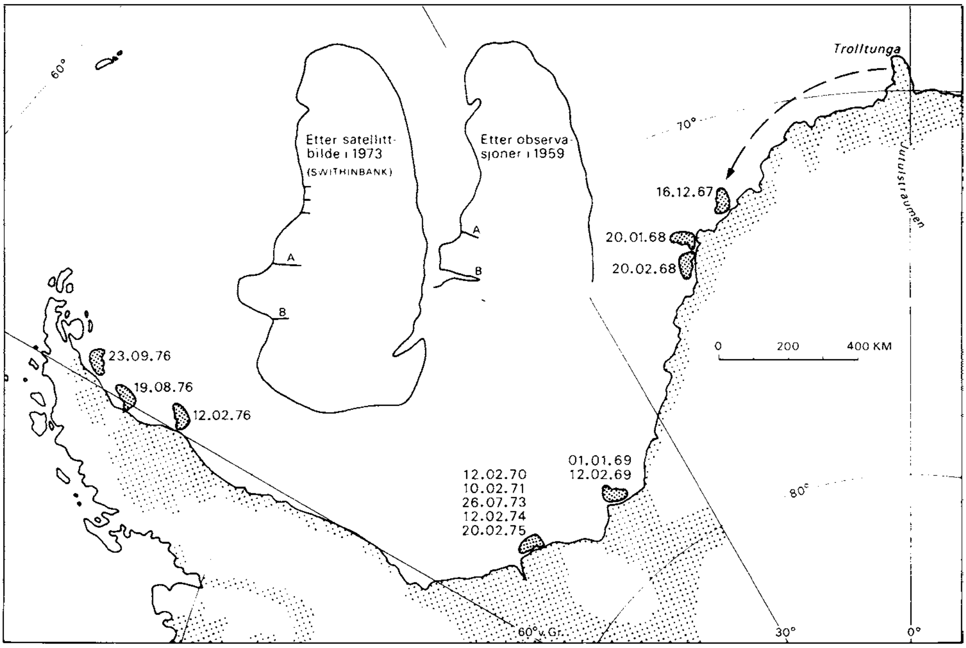

Fig. 1. *Observasjoner av Trolltunga ut fra satellittbilder. Innfelt sees Trolltunga slik den viser seg på bilder fra satellitter med stor oppløsning, innerst i Weddellhavet. Til høyre sees observasjoner fra fly og båt i 1959 på dens opprinnelige plass.*

Drift av Trolltunga i Weddellhavet

Trolltunga var navnet på en kjempemessig tunge av is-shelfen som strakte seg nordover langs nullmeridianen mellom 69° og 70°S. Den brakk løs, sannsynligvis i siste halvdel av juli 1967, og drev langs kysten inn i Weddellhavet med en hastighet av 4,4 km pr. døgn til å begynne med. Dette kjempemessige isfjellet var opprinnelig omkring 100 km langt og 50 km bredt — altså et areal på 5000 km². Det grunnstøtte innerst i Weddellhavet i 1969—70 og ble stående der til ut i 1975 da det fortsatte videre nordover. Nedenfor er angitt de perioder da Trolltunga antas for det meste å ha drevet fritt, med tilhørende driftshastigheter.

Periode	16/12–67 til 20/1–68	minst	4,4	km	pr.	døgn
	20/2–68 » 12/2–69	»	2,0	»	»	»
	20/2–75 » 12/2–76	»	3,0	»	»	»
	19/8–76 » 23/9–76	»	3,4	»	»	»

Driften til Trolltunga er angitt på Fig. 1. Observasjonene bygger på amerikanske satellittbilder. Fra et Landsat-1 bilde bestemte C. SWITHINBANK formen på kjempeberget da det var innerst i Weddellhavet. Denne formen er innfelt i Fig. 1 sammen med de norske observasjonene i 1956.

Trolltunga har fremdeles i hovedtrekkene sin opprinnelige form, men er blitt redusert i utstrekning til bortimot 4500 km². Tykkelsen antas å være omkring 300 meter.

Torgny E. Vinje

Research on the Ordovician Rocks of North Ny Friesland, Spitsbergen

Fossiliferous Lower Palaeozoic rocks at the top of the Hecla Hoek Series in North Ny Friesland, were first discovered in 1965 by a party of survey geologists from the University of Cambridge, England. Part of the early Ordovician (Arenig-Llanvirn) section was measured and collected in 1967, and a preliminary account of the succession given by VALLANCE and FORTEY (1968). Following this, description of the trilobite faunas was started by FORTEY at the University of Cambridge, and in 1971 he joined a joint expedition to Ny Friesland organised by the Palaeontological Museum, University of Oslo and Norsk Polarinstitutt.

In 1971 the field work was extended both downward and upward in the succession and mapping and collecting was done from a new outcrop area to the south of that previously worked on. Results of this fieldwork were published by FORTEY and BRUTON (1973).

Large collections of macro- and microfossils and sediment samples from these expeditions are now housed in the Palaeontological Museum, University of Oslo and in the Sedgwick Museum, Cambridge, England. Some of the remarkably well preserved fauna has been described and published (see reference list) and work is still in progress by scientists from a number of countries. Collections in Oslo have been curated by D. L. BRUTON, and the following fossil groups distributed to the listed scientists for description.

Brachiopods (Dr. R. COCKS, British Museum (Nat. Hist.) London).

Cephalopods (Dr. R. FLOWER, Department of Mines, Socorro, New Mexico, USA).

Chitinozoans (Cand. mag. T. G. BOCKELIE, Paleontologisk Museum, Oslo).

Conodonts (Dr. S. M. BERGSTRÖM, Ohio State University, USA and Dr. C. BARNES, University of Waterloo, Canada).

Echinoderms (Cand. real. J. F. BOCKELIE, Paleontologisk Museum, Oslo).

Gastropods and Monoplacophora (Dr. E. YOCHELSON, U.S. Geological Survey, Washington D.C. USA).

Graptolites (Dr. R. A. FORTEY, British Museum (Nat. Hist.) London).

Radiolaria (Dr. B. K. HOLDSWORTH, University of Keele, England).

Trilobites (Dr. R. A. FORTEY, Dr. D. L. BRUTON).

Vertebrate remains (Cand. mag. T. G. BOCKELIE and Dr. R. A. FORTEY).

Worm tubes (Cand. mag. T. G. BOCKELIE and Dr. E. YOCHELSON).

Other groups still unassigned, include acritarchs, bivalves, bryozoa, scolecodonts, sponges, and a variety of microfossil miscellania.

The predominantly carbonate succession has yielded faunas of Early Cambrian and Early Canadian to Whiterock ages. Middle and Late Cambrian faunas are absent. The lower part of the succession compares closely with other sections in the North Atlantic, which were deposited under shallow water and platform conditions with faunas of "Pacific" type. Black graptolitic limestones and shales of the younger part of the succession (Arenig-Llanvirn age) contain trilobites of European aspect which probably represent deep water conditions (FORTEY 1975).

The rich and varied microfossil residues handled independently by R. A. FORTEY and T. G. BOCKELIE, have recently yielded a number of fossil fragments, 1–3 mm in length, and thought to belong to an early vertebrate of the class Heterostraci. All fragments are covered by small scales (25–100 μm), lancelate and rhombic in shape (Pl. fig. 1,2). Some of the fragments are sheet-like to slightly curved, while others are spine-like (Pl. fig. 1) and are remarkably thin (70–100 μm) and fragile. A more complete morphological description of the present material has appeared in *Nature* (BOCKELIE and FORTEY 1976), and it is hoped that this will be followed by a detailed histological description based on additional material.

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T. G. Bockelie and D. L. Bruton
Paleontologisk museum
Sarsgate 5
Oslo 5, Norway

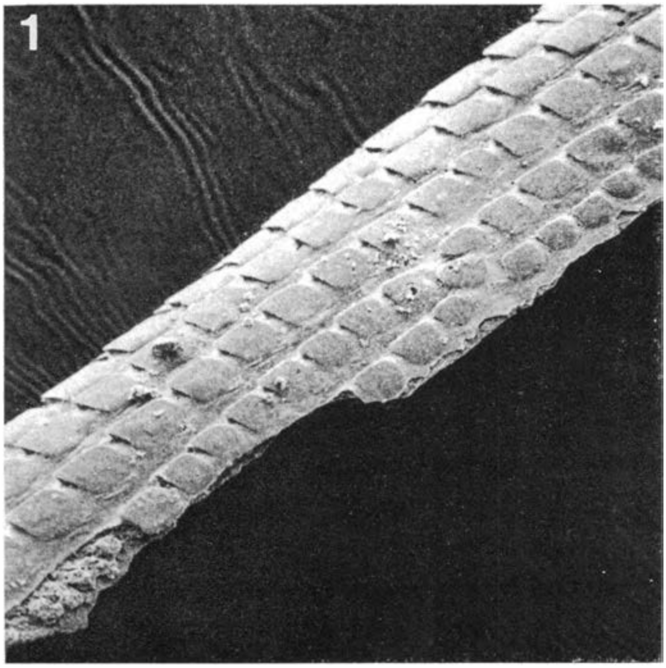
R. A. Fortey
Department of Palaeontology
British Museum (Natural history)
London SW7 5BD, England

PLATE

Scanning electron microscope micrographs of fragments of an early Ordovician vertebrate recovered from Valhallfonna Formation, Profilbekken Member, Ny Friesland, Spitsbergen.

1. Spine-like fragment with rows of rhomboid scales, X175.
2. Details of scale covering, X300.

Palaeontological Museum, Oslo: Cat. no. PMO NF.3263/7.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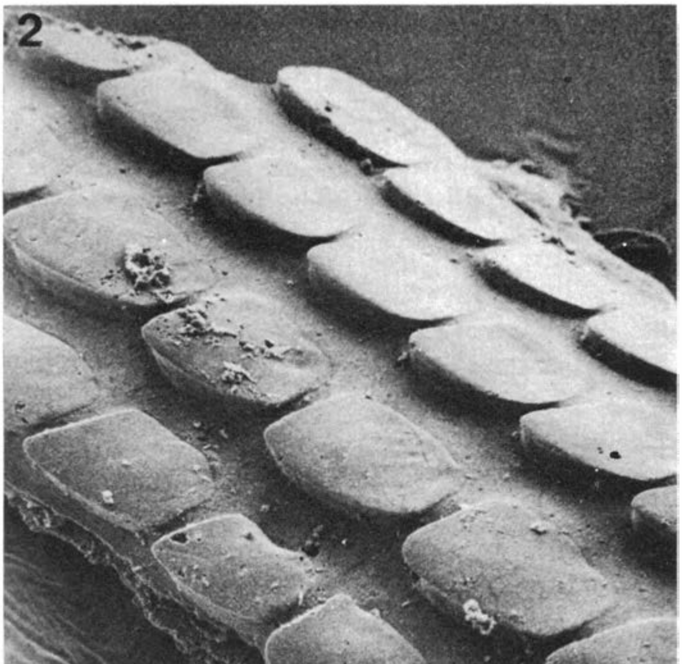
2

A sample of spiders (Araneida) from Svalbard

Abstract. — Localities and short habitat descriptions are given for the following spiders collected on the west coast of Spitsbergen during June and July 1968: *Erigone psychrophila* Thorell, *Erigone arctica palaearctica* Brændegaard, *Collinsia spetsbergensis* (Thorell), *Hilaira glacialis* (Thorell), and *Lepthyphantes sobrius* (Thorell). All the four last species show great tolerances for different habitats.

Introduction

The present material was collected by the first author in connection with the activity of Norsk Polarinstitutt in Svalbard during the summer of 1968. The collections were made on the west coast of Spitsbergen and on Prins Karls Forland. Identification of the species has been performed by the second author.

Records

Collinsia spetsbergensis (Thorell).

– Isfjord Radio. 13 June: 1♂ and 1♀ under a piece of tarboard. Flat area with *Saxifraga oppositifolia* L. 18 June: 4♀♀ under stones. 24 June: 1♀ in an old nest of Eider (*Somateria mollissima* (L.)). 23–27 June: 3♂♂ and 4♀♀ in a pit-fall trap placed on a dry ridge with mosses, lichens and *S. oppositifolia.* — Levinhamna, Prins Karls Forland. 1 July: 1♀ under stone. 2–7 July: 2♂♂, 4♀♀ and 2 juv. in a pit-fall trap placed at the bottom of a 1 m wide, moist suppression in the tundra, with rich moss vegetation. 3–7 July: 4♀♀ in a pit-fall trap placed on a dry, mosscovered ridge. — Hermansenøya. 9 July: 1♂, 1♀ and 1 juv. under stones. —Near Signehamna, Krossfjorden. 11 July: 1♀ under stone, under large bird cliff. Rather rich vegetation due to bird excrements.

Erigone arctica palaearctica Brændegaard.

— Hermansenøya. 9 July: 1 juv. under stone. —Near Signehamna, Krossfjorden. 15 July: 1♂ and 1♀ under stones, under large bird cliff. Rather rich vegetation. — Gerdøya, Kongsfjorden. 20 July: 1♂ and 2♀♀ under stones. Moist area with rich moss vegetation. — Sigridholmen, Kongsfjorden. 28 July: 1♂ and 1 juv. under stones. Sparse vegetation.

Erigone psychrophila Thorell.

— On a small isle just in front of a glacier, outside Irgensfjellet on Blomstrandhalvøya. 22 July: 1♀ under stone. Relatively rich vegetation.

Hilaira glacialis (Thorell).

— Signehamna, Krossfjorden. 12 July: 2♀♀ under stones. Tundra with moss vegetation. — Gerdøya, Kongsfjorden. 20 July: 1♀ under stone. Moist area with rich moss vegetation. —Juttaholmen, Kongsfjorden. 21 July: 1♀ and 1 juv. under stones. Rich grass vegetation. — Blomstrandhalvøya, Kongsfjorden. 22 July: 1♀ under stone, under large bird cliff (Irgensfjellet). Rather rich vegetation.

Lepthyphantes sobrius (Thorell).

— Signehamna, Krossfjorden. 12 July: 2♀♀ under stones. Tundra with moss vegetation. 16 July: 3♀♀ under stones on dry tundra rich in stones. Moss vegetation. — About 2 km W. of Signehamna. 14 July: 1♀ found on a stone in a large, rather homogenous area, consisting almost exclusively of stones with a sparse lichen vegetation. — Near Signehamna, Krossfjorden. 15 July: 2♀♀ under stones, under large bird cliff. Rather rich vegetation. — Ossian Sars-fjellet, Kongsfjorden. 23 July: 6♀♀ under stones, under large bird cliff. Very rich vegetation.

Discussion

C. spetsbergensis, which makes up a great part of the material, is evidently one of the most common species in many localities. In a study of the spider fauna at Kapp Wijk and near Ny Ålesund, this species was often found to be dominant (HEGSTAD unpubl.). All the species presented in this paper were also recorded by him. The data presented above shows that *C. spetsbergensis* tolerates very different habitats: both dry and moist, and with both poor and rich vegetation. Also HEGSTAD (unpubl.) found great tolerances for variations in habitat for this species, as well as for *E. arctica*. The present records of *E. arctica* includes both rich habitats under bird cliffs and areas with sparse vegetation.

E. psychrophila has been found only on moist areas by HEGSTAD (unpubl.), e.g. shore meadow at Kapp Wijk. However, according to HOLM (1958), the species may be found also in dry habitats.

H. glacialis is considered by HOLM (1958) to be endemic for Svalbard. Apart from *E. arctica*, he characterizes the species as the most common spider in Svalbard, with great tolerance for different habitats. The records from both moss-covered tundra and from the rich habitats below bird cliffs support HOLM's last conclusion. However, HEGSTAD (unpubl.) found it to prefer habitats with rich vegetation. In Tetragonodryadetum associations (RÖNNING 1965), he found it to be the dominant species.

In this material, *L. sobrius* is the species recorded from the most varied habitats: both from a large "stone desert" with only a sparse lichen vegetation, and below bird cliffs in habitats containing the richest soil and vegetation that can be found in Svalbard. A corresponding tolerance has been recorded by HEGSTAD (unpubl.). According to SUMMERHAYES and ELTON (1923), the species prefers unstable mountain slopes and demands more space under stones than for instance the *Erigone* and *Collinsia* species. This is, however, not evident from the present study.

The great habitat tolerance characteristic for at least four of the five species recorded, may be considered as an adaptation to Svalbard conditions. All species are active on the soil surface and in vegetation and may encounter habitats of different character. Often the Svalbard landscape consists of a mosaic of different habitats, of which each may be rather small. The more tolerant a species is for such changes, the more successful it will be in establishing, and in achieving a large geographical distribution.

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Sigmund Hågvar
Norwegian Forest Research Institute
N-1432 Ås-NLH

Arvid Hegstad
Organistvegen 11
N-7500 Stjørdal

A.s John Grieg