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A comparative study of the spectral composition of the zenith sky radiation

(Сравнительное изучение спектрального состава радиации зенитного неба)

BY
VIDAR HISDAL

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Abstract

The spectral composition of the zenith sky radiation was measured in Svalbard and in Oslo, using a grating monochromator with a photomultiplier tube as detector. The apparatus was calibrated by means of a tungsten filament lamp operated at a colour temperature of 2500°K. To reduce the number of factors influencing the spectral distribution, only measurements referring to a completely clear sky, or a completely overcast sky, and to a solar altitude close to 30°, are considered in the present discussion. The spectral curves show several characteristic dips, which may be traced back either to solar Fraunhofer lines, or to selective absorption in the earth's atmosphere. The spectral distribution for Ny-Ålesund, clear sky, which was measured on a day with advection of arctic air, corresponds surprisingly well to that computed for a Rayleigh atmosphere on the basis of CHANDRASEKHAR's theory. The considerable differences found between some of the spectral distributions are supposed to be partly due to typical regional inequalities with regard to the factors determining the atmospheric scattering conditions at the individual stations. However, the observations reveal that "sampling fluctuations" no doubt play an important part as well. The colour of the zenith sky is evaluated by means of the CIE chromaticity co-ordinates, and a comparison is made between observed spectral distributions and those of a black-body at the corresponding correlated colour temperature.

Резюме

Спектральный состав радиации зенитного неба был измерен на Свальбарде и в Осло с применением решетчатого монохроматора с фотомножительной трубой, служащей детектором. Прибор был прокалиброван при помощи лампы с вольфрамовой нитью накала, работающей при цветной температуре в 2500°К. Для того чтобы сократить число факторов, влияющих на спектальное распределение, в данной статье учтены только измерения, относящиеся к небу или совершенно ясному, или совершенно покрытому облаками, и к солнечной высоте близкой к 30°. Спетральные кривые показывают несколько характерных колебаний, которые могут быть причинены или солнечными фраунгоферовыми линиями, или избирательным поглощением земной атмосферы. Спектральное распределение для Ню-Олесунда (на острове Западный Шпицберген) при ясном небе, измеренное в день с адвекцией арктического воздуха, поразителтно хорошо соответствует вычисленному для релеевской атмосферы на основании теории Чандрасекхара. Значительные установленные расхождения между некоторыми из спектральных распределений предположительно вызваны отчасти типичными, региональными различиями, связанными с факторами, определяющими атмосферные условия рассеяния на отдельных станциях. Однако наблюдения показывают, что «выборочные варации» несомненно также играют важную роль. Окраска зенитного неба определяется по хроматическим координатам (CIE), и произведено сравнеие между отмеченными спектральными распределениями и распределениями черного тела при соответствующей, соотнесенной цветной температуре.

Introduction

The spectral distribution of the scattered sky radiation may be considered as a solar spectrum more or less distorted by processes in the earth's atmosphere, and also, in some measure, by the reflecting properties of the ground.

There is a number of factors influencing the spectral distribution of the scattered radiation: (1) changes of the solar radiation entering the earth's atmosphere, (2) different parameters determining the attenuation effect of the atmosphere: (a) the altitude of the sun, (b) the optical thickness at the various wave-lengths of the molecular atmosphere and (c) of the atmospheric aerosol, parameters that change with time and location (including height above sea level), (d) amount, distribution and types of clouds present, which although forming part of the atmospheric aerosol, should be considered as a separate factor, (3) magnitude and spectral character of the reflectivity of the ground, and finally, provided the radiation from the whole celestial hemisphere is not considered, (4) which part of the sky that is observed.

All these variable factors make it difficult to draw definite conclusions as to what conditions are most important for the understanding of differences between spectra observed at different times, and (or) in different localities. Obviously, the more factors that are kept constant, the more reliable is the information generally obtained about the influences of the factors that change.

The present investigation has a fairly limited scope: We want to study the form and structure of some spectral distributions of scattered sky radiation. Furthermore, by comparing three groups of spectra, viz. spectra observed in high northern latitudes (Svalbard), spectra from intermediate latitudes, and a spectrum derived on a theoretical basis, we hope to obtain information as to what influence changes of the atmospheric aerosol (point 2c above) has on the spectral distributions. For the stations considered we suppose this influence to be large compared with the effects of dissimilarities regarding the reflectivity of the ground (point 3). We are considering only the part of the observation material referring to a solar altitude equal to, or close to 30° (point 2a). As to the sky conditions (point 2d), only two cases are considered: completely clear sky, and completely overcast sky. Practically all measurements discussed refer to the zenith sky (point 4). Changes due to the factors mentioned under point 1 (variations of the extraterrestrial solar radiation), and point 2b (optical thickness of the molecular atmosphere) are supposed to be so small that they may be disregarded in the following discussion. (Concerning point 2b, an exception must be made for one of the stations used as a basis of comparison, Arosa, which is situated at a relatively great altitude.)

The measurements from Svalbard were carried out during the summers of 1964 (Slettebu) and 1966 (Ny-Ålesund). Both stations were situated close to the sea, on the west-coast of Vestspitsbergen. In addition to plains covered by sand, stone, and sparse vegetation, the surroundings consisted of water, partly snow-free mountains, and glaciers.

Unfortunately, during the second summer various difficulties, especially a troublesome repair of an instrument which was damaged, meant that some favourable weather situations in the first part of the observation period could not be utilized. During the last part of our stay, however, a few spectral series of the types discussed here were obtained.

Measurements corresponding to those made in Svalbard were carried out in Oslo as well. The instruments were placed on the roof of the office building (about 60 m above sea level). The building is situated in a mainly residential region, with large park areas in the immediate vicinity.

Apparatus and observation method

Since the observation equipment was to be used under field conditions, it had to be easy to carry, and of sturdy construction. These properties were also of importance because of the long and not too gentle transport to and from Svalbard.

A small Hilger & Watts grating monochromator (D292) was used as dispersion system. With a grating of 576 lines per mm the wave-length could be varied from 200 to 1000 mμ. In order to obtain sufficient signal in the spectral regions where the sensitivity of the photomultipliers used was low, comparatively wide entrance and exit slits were applied, corresponding to a half-band width slightly below 7 mμ. In front of the entrance tube was fastened a tube with internally blackened surface, and between this tube and the slit was placed a slide with two filter holders. The instrument, which was mounted on a theodolite tripod, had an angular field of view of 6°.

During the first series of observations (1964–65) a RCA–931A, 9 stage photomultiplier tube with caesium-antimony cathode, supplied with a stabilized voltage of 750V from a series of dry batteries, was used as detector. During the second period a Philips XP 1002, 10 stage tube was used, which has a trialkali semitransparent cathode. In this case an 18V battery supplied power to an oscillator, the output of which was transformed to give a high voltage, which was subsequently rectified. The 1600V output voltage was stabilized by means of a series of zener diodes.

With the equipment used, and under the existing observation conditions, a usable signal was obtained from the RCA-tube in the wave-length range 320–600 mμ, and from the Philips tube in the range 300–800 mμ. However, especially in the latter case, the values obtained near the ends of the spectral range, should not be considered as very well established. In order to avoid the influence of a second order spectrum, a Schott GG 14 filter was used for wave-lengths greater than 590 mμ.

The output current of the photomultiplier tubes was measured with a Norma light-spot galvanometer, which had a maximum sensitivity, with sufficient damping, of $3.9 \cdot 10^{-8}$ A mm^{-1}.

Simultaneously with the spectral measurements the current from a selenium barrerier-layer cell, that received radiation from the zenith sky through a vertical tube, was read on a microammeter to obtain an indication of the stability of the radiation conditions. This was particularly important in situations with an overcast sky. Even though an observation series was not initiated unless the cloud cover had a fairly uniform appearance, considerable variations of the microammeter readings might occur. If these variations exceeded 10% of the average reading, the measurements were discontinued. It should be added that for the majority of spectral series completed for an overcast sky the variations were well below 5%. With a clear sky the signal from the selenium cell was practically constant. Only a slight trend was present, no doubt mainly caused by the changing altitude of the sun. Experiments showed that for the relatively small variations in question, the galvanometer reading for a certain wave-length was nearly proportional to the microammeter reading. Consequently, whenever necessary the observed signals of the photomultiplier could easily be reduced to the average value of the selenium cell signal.

With only one observer readings every 10 mμ in the range 320–600 mμ required about 6 minutes. The corresponding time for the range 300–800 mμ was about 10 minutes. Frequently, however, I was assisted by a colleague, and the observation time was then reduced by more than one third. It would of course have been desirable to reduce the observation time still more, which, among other things, would mean that not so many series would have to be cut out because of too variable radiation conditions. However, with the equipment available this was not possible.

In a few cases readings were made at every 5 mμ to establish the course of the spectral curve between the 10 mμ values.

In order to correct to some extent for possible long period trends in the output signal of the photomultiplier tube, a series of spectral measurements starting at the short wave-length end was immediately repeated in the reverse direction, and the two series were averaged. Generally, the differences between the two series were small.

A photograph of the observation arrangement is shown in Fig. 1.

Fig. 1. *Observation arrangement, Ny-Ålesund.*

Calibration

It was decided to restrict the investigation to relative spectral distributions. During the calibration procedure the conditions were so arranged as to resemble as closely as possible those existing when the observations were made.

A calibrated tungsten filament lamp operated at a colour temperature of 2500°K was used as a standard source. The lamp had a quartz-glass envelope, and a diffusing filter of the same material was placed between the lamp and the measuring device. The spectral transmission of the glass is known.

For obvious reasons it was not possible to make calibration measurements in Svalbard. These had to be carried out in Oslo. However, calibrations made shortly before our departure for Svalbard, and after the return home, showed no noteworths differences. It seems therefore safe to conclude that the results of the calibrations made in Oslo, are valid for the Svalbard observations too.

The most troublesome part of the calibration work was that of finding a reliable correction for the effect of scattered radiation (stray light) in the monochromator. Although the instrument had been so designed as to minimize this effect, it caused a high "noise to signal ratio" near the short-wave and long-wave limits of the spectrum measured. The variation of the intensity of the scattered radiation was determined by placing different "cut-out" filters in front of the entrance slit, and reading the output signal for a series of wave-lengths. Readings were taken also at wave-lengths for which the photomultiplier tube should not longer be sensitive. Such measurements were carried out during the calibrations as well as in the different types of observation conditions. It turned out that, except for minor fluctuations, the intensity of the scattered radiation decreased as the monochromator was adjusted to constantly increasing wave-lengths. It should be added that the filter (GG14) used during all spectral measurements for wave-lengths greater than 590 mμ considerably reduced the influence of scattered radiation for this part of the spectrum. We may mention, as an example of the relative effect, that for Ny-Ålesund, clear sky, the scattered radiation in the monochromator was responsible for 26% of the signal read on the galvanometer at 300 mμ, 2.2% at 320 mμ, 0.7% at 400 mμ, 1.1% at 600 mμ, 4.2% at 700 mμ, and 43% at 800 mμ.

Whenever the monochromator had been transported a long way, the wave-length scale was checked by means of a set of interference filters with narrow transmission bands. However, in no case was it found necessary to re-adjust the instrument.

Form and structure of the spectral distributions

The data discussed in this and the following sections are specified in Table 1. Fig. 2 shows the spectral distributions for Ny-Ålesund and Oslo for clear and overcast sky. The ratio of corresponding spectral irradiances of two distributions may be considered as approximately correct.

Except for the far ultra-violet part of the spectrum, the irradiances are notably larger when the sky is overcast than when the sky is clear, especially in the case of Ny-Ålesund. For both types of sky conditions the radiant energy received is much higher in Ny-Ålesund than in Oslo. Thus, the ultra-violet content is about twice as great in Ny-Ålesund. We furthermore observe that for a clear sky the curves have a maximum at 410 mμ, while for an overcast sky the maximum occurs at 460 mμ.

In spite of the comparatively small resolution applied, the course of the curves is rather irregular, with many wave-shaped variations, which, as might be expected, are particularly in evidence for the spectral curve distinguished by the highest

Table 1

Station	Lat.	Long.	Sky conditions	Year	Day	Number of spectra	Mean solar altitude	Spectral range (mμ)
Slettebu	77°32′N	15°21′E	Clear	1964	12, 13, 18, 20 July	12	31.9°	320–600
			Overcast	»	14, 16, 17, 23, 24, 29 July	18	31.1°	»
			Cs (thin veil)	»	21 July	4	26.1°	»
Ny-Ålesund	78°56′N	11°58′E	Clear	1966	30 July	2	29.1°	300–800
			Overcast	»	2, 3, 4 August	12	28.6°	»
Oslo	59°56′N	10°44′E	Clear	1965	3, 8 April	10	30.8°	320–600
			Clear	1967	14, 15 Sept.	6	30.2°	300–800
			Overcast	1965	3, 5 April	6	31.3°	320–600
Cleveland	41.5°N	81.7°W	Clear	1939–40		4		400–700
Arosa	46°47′N	09°40′E	Clear	1946	11 Sept.	1	30°	330–550
Theoretical			Rayleigh atm.		(Albedo: 0.25)		30°	300–800

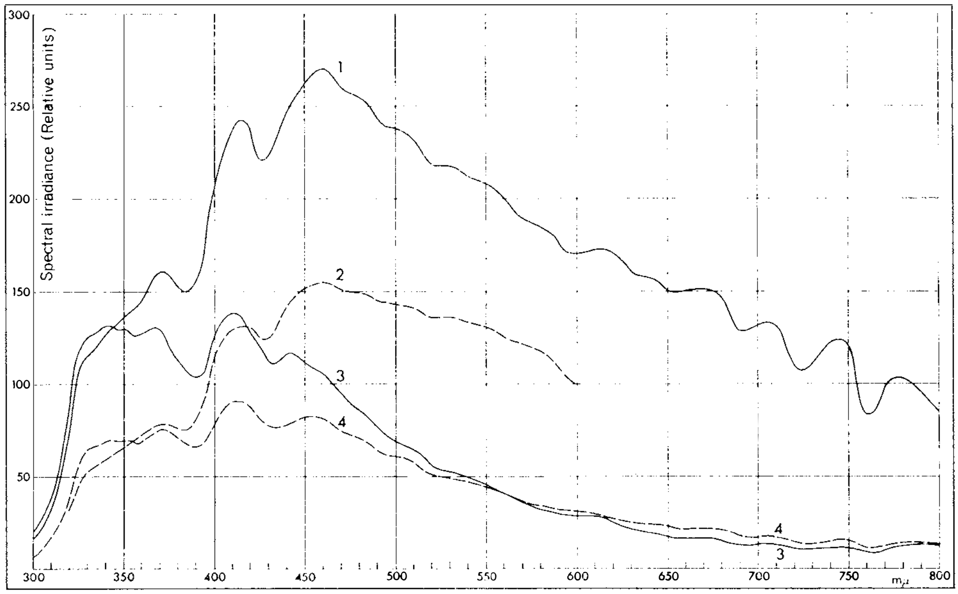

Fig. 2. *Spectral distribution of zenith sky radiation. Curve 1: Ny-Ålesund, overcast. Curve 2: Oslo, overcast. Curve 3: Ny-Ålesund, clear. Curve 4: Oslo, clear.*

irradiance values (curve 1). The various dips may partly be ascribed to solar Fraunhofer lines, partly to absorption in the earth's atmosphere. Strong solar Fraunhofer lines, or rather the combined effect of several strong neighbouring lines, are no doubt responsible for the marked decrease of irradiance in the region from 410 mμ to 390 mμ (H- and K-line of Ca), and also for the marked minimum at about 430 mμ (several strong lines, primarily the g-line of Ca, the G-lines of Ca and Fe, and the H_γ-line of H). Some of the smaller dips too are obviously caused by solar Fraunhofer lines, the most prominent one in our case being that at about 520 mμ (b-lines due to Mg, and E-lines due to Ca and Fe).

Absorption by oxygen and water vapour in the earth's atmosphere has left clear traces in the curves. There are conspicuous dips in the following regions: 590–610 mμ, (H_2O, and probably a perceptible contribution from the Fraunhofer D-lines), 650–660 mμ (H_2O, and probably a perceptible contribution from the H_α-line of the Balmer series), 680–700 mμ (H_2O and O_2), 710–740 mμ (H_2O), and 750–770 mμ (O_2). The long-wave end of the curves seems to be descending towards a minimum somewhat above 800 mμ, which may be attributed to the water vapour absorption band centred about 810 mμ. As is well known, ozone, in addition to "removing" the far ultra-violet part of the solar spectrum, has a system of weak absorption bands (the Chappuis bands) in the range 450–750 mμ, with a maximum absorption about 600 mμ. Traces of this effect are found when, later on, we compare a theoretical spectral curve with an observed one, the former being unaffected by ozone absorption.

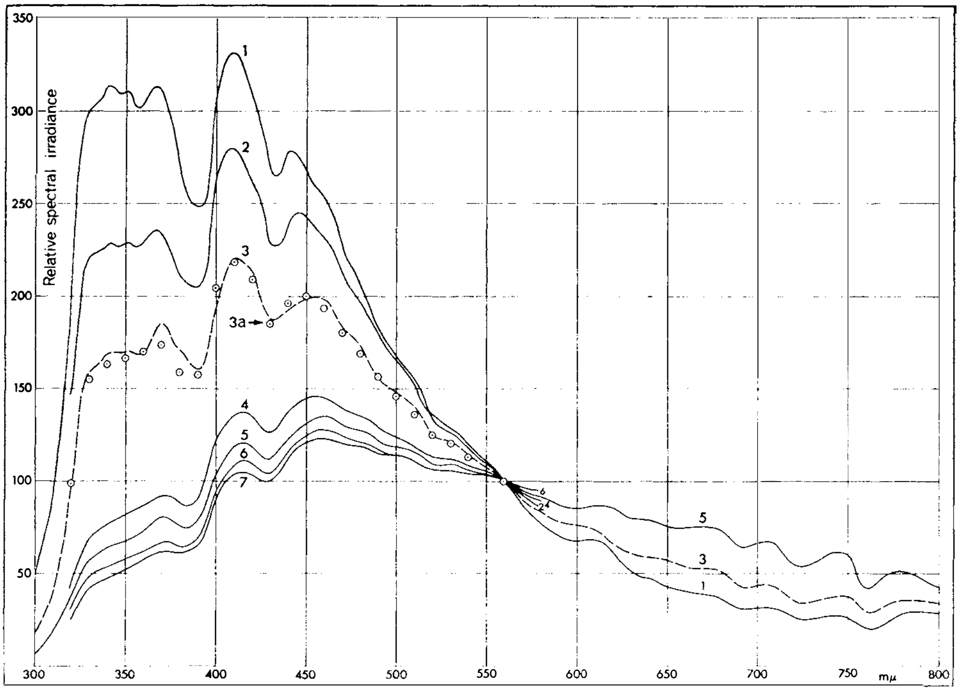

Fig. 3. *Spectral distribution of zenith sky radiation (normalized at 560 mμ). Curve 1: Ny-Ålesund, clear. Curve 2: Slettebu, clear. Curve 3: Oslo, clear (1967). Points 3a: Oslo, clear (1965). Curve 4: Slettebu, thin veil of Cirrostratus. Curve 5: Ny-Ålesund, overcast. Curve 6: Slettebu, overcast. Curve 7: Oslo, overcast.*

Comparison of the spectral distributions

In order to facilitate the comparison between different spectral distributions of sky radiation, the spectral irradiances are usually normalized by expressing them as percentages of the value at 560 mμ. The initial reason for choosing this scale seems to have been that the magnitude of the irradiance at this wave-length was found to be nearly proportional to the luminous flux (cf. WALSH 1958). Although it may be doubtful whether this is a useful property when spectral distributions of radiant energy are discussed, we have here normalized our values in the usual way, chiefly because we do not know enough about the possibility of specifying a wave-length at which the spectral irradiance is approximately proportional to the total irradiance received. We shall return to this question in the succeeding section. We confine ourselves here to pointing out that the spectral curves compared in the following do not refer to one and the same total irradiance. Ordinates of curves that are distinguished by high values in the ultra-violet and blue part of the spectrum refer to a somewhat larger total irradiance than do the ordinates of curves that are low in the same spectral region.

In Fig. 3 are entered the normalized spectral distributions for clear and overcast sky for Ny-Ålesund, Slettebu and Oslo. The ratio of the irradiance in the ultra-violet and blue part of the spectrum to that in the yellow and red part decreases radically from Ny-Ålesund, clear sky, to Oslo, overcast. As would be expected, the curve representing a very thin veil of cirrostratus (Slettebu, curve 4), is situated between the curves representing a clear sky, and an overcast sky, respectively.

The number of days during which observations were carried out is small (cf. Table 1), and the question arises as to how representative the observed spectral distributions are, or in other words, how close they are to those representing the average conditions at the individual stations. There is an unexpectedly great difference between the spectral distributions for Ny-Ålesund and Slettebu, particularly in the case of a clear sky. There seems to be no obvious reason why, on an average, the quantity of non-Rayleigh scatterers should be greater over the latter station. Nor does it seem likely that the reflectivity of the ground should be essentially different. It may be mentioned that the observation series for Slettebu, clear sky, with the highest ultra-violet content gives a curve that is situated approximately midway between the curves representing Slettebu and Ny-Ålesund in Fig. 3. The corresponding curve with the lowest ultra-violet contents lies approximately midway between the Oslo- and the Slettebu-curve, which indicates that even for the same type of sky conditions a comparatively large variation of the spectral composition of the sky radiation may occur in these regions.

Studying the weather maps for the periods in question, we find that the day with the relatively strongest ultra-violet radiation at Slettebu (13 July 1964) was characterized by a rather weak advection of polar maritime air from the southwest. On 20 July of the same year, the day when the lowest values of the ultra-violet radiation were measured, there was a stronger advection of air of polar maritime character from the southwest. On 30 July 1966, on the other hand, when the spectral distribution for Ny-Ålesund was observed, the situation was quite different. There was a moderate north-easterly wind between a high pressure area north of Siberia and depressions passing over Scandinavia (foehn effect in the Ny-Ålesund region), and the Svalbard area was under the influence of an arctic air mass, which, a priori, is likely to be the air mass that has the lowest turbidity. Thus, there seems to be valid reasons to assume that the great difference between the spectral distributions observed at Slettebu and Ny-Ålesund may be ascribed, at least partly, to the fact that "accidentally" the air masses prevailing over the Svalbard area during the observation periods were distinguished by different turbidity conditions.

For Oslo, clear sky, the difference between the series with the highest and lowest ultra-violet content is far less than in the case of Slettebu. We may note that the spectral distribution for the two spring days in 1965 agrees well with that of the two autumn days in 1967, in spite of the fact that the life history of the air masses differs considerably in the two cases. This seems natural, since for this station we may assume that the atmospheric turbidity is to a greater extent determined by air pollution of local character.

We furthermore note that, qualitatively, the relationship between the spectral curves for an overcast sky, corresponds well to that found for a clear sky.

These facts indicate that "sampling fluctuations" are not completely masking influences that are typical for the individual stations. Evidently, this applies especially to the relationship between the spectral distributions observed in Svalbard, on the one hand, and in Oslo, on the other.

It may be of interest to compare the spectral distribution for Ny-Ålesund, clear sky, with the theoretical distribution for a Rayleigh atmosphere (in which the attenuation of solar radiation is due to molecular scattering only). The computation of the latter distribution was carried out by means of data tabulated by COULSON et al. (1960), based on the theory of CHANDRASEKHAR (1950), which, on the assumption of a plane-parallel atmosphere, make it possible not only to take into account all orders of molecular scattering, but to include also the influence of radiation reflected from the ground. For further details reference is made to the work of CHANDRASEKHAR, and to DEIRMENDJIAN and SEKERA (1954). Some particulars regarding the basis of the present calculation are given below.

Judging from albedo measurements at Ny-Ålesund, and photos made of the station area from an airplane on 28 July 1966, a value of 0.25 seemed to be a "reasonable estimate" of the "average albedo" of the surface surrounding the station. It goes without saying, that this value cannot be considered as very well established. The surface of the area is of very heterogeneous character, and, furthermore, some sort of weighted average albedo seems relevant in this connection, where the weight is a function of the distance from the station. The altitude of the sun was put equal to 30°. As to the extraterrestrial spectral distribution of solar radiation, the latest and probably most reliable data available to us were those published by GAST (1965).

The relative spectral irradiances of the zenith sky radiation were computed for band-widths of 10 mμ. The resulting theoretical curve and the Ny-Ålesund curve are presented as curves 1 and 2 in Fig. 4. In view of the many uncertainties involved, the agreement between the two curves is surprisingly good. It should perhaps be mentioned that the theoretical distribution in Fig. 4 is the only one computed, and, consequently, is not the final result of a "trial and error method". The theoretical curve is not affected by atmospheric absorption, which may account, at least partly, for the relatively high values in the far ultra-violet part, where the observed curve is strongly influenced by the Hartley-Huggins bands. There are other factors that may make the two curves not fully comparable. This applies, among other things, to the fact that the value used for the albedo, as previously mentioned, may be considered only as a rough estimate, and perhaps more important, to the fact that the reflectivity of the ground is dependent on wave-length, while the computations are based on a constant albedo. Of course, the fact that the spectral composition of the solar radiation outside the earth's atmosphere is still somewhat uncertain, may be of significance in this connection too.

As far as we know, the only spectral distributions of radiation from the zenith sky published previously are those measured in Cleveland by TAYLOR and KERR (1941), and in Arosa by GÖTZ and SCHÖNMANN (1948). They all refer to a clear sky. Further specifications concerning these measurements are given in Table 1.

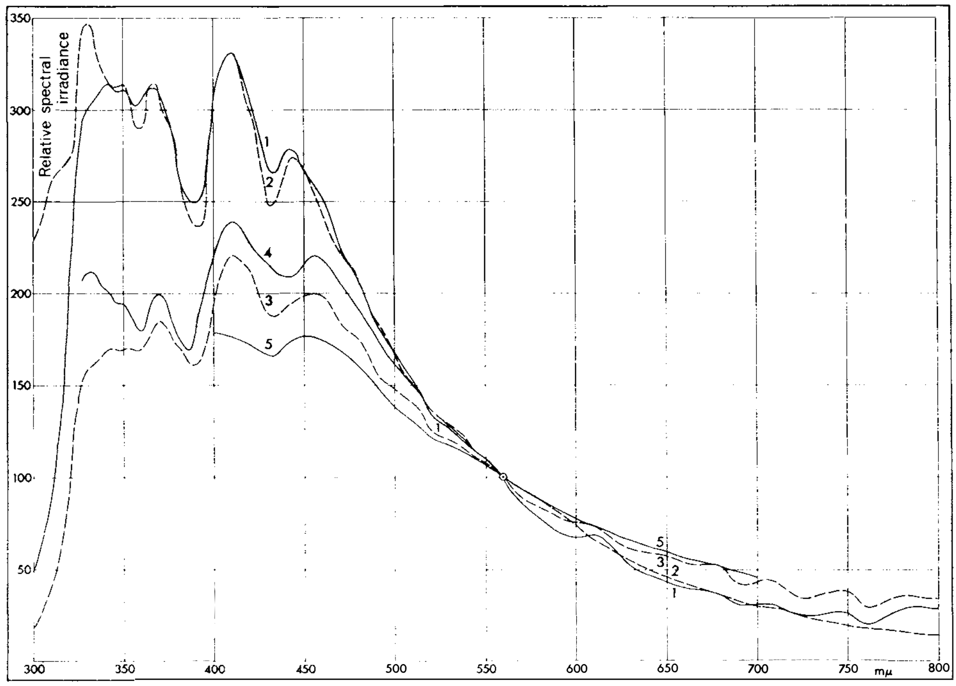

Fig. 4. *Spectral distributions of zenith sky radiation (normalized at 560 mμ). Curve 1: Ny-Ålesund, clear. Curve 2: Theoretical distribution, Rayleigh atmosphere. Curve 3: Oslo, clear. Curve 4: Arosa, clear. Curve 5: Cleveland, clear.*

An average spectral curve for Cleveland, and a curve referring to a solar altitude of 30° for Arosa are shown in Fig. 4, together with the average curve for Oslo. The solar altitude during the measurements in Cleveland is not given, which makes their relation to the data of the two other stations somewhat ambiguous. Disregarding this circumstance, the comparatively low course of the Cleveland curve in the blue part of the spectrum agrees well with the fact that over this station "the sky is seldom completely free of some haze and smoke" (op. cit. p. 3). It appears that, on an average, the irradiance for this station is higher at 400 mμ than at 410 mμ, which is most surprising, and it seems doubtful whether this feature is real.

The spectral distributions published by Götz and Schönmann are much more detailed for the shorter wave-lengths than our own measurements, and correspondingly less detailed for the longer wave-lengths, which no doubt is due to the fact that the quartz prism monochromator used was operated with constant slit width. In order to facilitate the comparison we have smoothed the relative spectral irradiances for Arosa by means of the well-known formula: $\bar{x}_2 = \frac{1}{4}(x_1 + 2x_2 + x_3)$. For wave-lengths above, say, 440 mμ the influence of the smoothing procedure is negligible.

We see that the Arosa-curve, which refers to a clear autumn day, is distinguished by a relatively high ultra-violet content. The upward tendency of the curve towards the ultra-violet end may probably be ascribed to a less pronounced influence of the ozone absorption than in the case of the spectral distributions observed in Oslo and Ny-Ålesund. One would perhaps have expected the spectral curve for a high altitude station like Arosa to be still higher in the ultra-violet and blue region, i. e. closer to that of a Rayleigh atmosphere. Evidently, a smaller reflectivity of the ground than 0.25 for the shorter wave-lengths may partly explain the discrepancy between the two curves. On the other hand, estimating the theoretical distribution corresponding to the height of Arosa by means of the optical thicknesses computed by DEIRMENDJIAN (1955) for different heights in a further specified molecular atmosphere, we find that the normalized Rayleigh distribution shows somewhat higher values in the ultra-violet than the distribution representing the conditions at sea level. Thus, the ratio of the irradiance at 370 $m\mu$ to that at 520 $m\mu$ is increased by about 6%. Therefore, the conclusion reached by GÖTZ and SCHÖNMANN, that on clear days the spectral distribution observed in Arosa corresponds quite well to that of a Rayleigh atmosphere, seems not to be verified when newer and more reliable data for the spectral composition of solar radiation outside the earth's atmosphere are introduced, and a more advanced method of computing the spectral distribution of scattered radiation in a Rayleigh atmosphere is applied.

During the summer of 1929 GÖTZ (1931) carried out a series of radiation measurements in Ny-Ålesund. It is, however, difficult to compare his data with those presented here, as he was primarily concerned with different types of measurements of direct solar radiation. His results seem, generally speaking, to be in accordance with those of the present discussion. This applies, among other things, to the fact that the turbidity of the air may be very low: "Trotz Meeresniveau ist die Spitzbergensonne von 20–30° Sonnenhöhe noch etliche Prozent heller als die gleich hoch stehende Davoser Sonne, und nur etwa 15% weniger hell, als ich die Sonne am 18. September 1928 auf Jungfraujoch fand." (Op. cit. p. 128.)

In Ny-Ålesund we also measured the spectral composition of radiation received from the whole celestial hemisphere, using an integrating sphere covered by bariumsulphate. This investigation is not yet completed, and we shall confine ourselves here to comparing spectral distributions measured at practically the same time of scattered radiation from the zenith sky, and from the whole sky, respectively. The curves representing a clear sky are indicated by the numbers 1 and 2 in Fig. 5, and those representing an overcast sky (3 and 4 Aug. only) by the numbers 3 and 4. In relation to the irradiances for the longer wave-lengths, the irradiances for a clear sky in the ultra-violet and violet part of the spectrum is much higher for the zenith sky than for the whole sky. In the case of an overcast sky, on the other hand, the zenith spectrum is relatively lower in the blue part than that representing the whole celestial hemisphere.

A clear picture of the relationship between two spectral distributions may be obtained by taking the quotient of corresponding spectral irradiances. The variation of this quotient with wave-length for different combinations of spectral distributions is shown in Fig. 6. Obviously, if the inter-relationships between the scales of the spectral irradiances were changed, e. g. so as to correspond to absolute irradiance values, the numerical values of the quotients would be changed too, but the tendency and general form of their variations would be unaltered.

Curves 1 and 2 in Fig. 6 illustrate how the spectral irradiance for a clear sky increases relatively to that of an overcast sky as the wave-length decreases. Evidently, this feature is mainly due to the fact that the scattering effect of the cloud elements is practically independent of wave-length. The minimum at 310 mμ (curve 1) may probably be ascribed to "non-real" fluctuations caused by the previously mentioned inaccuracy of the measurements near the ends of the spectral range, where the sensitivity of the photomultiplier tube is small. Whether this circumstance may fully explain the increase of the values towards the infrared end of the spectrum is perhaps more questionable. This increase is more or less clearly in evidence in all cases where the curve for Ny-Ålesund, clear sky, is compared to other spectral curves. For the same set of comparisons, there is a small maximum at 610–620 mμ, the origin of which is somewhat obscure.

A comparison of corresponding spectral curves for Ny-Ålesund and Oslo is represented by curves 3 and 4. The more or less regular decrease of the quotients

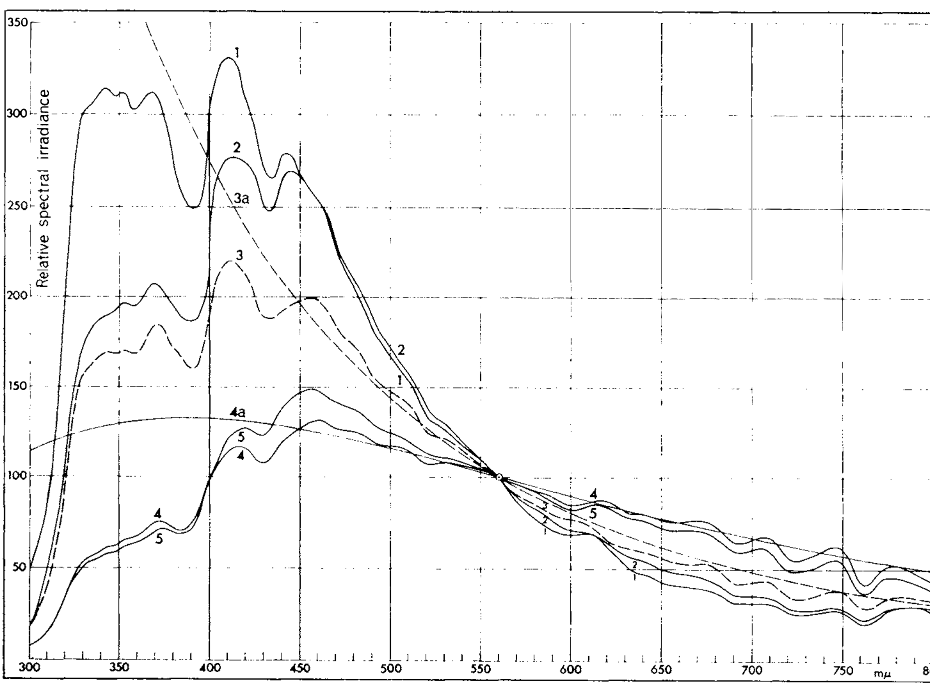

Fig. 5. *Spectral distributions of zenith sky radiation, of radiation received from the whole celestial hemisphere, and of a black-body radiator (normalized at 560 mμ). Curve 1: Ny-Ålesund (zenith), clear. Curve 2: Ny-Ålesund (whole sky), clear. Curve 3: Oslo (zenith), clear. Curve 3a: Black-body at 18450°K. Curve 4: Ny-Ålesund (zenith), overcast. Curve 4a: Black-body at 7490°K. Curve 5: Ny-Ålesund (whole sky), overcast.*

towards longer wave-lengths is no doubt mainly caused by a greater abundance of non-Rayleigh scatterers in the atmosphere over the latter station. In all probability considerable differences between the two stations concerning the magnitude and spectral variation of the reflectivity of the ground are present as well, but lack of adequate data makes it difficult to judge the influence of this factor.

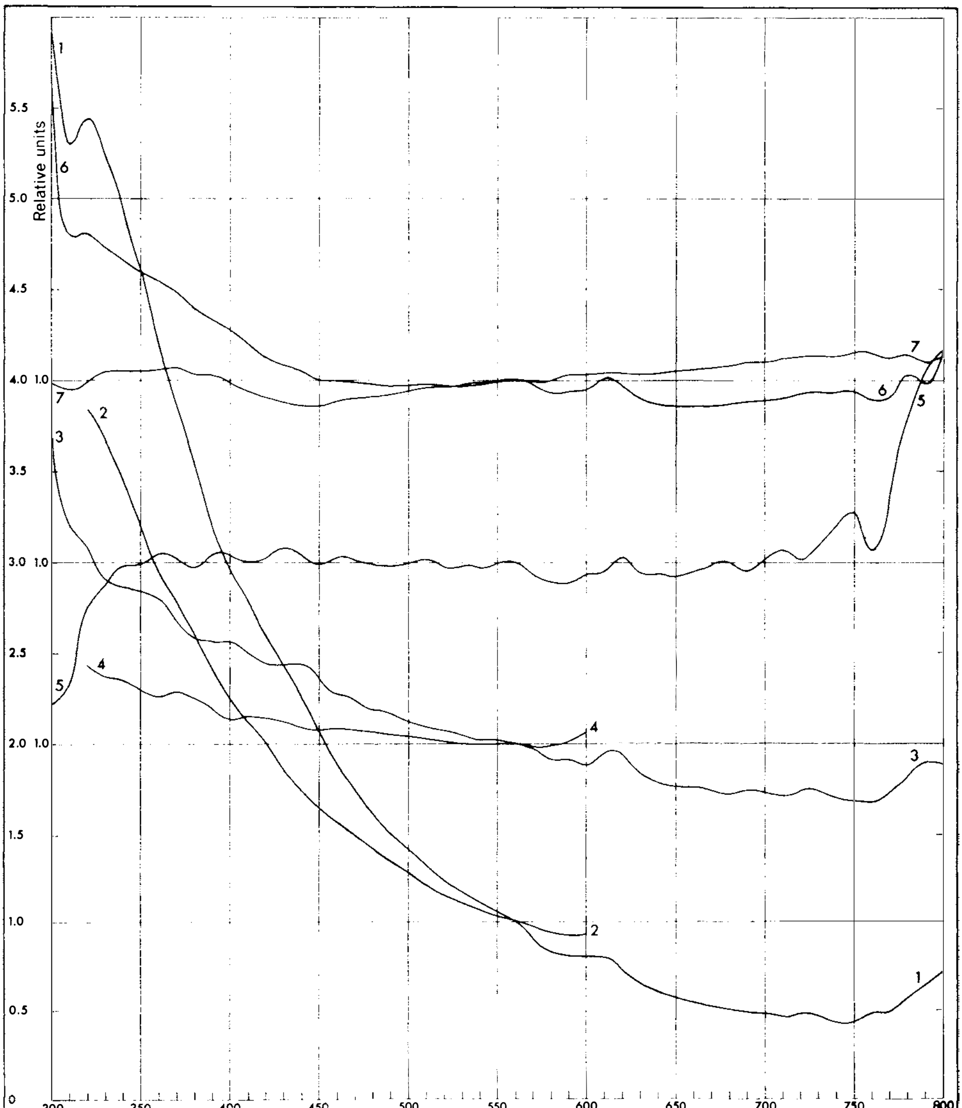

Fig. 6. *Ratio of relative spectral irradiances for various sets of spectral distributions. Curve 1: Ratio of Ny-Ålesund, clear, to Ny-Ålesund, overcast. Curve 2: Ratio of Oslo, clear, to Oslo, overcast. Curve 3: Ratio of Ny-Ålesund, clear, to Oslo, clear. Curve 4: Ratio of Ny-Ålesund, overcast, to Oslo, overcast. Curve 5: Ratio of Ny-Ålesund, clear, to Theoretical distribution. Curve 6: Ratio of Ny-Ålesund (zenith), clear, to Ny-Ålesund (whole sky), clear. Curve 7: Ny-Ålesund (zenith), overcast, to Ny-Ålesund (whole sky), overcast.*

Except near the limits of the spectral range considered, the relation between Ny-Ålesund, clear sky, and a Rayleigh atmosphere is remarkably constant, as demonstrated by curve 5. Some of the variations of the curve may be explained as a result of absorption in the earth's atmosphere, which, as previously mentioned, is not taken into account when the theoretical distribution is computed. This applies, among other things, to the strong decrease of the quotient towards the ultra-violet end of the spectrum (Hartley-Huggins-bands of O_3), and to the wave-formed structure of the curve in the red and infra-red part of the spectrum (H_2O and O_2). There are signs also of an influence of the Chappuis-bands (maximum absorption about 600 mμ).

Finally, curve 6 and 7 present a comparison of the zenith sky radiation with that received from the whole celestial hemisphere. As pointed out previously, the zenith radiation for a clear sky is relatively richer in the ultra-violet and blue part of the spectrum and correspondingly poorer in the red part. This is in accordance with the fact that for low and moderate solar altitudes the zenith sky is "more blue" than the lower part of the celestial hemisphere. When the sky is overcast, the zenith sky, although slightly richer in the ultra-violet region, is less blue than the radiation received from the whole sky, which means that the spectral composition of the zenith radiation is slightly closer to that of the direct solar radiation. It clearly appears that the radiation observed from the overcast sky cannot be considered as isotropic.

Some derived characteristics

The relation between spectral and total irradiances

In the preceding section we mentioned the question as to whether there exists a wave-length at which the irradiance is approximately proportional to the total irradiance. The question may be of a certain interest, e. g. when comparing spectral distributions that are known for a limited wave-length range only.

Previous measurements at a station in western Norway of the spectral distribution of radiation from the zenith sky, by means of interference filters, showed that for a wave-length of approximately 460 mμ the irradiance was very nearly proportional to the total irradiance in the spectral range considered, viz. 340–590 mμ (HISDAL 1959). Dividing the spectral irradiances given in Fig. 3 by the respective total irradiances in the interval 340–590 mμ, the seven curves all cross each other in the vicinity of 450 mμ. At this wave-length the difference between the highest and lowest value of the new curve ordinates does not amount to more than 3.7% of the highest ordinate. Thus, we may say that the result obtained previously is confirmed.

The choice of the wave-length interval 340–590 mμ is purely arbitrary, as it was dictated by the selection of interference filters and the photocell at our disposal. However, the result pointed out above suggests that it may be possible to specify a wavelength where the irradiance is, to a fair approximation, proportional to the total irradiance over the whole solar spectrum. For the three spectral distributions covering the range 300–800 mμ (see Fig. 3) we have tried to estimate the energy for wave-lengths exceeding 800 mμ by assuming that the ratio of this energy to that contained in the range 600–800 mμ is a linear function of the ratio of the energy in the range 700–800 mμ to that in the range 600–700 mμ. The constants of this function were determined by means of the spectral distributions of sky radiation and global radiation tabulated by DOGNIAUX (1966) for a solar altitude of 30°. For the three cases referred to above the spectral irradiances were divided by the respective total irradiances estimated in this way. The difference between the ordinates of the spectral curves obtained are least in the region 510–520 mμ. However, the difference between the highest and lowest ordinate is considerably greater than in the former case, about 10% at 520 mμ. At 560 mμ, the usual wave-length used when normalizing the spectral curves, the difference between the highest and lowest ordinate is as large as 25%. This is the reason for our previous statement that in Figs 3–5 the ordinates of spectral curves that have a high course in the ultra-violet and blue part of the spectrum refer to a larger total irradiance than do the ordinates of curves that are low in the same spectral region. The results indicated above give no final answer to the question as to whether the irradiance at a certain wave-length may be taken as a sufficiently reliable measure of the total irradiance. This question has to be investigated further on the basis of a larger and more complete material than here available.

Chromaticity co-ordinates

A quantitative expression of the colour of the zenith sky may be obtained by computing the chromaticity co-ordinates of the CIE (Commission Internationale de l'Éclairage) system. They are given in Table 2 for all spectral distributions covering the whole visible region. The table also contains the corresponding values of the so-called dominant wavelength, which is the wave-length of monochromatic light that, when mixed with an appropriate amount of white light,

Table 2

Station	Sky conditions	Chromaticity co-ordinates		Dominant wave-length (mμ)	Purity (%)	Correlated colour temp. (°K)
		x	y			
Ny-Ålesund	Clear	.2282	.2267	477	46	
	Overcast	.2994	.3143	484	13	7490
Oslo	Clear	.2536	.2648	479	33	18450
Cleveland	Clear	.263	.279	481	28	13700
Theoretical	Rayleigh atm.	.2323	.2338	477	44	

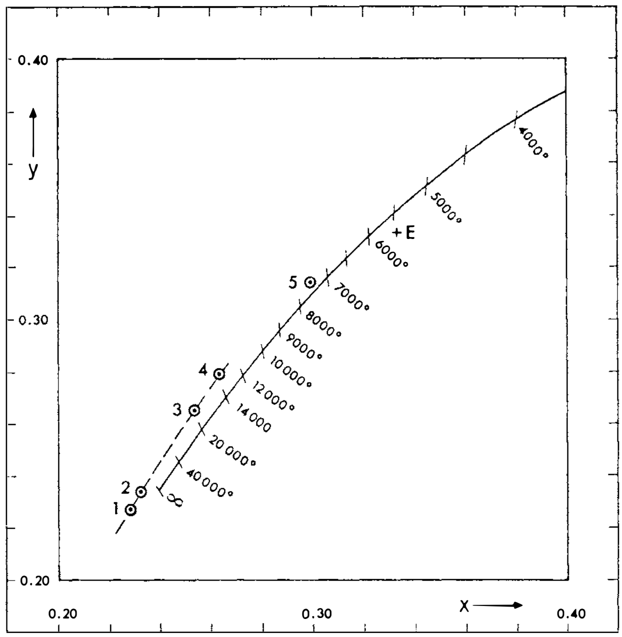

Fig. 7. *Chromaticities of the zenith sky compared with the black-body locus (solid curve) in the 1931 CIE chromaticity diagram. Point 1: Ny-Ålesund, clear. Point 2: Rayleigh atmosphere. Point 3: Oslo, clear. Point 4: Cleveland, clear. Point 5: Ny-Ålesund, overcast. Cross E: white point corresponding to constant spectral irradiances.*

would match the colour in question, and the purity (strictly "excitation purity") of the colour (cf. WRIGHT 1964).

As was to be expected, the colour of a Rayleigh atmosphere and that of Ny-Ålesund, clear sky, are characterized by the shortest dominant wave-lengths and the greatest purity. Ny-Ålesund, overcast sky, has the dominant wave-length nearest to the green part of the spectrum (corresponding to a greenish blue colour), but the purity is so low that the colour is scarcely perceptible, in agreement with the fact that in ordinary conditions an overcast sky is found to be grey.

Fig. 7 shows colours of the zenith sky represented in the CIE chromaticity diagram. The curved line is the locus of the chromaticities of a black-body radiator at different temperatures. In accordance with the results of previous investigations of the colour of daylight (see e. g. JUDD et al. 1964) the points representing the observed spectral distributions lie slightly on the green side of the black-body locus.

Correlated colour temperature

Since the chromaticities are so close to those of a black-body radiator, it may be of interest to identify the spectral composition of the zenith sky radiation in terms of the so-called correlated colour temperature, which is the temperature of a black-body giving the nearest chromaticity match to the radiation source in question. As is evident from Fig. 7, the points representing Ny-Ålesund, clear sky, and a Rayleigh atmosphere are situated outside the range of the black-body chromaticities. In other words, the colours in these two cases cannot be matched with those of a black-body, however high the temperature.

Following KELLY (1963), the correlated colour remperatures for Oslo, clear sky, and Ny-Ålesund, overcast, were estimated by means of the isotemperature lines of a large-scale copy of MacAdam's uniform-chromaticity-scale diagram. The resulting temperatures are given in the last column of Table 2, together with that of Cleveland.

In Fig. 5 are entered the spectral curves of a black-body at the correlated colour temperatures 7490°K and 18450°K together with the corresponding curves representing the observed distributions. It appears that for wave-lengths above 450 mμ the black-body curves represent quite well the general course of the observed spectral distributions. Below 450 mμ the observed values become rapidly much smaller than the corresponding black-body values. Since the spectrum below, say, 420 mμ is of small significance for the computation of the chromaticities, the fact that the colour of daylight are slightly on the green side of the black-body locus in all probability may chiefly be ascribed to the previously mentioned concentration of several strong solar Fraunhofer lines in the region about 430 mμ. This feature would have appeared still clearer in Fig. 5 had it not been for the fact that the pronounced dip in this region has had already a reducing effect on the estimated colour temperatures, resulting, among other things, in the relatively high course of the observed curves as compared with the black-body curves in the interval 450–500 mμ.

Summary and final remarks

It was found that all conspicuous dips in the observed spectral distributions might be attributed either to the combined effect of strong solar Fraunhofer lines, concentrated in comparatively narrow regions, or to absorption by atmospheric gases.

For Ny-Ålesund, clear sky, the observed spectral composition agreed surprisingly well with that computed for a Rayleigh atmosphere. Some of the most important deviations of the observed spectrum from the theoretical one was obviously due to selective absorption by the earth's atmosphere. This indicates an extreme purity of the air during the observation period, which is in accordance with the fact that for the day in question the Svalbard area is under the influence of an arctic air mass.

For a clear sky the ratio of radiant energy contained in the ultra-violet and blue part of the spectrum to that in the red part decreases from Ny-Ålesund to Slettebu, followed by Arosa, Oslo and Cleveland. This is supposed to be mainly due to a change of the amount and character of non-Rayleigh scatterers in the atmosphere. For an overcast sky this ratio is naturally much smaller, but it shows a similar regional change as that found for a clear sky.

The measurements from Ny-Ålesund reveal that as compared with the spectral curve representing the diffuse radiation from the whole celestial hemisphere, that representing zenith, clear sky, is relatively higher in the ultra-violet and blue part of the spectrum, and lower in the red part. For an overcast sky the zenith radiation is less blue and more red in comparison with the total sky radiation.

In agreement with the results of previous investigations of the colour of daylight, the CIE chromaticities of the zenith sky are found to lie slightly on the green side of the black-body locus, when plotted in a chromaticity diagram. The main reason for this feature seems to be the existence of several strong solar Fraunhofer lines in the region about 430 mμ. The chromaticities representing Ny-Ålesund, clear sky, and a Rayleigh atmosphere, which are distinguished by having the lowest dominant wave-lengths and the highest purity, fall outside the range of the black-body chromaticities.

Although there are evidences that the differences found between the spectral distributions of the individual stations reflect typical dissimilarities between the stations regarding the atmospheric scattering conditions, "sampling fluctuations" may play an important part as well, due to the modest size of the observation material. It is desirable, therefore, to test the results of the present investigation by collecting considerably more data.

The observations discussed refer to the zenith sky, and to a nearly constant solar altitude. Furthermore, all our measurements are carried out close to sea level. A natural expansion of the observation programme would consist in removing one or more of these restrictions. Special interest attaches to the spectral composition, for different meteorological situations, of the integrated radiation from the whole celestial hemisphere, and to the character and seasonal variation of the spectral reflectivity of the ground, which, among other things, are of importance for a proper understanding of the radiation balance. Also, a closer study of the connection between the spectral distribution of the scattered radiation and the turbidity of the air is of great meteorological interest.

I hope to get the opportunity later on, when a greater amount of data has been gathered, to discuss some of the problems mentioned above.

Acknowledgement

I am indebted to Mr. B. Hisdal (Sentralinstitutt for industriell forskning) for valuable discussions and suggestions. My thanks are also due to Mr. T. Vinje (Norsk Polarinstitutt) for assisting me in making the measurements in Svalbard as often as his own investigations permitted. Basic data for computing the spectral distribution of the zenith sky radiation of a Rayleigh atmosphere have kindly been provided by Professor Z. Sekera (University of California).

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On the fauna and age of the Cancrinella Limestone (Permian) at Kopernikusfjellet, Vestspitsbergen

BY

KRZYSZTOF BIRKENMAJER[1] and ALAN LOGAN[2]

Abstract

A small collection of brachiopods from the Cancrinella Limestone of Kopernikusfjellet, Vestspitsbergen, has been studied in an attempt to establish the age of this member on sound faunal evidence. In addition to one species previously recorded by earlier authors, twelve species have been identified and described, including one new species, *Pugnoides svalbardensis*. The faunal evidence, although not overwhelming, suggests a correlation of the Cancrinella Limestone with the Cora Limestone of Bjørnøya and the Upper Wordiekammen Limestone and Upper Cyathophyllum Limestone of Central Vestspitsbergen, rather than with the Spirifer Limestone of the Brachiopod Cherts.

In the Hornsund–Kopernikusfjellet area, there is little additional palaeontological evidence to support a correlation of the Cancrinella Limestone with the V Coral Limestone Horizon of the Treskelodden Beds. Two alternative hypotheses for the age of the limestone in this area are suggested. Firstly, the Cancrinella Limestone may be the equivalent of the V Coral Limestone Horizon, but the palaeoenvironmental conditions favourable to coral growth, which prevailed during the formation of this limestone horizon, may have given rise to a more prolific and varied brachiopod fauna. A second and more likely explanation is that the Cancrinella Limestone is younger than the V Coral Limestone Horizon and represents a facies of all or part of the Cyathophyllum Limestone of Svartperla.

Introduction

In 1958 K. BIRKENMAJER (1959, 1960) collected some brachiopods from the limestone cropping out on the west slope of Kopernikusfjellet, Vestspitsbergen, where the presence of the "Cyathophyllum Limestone" was recorded in 1934 by RÓŻYCKI (1959). These brachiopods, as determined by CZARNIECKI (in BIRKENMAJER and CZARNIECKI 1960), appeared to be a monospecific assemblage of "*Productus* (*Cancrinella*) *koninckianus* KEYSERLING",[3] a species known to occur in both the Upper Carboniferous and Lower Permian. The limestone, named the Cancrinella Limestone, was initially correlated with the Middle Wordiekammen

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[3] *P.* (*Cancrinella*) *koninckianus* is DE VERNEUIL's species, and it is used with this author's name in the palaeontological and stratigraphical parts of the present paper.

Limestones (BIRKENMAJER and CZARNIECKI 1960) but later, after the discovery of the same species in the V Coral Limestone Horizon of the Upper Treskelodden Beds (Sakmarian) of Hornsund, with the Upper Wordiekammen Limestones of central Vestspitsbergen (BIRKENMAJER 1964). This latter correlation has been accepted by CZARNIECKI (1966), who nevertheless considers the fossiliferous Upper Treskelodden Beds and the Upper Wordiekammen Limestones to represent the Upper Carboniferous (Schwagerina Zone, Uralian). GOBBETT (1964), on the other hand, has included the Cancrinella Limestone from Kopernikusfjellet in the Sakmarian.

The Upper Wordiekammen Limestones were correlated by FORBES *et al.* (1958) and HARLAND (1961) with the Sakmarian. CUTBILL and CHALLINOR (1965), in their stratigraphical revision of the Carboniferous and Permian rocks of Svalbard, included them within the Tyrrellfjellet Member of the Nordenskiöldbreen Formation (Asselian-Sakmarian), while the Treskelodden Beds (renamed the Treskelodden Formation) were equated with the Gipshuken Formation (Artinskian) by these authors.

The problem now appears to be whether the Cancrinella Limestone of Kopernikusfjellet really belongs to the Treskelodden Beds (Formation), as suggested by BIRKENMAJER (1964), or to the Kapp Starostin Formation (*sensu* CUTBILL and CHALLINOR *op. cit.* = Brachiopod Cherts of the previous authors), and particularly to its lowest member (Vøringen Member of CUTBILL and CHALLINOR = Limestone A or Spirifer Limestone of the previous authors).

In 1966 K. BIRKENMAJER had an opportunity to collect more fossils from the limestone in question during field investigations in Vestspitsbergen for Norsk Polarinstitutt. He is responsible for the geological part of this paper, while A. LOGAN, who examined the fauna, is responsible for fossil identifications and stratigraphic conclusions.

The field assistance of Messrs. G. O. NIELSEN and H. CHR. OLSEN is gratefully acknowledged by K. BIRKENMAJER, while A. LOGAN wishes to thank D. W. HARVEY of the Department of Geology, University of Calgary, Alberta, Canada, for the preparation of the photographs.

Geological situation of the Cancrinella Limestone

Kopernikusfjellet (77°15′N – 15°40′E) is a characteristic peak in the main mountain range (Chief Range of RÓŻYCKI 1959) that stretches NW–SE from Van Keulenfjorden to Hornsund (Fig. 1). It has three summits at 1055 m, 1035 m and about 1045 m, capped by ice and perennial snow, and projecting about 350 m above Amundsenisen, the highest ice plateau of Wedel Jarlsberg Land. The geological structure of the mountain is best seen on the rocky ridges (ribs) that radiate from the highest peaks.

The mountain lies within the belt of strong Alpine folding recognized here by RÓŻYCKI (1959). In the lower part of the south slope, above Nornepasset, strongly folded Middle-Upper Triassic shales and silty limestones form an autochthonous

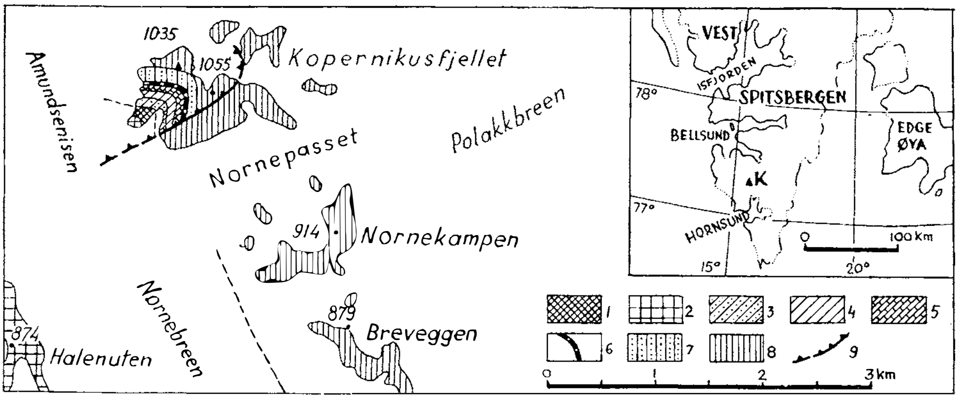

Fig. 1. *Geological map of the vicinity of Kopernikusfjellet* (*after* BIRKENMAJER *1964*). *Key map shows the position of Kopernikusfjellet* (*K*) *in Vestspitsbergen. Hecla Hoek Succession*: *1 – Eo-Cambrian and Lower Cambrian*; *2 – Lower Ordovician. Late Palaeozoic*: *3 – Hyrnefjellet Beds*; *4 – Treskelodden Beds*; *5 – Cancrinella Limestone*; *6 – Brachiopod Cherty Limestone. Mesozoic*: *7 – Lower Trias*; *8 – Middle-Upper Trias. 9 – Overthrust.*

unit, separated from the upper, allochthonous, unit by a thrust plane distinctly visible in the SW rib. The thrust sheet of the upper unit is formed by an overturned sequence of rocks represented by the Hecla Hoek Succession (Eo-Cambrian to Lower Ordovician), and younger beds of late Palaeozoic and Triassic age (Fig. 1).

The late Palaeozoic beds are best exposed on the western slopes of the mountain. Here they are separated from strongly folded Hecla Hoek rocks by an angular unconformity. The Palaeozoic sediments begin with a basal sedimentary breccia which is overlain by conglomerates with quartzite intercalations – the Hyrnefjellet Beds (30 m). The Treskelodden Beds (30 m), which consist of quartzites and fine conglomerates with dolomitic intercalations, the Cancrinella Limestone (20 m), and the Brachiopod Cherty Limestone (6 m) complete the Palaeozoic sequence in this area. The Mesozoic is represented by shales with a sandstone-quartzite horizon of Lower Triassic (Eo-Triassic) age, and by shales with silty limestone horizons of Middle-Upper Triassic age, which form the summits and the eastern slope of Kopernikusfjellet.

Along the SW rib of Kopernikusfjellet, branching from peak 1055 m, the Cancrinella Limestone is represented by light grey, light brownish limestones in layers 0.2–0.5 m thick, which have yielded numerous *Productus* (*Cancrinella*) *koninckianus* (DE VERNEUIL) (determined by CZARNIECKI, in BIRKENMAJER and CZARNIECKI 1960).

Along the NW rib of the mountain, branching from peak 1035 m, the Cancrinella Limestone is rather poorly exposed, being partly covered by scree. The limestone is grey, and slightly bituminous, often with some admixture of quartz grains and with scattered pebbles of quartz and black Ordovician cherts, 3–10 mm in diameter. In some parts the limestone is slightly silicified; the same is often

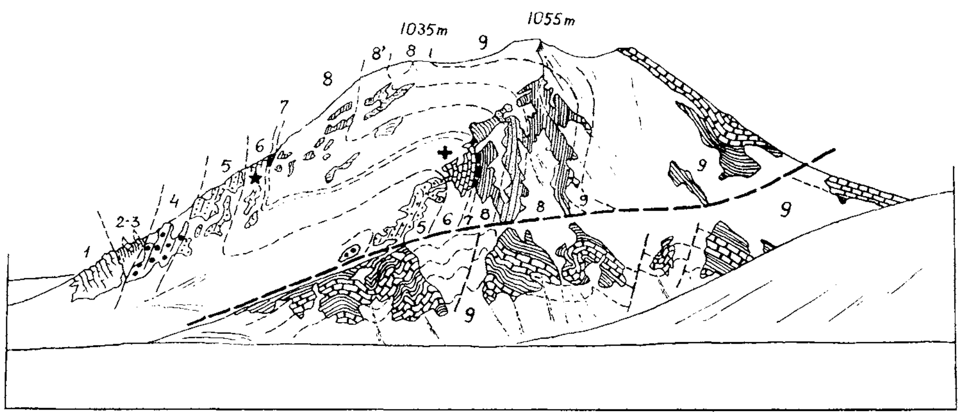

Fig. 2. *Geological panorama of Kopernikusfjellet as seen from the south (drawn by* BIRKENMAJER *on July 18, 1958). Hecla Hoek Succession: 1 – Dusken Limestone, Lower Ordovician; 2,3 – Blåstertoppen Dolomite, Lower Cambrian and Gåshamna Series, Eo-Cambrian (phyllites and shales with quartzite intercalations). Late Palaeozoic: 4 – Hyrnefjellet Beds (sedimentary breccias and conglomerates with quartzite intercalations); 5 – Treskelodden Beds (quartzites and fine conglomerates with dolomite intercalations); 6 – Cancrinella Limestone; 7 – Brachiopod Cherty Limestone. Mesozoic: 8 – Lower Trias (mostly shales. 8' – Sandstone-quartzite horizon); 9 – Middle-Upper Trias (shales with silty limestone horizons). Faunal localities in the Cancrinella Limestone: + – Fauna collected in 1958; * – Fauna collected in 1966. Heavy dashes denote major overthrust plane and faults.*

the case with the brachiopod shells. The fossils (collected mostly from blocks) occur, in general, as lenses and nests. Some of the smaller brachiopods occur mostly as monospecific associations, especially at the base of some limestone layers. This may have been caused by redeposition of the shells by wave action or bottom currents. A shallow sedimentary environment is also suggested by the detrital character of some parts of the limestone, which, in addition, contains bigger shells (mainly Productoid brachiopods) mixed with rare crinoid segments, the latter up to 4–5 mm in diameter. Sometimes sand grains are arranged in streaks, marking faint stratification in the limestone; in other cases they form lenses and chert-like associations.

Owing to insufficient exposures, it was not possible to examine in detail the bottom and top stratigraphic contacts of the Cancrinella Limestone. Nevertheless, it would seem that there is a general conformity between this member and the underlying Treskelodden Beds, and that there is a hiatus and slight unconformity at the base of the Brachiopod Cherty Limestone.

Tha fauna and age of the Cancrinella Limestone

The fossils obtained from the Cancrinella Limestone consist mainly of brachiopods, a group which is predominant in Arctic Upper Palaeozoic faunas. The limestone derives its name from the common occurrence of the linoproductid brachiopod *Cancrinella koninckiana* (DE VERNEUIL), which was first recorded by BIRKENMAJER and CZARNIECKI (1960) from this stratum. Later, BIRKENMAJER (1964) reported that this species had been discovered by CZARNIECKI, together with *Juresania juresanensis* (CHERNYSHEV), in the V Coral Limestone Horizon (Treskelodden Beds) at Treskelen, Hornsund, and he suggested a tentative correlation of the Cancrinella Limestone of Kopernikusfjellet with the V Coral Limestone of the Treskelodden Beds of Hornsund. GOBBETT (1964) has since advocated that the specific epithet *koninckiana* not be used for species of *Cancrinella* from Svalbard. Following this author, the specimens from the Cancrinella Limestone previously referred to *C. koninckiana* by BIRKENMAJER and CZARNIECKI should probably now be assigned to *C. singletoni* GOBBETT, a species known to occur in the IV and V Coral Limestone Horizons of the Treskelodden Beds of Hornsund (CZARNIECKI 1966), in the Upper Wordiekammen Limestone, Cyathophyllum Limestone and Upper Gypsiferous Series of Spitsbergen and in the Cora Limestone of Bjørnøya (GOBBETT *op. cit.*). The species has not so far been recorded from the Brachiopod Cherts of Svalbard, however.

In view of the limited nature of the faunal evidence, the age of the Cancrinella Limestone has never been satisfactorily demonstrated. This report records the discovery of the following additional species from the Cancrinella Limestone. See page 33.

Thirteen species of brachiopods have now been recorded from the Cancrinella Limestone, of which three are insufficiently known to merit specific names. Six of the species also occur in the Cora Limestone of Bjørnøya, while three are common to the Upper Cyathophyllum Limestone and the Spirifer Limestone (= Vøringen Member, Kapp Starostin Formation of CUTBILL and CHALLINOR 1965), respectively, and two also occur in the Upper Wordiekammen Limestone. BIRKENMAJER (1964) and CZARNIECKI (1966) have correlated the Treskelodden Beds of Hornsund with the Wordiekammen Limestones of Central Vestspitsbergen, mainly on the basis of similarity in coral and brachiopod species. Of the 40 brachiopod species listed by CZARNIECKI (*op. cit.*) from this formation, 24 (of which 7 are stated to be doubtful identifications) also occur in the Wordiekammen Limestones, while only 5 are present in the Brachiopod Cherts. A comparison between CZARNIECKI's species from the upper part of the Treskelodden Beds of Hornsund and those from the Cancrinella Limestone of Kopernikusfjellet shows only one species common to both members. However, if one accepts CZARNIECKI's conclusion that the Upper Wordiekammen Limestone and the upper part of the Cyathophyllum Limestone are equivalent in age to the IV and V Coral Limestone Horizons of the Treskelodden Beds, then 4 species are common to this group and the Cancrinella Limestone. The Treskelodden Beds of Hornsund have been equated with the Cora Limestone of Bjørnøya by GOBBETT (1964) and CUTBILL and CHALLINOR (1965), although the faunal evidence for this correlation is not strong. Nevertheless, it seems clear that the Cancrinella Limestone has a greater faunal affinity with these horizons than with the Spirifer Limestone of the Brachiopod Cherts. However, whether the Cancrinella Limestone can be directly

Faunal list

Species recorded from Kopernikusfjellet	*Previously recorded occurrences in Svalbard* (Mainly after GOBBETT 1964) (Stratigraphic names in parentheses after CUTBILL and CHALLINOR 1965)
Rhipidomella sp.	—
Probolionia cf. *involuta* (CHERN.)	Cora Limestone, Ymerdalen, Bjørnøya; Spirifer Limestone (Vøringen Member, Kapp Starostin Formation), Miseryfjellet, Bjørnøya.
Waagenoconcha irginae (STUCKENBERG)	Cora Limestone, Ymerdalen, Bjørnøya; Spirifer Limestone (Vøringen Member, Kapp Starostin Formation), Miseryfjellet, Bjørnøya; Spirifer Limestone and Brachiopod Cherts (Kapp Starostin Formation), Spitsbergen, at several localities.
Costiferina arctica (WHITFIELD)	Cora Limestone, Ymerdalen, Bjørnøya; Spirifer Limestone (Vøringen Member, Kapp Starostin Formation) at three localities on Bjørnøya; same horizon on Spitsbergen, at several localities.
Cancrinella crassa GOBBETT	Upper Cyathophyllum Limestone (Tyrrell-fjellet Member, Nordenskiöldbreen Formation), Komarovfjellet, Oslobreen, Ny Friesland, Spitsbergen.
Pugnoides svalbardensis sp. nov.	—
Rhynchopora sp.	Upper Gypsiferous Series (Gipshuken Formation), Bünsow Land, Spitsbergen.
Neophricadothyris asiatica (CHAO)	Cora Limestone, Ymerdalen, Bjørnøya; Upper Wordiekammen Limestone (Tyrrell-fjellet Member, Nordenskiöldbreen Formation), Sassenfjorden, Spitsbergen; Brachiopod Cherts (Kapp Starostin Fm.), Spitsbergen.
Neospirifer cf. *tegulatus* (TRAUTSCHOLD)	Upper Cyathophyllum Limestone (Tyrrell-fjellet Member, Nordenskiöldbreen Formation), Skedvifjella, Von Postbreen, Spitsbergen.
Paeckelmannella ? sp.	—
Composita cf. *naruensis* REED	—
Dielasma ? cf. *itaitubense* (DERBY)	Cora Limestone, Ymerdalen, Bjørnøya.

correlated with the V Coral Limestone of the Treskelodden Beds, as suggested by BIRKENMAJER (1964), is questionable, for of the 23 species of brachiopods listed by CZARNIECKI (1966) from this horizon, only one has been found in the Cancrinella Limestone. Two hypotheses may be advanced to account for this apparent anomaly. Firstly, it may be assumed that the Cancrinella Limestone is the equivalent of the V Coral Limestone Horizon but that the warm, shallow-water, near-shore palaeoenvironment (see CZARNIECKI *op. cit.*) which fostered the growth of corals in this limestone also resulted in a more prolific and varied brachiopod fauna.

Alternatively, the Cancrinella Limestone might be regarded as being younger in age than the V Coral Limestone Horizon, but older than the lowest part of the Brachiopod Cherts. At Kopernikusfjellet, where unfossiliferous dolomites replace the coral limestone intercalations, the Treskelodden Beds are attenuated (30 m) and may represent the whole thickness of the Treskelodden Beds of north-east Hornsund (150–170 m). The Cancrinella Limestone may thus be a facies of all or part of the thick (200 m) Cyathophyllum Limestone which is developed at Svartperla and is thought to be younger than the Treskelodden Beds of Hornsund (BIRKENMAJER and CZARNIECKI 1960). Although the presence of isolated corals and productoid brachiopods was reported from the Cyathophyllum Limestone of Svartperla by these authors, no specific determinations have been released. Thus this correlation cannot yet be verified by palaeontological evidence. Similarly, the Upper Gypsiferous Series of Central Vestspitsbergen, which is generally regarded as being equivalent in age to the uppermost part of the Cyathophyllum Limestone, is relatively poor in brachiopods. Only four species are listed from this member by GOBBETT (1964), of which two occur in the Cancrinella Limestone.

According to GOBBETT (*op. cit.*), the brachiopod fauna of the Brachiopod Cherts has a definite Upper Permian character. Fossils from the thinly-developed (6 m) Brachiopod Cherts of Hornsund were listed by BIRKENMAJER and CZARNIECKI (1960) and show Zechstein affinities, suggesting an Upper Permian age. These authors believe the Brachiopod Cherts from Hornsund to be the youngest element of these beds in Svalbard and this opinion is shared by GOBBETT (*op. cit.*). From the faunal evidence, it seems very unlikely that the Cancrinella Limestone represents the lower part of the Brachiopod Cherts at Kopernikusfjellet, and the Spirifer Limestone (and probably also the Middle Brachiopod Cherts) may be assumed to be absent from this locality (BIRKENMAJER 1964).

In conclusion, the Cancrinella Limestone fauna, although restricted, appears to belong to GOBBETT's (1964) "second" brachiopod fauna, which occurs in the upper part of the Cyathophyllum Limestone and characterizes the Upper Wordiekammen Limestone of Bünsow Land and the Cora Limestone of Bjørnøya. In the Hornsund area, it seems probable that the Cancrinella Limestone is contemporaneous with, or slightly younger than, the Upper Treskelodden Beds and does not represent the Spirifer Limestone of the Brachiopod Cherts. The presence of a slight unconformity at the base of the Brachiopod Cherts at Kopernikusfjellet also supports the idea that the Cancrinella Limestone belongs with the Upper Treskelodden Beds rather than with the Brachiopod Cherts.

It is possible that the Cancrinella Limestone brachiopod assemblage is transitional between that of the V Coral Limestone Horizon of the Treskelodden Beds and the later Brachiopod Chert fauna, but discussion of this possibility must await the publication of systematic studies now in progress by CZARNIECKI.

Systematic descriptions[1]

Phylum Brachiopoda DUMÉRIL, 1806
Class Articulata HUXLEY, 1869
Suborder Orthidina SCHUCHERT and COOPER, 1932
Superfamily Enteletacea WAAGEN, 1884
Family Rhipidomellidae SCHUCHERT, 1913
Genus *Rhipidomella* OEHLERT, 1890

Rhipidomella sp.
Pl. 1, Figs. 1a–c, 2a–c.

Description. Shell small, outline variable, from sub-quadrate to triangular, greatest width near mid-point of valves. Biconvex or dorsibiconvex, flanks steep, pedicle valve sometimes slightly resupinate. Hinge line short, ventral interarea moderately low, triangular, apsacline; dorsal interarea much reduced, orthocline, delthyrium and notothyrium not observed. Ornament of fine radial costellae, about 4 per mm at anterior margin and increasing by intercalation; costellae crossed by irregular growth lines.

Pedicle valve muscle field shows traces of large elongate diductor muscle scars separated in front of adductor scars by ridge which continues just beyond muscle field. Brachial valve has strong median septum separating obscure traces of muscle scars.

Remarks. The genus *Rhipidomella* is long-ranging, existing from the Lower Silurian to the Upper Permian, where it has a cosmopolitan distribution. Species of *Rhipidomella* have not so far been recorded from the Permian strata of Svalbard, but GOBBETT (1964, p. 47, pl. 1, fig. 7) has described *Rhipidomella michelini* (L'ÉVEILLÉ) from the Middle Carboniferous Tårnkanten Sandstone of Oscar II Land. Our specimens are unlike the Carboniferous form and most of the previously described Permian forms. Externally they resemble most closely those described under the name of *Schizophoria juresanensis* by CHERNYSHEV (1902, p. 591, pl. 27, figs. 13–15; pl. 60, figs. 5–8) from the Cora and Schwagerina Horizons (Sakmarian-Artinskian) of the Ural Mountains, U.S.S.R. The Pennsylvanian form *R. carbonaria* (SWALLOW), as described by DUNBAR and CONDRA (1932, p. 52, pl. 2, figs. 1–4) is also similar, but has straight, more sharply tapering postero-lateral margins.

[1] The suprageneric categories used in this report follow, for the most part, those defined by WILLIAMS and ROWELL (1965).

Specimens of *Rhipidomella* sp. commonly occur in almost monospecific associations near the base of the Cancrinella Limestone. The form here described probably represents a new species but the shell is susceptible to silification, and the relatively poor preservation precludes accurate identification of diagnostic internal structures.

Suborder Productidina WAAGEN, 1883
Superfamily Productacea GRAY, 1840
Family Marginiferidae STEHLI, 1954
Subfamily Probolioniinae MUIR-WOOD and COOPER, 1960
Genus *Probolionia* COOPER, 1957

Probolionia cf. *involuta* (CHERNYSHEV)

For synonymy, see GOBBETT, 1964, p. 67.

Remarks. Five incomplete pedicle valves, all of which are partially exfoliated, probably belong to this species. The shells are elongate and show a strongly convex pedicle valve with a rather deep and narrow median sulcus which is almost uniform in width from the umbo to the anterior margin. The visceral humps are prominent, but the ears are not preserved in any of our examples. The extended trail and the poorly defined ornament of low rounded costae and scattered spine bases are all typical of the genus *Probolionia*.

The specimens figured as *Marginifera involuta* by CHERNYSHEV (1902, p. 645, pl. 36, figs. 7–9; pl. 58, figs. 4–6) and WIMAN (1914, p. 77, pl. 19, figs. 1–11) most closely resemble our specimens.

The species has been recorded from the Cora Limestone of Ymerdalen, Bjørnøya, and from the Spirifer Limestone of Miseryfjellet, Bjørnøya, as well as from the Lower Permian of Russia and Arctic Canada (GOBBETT 1964).

Family Echinoconchidae STEHLI, 1954
Subfamily Waagenoconchinae MUIR-WOOD and COOPER, 1960
Genus *Waagenoconcha* CHAO, 1927

Waagenoconcha irginae (STUCKENBERG)
Pl. 1, Figs. 3a–d

For synonymy, see GOBBETT, 1964, p. 76.

Description. Shell medium-sized, sub-circular in outline, with length and width subequal; pedicle valve moderately convex, with shallow sulcus; umbo incurved beyond hinge. Hinge-line narrower than the greatest width of the shell, which occurs near mid-point of the valves; auricles poorly developed. Pedicle valve ornament of closely spaced, fine radiating spine bases arranged in quincunces and becoming increasingly finer towards the anterior margin. Faint irregular concentric growth lines are also present.

Brachial valve flat and geniculated into very short trail; median fold low. Ornament of fine radiating spine bases, as in pedicle valve.

Pedicle valve interior with shallow adductor muscle scars flanked by larger striated diductor scars. Brachial valve interior not observed.

Remarks. GOBBETT (1964, p. 76, pl. 5, fig. 7; pl. 6, figs. 1–5) has re-described this species and included an extensive synonymy. *W. irginae* is a common and widely distributed species, occurring in the Spirifer Limestone and Brachiopod Cherts of Spitsbergen and in the Cora Limestone and Spirifer Limestone of Bjørnøya. Material collected from the Cancrinella Limestone consists of one almost complete specimen (Pl. 1, Figs. 3a–d) and several large but fragmentary examples.

Family Dictyoclostidae STEHLI, 1954
Subfamily Dictyoclostinae STEHLI, 1954
Genus *Costiferina* MUIR-WOOD and COOPER, 1960

Costiferina arctica (WHITFIELD)

For synonymy, see GOBBETT, 1964, p. 91.

Remarks. This species is represented by one almost complete specimen showing the external characters of both valves but without the ears preserved. The shell is large and elongate, with a highly convex pedicle valve bearing a narrow median sulcus of almost constant width. The trail is long and medianly sulcate. The brachial valve is flat or slightly concave, with a median fold and a sharp geniculation near the anterior border, producing a long trail. Both valves are ornamented with coarse costae and less prominent concentric rugae in the region of the visceral disc. Spine bases are erect and scattered over the trail and the visceral disc of the pedicle valve, while the brachial valve is devoid of spines but has a reticulate ornament and isolated tubercles along many of the radial costae. A median longitudinal section shows the brachial valve with a massive cardinal process supported by a strong median septum which thickens near the point of geniculation, simulating a submarginal ridge. Interior of pedicle valve not observed.

Our example from the Cancrinella Limestone resembles most closely those figured by STEPANOV (1937, p. 113, pl. 1, figs. 9, 10) and GOBBETT (1964, p. 91, Pl. 9, figs. 2–6) from the Spirifer Limestone of Spitsbergen. The species was also recorded by WIMAN (1914, p. 63, pl. 13, figs. 7–10) under the name of *Productus boliviensis* from the Cora Limestone of Bjørnøya.

Family Linoproductidae STEHLI, 1954
Subfamily Linoproductinae STEHLI, 1954
Genus *Cancrinella* FREDERICKS, 1928

Cancrinella crassa GOBBETT
Pl. 1, Figs. 4, 5.

1964 *Cancrinella crassa* GOBBETT, p. 105, pl. 12, figs. 16–21.

Description. Shell small, elongate, pedicle valve strongly convex, subtriangular in outline, with rather narrow, pointed umbo. The hinge-line is short, with small ears; greatest width of shell occurs near anterior margin. Brachial valve not observed.

Pedicle valve ornament of coarse, rounded costae becoming irregular and sinuous on trail. Most costae with spine bases, each spine formed from a single costa. Concentric rugae not prominent except in region of ears.

Remarks. There are two small examples (Pl. 1, Figs. 4, 5) in the collection from Kopernikusfjellet which appear to be conspecific with *Cancrinella crassa* GOBBETT, originally described from the Upper Cyathophyllum Limestone of Komarovfjellet, Oslobreen, Ny Friesland, Spitsbergen. Our examples appear to differ slightly from those of GOBBETT in possessing a narrower and more pointed umbo. From *C. singletoni* GOBBETT, also recorded from the Cancrinella Limestone, this species can be distinguished by its coarser, wider costae and smaller spine bases, each of which is restricted to a single costa.

Order Rhynchonellida GRAY, 1848
Superfamily ? Pugnacidae RZHONSNITSKAYA, 1956
Genus *Pugnoides* WELLER, 1910

Pugnoides svalbardensis sp. nov.
Pl. 1, Figs. 6a–e, 7a–c; text-fig. 3.

Description. Shell small, biconvex, transversely oval to rounded triangular in outline, width usually exceeding length and greatest width near mid-point of shell; pedicle valve moderately convex, umbo prominent, pointed, probably with small foramen; below beak is pair of narrow triangular deltidial plates. Pedicle valve with broad sinus; valve almost smooth posteriorly, but rounded or sub-angular costae developed anteriorly, with 2–4 costae in sulcus and 2–4 on anterior part of lateral flanks, depending upon the growth stage of the individual. Anterior commissure strongly denticulated. Shell substance impunctate.

Brachial valve highly convex, with broad median fold containing 3–5 costae and 2–4 costae present on lateral flanks.

Interior of pedicle valve with slender, sub-parallel dental plates demarcating large delthyrial and umbonal cavities. Crural plates united to form an open septalium supported by a strong dorsal median septum.

Remarks. Although somewhat similar to *Wellerella* DUNBAR and CONDRA externally, *Pugnoides* WELLER differs from that genus in its possession of a divided hinge-plate and a septalium supported by a strong medium septum. Transverse serial sections (text-fig. 3) indicate that the examples from the Cancrinella Limestone belong to *Pugnoides*, a genus which is not commonly found in Permian strata. No species of *Pugnoides* has previously been recorded from the Permian of Svalbard or Greenland, although CHERNYSHEV (1902) has described several species of *Pugnax* from Timan and the Urals which may belong to *Pugnoides*. For instance, *Pugnax* sp. of CHERNYSHEV (1902, p. 484, pl. 44, fig. 7) appears to be closely related to our species but is inadequately described and illustrated and there is thus no information regarding its internal structure. *Wellerella multiplicata* COOPER (1957, p. 49, pl. 10B, figs. 7–11) from the Permian of Oregon is rather similar externally to the Svalbard form but little is known of the internal structure of this species. *Pugnoides ottumwa* (WHITE), the type species of *Pugnoides*, is a Lower Carboniferous representative of the genus strongly resembling our species but possessing very deep, angular costae.

Specimens of *P. svalbardensis* are common near the base of the Cancrinella Limestone, sometimes occurring in association with examples of *Rhipidomella* sp., which have a similar size range.

Dimensions of figured specimens. (in mm)

Specimen	*Length* (P.V.)	*Length* (B.V.)	*Width*	*Thickness*
Holotype	9.8	8.9	11.1	8.1
Paratype A	8.8 est.	8.0	8.5	5.0

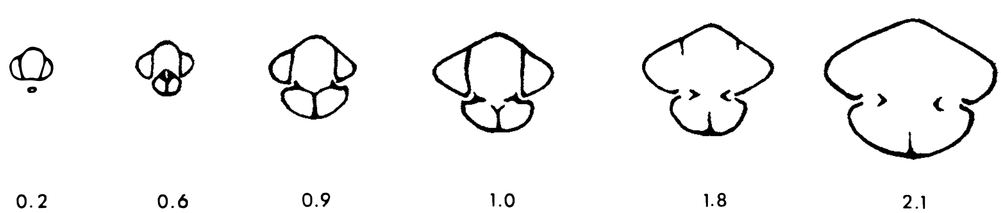

Fig. 3. *Pugnoides svalbardensis sp. nov. Transverse serial sections of specimen No. P.M.O. A 32710,* $\times$ 3. *Numbers refer to the distance in mm from the posterior extremity of the shell.*

Superfamily Rhynchoporacea MUIR-WOOD, 1955
Family Rhynchoporidae MUIR-WOOD, 1955
Genus *Rhynchopora* KING, 1865

Rhynchopora sp.

1964 cf. *Rhynchopora* sp. GOBBETT, p. 131, pl. 16, figs. 22–25.

Remarks. A single example which is tentatively identified with *Rhynchopora* sp. described by GOBBETT from the Upper Gypsiferous Series of Burn Murdochbreen, Bünsow Land, Spitsbergen, is recorded from the Cancrinella Limestone. Although the specimen is partially exfoliated, traces of punctate shell are present. The costae are coarsely rounded and restricted to the anterior third of the shell. There are 2 costae in the fold and one in the sulcus in our example, with 2–3 costae on the lateral flanks. The impression of a dorsal median septum extends for over one-half of the length of the shell. No other internal features have been observed.

Suborder Spiriferidina WAAGEN, 1883
Superfamily Reticulariacea WAAGEN, 1883
Family Elythidae FREDERICKS, 1919
Genus *Neophricadothyris* LICHAREW, 1934

Neophricadothyris asiatica (CHAO)
Pl. 1, Figs. 8, 9.

For synonymy, see GOBBETT, 1964, p. 132.

Description. Shell small, biconvex, subcircular to transversely oval in outline, with broadly rounded cardinal extremities; slightly wider than long in some examples, longer than wide in others. Umbo of pedicle valve strongly incurved over small triangular interarea; umbo of brachial valve not present in our examples. Anterior commissure rectimarginate, although pedicle valve occasionally has an almost imperceptible median groove.

Shell surface somewhat worn, but shows external ornament of closely spaced concentric growth lamellae, each terminating anteriorly in a single row of small elongate spine bases. Internal characters not seen.

Remarks. Four examples from the Cancrinella Limestone, all incomplete, are referred to this species. A rather transverse specimen (Pl. 1, Fig. 9), which strongly resembles the example figured by CHAO (1929, p. 91, pl. 11, fig. 14a–g) as *Squamularia asiatica*, is included in this species rather than in *S. ovata* CHAO, which is also transverse in outline.

The species has been recorded by GOBBETT (1964) from the Cora Limestone of Bjørnøya and the Upper Wordiekammen Limestone of Sassenfjorden, Spitsbergen, and from the Brachiopod Cherts of Hornsund by BIRKENMAJER and CZARNIECKI (1960) and BIRKENMAJER (1964).

Superfamily Spiriferaceae KING, 1846
Family Spiriferidae KING, 1846
Genus *Neospirifer* FREDERICKS, 1919

Neospirifer cf. *tegulatus* (TRAUTSCHOLD)

For synonymy, see GOBBETT, 1964, p. 141.

Remarks. Two incomplete internal moulds are tentatively referred to this species, mainly on the basis of sculpture, the lateral slopes and fold-sulcus region being ornamented with fine fasciculate costae traversed by strong growth lamellae. Our specimens are comparable in outline and ornamentation with those described by GOBBETT (1964, p. 141, pl. 18, fig. 9; pl. 19, fig. 1) from the Upper Cyathophyllum Limestone of Von Postbreen, Central Vestspitsbergen.

Family Syringothyrididae FREDERICKS, 1926
Subfamily Licharewiinae SLUSAREVA, 1958
Genus *Paeckelmannella* LICHAREW, 1934

Paeckelmannella ? sp.

Remarks. Six specimens from the Cancrinella Limestone appear to belong to *Paeckelmannella*, although differing from typical members of that genus in their poor development of a medianly costate sulcus. The specimens are all biconvex and highly transverse, with pointed cardinal extremities and concave rectangular interareas, the pedicle valve interarea being apsacline and the brachial valve interarea being anacline to orthocline. The median fold and sulcus are well developed, and although the fold is carinate, the sulcus shows little sign of a median costa. There are only 3–4 rounded to subangular costae on the lateral slopes. The micro-ornament consists of fine concentric growth lamellae without capillae or punctae. The interior of the pedicle valve shows well developed dental plates and a strong median septum, while some apical callosity is present in the delthyrial cavities.

No previously described species known to the authors closely resembles these specimens from the Cancrinella Limestone but, owing to their incomplete nature, they can only be tentatively assigned to the genus *Paeckelmannella* for the present.

Suborder Athyrididina BOUCOT, JOHNSON and STATON, 1964
Superfamily Athyridacea M'COY, 1844
Family Athyrididae M'COY, 1844
Subfamily Athyridinae M'COY, 1844
Genus *Composita* BROWN, 1849

Composita cf. *naruensis* REED
Pl. 1, Figs. 10a–e; text-fig. 4.

1944 *Athyris* (*Composita*) *globularis* PHILLIPS var. *naruensis* REED, p. 276, pl. 34, figs. 8–10.

Description. Shell small to medium-sized, transversely oval in outline, with width exceeding length; pedicle valve moderately to weakly convex, with postero-lateral margins flat or slightly concave; umbo prominent, probably furnished with foramen. Faint median sulcus, ill-defined posteriorly, slightly defined anteriorly, narrow, widening gradually towards anterior margin. Hinge-line less than greatest width of shell, which occurs near mid-point of valves. Surface of shell smooth, faint striations on lateral slopes of partially exfoliated specimens; concentric growth lines not prominent, except near anterior margin.

Brachial valve moderately convex, with slight median fold bearing narrow, almost imperceptible median groove extending over half length of valve. Anterior commissure broadly uniplicate. Ornament similar to that of pedicle valve.

Pedicle valve interior with deep, well-marked adductor muscle platform, posteriorly placed; diductor impressions shallow. Hinge teeth borne by margins of shell, while flat cardinal plate of brachial valve perforated apically and supported by crural plates which form the inner side of dental sockets. Slight dorsal myophragm present as faint ridge. Jugum not preserved but traces of at least seven volutions of spiralia present.

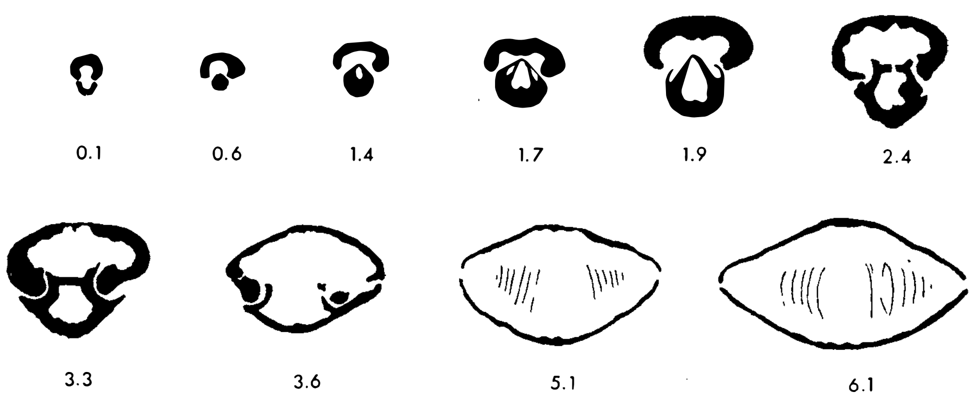

Fig. 4. *Composita cf. naruensis* REED. *Transverse serial sections of specimen No. P.M.O. A 32715,* × 1½. *Numbers refer to the distance in mm from the posterior extremity of the shell.*

Remarks. The form here described differs from typical *Composita* in its transverse outline, poorly-developed sulcus and fold, and absence of lateral sulci on the flanks. On the other hand, the smooth shell and internal structure are characteristic of the genus and distinguish this form from certain less transverse varieties of *Cleiothyridina royssiana* (KEYSERLING), to which there is a superficial resemblance. Few described species known to the authors closely resemble this form. The specimens described by REED (1944, p. 276, pl. 34, figs. 8–10) as *Athyris* (*Composita*) *globularis* PHILLIPS var. *naruensis* REED from the Productus Limestones of the Salt Range of West Pakistan have a similar transverse outline but possess a slightly deeper sulcus and fold. REED's form is here raised to specific rank because of its rather questionable identity with PHILLIPS's species *Athyris globularis*. *Composita* sp. B, described by GOBBETT (1964, p. 168, pl. 22, figs. 22–24) from the Upper Cyathophyllum Limestone ? of Chydeniusbreen, Mertonberget, Spitsbergen, also possesses a uniplicate anterior commissure, but is pentagonal to sub-triangular in outline.

Only two examples of *C.* cf. *naruensis* have so far been obtained from the Cancrinella Limestone.

Suborder Terebratulidina WAAGEN, 1883
Superfamily Dielasmatacea SCHUCHERT, 1913
Family Dielasmatidae SCHUCHERT, 1913
Subfamily Dielasmatinae SCHUCHERT, 1913
Genus *Dielasma* KING, 1859

Dielasma ? cf. *itaitubense* (DERBY)
Pl. 1, Figs. 11a–b.

1874 cf. *Terebratula itaitubensis* DERBY, p. 1, pl. 2, figs. 1, 3, 8, 16; pl. 3, fig. 24; pl. 6, fig. 15
1902 cf. *Dielasma itaitubense* CHERNYSHEV, p. 457, pl. 3, fig. 1a–d.
1914 cf. *Dielasma itaitubense* WIMAN, p. 25, pl. 1, figs. 9–12.
1964 cf. *Dielasma* ? aff. *itaitubense* GOBBETT, p. 184, pl. 25, figs. 17–19.

Remarks. This species is represented in the Cancrinella Limestone by two specimens, both incomplete. The shell is elongate-oval in outline, biconvex to ventribiconvex, with the greatest width occurring just anterior to mid-point of shell. The pedicle valve has a broad, ill-defined sulcus developed anteriorly, while the brachial valve has a corresponding median fold, producing a broadly uniplicate anterior commissure. The pedicle valve interior is furnished with divergent dental plates but details of the brachial valve internal features were not observed. *Dielasma* is distinguished from its external homeomorph *Beecheria* by differences in the form of the brachial valve cardinalia (STEHLI 1956); thus correct generic assignation is in doubt in the case of our specimens.

GOBBETT (1964, p. 184, pl. 25, figs. 17–19) has tentatively identified specimens from the Cora Limestone of Bjørnøya with DERBY's species. Our specimens most closely resemble the example described and figured by WIMAN (1914, p. 25, pl. 1, figs. 9–12) from the Cora Limestone and differ slightly from GOBBETT's specimens in being ventribiconvex rather than dorsibiconvex.

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PLATE I →

(All specimens were collected by K. BIRKENMAJER from the Cancrinella Limestone of Kopernikusfjellet, Vestspitsbergen, and are in the Paleontologisk Museum, Sarsgate 1, Oslo, Norway.)

Fig. 1a–c. *Rhipidomella* sp., hypotype A (No. P.M.O. A 32701); ventral, dorsal and lateral views, showing traces of external ornament and muscle field of brachial valve, ×1.

Fig. 2a–c. *Rhipidomella* sp., hypotype B (No. P.M.O. A 32702); ventral, dorsal and posterior views of immature individual with external ornament preserved, ×2.

Fig. 3a–d. *Waagenoconcha irginae* (STUCKENBERG), hypotype A (No. P.M.O. A 32704); ventral, dorsal, posterior and lateral views of partially exfoliated individual, ×1.

Fig. 4. *Cancrinella crassa* GOBBETT, hypotype A (No. P.M.O. A 32705); pedicle valve of small example, ×3.

Fig. a. *Cancrinella crassa* GOBBETT, hypotype B (No. P.M.O. A 32706); pedicle valve, ×2.

Fig. 6a–e. *Pugnoides svalbardensis* sp. nov., holotype (No. P.M.O. A 32707); ventral, dorsal, anterior, posterior and lateral views of mature specimen, ×2.

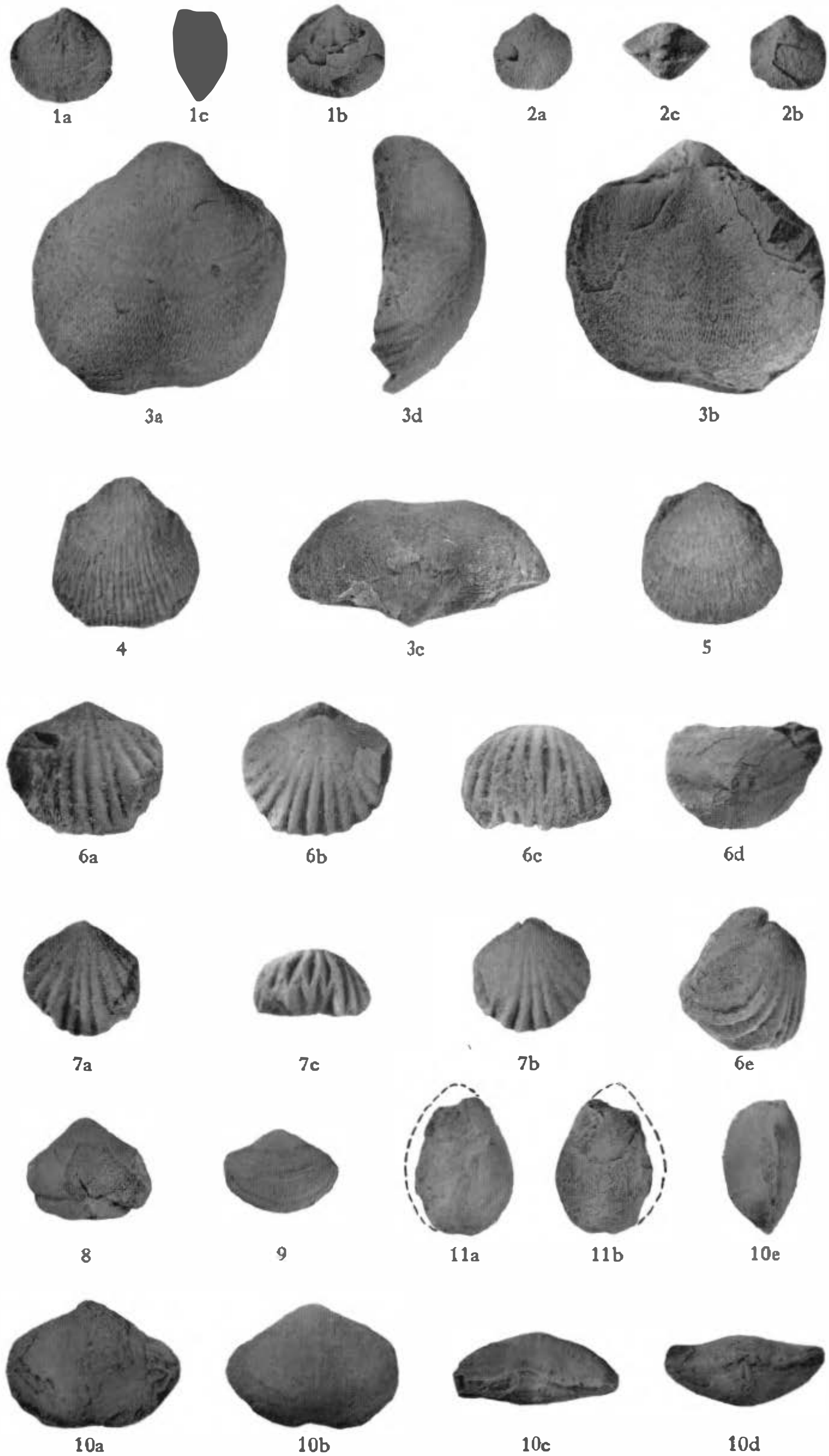
Fig. xa–c. *Pugnoides svalbardensis* sp. nov., paratype A (No. P.M.O. A 32708); ventral, dorsal and anterior views of elongate variety, ×2.

Fig. x. *Neophricadothyris asiatica* (CHAO), hypotype A (No. P.M.O. A 32711); pedicle valve, ×1.

Fig. z. *Neophricadothyris asiatica* (CHAO), hypotype B (No. P.M.O. A 32712); ventral view of transverse variety, ×1.

Fig. 10a–e. *Composita* cf. *naruensis* REED, hypotype A (No. P.M.O. A 32714); ventral, dorsal anterior, posterior and lateral views, ×1.

Fig. 11a–b. *Dielasmc.?* cf. *itaitubense* (DERBY), hypotype A (No. P.M.O. A 32716); ventral and dorsal views of incomplete specimen, ×1.


1a 1c 1b 2a 2c 2b
3a 3d 3b
4 3c 5
6a 6b 6c 6d
7a 7c 7b 6e
8 9 11a 11b 10e
10a 10b 10c 10d

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Stratigraphical correlation of Hecla Hoek successions north and south of Bellsund

BY

AUDUN HJELLE

Abstract

A comparison is made of Hecla Hoek stratigraphy in two localities: 1) at Konglomeratfjellet, south of Recherchefjorden, Bellsund, and 2) north and north-west of Kapp Martin, on the north side of Bellsund. The rocks involved are tillite conglomerate, quartzite, phyllite, volcanic rocks, calcareous rocks, and quartzite conglomerate, all of late Pre-Cambrian age. A stratigraphical correlation is suggested between the two localities.

Correlation of the Hecla Hoek rocks around Bellsund and Hornsund with those elsewhere in Vestspitsbergen and Nordaustlandet have been suggested by several authors. KULLING (1934) stated that the "Fox Point tillite", described by GARWOOD and GREGORY (1898) from the south side of Bellsund, might well represent the same conglomerate-forming epoch as the Sveanor tillite in Nordaustlandet. MAJOR and WINSNES (1955) suggested that the tillite south of Bellsund (GARWOOD and GREGORY 1898, ORVIN 1940) is situated between the Gåshamna phyllite and the Slakli Series of Lower Cambrian age, described by them from south of Hornsund. They also maintained that the mainly calcareous Höferpynten Series in the area corresponds to the Murchison Bay Formation described by KULLING from Nordaustlandet. HARLAND (1956) correlated the Akademikerbreen Series (*group* of HARLAND *et al.* 1966) with the Höferpynten Series, and the tillite-bearing Polarisbreen Series (group) with the Gåshamna phyllite south of Hornsund. Comparing the stratigraphy just north of Bellsund with that of the Upper and Middle Hecla Hoek in Olav V Land, I correlated the dolomite conglomerates north and south of the mouth of Bellsund with the Draken conglomerate in the lower part of the Akademikerbreen group, and the calcareous beds found at Lågnesrabbane with the upper part of the same group (HJELLE 1962). Additional observations from the north and south side of Bellsund in 1967 and 1968 by B. FLOOD and the author, have contributed some new information, and the following description and interpretation are mainly based on our observations from two localities: 1) Konglomeratefjellet, south of Recherchefjorden, Bellsund, and 2) the area just north and north-west of Kapp Martin on the north side of Bellsund (Fig. 1).

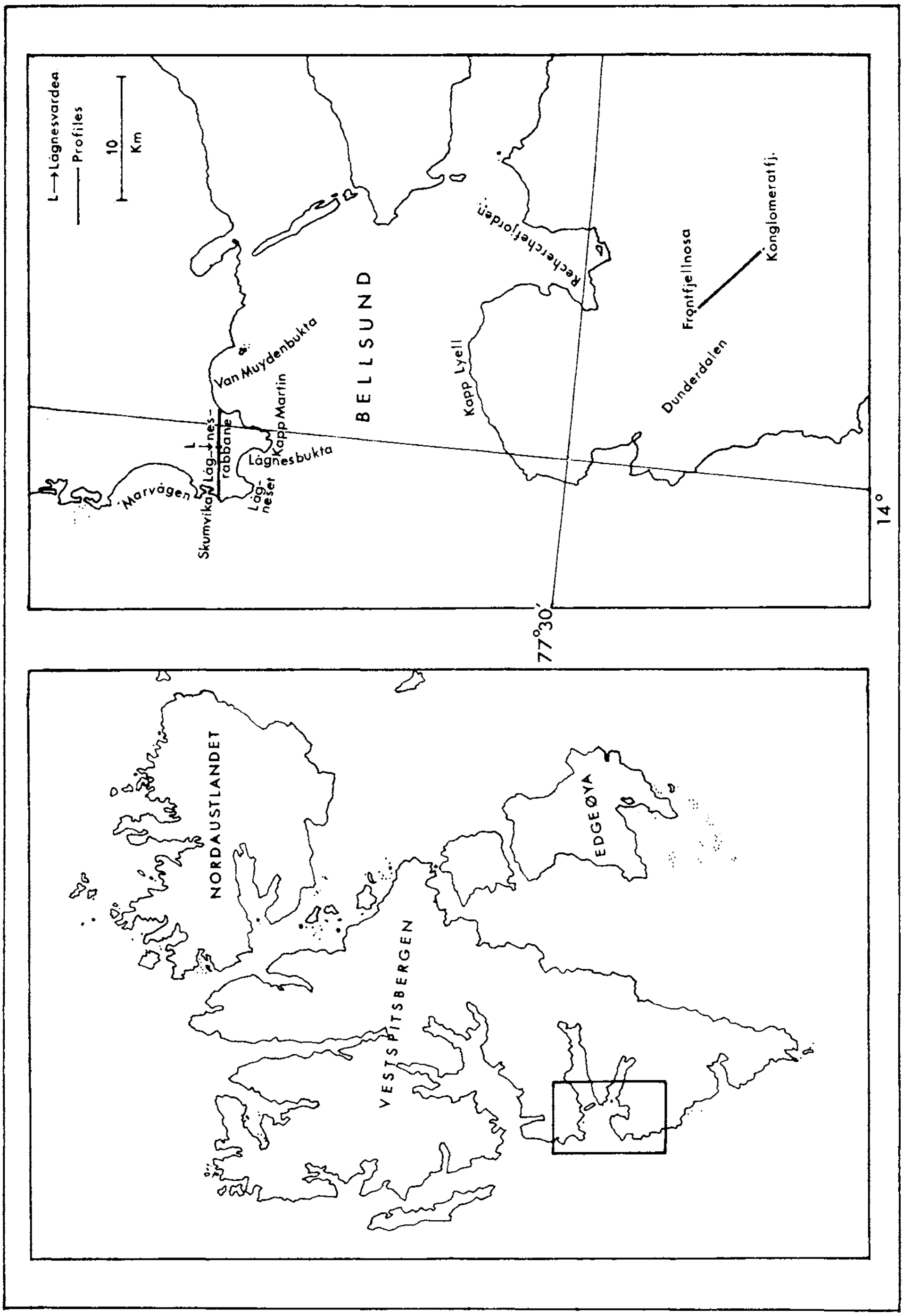

Fig. 1. *Key map showing the localities and the position of the described profiles.*

The beds at Konglomeratfjellet

From Frontfjellnosa, north of the innermost part of Dunderdalen, towards Konglomeratfjellet the following beds occur from north-west to south-east, going downwards in the succession:

1) Tillite-like dolomite conglomerate with a sandy calcareous matrix and isolated bands of lime-sandstone, 1–5 m wide. Generally the conglomerate has a boulder content of about 50% grey dolomite, 30% grey quartzite, and 20% grey and black limestone, grey shale, and green volcanic shale, all rocks belonging to the lower part of the Hecla Hoek succession in this area, and also exposed further east. The boulders are sub-angular to well rounded, and the size may approach 100 cm, with an average of 2–15 cm. The lower contact of the conglomerate in the east is not exposed. ORVIN suggested here an unconformity and a considerable hiatus in the sequence. A tectonic discontinuity between the relatively rigid tillite and the incompetent shales may, however, not be precluded.

2) Grey shale with light grey quartzite. In the eastern part a band of brecciated grey dolomite occurs, 1–3 m wide(?). The total thickness is uncertain due to repetition of folding.

3) Green phyllitic shales of volcanic origin. The estimated thickness is 10 m, increasing northwards.

4) Grey homogeneous limestone with dolomitic horizons. The limestone contains a few pebbles of pink quartzite, the amount of which seems to increase towards south-east, where also some black oolitic limestone and black and grey shales occur. As in the other beds described, the thickness is uncertain due to folding; it is estimated at c. 150 m.

5) Quartzite conglomerate with a marly or sandy matrix, alternating with beds of lime-sandstone. The boulders are well rounded and consist mainly of grey quartzite; less than 10% are of dolomitic composition. The maximum size of the boulders is about 50 cm, the common size is 2–10 cm, the boulders being somewhat elongated. The quartzite conglomerate extends to the summit of Konglomeratfjellet, although the grey limestone reappears in the upper parts of the slope.

The rocks in the described profile are isoclinally folded, and, as mentioned, the estimated thicknesses are rather tentative. The general western dip of the beds suggests that the older beds are situated to the east. Prominent fold axes are: F 1 (?), almost horizontal N-S; F 2 (?), plunging c. 50°W.

Towards Recherchefjorden, further north, the volcanic beds of green phyllitic shales and greenstones are intimately associated with partly serpentinized ultrabasic intrusives, into which they occasionally seem to pass transitionally. In some localities the volcanic rocks show the typical textures of lavas and agglomerates. The ultrabasic intrusions, often showing shapes of sills, transgress both the grey shales and the calcareous rocks, which show signs of contact metamorphism.

Rocks lithologically similar to those in the profile described above, suggesting the same stratigraphical position, occur in Orvinfjellet (10 km south of Konglomeratfjellet) and around Skoddebreen (15–20 km south-southeast of Konglomeratfjellet), the latter being a possible link between the Slyngfjellet Conglomerate and the conglomerate beds further north.

The beds in the Kapp Martin — Lågneset area

In a profile from Skumvika to Van Muydenbukta, through the highest point of Lågnesrabbane (56 m a. s. l.), the following beds occur from west to east:

1) In the low ground between Lågneset and Marvågen: tillite-like conglomerate with a sandy calcareous matrix. The boulder material mainly consists of grey dolomite with subordinate pink quartzite and grey limestone. The maximum size of the boulders is about 50 cm; a common size is 1–10 cm. The contact with the beds in the east was not seen.

2) In the northern part of Lågnesbukta grey and green phyllites are found alternating with beds of grey and greyish white limestone.

3) Between the northern part of Lågnesbukta and Lågnesvarden, and between the western part of Lågnesbukta and Kapp Martin: alternation between grey oolitic dolomites, some of them containing cherty horizons, and dark limestones. However, the alternation may, to some extent, be due to the isoclinal folding developed in the area. Prominent fold axes are: F 1 (?), almost horizontal NNE-SSW; F 2 (?), plunging c. 40°SW. In the eastern part of these beds there seems to be a gradual transition through grey and black limestones, containing few pebbles of pink quartzite and occasionally some horizons of black shale, to the conglomerate described below.

4) Near Lågnesvarden and from Lågnesvarden to Kapp Martin: quartzite conglomerate with a marly or sandy matrix. More than 80% of the boulders consist of grey quartzite, about 10% of grey dolomite, 5% of grey and black limestone, and less than 5% of volcanic rocks and various shales. The size of the boulders was not seen to exceed 60 cm; a normal size is 2–15 cm.

North and south of the westernmost part of the profile, and north-east of Lågnesvarden, relatively small bodies (50–500 m) of gabbroic rocks intrude limestones and dolomites (HJELLE 1962). The intrusions, which correspond well in occurrence and composition to those mentioned from south of Recherchefjorden, are accompanied by green phyllitic shales, and the adjacent rocks often show local metamorphism with development of tremolite and micas. East of Lågnesrabbane the Hecla Hoek rocks are covered by a small occurrence of Culm-sandstone. The whole western area has been faulted down, and east of the fault the tillite-like conglomerate reappears.

Concluding remarks

Between the dolomite conglomerates north and south of Bellsund there is close resemblance both in composition and texture. The common alternation of relatively homogeneous conglomerates with a certain degree of sorting, horizons with large boulders in a relatively fine-grained matrix, and lime-sandstone bands, might indicate that the bulk of the conglomerate has been deposited under glaciofluvial conditions. In both localities a depositional or tectonic discontinuity may exist between the tillite conglomerate and the suggested older beds to the east. Further field work might give an answer to this question.

East of the tillite conglomerate the same general sequence occurs south and north of Bellsund. The gradual transition, from grey and black limestones with quartzite pebbles and horizons of black shale, down into the quartzite conglomerate, is also seen in both localities. The quartzite was not seen in the northern profile, and the shales are apparently less extensive, but there are so many compositional and textural similarities that a stratigraphical correlation appears justified.

Gabbroic intrusion, in part ultrabasic, has taken place after the deposition of the calcareous rocks described here. Volcanic rocks related to the gabbroic rocks are overlying the calcareous rocks. However, the occurrence of pebbles of volcanic rocks, similar to those mentioned above, in the quartzite conglomerate would indicate that the volcanic activity commenced before or during the deposition of the quartzite conglomerate.

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Table I.

Stratigraphical correlation with other areas.

<table>
<tr><th>Hornsund
Major and Winsnes
1955
Birkenmajer 1960</th><th>S of Bellsund</th><th>N of Bellsund</th><th>Olav V Land
Harland and Wilson
1956
Harland, Wallis and
Gayer 1966</th></tr>
<tr><td></td><td colspan="2">This paper</td><td></td></tr>
<tr><td rowspan="2">Gåshamna Series

Upper part:
Phyllitic limestones</td><td>Bellsund-Dunderdalen
tillite</td><td>Lågneset tillite</td><td rowspan="2">Polarisbreen Group

Mainly shale
and tillite</td></tr>
<tr><td colspan="2">Mainly dolomitic</td></tr>
<tr><td rowspan="2">Lower part:
Phyllites and
quartzites</td><td>Konglomeratfjellet
shale and quartzite
beds</td><td rowspan="2">Lågneset-Kapp Martin

Grey and green
shales</td><td rowspan="2"></td></tr>
<tr><td>Konglomeratfjellet
volcanic beds</td></tr>
<tr><td>Höferpynten Series</td><td>Konglomeratfjellet
calcareous beds</td><td>Lågnesrabbane
calcareous beds</td><td>Backlundtoppen fm.</td></tr>
<tr><td colspan="4">Mainly limestone and dolomite beds, partly with oolite and silicified horizons</td></tr>
<tr><td></td><td colspan="3">Subordinate dark shales</td></tr>
<tr><td rowspan="2">Slyngfjellet
conglomerate</td><td>Konglomeratfjellet
conglomerates beds</td><td>Kapp Martin
conglomerate beds</td><td rowspan="2">Draken Conglomerate

Mainly dolomitic
with micro-conglo-
merates and locally
with bands and len-
ticles of black chert</td></tr>
<tr><td colspan="2">Quartzite conglomerate with
subordinate dolomite and with
marly horizons</td></tr>
</table>

The geology and structure of metamorphic rocks in the Smeerenburgfjorden area, north-west Vestspitsbergen

BY

YOSHIHIDE OHTA[1]

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Abstract

A structural study of the metamorphosed Hecla Hoek complex on the eastern side of Smeerenburgfjorden, north-west Vestspitsbergen, has been done, based on the field survey of Norsk Polarinstitutt's expedition 1966. The metamorphic rocks were classified into three groups, and also three different kinds of granitic rocks were distinguished. The mapped area was divided into 12 tectonic subunits, and the mesoscopic tectonic elements were summarized on the Schmidt net.

Through these studies, three different phases of tectonism were distinguished in the metamorphic rocks, and a post-kinematic intrusion of the granitic rocks was established:

1) Formation of the schistose cleavages, nearly parallel to the compositional layering of the original sedimentary rocks having roughly N–S strike. The striation-lineation (L-1) is characteristic on these cleavages.

[1] Hokkaido Univ., Sapporo, Japan.

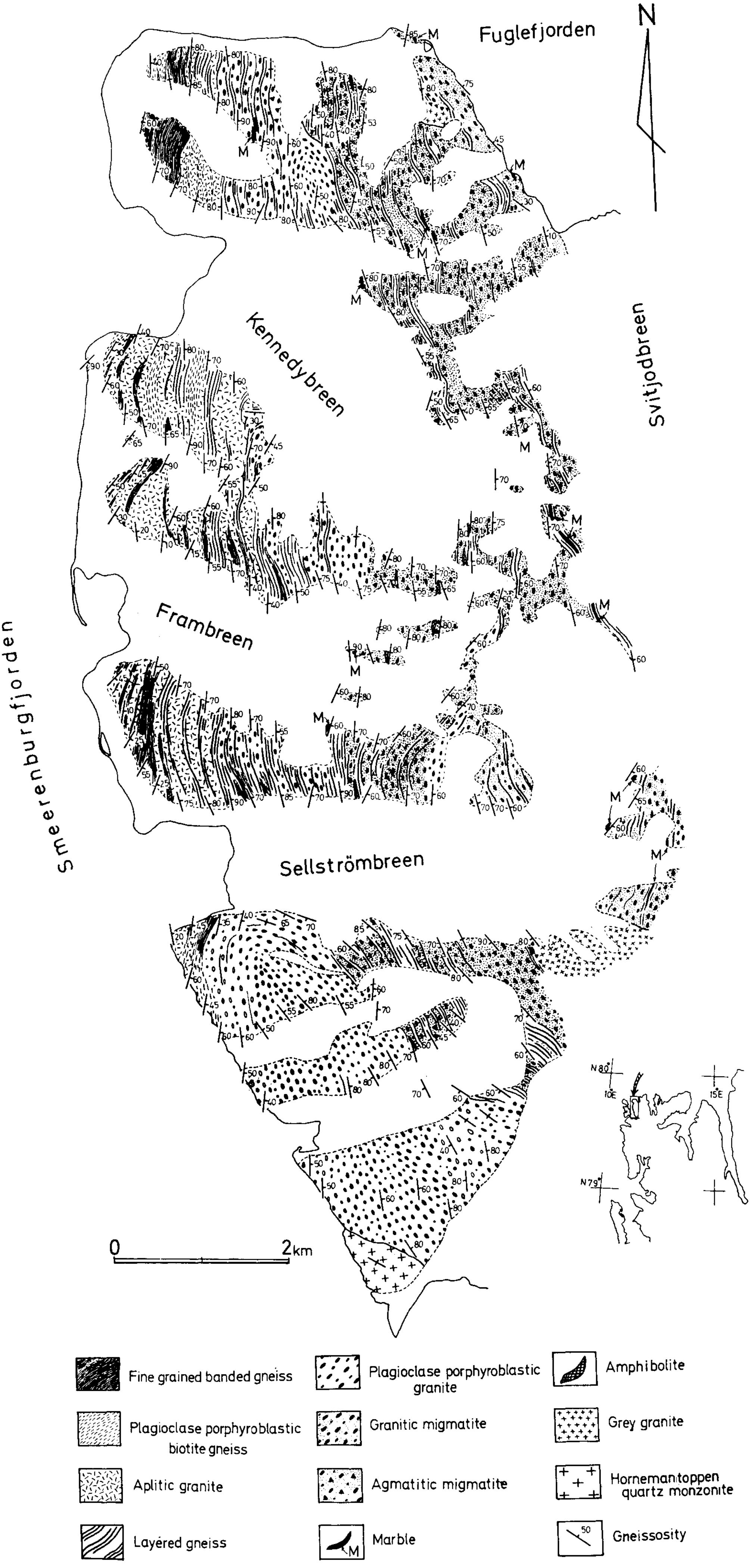

Fig. 1. Geological map of the Smeerenburgfjorden area.

2) Formation of the axial plane gneissosity along the axial surface of the small-folded schistose cleavage, the axis of which is the L-2.

3) Emplacement of the plagioclase-porphyroblastic granites at the core of the synform structure, the axis of which is in diagonal direction to the general structural trend of the metamorphic rocks

4) Intrusion of the late-kinematic grey granite, and the post-kinematic Hornemantoppen quartz monzonite.

Introduction

Recently, some papers concerning petrography and regional tectonic structure of the north-western part of Vestspitsbergen have been published. This area is mainly composed of metamorphosed Lower Hecla Hoek rocks, whose grade of metamorphism becomes higher to the north. The general structures of these rocks have been summarized by GEE and HJELLE (1966), and successive detailed investigation is desirable.

This is one of such attempts on the eastern side of Smeerenburgfjorden area, where highly metamorphosed Hecla Hoek rocks occur. The tectonic study presented in this paper is based on mapping in the summer of 1966.

Petrographical and chemical studies will be presented in a later report.

General description of the rocks

STATEMENT AND CLASSIFICATION OF THE ROCKS

The Smeerenburgfjorden area is mainly composed of regional metamorphic rocks like banded gneisses and granitic migmatite, and of different kinds of granitic rocks. The gneisses are mostly of pelitic composition, and the granitic migmatite might be derived from the same kind of pelitic sedimentary rocks (Fig. 1).

As for the mineral paragenesis, the regional metamorphic rocks are quite monotonous, i. e., mostly biotite gneisses and migmatite, except for some small masses of amphibolites and calcareous rocks. However, the textural development of these rocks, from hornfelsic gneiss to granitic migmatite, is remarkable, and is gradationally very well traceable. They are divided into three groups, based on the textural characteristics:

1. Fine-grained banded gneiss
2. Layered gneiss
3. Granitic migmatite

The granitic rocks in this area are tentatively divided into three groups as follows:

1. Plagioclase-porphyroblastic granite
2. Grey granite
3. Hornemantoppen quartz monzonite

The former two are probably related to the formation of the regional structure of this area, while the last one is independent of other rocks, and might be a post-kinematic granite.

DESCRIPTION OF THE ROCKS

The regional metamorphic rocks

Fine-grained banded gneiss

This is the rock which still preserves its original compositional banding of pelitic and siliceous composition. These rocks often show very frequent alternation of pelitic and siliceous layers from a few cm up to several dm thick and, on a large scale, pelitic or siliceous rock may be predominant on the scale of several decametres.

The pelitic rocks are very fine-grained, hornfels-like rocks with well developed schistose cleavages, which are nearly parallel to the compositional banding and have a striation-type lineation on the cleavage plane.

The extremely pelitic parts are always somewhat feldspar porphyroblastic, while relatively siliceous parts are fine-grained compact rocks. The siliceous layers are mainly impure quartzite, accompanied by a small amount of almost pure quartzite, having grey to pale brown colour. They often show intense intra-layer folding of small scale, representing well developed microfold axes, which have almost the same direction as that of the striation-lineation in the alternating pelitic layers. These impure quartzite layers are often broken by pinch and swell structure into boudinages and subangular fragments, indicating relatively high rigidity compared to the surrounding pelitic rock, which has been deformed, mainly by mode of formation of schistose cleavages. Some interspaces between siliceous boudinages have been filled with pure quartz pools.

This kind of fine-grained banded gneisses occurs typically in the western part of Fuglepyntfjellet as a somewhat large mass, while in other areas they occur as small masses, less than 10–20 m thick in the center of the predominant biotite gneiss of the layered gneiss. In such case, almost all the fine-grained banded gneisses are more or less of quartzitic composition, which might prevent them from changing into petroblastic gneiss. The fine-grained banded gneiss is often interlayered by white aplitic granite layers, most of which are subparallel to the general gneissosity of the gneiss, while some are slightly oblique. These aplites always have a very sharp contact against the country rocks, even if they have a concordant structure. The lithologic characteristics of these aplitic granites do not differ so much from that of the granitic layer in the layered gneiss, except for the occurrence of garnet in the former. However, in the latter case the pelitic gneiss transforms gradationally into the granitic layer with increase of plagioclase-porphyroblasts.

Transformation from fine-grained banded gneiss to layered gneiss

The first transformation appears as plagioclase porphyroblastesis, which occurs somewhat selectively in the fine-grained banded gneiss, first from the compositionally intermediate layer between the pelitic and siliceous layer, next in the pelitic layer, and at last in the siliceous layer. The plagioclases have a round to sub-idiomorphic shape and often occur thickly along the banded structure.

The fine-grained banded gneiss near to the layered gneiss always has well developed microfolding, especially where the siliceous layers alternate frequently, and form a lot of drag-fold crests. The plagioclase-porphyroblasts are accumulated in such crests of folds. The pelitic layers are often feldspathized homogeneously, and the porphyroblasts do not accompany the striation-type lineation on the gneissosity planes, which are nearly parallel to the primary compositional banding. The drag-type microfoldings are stretched into thin lenses, seams, and small-scale layers, and, at last, develop into a plagioclase-porphyroblastic granitic layer of the layered gneiss.

This mode of formation of the plagioclase-porphyroblastic layers is well observed in the western part of Fuglepyntfjellet and the western shore of Vest-plana, while in other areas the plagioclase-porphyroblastic parts were already removed along the plane of differential movement, and their contact against the gneissic part is sharp.

They partially show injection types of layering because of such movement; however, the rock composing such granitic layers has the same composition as the rock, which develops gradationally into the gneissic part through the process mentioned above.

Some of the granitic layers might also be mobilized because the plagioclase-porphyroblastic pelitic gneiss has been broken into angular to subangular shape and agmatized.

The siliceous layers often remain as fine-grained, compact layers in the layered gneiss, and even in the parts where the granitic rock has been mobilized, they show characteristic quartz-rich layers having faint gneissosity and homogeneously scattered small plagioclase porphyroblasts.

From these observations, three different types of gneissosity are distinguished. The first, S_1, is the primary banded structure of different compositional layers and schistose cleavages, typically seen in the fine-grained banded gneiss. The second, S_2, is the axial plane gneissosity of the drag-folded primary banding structure, followed by plagioclase-porphyroblasts, typically developing in the layered gneiss, and the last, S_3, is the flow structure of granitic rocks, already mobilized and intruded into the country rocks.

Layered gneiss

This group of the regional metamorphic rocks includes all varieties between the fine-grained banded gneiss and the granitic migmatite, which is evidently characterized by a mobilization of the rock. The main part of them are regularly or irregularly layered gneiss of pelitic composition and plagioclase-porphyroblastic granite with some agmatitic gneiss, small-folded gneiss, and nebulitic gneiss.

The pelitic gneiss layers in these rocks always have plagioclase-porphyroblasts, some of which are more than 3 cm in size, arranged parallel to the gneissosity plane, but have no linear arrangement on the plane. The thicknesses of the individual layers vary from a few cm to 3 m, and they can be followed along the strike direction, sometimes for more than a hundred metres in a thick layer.

In the middle part of the Blessingberget area and the western half of the Sverdrupfjellet area, thin layers of the fine-grained banded gneiss are still preserved in the core of thick, pelitic gneiss layers. The primary compositional bandings have usually been lost in the layered gneiss. However, some thick gneiss layers still have many shadowy micro-folded structures and faint alternations of pelitic and quartzitic layers. The siliceous layers are also feldspathized and have a composition of quartz-rich aplitic gneissose granite. Some granitic layers in the layered gneiss are evidently granitized siliceous layers of above-mentioned type.

While the large parts of the granitic layers have a composition of plagioclase-porphyroblastic granodiorite to quartz diorite, mostly concordant to the general layered structure, some are slightly oblique and often have a garnet-bearing aplitic granite composition.

These granitic layers increase in number and gradually transform into predominant granite facies, and locally become completely homogeneous plagioclase-porphyroblastic quartz diorite. The pelitic gneiss layers have been broken into thin and small patches, and the granite shows a streaky granite structure.

The plagioclase porphyroblastesis sometimes covers homogeneously both pelitic and granitic layers and change them into homogeneous metablastic granite, having faint traces of layered structure. In other cases, the granitic material penetrates the gneissosity planes, cross joints, and the axial planes of the small-folding of the gneissic layers, and form a polyvenite, nebulite, and agmatitic structure. These gneisses are more predominant in the eastern part of the area than in the western part.

Small calcareous masses occur, having small or large boudinage shape, in the layered gneiss. They are coarsely recrystallized marbles with a skarn zone around their margin with different stages of development. Some marbles have small graphite flakes scattered among the calcite grains. The skarn minerals are usually diopside-groussuralite paragenesis; some have wollastonite, serpentine, epidote and zoisite. A boudinage of marble at the western coast of Fuglebukta has a special skarn paragenesis of diopside, phlogopite, forsterite and spinel. The individual marbles are of short continuity, 20–100 m long, and as a whole, they occur in an en échelon arrangement, which is traceable over a long distance, indicating a general stratigraphic horizon.

Some amphibolites also occur in the layered gneiss, always having an agmatitic structure. Most of them are intensely recrystallized into gneissose amphibolite and contain a lot of biotite. They are also traceable on certain stratigraphic positions.

Granitic migmatite

This rock exposes typically in the eastern part of Larusfjellet, extending to the south in the upper part of the Kennedybreen, Frambreen and Sellströmbreen area.

The rock has a metasome of quartz-dioritic to grano-dioritic composition with many agmatitic and nebulitic paleosomes of biotite gneiss. One distinct layer of marble-with-skarn zone also occurs.

The gneissic paleosomes have characteristic spindle-shaped small bodies, elongated parallel to the main gneissosity. The gneissosity of the metasome flows around these paleosomes quite concordantly. Many different sizes of schlierens and streaks of gneissic rock are scattered in all parts of the sequence. The metasome itself is also very heterogeneous, showing well developed gneissosity.

These granitic migmatites transform gradationally from the layered gneiss with increase of their granitic layers in Fuglepyntfjellet, while in the Frambreen area, a plagioclase-porphyroblastic quartz diorite mass occurs between the layered gneiss and the granitic migmatite, and in the Sellströmbreen area a grey granite separates the granitic migmatite from the layered gneiss.

In the upper part of the Kennedybreen and Frambreen area, the granitic migmatite has several zones of predominant gneiss, including a marble layer, 10–15 m thick, which is nearly parallel to the general structure of the layered gneiss. The marble layer is traceable from the northern shore of Lestrisbreen, the top of Tringafjellet, goes round to the east of the 845 m peak in Jegerfjellet, to the upper part of Sellströmbreen, indicating a stratigraphic horizon of the original rocks of granitic migmatite.

The granites

There are three different kinds of granitic rocks in this area. Two of them have more or less concordant occurrences with the structure of the surrounding metamorphic rocks, while the third one is a completely independent intrusion, which is continuous with the large batholith, called the Hornemantoppen quartz monzonite, extending to the south.

The former two, the grey granite and the plagioclase-porphyroblastic granite, are not of true granite composition, but a quartz-dioritic to granodioritic one.

The grey granite occurs as small bodies in the granitic migmatite area, sometimes as sharp-cut dykes, but in other cases without any sharp boundary against the country rocks. This rock has almost homogeneous granodioritic to quartz-dioritic composition, not gneissose, and no gneissic schlierens and paleosomes. This granite might be a mobilized and homogenized granitic product of the migmatization, and might have intruded slightly later than the formation of the migmatite.

The same kind of homogeneous but somewhat leucocratic granitic rock occurs in the eastern part of Vestplana, having a sharp contact against the granitic migmatite in the east and a narrow agmatite zone against the granitized layered gneiss in the west.

The plagioclase-porphyroblastic granite occurs in the south-western part of the area from Vestplana to Uddevallaryggen, and in the middle part of Blessingberget, filling the core of the synform structure of the metamorphic rock. This rock is characterized by a large amount of subidiomorphic plagioclase-porphyroblasts, and has a quartz-dioritic composition. The western margin of the granite has a moderate amount of pink-coloured potash feldspars; thus the rock is of a more truly granitic composition. Such a type of granitic part is also developed as some layers in the eastern half of the mass, parallel to the general gneissosity of the rock. The western border of the granite, against the fine-grained banded gneiss, is very sharp, representing a drag contact, while in the east the granite has a sharp but intrusive contact against the granitized layered gneiss.

This granite may be the end product of the granitization of regional metamorphic rocks, and might be emplaced in the syn-kinematic stage of the metamorphism. The lithologic characteristics of the rock are almost the same as the granitic layers in the layered gneiss.

The red granite of a quartz-monzonitic composition occurs in small areas at the south-western end of the Vestvallafjellet area. The rock has a lot of large, reddish potash feldspars, weak gneissosity, and is very often massive. The contact against the plagioclase-porphyroblastic granite is a sharp, intrusive one. This granite extends to the south and continues to the large Hornemantoppen batholith, established by GEE and HJELLE in 1965.

Description of the structure

MESOSCOPIC TECTONIC ELEMENTS

All kinds of regional metamorphic rocks have a distinct, banded structure, the characters of which, however, in different kinds of rocks differ.

As already mentioned in the foregoing chapter, the schistose cleavages of the fine-grained banded gneiss are roughly parallel to the layered structure of the original sedimentary material. These cleavages and the original compositional layering have been defined as S_1, which may represent the structure of the original sedimentary sequence.

In the layered gneiss the main banded structure is composed of a granitic layer with or without plagioclase-porphyroblasts and medium-grained biotite gneiss in which the S_1 planes have been folded intensely into drag folds. The granitic layers were concordant seams at the crests of the drag fold of the S_1 planes, and were stretched along the direction of axial surface of the fold into elongated lenses.

The layered structures in the layered gneiss are thus parallel to the axial plane of the folded S_1 plane. Fine-grained banded gneiss remnants in the layered gneiss rarely preserve the S_1 planes, which show intense minor folds of similar type and drag type. These minor folds of the S_1 plane might be formed in connection with the emplacement of the granitic rock.

The gneissose structures in the granitic migmatite and in the plagioclase-porphyroblastic granite are a kind of flow structure of the mobilized granitic material, concordantly enclosing many gneissic paleosomes.

The linear structure in the fine-grained banded gneiss is a striation on the cleavage plane, which is well observed in the pelitic gneiss. No mineral arrangements have been seen. The linear structure in the layered gneiss is the axis of the minor folds of the S_1 plane, and is parallel to the elongation of the feldspathic seams in the plagioclase-porphyroblastic gneiss. However, the plagioclase-porphyroblasts themselves have no regular arrangement on the gneissosity plane.

No predominant linear structures were observed in the granitic migmatites or the plagioclase-porphyroblastic granites, but locally the elongation of the gneissic paleosomes shows a weak arrangement.

Thus there are three different mesoscopic tectonic elements: 1) the S_1 cleavage and striation-lineation, formed in connection with the regional folding of the metamorphic rocks; 2) the axial plane gneissosity and microfold axis of the S_1 plane, formed later than the S_1 formation, having close relations to the formation of the granitic layers in the layered gneiss; 3) the flow structure and elongation of the paleosomes produced by the plastic movement of mobilized granitic material.

In general the first one might be related to the regional metamorphism, and the latter two have been produced in connection with the formation of granitic migmatites and the emplacement of granitic massifs.

GENERAL STATEMENT AND THE DIVISION OF THE TECTONIC UNIT

The general structure of this area is essentially illustrated by the relation between the regional metamorphic rocks and plagioclase-porphyroblastic granites.

For convenience, and to summarize these structures, the whole area has been divided into four topographic areas, marked I, II, III, and IV, and furthermore, each topographic area has been subdivided into three tectonic subunits according to the lithological characteristics, roughly corresponding to the divisions of the fine-grained banded gneiss, the layered gneiss, and the migmatite-granite areas (Fig. 2). From statistical consideration on the Schmidt projection of the structural elements, the general characteristics of each tectonic subunit will be described here with reference to the fabric diagrams, and summarized as a whole in the last part of the description.

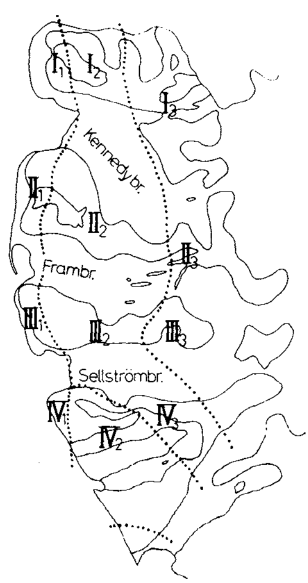

Fig. 2. *Tectonic subdivision of the Smeerenburgfjorden area.*

DESCRIPTION OF THE TECTONIC SUBUNITS

I area

This topographic area includes all mountains north of Kennedybreen.

I-1. – This subunit is mainly composed of the fine-grained banded gneiss showing well preserved original compositional layering. Both gneissosities and lineations in this subunit have a small deviation of strike and dip (Figs. 3, 4). The gneissosity has a rough N-S strike and a vertical to steep dip to the east. The estimation of the β from the gneissosity diagram is somewhat arbitrary, because of their small scattering. The measured lineations have a trend of deviation on two large girdles on the diagram. The variation in the N–S direction is due to the striation-lineation, and the E–W variation is caused by the small drag folds around the aplitic layers in the gneiss.

I-2. (Figs. 5, 6). – This subunit is mainly composed of the layered gneiss, gradationally changing into the granitic migmatite in the east. A plagioclase porphyroblastic granite mass occurs in this area, having indistinct borders. The gneissosities are scattered from the N–S to NW–SE strike because of some disturbances by the formation of layered structure and the emplacement of the plagioclase-porphyroblastic granite. The lineations are spread into a large girdle in the N–S direction, and coincide well with the estimated β from the gneissosity diagram. This may mean that these linear structures have been formed earlier than the formation of the plagioclase-porphyroblastic granite and that they have been disturbed in the girdle later. Some cross-cut aplite dykes have almost vertical strike against the general gneissosity of the layered gneiss.

I-3 (Figs. 7, 8). – This area is mostly composed of the granitic migmatite with a small amount of layered gneiss. The scattering range of the gneissosity projec-

Fig. 3

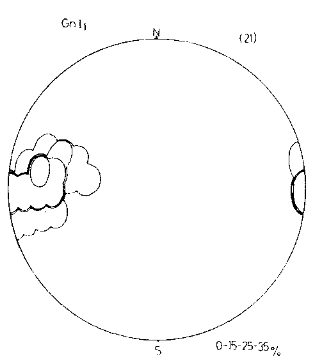

Fig. 4

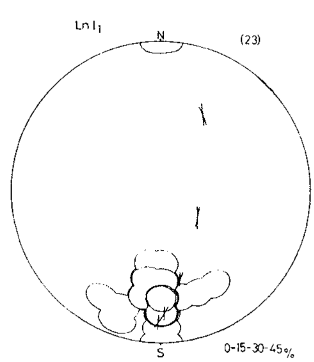

Fig. 3. *Schmidt net projection of the gneissosities from subunit I_1. All fabric diagrams are projected in the lower hemisphere of the Schmidt net, and the number of measurements is at the upper right. The number of the lower right is concentration percentages of the contours.*

Fig. 4. *Projections of the lineations from subunit I_1. The cross marks are the estimated β from the gneissosity diagram of the same area.*

tions and lineations is larger than in the former two subunits, but has the same trend of deviation as the I-2 subunit. The estimated main β coincides well with the maximum of the measured lineation. The lineations deviate over an incomplete large girdle. The linear structures in this subunit are always observed on the gneissosity planes of the gneissic paleosomes, and are evidently older than the mobilization of the metasome of the granitic migmatite.

The lineation diagram shows two trends of deviation; one trend is nearly in the N–S direction with different dips and the other has a well concentrated maximum in the SE direction. The former coincides roughly with the general deviation of lineations in the I-2 subunit, but the latter is characteristic of the area where the granitic migmatite is predominant.

II area

This topographic area includes all mountains between Kennedybreen and Frambreen with Archerfjellet on the top of Frambreen.

II-1 (Figs. 9, 10). – This area is composed mainly of the layered gneiss with small occurrences of fine-grained banded gneiss in the western part of Strindbergfjellet. The main deviation of the gneissosities is the difference in dip towards the east, together with some deviation of strike from N–S to NE–SW. This deviation means that the gneiss rperesents the eastern limb of an open antiform structure, the axis of which may lie slightly west of the shore, with a rough N–S strike, and a gentle dip to the south. The lineation maximum indicates the direction of the axis of estimated antiform structure of the original fine-grained banded gneiss.

II-2 (Figs. 11, 12). – The western half of the subunit is mainly composed of the layered gneiss with well developed aplitic granite and plagioclase-porphyroblastic granite layers. Intensely small-folded, fine-grained gneiss occurs in the middle of this subunit. The eastern half is composed of a homogeneous plagioclase-porphyroblastic granite, showing a sharp boundary to the layered gneiss. The main deviation trend of the gneissosity is from N–S to NW–SE, which is the same as in the I-2 subunit, while the dip towards east is more gentle than that of the latter. A few projections, scattering across the middle of the northern hemisphere of the diagram, show that here exists a local open synform structure which has been intensely disturbed by formation of the layered gneiss, the gneissosities of which have been formed along the axial planes of the re-folded preexisting folds. The nose of this synform is situated at the drag tip of the plagioclase-porphyroblastic granite, which extends widely to the south-east.

The observed lineation diagram has two distinct characters; one, including the second maximum, is the deviation on an incomplete large girdle, which coincides very well with the estimated β from the gneissosity diagram. The second, with the main maximum, corresponds to the axis of the estimated open synform, with a NW–SE strike and a gentle dip to the SE. The angle between the main and the second maximum is about 45°–50°.

II-3. – This is the area of the granitic migmatite. In the western part of the area the rock is gradationally transformed to the homogeneous plagioclase-porphyro-

Fig. 5

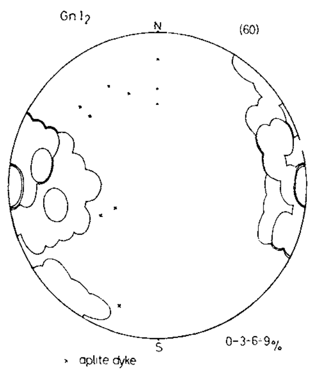

Fig. 6

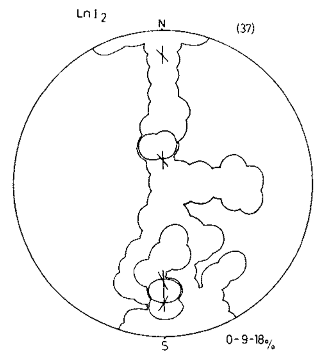

Fig. 7

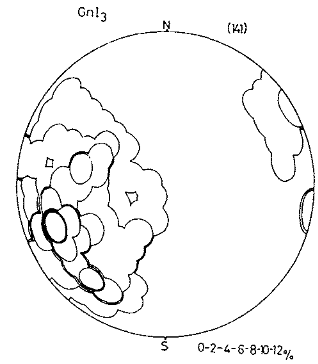

Fig. 8

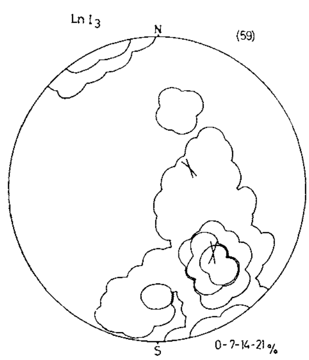

Fig. 9

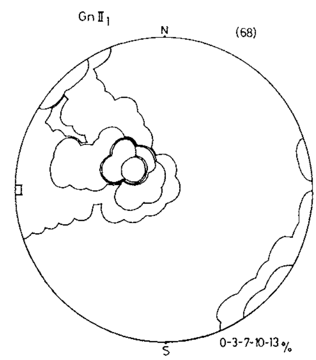

Fig. 10

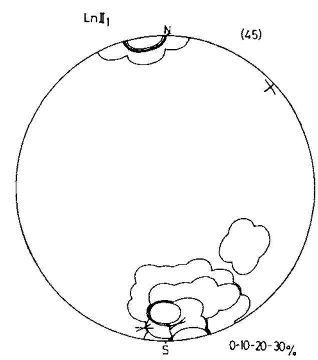

Fig. 11

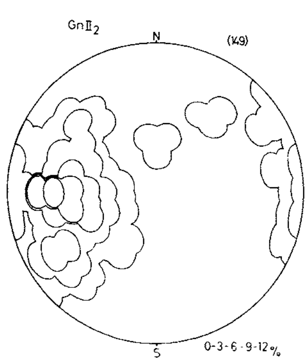

Fig. 12

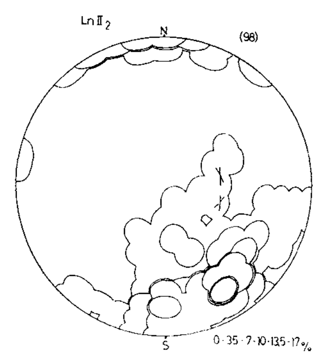

Fig. 13

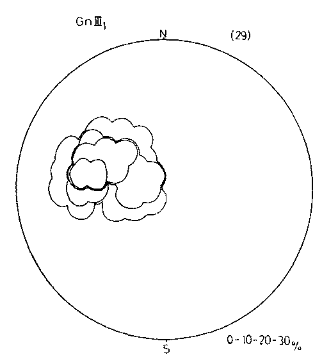

Fig. 5. *Projection of gneissosities from subunit I_2.* Fig. 6. *Projection of lineations from subunit I_2.* Fig. 7. *Projection of gneissosities from subunit I_3.* Fig. 8. *Projection of lineations from subunit I_3.* Fig. 9. *Projection of gneissosities from subunit II_1.* Fig. 10. *Projection of lineations from subunit II_1.* Fig. 11. *Projection of gneissosities from subunit II_2.* Fig. 12. *Projections of lineations from subunit II_2.* Fig. 13. *Projection of gneissosities from subunit III_1.*

blastic granite. A discontinuous agmatitic amphibolite layer occurs around the western border of the rock. The number of measurements from this subunit have not been sufficient to make a contoured diagram. The general trend of the structure is illustrated on the gneissosity and lineation map (Figs. 31, 32).

III area

The mountains between Frambreen and Sellströmbreen are included in this topographic area.

III-1 (Figs. 13, 14). – This subunit is the area of the fine-grained banded gneiss with concordant layers of the aplitic granite. A distinct character of the gneissosity diagram is a gentle dip of all gneissosities. The dips are relatively steep in the east and gentle in the west coast area; thus the structure forms the eastern limb of an open antiform, the axis of which may be situated slightly west of the coast. The main maximum of the observed lineation is in the N–S direction, with a gentle inclination, and the second maximum is roughly 45°E from the main maximum.

This mutual relation is the same as that of the I-3 and II-2 subunits, i. e., the main maximum represents the folding trend of the regional metamorphic rock, and the second one may reflect the structural disturbance due to the emplacement of the plagioclase-porphyroblastic granite in the IV-2 subunit.

III-2 (Figs. 15, 16). – This subunit is composed of the layered gneiss with the aplitic granite in the west and the plagioclase-porphyroblastic granite as its granitic bands in the east. The strikes of the gneissosities deviate in a wide range from N–S to NW–SE. The N–S striking ones have moderate dips to the south-east in the eastern part of the area, while the NW–SE ones are steep to the north-east in the western part. The plagioclase-porphyroblastic granite in this subunit has mainly a NW–SE strike and a gentle dip to the south-east. The lineation diagram has nearly the same trend as that of the II-2 and III-1 subunits, i. e., one maximum coincides with the regional β, and the other, with the structure of the plagioclase-porphyroblastic granite. However, the estimated β in this subunit does not coincide with the maximum of the observed lineation, but corresponds with the supposed axis of the synform structure of the plagioclase-porphyroblastic granite in the south, the IV-2 subunit.

III-3 (Fig. 17). – This is the area of the granitic migmatite with many concordant schlieren of the layered gneiss. A distinct marble layer is included in the migmatite.

The gneissosity diagram shows a swing of the strikes. This swing is actually seen in the eastern part of Sverdrupfjellet, caused by the emplacement of the plagioclase-porphyroblastic granites, one in the II-2 subunit in the north, and another in the IV-2 subunit in the south-west.

The lineation could not be measured because the rock is a coarse-grained granitic migmatite without any distinct linear structure on the gneissosity plane.

Fig. 14

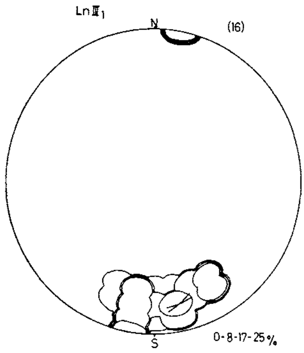

Fig. 15

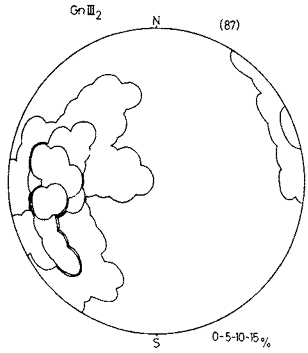

Fig. 16

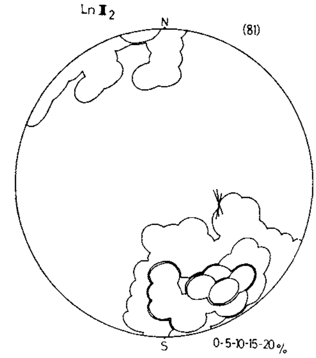

Fig. 17

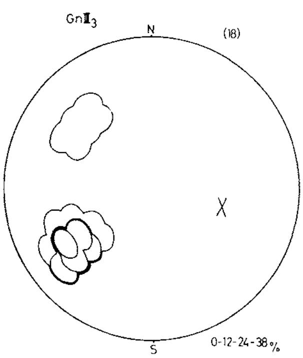

Fig. 18

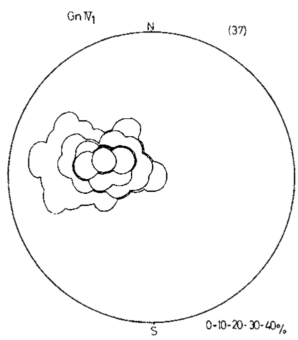

Fig. 19

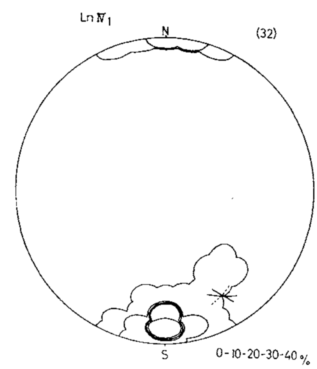

Fig. 20

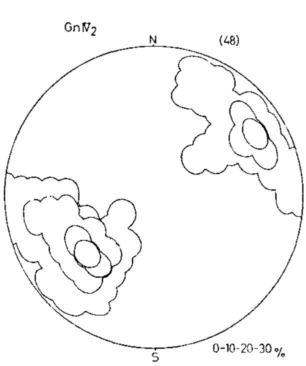

Fig. 21

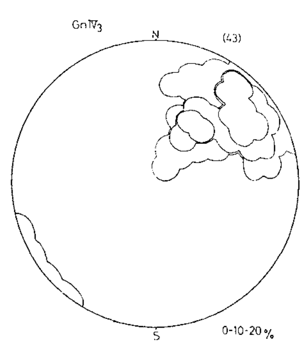

Fig. 22

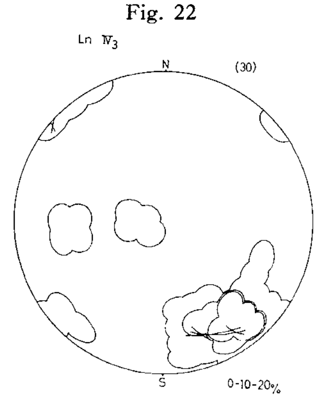

Fig. 14. *Projection of lineations from subunit III_1.* Fig. 15. *Projection of gneissosities from subunit III_2.* Fig. 16. *Projection of lineations from subunit III_2.* Fig. 17. *Projection of gneissosities from subunit III_3.* Fig. 18. *Projection of gneissosities from subunit IV_1.* Fig. 19. *Projection of lineations from subunit IV_1.* Fig. 20. *Projection of gneissosities from subunit IV_2.* Fig. 21. *Projection of gneissosities from subunit IV_3.* Fig. 22. *Projection of lineations from subunit IV_3.*

IV area

This is the area south of Sellströmbreen, including Vestplana, Vestvallafjellet and Uddevallaryggen, the southernmost area of the mapped district.

IV-1 (Figs. 18, 19). – This is the western half of the synform, which is filled with the Vestplana plagioclase-porphyroblastic granite, and is composed of the fine-grained banded gneiss and plagioclase-porphyroblastic biotite gneiss. All gneissosities of these rocks have nearly the same strike, but have a wide deviation range of the dips, all of them towards the east. The steep ones are from the western coast area, and the gentle ones, from the eastern part, near the plagioclase-porphyroblastic granite in the east, thus representing the western limb of an open synform in the east of this subunit. The lineation maximum from these rocks still has good coincidence with the regional β axis, and does not coincide with the axis of granite synform which has a strike of S 45°E.

IV-2 (Fig. 20). – This subunit is occupied by a gneissose plagioclase-porphyroblastic granite. The gneissosities of the rock represent an asymmetric synform with steep limbs striking NW–SE and a gently dipping axis to the south-east. This is one of the most typical mode of occurrences of the plagioclase-porphyroblastic granite in the area. Some pink potash feldspar-rich facies develop parallel to the synform structure near the margin of the granite. No lineation was observed in this rock.

IV-3 (Figs. 21, 22). – This is the eastern limb of the synform, whose core is occupied by the plagioclase-porphyroblastic granite. The dips deviate from steep in the eastern part to gentle in the western, near to the granite. The lineation maximum coincides well with the axis of the granite synform and the estimated β from the gneissosity diagram. The difference in lineation maximum between the IV-1 and the IV-3 subunits indicates that the former is the primary structural trend of the regional metamorphic rocks, while the latter has been produced by the emplacement of the granite mass. It may be suggested that the formation of the layered gneiss in the eastern limb is closely related to the development of the plagioclase-porphyroblastic granite.

The joint system

As a general impression in the field, the distinctly gneissose and banded rocks usually have a well developed cross and parallel joint system, while homogeneous granitic rocks have a cubical system of joints.

Measurements have been done on three distinctly developed joint sets at one observation point, and plotted on the Schmidt net for each topographic unit separately. The projections are scattered very much without any tendency. However, in general, the cross joints are predominant in the II and III areas, while the parallel joints develop in the I area. The IV area has both parallel and cross equivalent joints (Figs. 23, 24, 25, 26).

SUMMARY OF THE GEOLOGICAL STRUCTURE

To catch the general structure of the whole area, the maxima from each fabric diagram have been reprojected synthetically on a diagram (Figs. 27–30).

The maxima diagram of the gneissosity (Fig. 27) shows that the main gneissosity has a N–S strike with a deviation of 30°–40° to the NW–SE; all of them are dipping to the east. The fine-grained banded gneisses have well concentrated maxima, as in the I-1, II-1 and IV-1 subunits, within the above-mentioned deviation range of the strike. The deviation itself took place in connection with the formation of the layered gneiss, which is characterized by concordant layers of the plagioclase-porphyroblastic granite. Another deviation of the gneissosity traverses the diagram in its northern hemisphere, representing an open synform structure, the axis of which dips very gently to the south-east, and the core of the synform is occupied by the plagioclase-porphyroblastic granite.

The estimated β axes from each gneissosity diagram are projected on another diagram together with the estimated local synform axes of the granitic rocks (Fig. 28). The former ones show a large girdle with a small lateral deviation. This girdle deviation means that this was formed by the refolding of the S_1 gneissosities during the formation of the layered gneiss, illustrated by a N–S～NW–SE deviation of the strike of the gneissosity. The estimated synform axes concentrate around S 30°～50° E with a relatively gentle dip to the south-east.

The maxima diagram of the observed lineations (Fig. 29) has good coincidence with what is expected from the estimated β diagram mentioned above. One trend has a large girdle distribution and the other concentrates in the position where the granite synform axes are. The girdle has a large concentration around the S end of the diagram, and this is mainly composed of the maxima from the fine-grained banded gneiss area. (See Fig. 2, areas I-1, II-1, and IV-1.)

This evidence suggests that the original structural axes of the regional metamorphic rocks might be about this direction, i. e., a N–S strike with a gentle dip to the south. During the transformation of the rock from the fine-grained banded gneiss to the layered gneiss, the schistose cleavages of the former were refolded in similar folds and drag folds, the axial surfaces of which were followed by the plagioclase-porphyroblastic granite, and the layered gneiss was the result. This refolding of the cleavages caused the fracturing of the gneissosity in the layered gneiss, and the striation-lineations were disturbed on the Schmidt net. The new lineations of the micro-folding axis have their strike in a N–S direction and a moderate dip to the south. All these structures have been disturbed again by the emplacement of the plagioclase-porphyroblastic granite. As mentioned above, the granites occupy the core of the synform structures, the axes of which have a NW–SE direction and a gentle dip to the south-east. These axes are nearly 45° from the axes of the regional folds. Conclusively, the granites have been emplaced in a diagonal direction to the regional structures of the metamorphic rocks, showing an en échelon arrangement.

Fig. 23

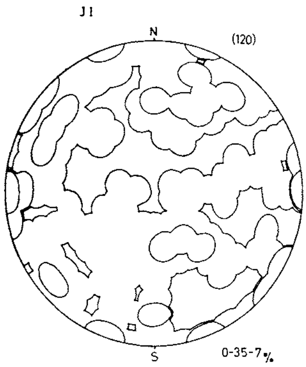

Fig. 24

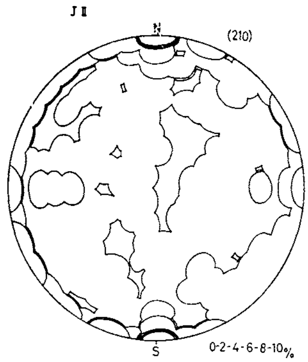

Fig. 25

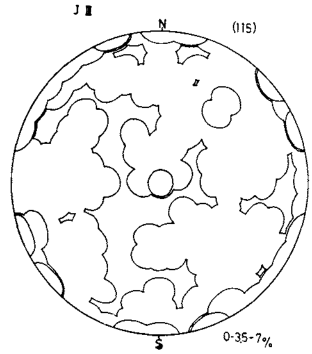

Fig. 26

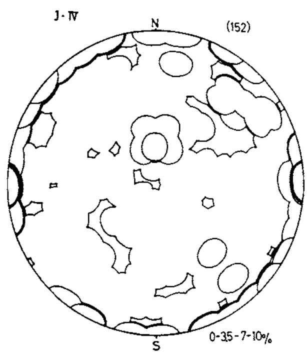

Fig. 27

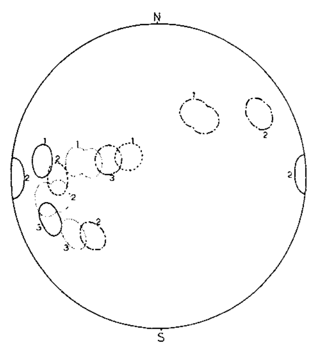

Fig. 28

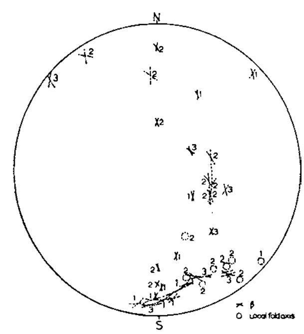

Fig. 29

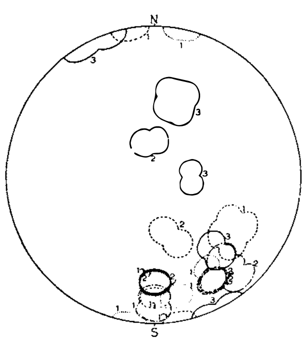

Fig. 30

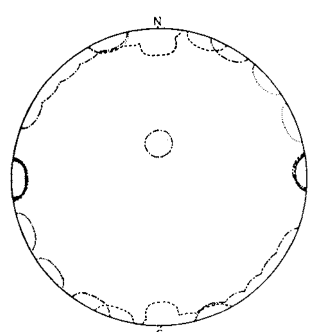

Fig. 23. *Projection of joints from I area.* Fig. 24. *Projection of joints from II area.* Fig. 25. *Projection of joints from III area.* Fig. 26. *Projection of joints from IV area.*

Fig. 27. *Summarized projection of maxima of gneissosity from each subunit. Lined circles: The I area, broken line circles: The II area, chain circles: The III area, dotted circles: The IV area. The numbers in the figure represent the subareas of each topographic unit.*

Fig. 28. *Summarized projection of estimated β from each gneissosity diagram. The numbers and different curves are the same as in Fig. 27.*

Fig. 29. *Summarized projection of observed lineation maxima from each subunit. The numbers and different curves are the same as in Fig. 27.*

Fig. 30. *Summarized projection of joint maxima from each subunit. The different curves are the same as in Fig. 27.*

The maxima from four joint diagrams are also summarized in a diagram (Fig. 30). The maxima concentrate generally in the cross joint of the granite synform and in the parallel joint position of the regional metamorphic structures. The angle between these two sets of maxima is about 75°.

Conclusions

It is clarified that there are three different kinds of tectonic elements, each of which reveals a different phase of tectonism. The axial plane gneissosity of the layered gneiss is related both to the refolding of the schistose cleavage of the fine-grained banded gneiss and the formation of the granitic migmatite. The plagioclase-porphyroblastic granite shows a sharp and somewhat dislocated contact to the layered gneiss in Vestplana, while in other cases they transform gradationally from the layered gneiss. These evidences suggest that the granites have been formed as advanced products of plagioclase metablastesis in the syntectonic stage of the layered gneiss formation and have partially been mobilized and intruded into the gneiss along the diagonal fissures of the synform structure.

Two other granites, the grey granite and the Hornemantoppen quartz monzonite, cut all structures mentioned above, and are obviously the late and post-tectonic granite, respectively.

Before the formation of the layered gneiss, the original sedimentary rocks were already metamorphosed into the fine-grained banded gneiss.

Thus the three different gneissosities correspond to the different phases of tectonism, and the observed linear structures represent the same different phases. The striation-lineations on the schistose cleavage of the fine-grained banded gneiss show a pronounced maximum in the N–S strike with a gentle dip, re-folded by the formation of the layered gneiss, and are scattered into a girdle on the Schmidt net. The lineations of the minor folded axes in the layered gneiss are re-orientated around the granite synforms from the N–S strike to the NW–SE strike about 45°.

Three phases of tectonism in the metamorphic rocks around this area have already been described by GEE and HJELLE (1966) in the Krossfjorden area about 40 km south of the present area, where the schistosity of the micaceous rocks has been defined as F-1, the crenulation of these schistosities as F-2, and the refolding of the axial surface of the crenulation, following major antiform and synform structures, has been described as F-3.

The result obtained from the present survey supports very well the division of tectonic phases established by GEE and HJELLE, though the fabric diagram they presented in their paper is somewhat different from the present study because of the very small number of data at hand.

They also mentioned the metamorphic grade of the rocks in the Krossfjorden area. The highest metamorphism is said to occur in the formation of the F-1 structure, and the F-2 is characterized by the retrogression of the metamorphism. However, in the present area, the fine-grained banded gneiss is characterized by

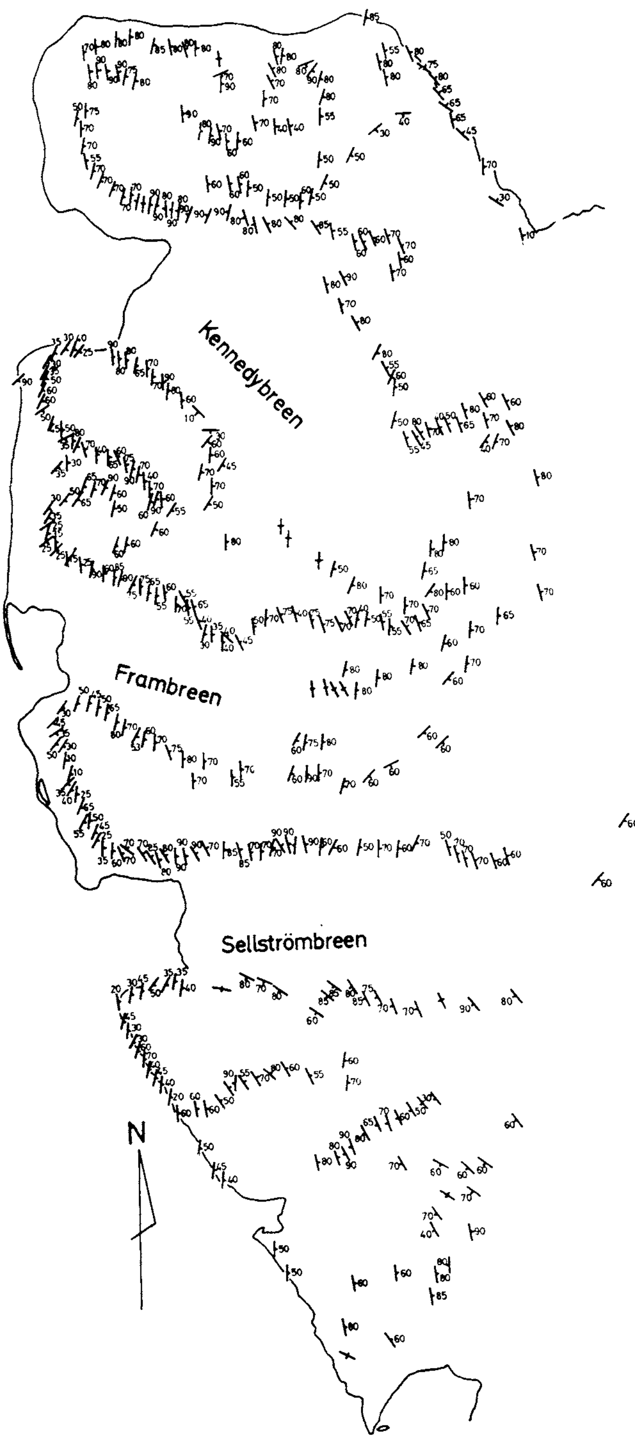

Fig. 31. *Gneissosity map of the Smeerenburgfjorden area.*

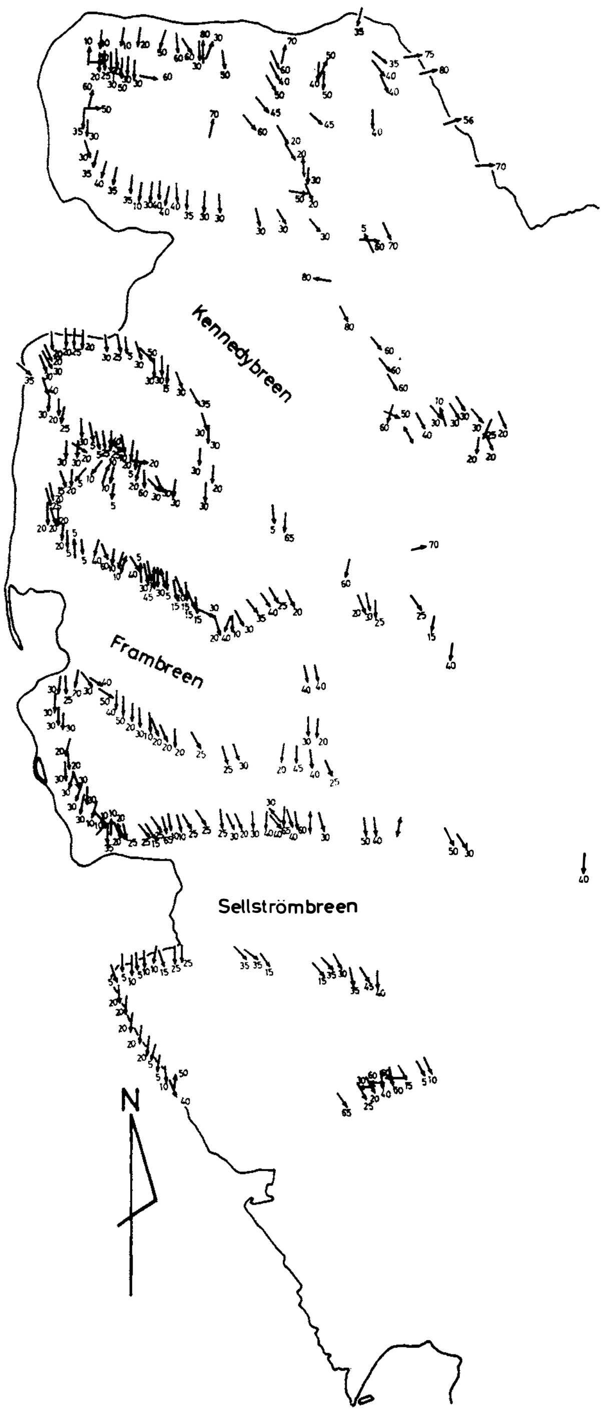

Fig. 32. *Lineation map of the Smeerenburgfjorden area.*

garnet-sillimanite-cordierite-biotite parageneses, and the layered gneiss has corundum-spinel-cordierite-sillimanite-biotite as its indicators of metamorphic grade in the pelitic rock, and a marble with forsterite-spinel-phlogophite skarn layer has been found in the granitic migmatite. These evidences clarify that the metamorphic grade of the F-1 stage is lower than that of the F-2 stage in the present area. However, since the general structure of the area from the Krossfjorden to the present area has a N-S strike and a gentle dip to the south, a shallower level of the metamorphic rocks is exposed in the south, in the Krossfjorden area, than in the present area. Therefore, the simultaneity of the different types of metamorphism at different levels may be expected. At any rate, the problems of the metamorphism will be discussed in a separate paper dealing with the bulk chemistry and mineral paragenesis of the rocks.

According to the stratigraphic classification in the paper of GEE and HJELLE, the metamorphic rock exposed in the present area is correlative with the lower part of the Nissenfjella Formation. Although a large part of the area has been strongly metamorphosed, some stratigraphic key layers, such as thin amphibolites and marbles, are still preserved. The estimated thickness of the metamorphosed sediment is about 4,000 m north of Kennedybreen, and 5,200 m in Sverdrupfjellet, presuming there is no repetition of the rock by folding.

Acknowledgments

The writer wants to express his heartful thanks to the director of Norsk Polarinstitutt, Dr. T. GJELSVIK, and the expedition leader, K. Z. LUNDQUIST, for giving him the chance to study in the Svalbard area, and for the necessary financial aids. He is also very much indebted to his two field assistants, Mr. T. JOHNSRUD and Mr. A. FOUGNER, who helped him during the expedition, and also to geologist A. HJELLE, who has given him a lot of advice about every kind of troubles. He thanks very much Prof. T. F. W. BARTH, who kindly recommended him to study this part of the Caledonian metamorphic area.

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PLATE I

a. *Fine-grained banded gneiss of pelitic composition with some plagioclase-porphyroblastic layers (west of Fuglepyntfjellet).*

b. *Siliceous layers in plagioclase-porphyroblastic gneiss (western part of Strindbergfjellet).*

c. *Marble mass in granitic migmatite (north of Lestrisfjellet).*

d. *Small folded part of fine-grained banded gneiss in layered gneiss (middle of Blessingberget).*

e. *Plagioclase-porphyroblasts on the gneissosity plane of plagioclase-porphyroblastic gneiss (west of Vestplana).*

f. *Feldspathized siliceous layer in granitic migmatite (west of Högstadiusberget).*

PLATE II

a. *Typical layered gneiss (north of Uriafjellet).*

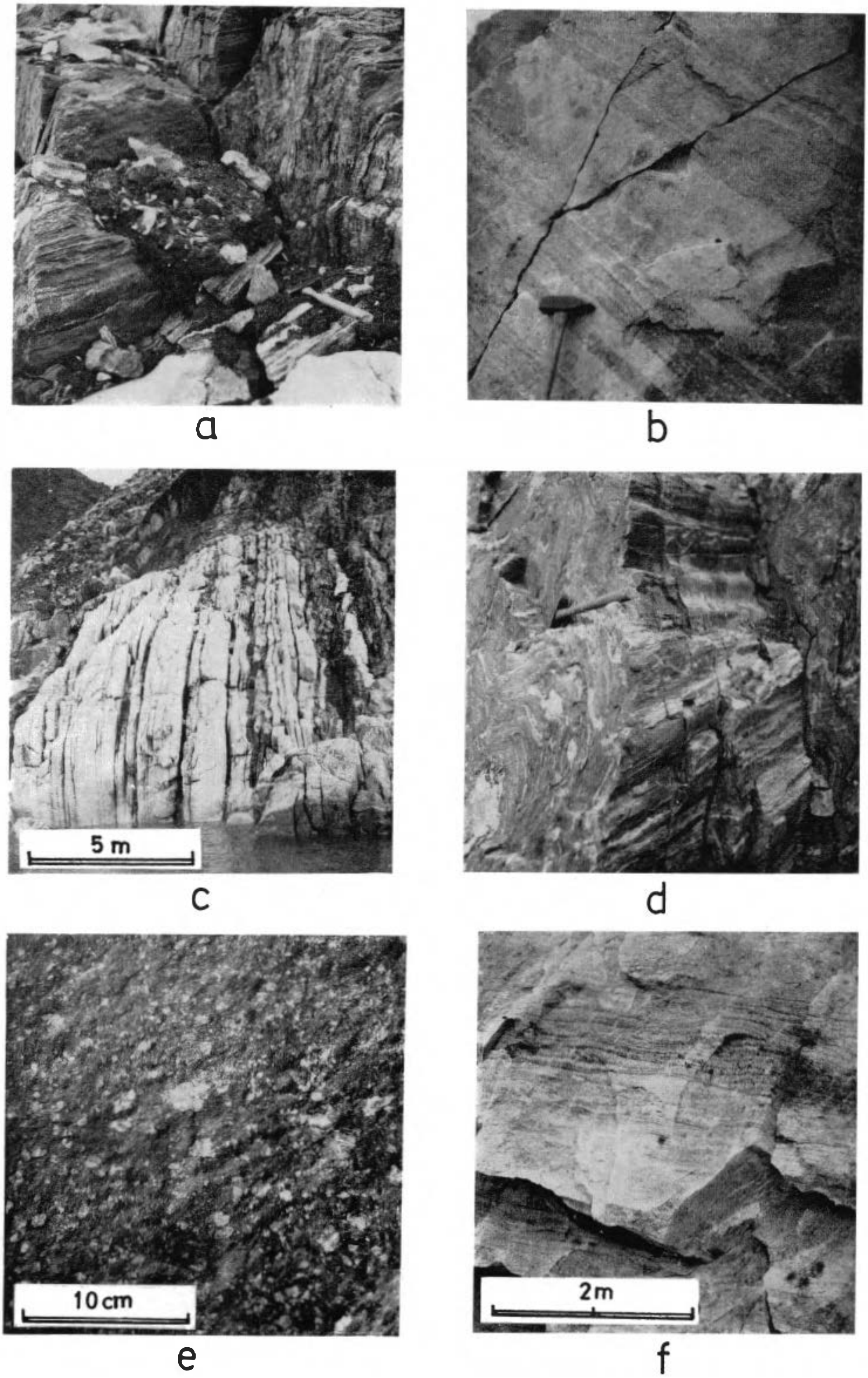
b. *Gneissic schlierens in the granitic migmatite (top of Uriafjellet).*

c. *Agmatitic paleosomes of the layered gneiss in the granitic migmatite (east of Lestrisfjellet).*

d. *Nebulitic part of the granitic migmatite (upper part of Kennedybreen, Sternafjellet).*

e. *Gneissic paleosomes in the granitic migmatite (upper part of Frambreen, Archerfjellet).*

f. *Homogeneous plagioclase-porphyroblastic granite (upper part of Vestvallafjellet).*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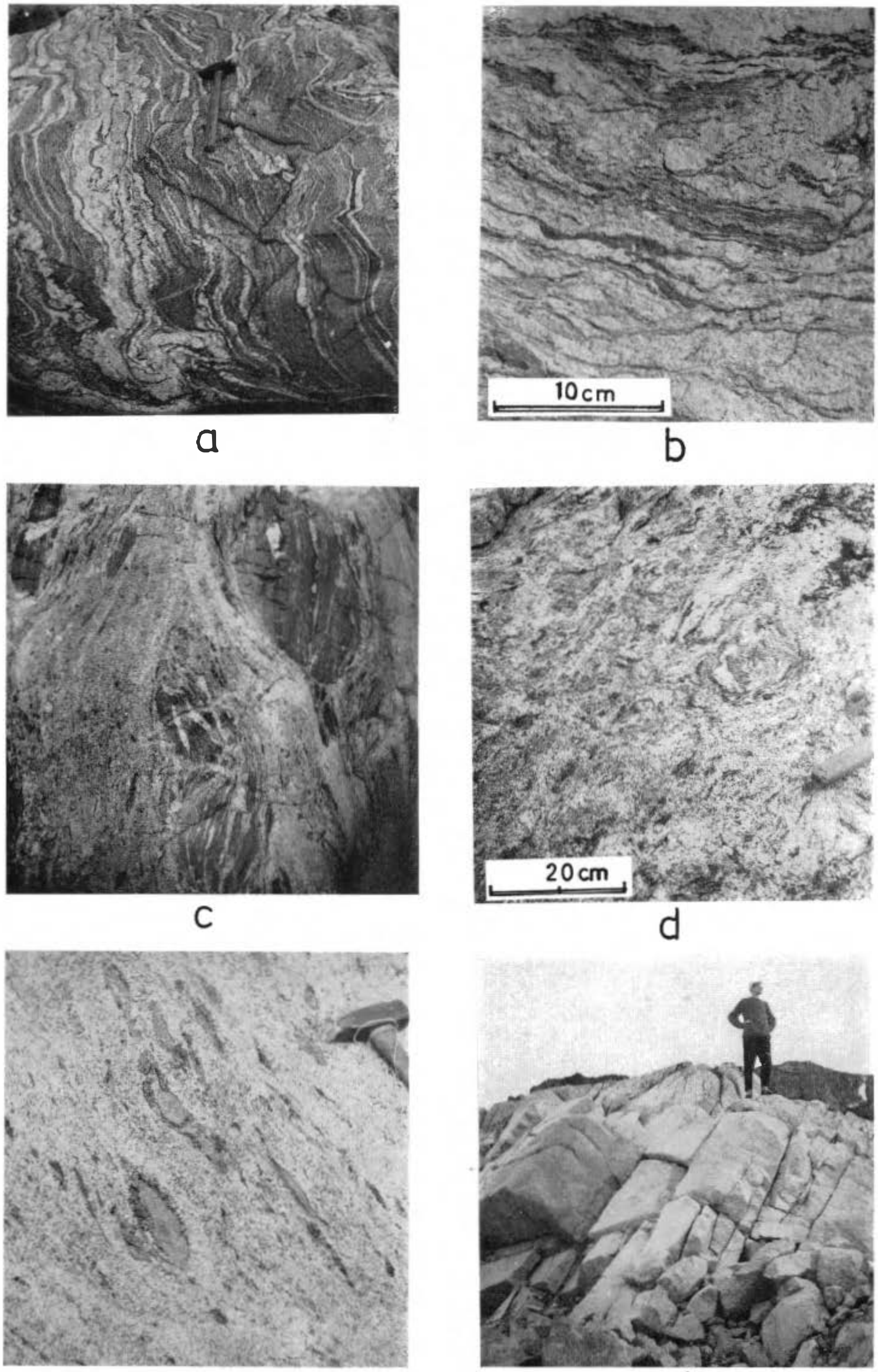
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Plants from the nunataks of Torell Land, Vestspitsbergen

BY

MARIAN KUC[1]

Abstract

The author identified plants collected by Doc. Dr. K. BIRKENMAJER in Torell Land in 1966. This area had till then not been investigated by botanists. The list of plants comprises 23 mosses and 19 vascular plants. A brief account of the geobotanical characteristics of the nunatak moss-flora is given. The distribution of the same mosses is shown on maps (Figs. 2–7) of the Spitsbergen archipelago.

Introduction

In the summer of 1966 Doc. Dr. KRZYSZTOF BIRKENMAJER made an interesting collection of plants on the nunataks of Torell Land, Vestspitsbergen, consisting principally of mosses and several vascular plants. The distribution of their localities is shown in Fig. 1.

Specimens studied were incorporated into the Herbarium of the National Museum of Canada, Ottawa (CAN).

The author wishes to express his thanks to Doc. Dr. K. BIRKENMAJER (Kraków, Poland), who gave me this collection and much valuable information, and to Dr. E. PORSILD (Ottawa, Canada), who was so kind as to verify my identification of the vascular plants.

Remarks on the moss-flora of nunataks of Torell Land

The present collection together with another one made by Doc. Dr. K. BIRKENMAJER in the north-east Sørkapp Land, Vestspitsbergen (KUC 1963a), and floristic data published by the author from the north coast of Hornsund, Vestspitsbergen (KUC 1963b), and in his manuscript, make up our knowledge of the nunatak moss-flora of this region.

Geobotanically, it is characterised by negative features. The number of species

[1] The National Museum of Natural Sciences, Ottawa, Canada.

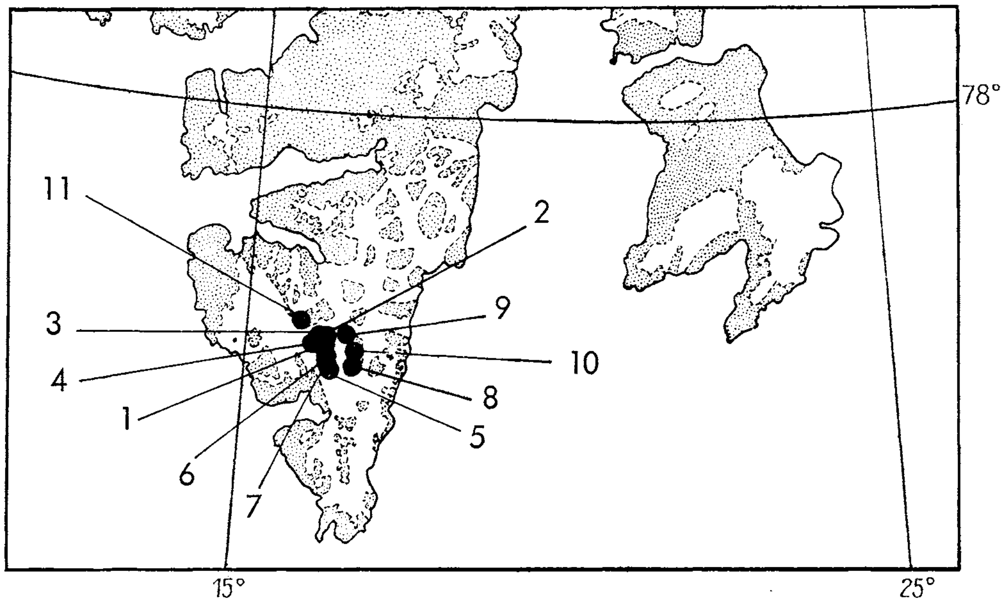

Fig. 1. Plant localities on nunataks of Torell Land: 1 – Langleiken, 2 – Blankfjella, 3 – Blåklettryggen, 4 – Trekløveren, 5 – Mezenryggen, 6 – Cholmfjellet, 7 – Cholmaksla, 8 – Stolbeinet, 9 – Besshø, 10 – Blåhø, 11 – Kopernikusfjellet.

growing there is much smaller than in the coastal part of Torell Land. As hitherto, mosses with ranges limited to the nunatak zone, or growing only there but not in other Arctic habitats, are not known. The majority of species have large life-scales and can occur not only in other Arctic environments but also in the temperate zone, even in forest communities, for instance, *Ceratodon purpureus, Drepanocladus uncinatus, Hylocomium splendens, Pohlia cruda, P. nutans, Polytrichum juniperinum, Rhacomitrium canescens* and others. Mosses of nunataks belong to wide plant-geographical elements: the pan-continental (*Ditrichum capillaceum, Hylocomium splendens, Mniobryum wahlenbergii, Pohlia cruda, P. nutans, Polytrichum juniperinum, P. piliferum, P. strictum, Tortula ruralis* and some others), the bipolar-mountains (*Andreaea rupestris, Calliergon sarmentosum, Drepanocladus uncinatus, Hypnum revolutum, Pogonatum alpinum, Rhacomitrium lanuginosum*), the alpine-arctic (*Aulacomnium turgidum, Cirriphyllum cirrosum, Cynodontium virens, C. wahlenbergii, Dicranoweisia crispula, Timmia austriaca* and others), the circumboreal (*Ditrichum flexicaule, Pogonatum urnigerum, Rhacomitrium canescens* and others). There are only a few mosses whose ranges are limited to the Arctic (*Bryum teres, Polytrichum fragile, P. hyperboreum*). In the morphology and anatomy of mosses from nunataks frequent anomalies and torn leaves occur, although these are relatively rare among specimens developed on tundra or in sheltered conditions. Other changes are also clearly seen such as these dwarf habits, scarcity of leaves; short, poorly branched and thin stems, which are usually very fragile. The production of sporophytes is a very rare phenomenon.

Nunataks are poorly covered by vegetation. Large areas are completely free from the moss-cover, especially in places which are windswept, eroded by weather and ice, or changed by slope phenomena.

As a positive geobotanical feature of the nunatak moss-flora one can only cite the more frequent occurrence of *Polytrichum hyperboreum* (and *Cardamine bellidifolia, Papaver radicatum* and *Usnea sulphurea* from other taxonomic groups), and several small taxa, such as *Ditrichum flexicaule* f. *densum, Hypnum revolutum* f. *pygmaeum, Pogonatum urnigerum* var. *subintegrifolium, Rhacomitrium canescens* f. *epilosum, Timmia austriaca* var. *arctica, Tortula ruralis* f. *gracilis,* and some others. These show that environmental conditions on nunataks are extremely difficult for newcomers. The inland or nunatak zone of vegetation cannot be separated from the coastal zone by any sharp limit. However, the great floristic differences between the two are strikingly seen on such nunataks as Strykjernet, Braemfjellet, Tuva, and some semi-nunataks surrounding them. Nunataks situated farther inland have very poor vegetation.

List of localities

(The numbers refer to the localities given in Fig. 1)

1. Langleiken N, the S slope, 450–550 m elev. (mosses), 600–650 m elev. (vascular plants), on the fine shale scree.
2. Blankfjella SE, c. 570 m elev., on the coarse sandstone rubble.
3. Blåklettryggen N, c. 460 m elev., on the fine scree (shale, sandstone and clay ironstone) arranged in incipient polygons.
4. Trekløveren W, the S slope, c. 550 m elev., on the fine shale scree and sandstone blocks arranged in incipient polygons.
5. Mezenryggen SE, c. 250 m elev., on strongly weathered sandstones and stony moraines.
6. Cholmfjellet E, the S slope, c. 400 m elev., on the sandstone scree.
7. Cholmaksla E, c. 400 m elev., on sandstone and shale screes.
8. Stolbeinet, the S slope, 445–560 m elev., on the fine shale detritus, often wet from snow patches.
9. Besshø NW, 450–580 m elev., on the scree.
10. Blåhø W, c. 530 m elev., on shale and sandstone fragments arranged in polygons.
11. Kopernikusfjellet, the SW slope, 700–900 m elev.

List of species

Musci (only sterile specimens)

Andreaea rupestris HEDW.: 1.
Aulacomnium turgidum (WAHLENB.) SCHWAEGR.: 8, 10.
Bryum inclinatum (BRID.) BLAND.: 6.
B. teres LINDB.: 8.
Ceratodon purpureus BRID. (typ. and a form): 5.
Calliergon sarmentosum (WAHLENB.) KINDB. (f.): 4.
Cirriphyllum cirrosum (SCHWAEGR.) GROUT: 4 – Fig. 2.
Cynodontium wahlenbergii (WAHLENB.) C. HARTM.: 4, 11.

Fig. 2. *Cirriphyllum cirrosum* (SCHWAEGR.) GROUT.

Fig. 3. *Mniobryum wahlenbergii* (WEB. et MOHR) JENN.

Fig. 4. *Pogonatum urnigerum* (HEDW.) P. B.

Fig. 5 *Pohlia obtusifolia.* (BRID.) L. KOCH.

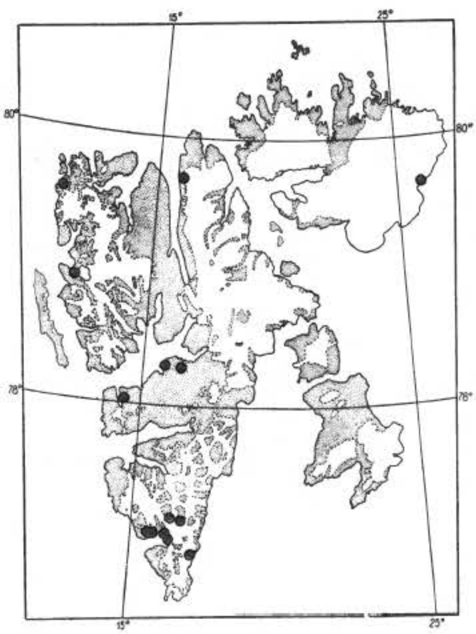

Fig. 6. *Polytrichum hyperboreum* R. Br.

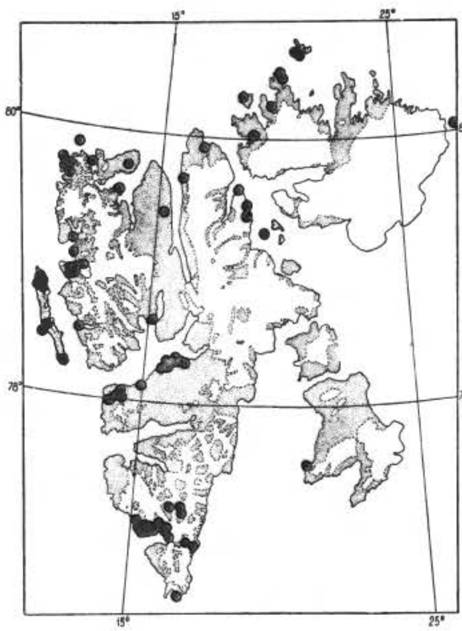

Fig. 7. *Rhacomitrium lanuginosum* (Hedw.) Brid.

Dicranoweisia crispula (Hedw.) Lindb.: 9, 11.
Dicranum elongatum Schleich.: 1, 10.
Drepanocladus uncinatus (Hedw.) Warnst. (typ. + var. *longicuspis* Z. Smirn.): 4, 8, 9.
Grimmia sp. (cf. incurva): 1.
Hypnum revolutum (Mitt.) Lindb. (f.): 4, 10.
Mniobryum wahlenbergii (Web. *et* Mohr) Jenn.: 5 – Fig. 3.
Pogonatum alpinum Hedw.: 5.
P. urnigerum (Hedw.) P. B. var. *subintegrifolium* (Arn. *et* Jens.) Møll.: 1, 4, 10 – Fig. 4.
Pohlia cruda (Hedw.) Lindb.: 4, 9.
P. obtusifolia (Brid.) L. Koch: 10 – Fig. 5.
P. nutans (Hedw.) Lindb. (typ. and form): 5, 8.
Polytrichum juniperinum Hedw.: 4, 5, 8.
P. hyperboreum R. Br.: 5, 8 – Fig. 6.
Rhacomitrium canescens (Hedw.) Brid. (f. *epilosum*): 4, 10, 11.
R. lanuginosum (Hedw.) Brid.: 1, 9, 10 – Fig. 7.

Vascular plants

Cardamine bellidifolia L.: 1, 4, 5, 8, 9.
Cerastium alpinum L.: 3, 4, 5, 7, 8.
Draba bellii Holm.: 5.
D. oblongata R. Br.: 7, 9.
D. subcapitata Simm.: 9.
Luzula confusa Lindeb.: 4, 9.
L. nivalis (Laest.) Beurl.: 8.
Oxyria digyna (L.) Hill.: 4, 7.
Papaver radicatum Rottb.: 1, 2, 3, 4, 5, 7, 8, 9, 10.
Phippsia algida (Sol.) R. Br.: 10.
Poa arctica R. Br.: 9.
Potentilla vahliana Lahm.: 9.
Ranunculus sulphureus Sol.: 1,8.
Sagina intermedia Frenzl.: 1, 9.
Salix polaris Wg.: 1, 2, 3, 9, 10.
Saxifraga caespitosa L.: 1, 8.
S. caespitosa ssp. *uniflora* (R. Br.) Porsild: 4, 7.
S. cernua L.: 4, 5, 7, 8, 10.
S. rivularis L.: 11.

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KUC, M., 1963a: Bryophytes from the northeast of Sørkapp Land, Vestspitsbergen. *Norsk Polar-inst., Årbok* **1962.** 140–145.

— 1963b: Flora of mosses and their distribution of the north coast of Hornsund (SW Spitsbergen). *Fragm. Flor. et Geobot.* **9** (3); 291–366 and IX.

— MS. Phanerogams from Spitsbergen in Polish herbaria, particularly the flora of the north coast of Hornsund.

The Planetfjella group of the Lower Hecla Hoek of Ny Friesland, Spitsbergen

BY

ROGER H. WALLIS[1]

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Abstract

Detailed stratigraphy and description of the Planetfjella Group is given for northern Ny Friesland. Correlation and variation is described for outcrops in central and south Ny Friesland. The group is thought to represent a sedimentary assemblage transitional between the Harkerbreen Group arkosic and acid pyroclastic facies and the Lower Middle Hecla Hoek orthoquartzite-turbidite facies. The view that, in Ny Friesland, there is no stratigraphic break between the Lower Hecla Hoek and the Middle Hecla Hoek is confirmed.

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Introduction

The Planetfjella Group outcrops for over 100 km through the interior of Ny Friesland, from Verlegenhuken in the far north to Terrierfjellet in the south, see Fig. 1.

The object of the present study was to review the nature and origin of the Planetfjella Group, the uppermost division of the Lower Hecla Hoek in Ny Friesland, and to reinvestigate the form and position of the junction between the Lower Hecla Hoek, generally an amphibolite facies (s. 1.) group of metamorphic rocks, with the lower Middle Hecla Hoek above, a group of generally unmetamorphosed orthoquartzites and turbidites.

The earliest observations of any Planetfjella rocks were made by C. W. BLOMSTRAND in 1861 during a visit to northern Ny Friesland (BLOMSTRAND 1864). In this area he recognised the stratigraphically conformable contact with the overlying rocks and the transitional nature of the sedimentary lithologies, and he also briefly described the bulk stratigraphy. Further published work on the Planetfjella Group in north Ny Friesland is confined to that accomplished during the visit in 1933 of FLEMING and EDMONDS (1941); and that of C. B. WILSON, who visited the area in 1955 (WILSON 1958).

To the south FLEMING and EDMONDS (1941) and WILSON (1958) visited the Gullfaksebreen area and demonstrated the conformable nature of the Lower/Middle Hecla Hoek boundary and the uniform nature of the uppermost Planetfjella rocks southwards from Sorgfjorden through the Gullfaksebreen area to Veteranen.

Veteranen contains the original type area of the Group in the Planetfjella mountains, and this area was briefly described by ODELL (1927), FAIRBAIRN (1933), and FLEMING and EDMONDS (1941) prior to studies by M. B. BAYLY, W. B. HARLAND and C. B. WILSON, in the period 1949–1956; (HARLAND and WILSON 1956, BAYLY 1957, WILSON 1958, HARLAND 1959).

To the south of Veteranen some of G. W. TYRRELL's descriptions (TYRRELL 1922) are of Planetfjella rocks, and the outcrops about Nordenskiöldbreen have been mapped by Cambridge parties during the periods 1949–53 and 1962–1965.

The author studied the northern sector, see Fig. 1, in 1965 and 1967, the central sector in 1967, and north Veteranen in 1964 (HARLAND 1965, HARLAND and WALLIS 1966, WALLIS and HARLAND 1968). South Veteranen, the original type area, and the southern sector have been described by BAYLY (1957), WILSON (1958), and HARLAND (1959). Thus the author has visited over 60% of the outcrop, and though he has not worked in the original type area, he has had access to the collections from south Veteranen available at the Sedgwick Museum, Cambridge.

HARLAND, WALLIS and GAYER (1966) have given a brief description of the stratigraphy and lithologies of the northern sector. This study, however, extends, revises and completes the descriptoin of the northern and central areas, and correlates these with exposures in south Ny Friesland. Thus this paper continues the series (GAYER and WALLIS 1966, WILSON 1958 and 1961, GOBBETT and

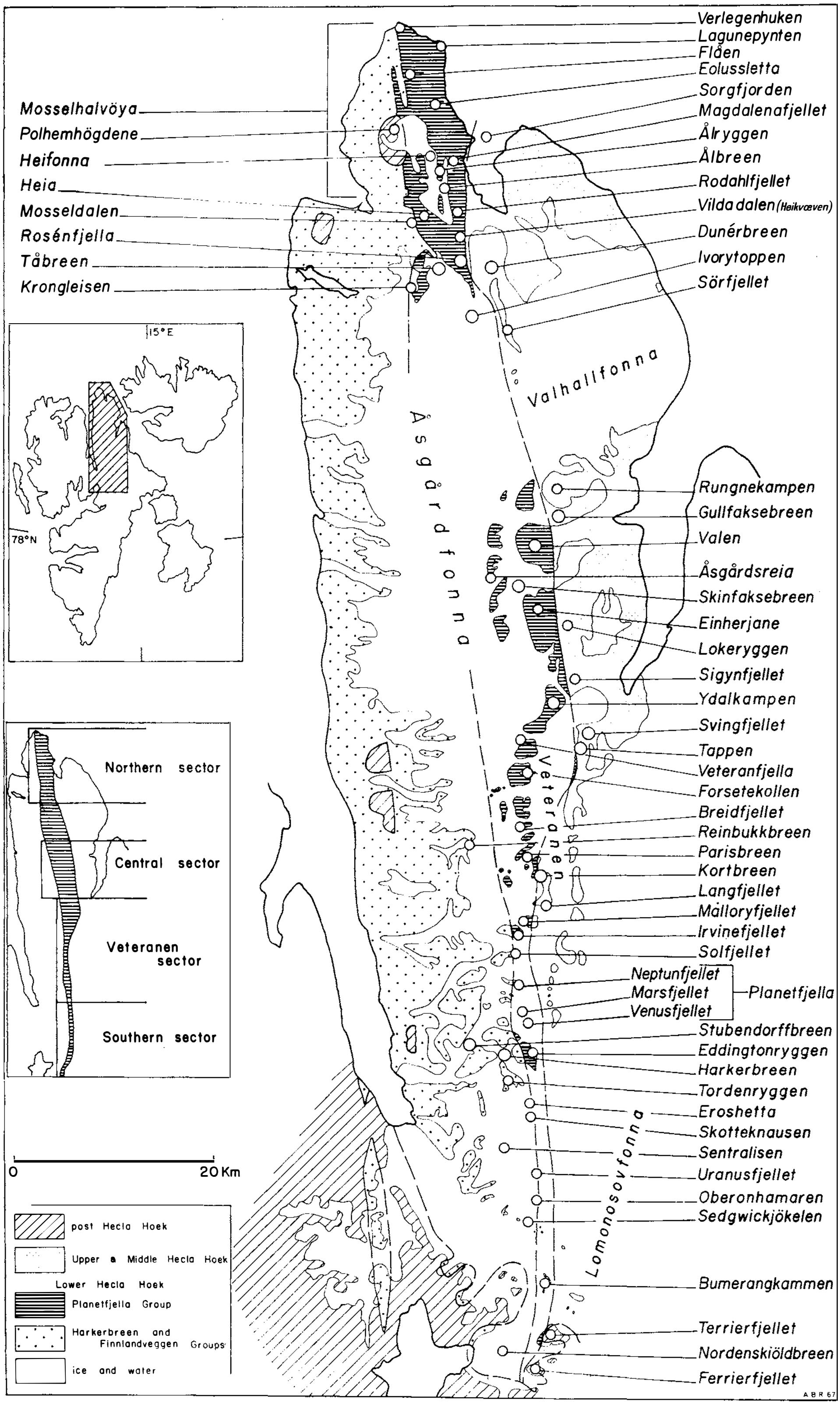

Fig. 1. *Diagrammatic map to show areas of outcrop of the Planetfjella Group and the location of place names used in the text. Insets show the position of Ny Friesland in Spitsbergen and the subdivisions of the Planetfjella Group outcrop used in the text.*

WILSON 1960, and WILSON and HARLAND 1964) on the detailed stratigraphy and petrology of the Hecla Hoek rocks of Ny Friesland carried out by Cambridge workers in the period 1949–1967.

Stratigraphy

GENERAL

Because research during the early 1950's was concentrated in southern Ny Friesland, the type section for the Planetfjella Group was selected from outcrops on Neptunfjellet, Marsfjellet and Venusfjellet, the Planetfjella mountains. The exposures provide an excellent sample of typical lithologies, but they are on remote hills with isolated steep cliffs. This area also lies within the aureole of the Chydeniusfjella granite, which introduces additional complications. Thus, as described in HARLAND *et al.* (1966), the type area is now taken from the Mosselhalvøya region in northern Ny Friesland, where the complete succession is well exposed and much more accessible.

Throughout its 100 km of outcrop the Planetfjella Group appears as two contrasted lithological assemblages, see Fig. 2: a lower, the Flåen Formation, and an upper, the Vildadalen[1] Formation.

The Vildadalen Formation lies conformably below the Kortbreen Formation (HARLAND *et al.* 1966) of the lower Middle Hecla Hoek, and it consists of graded greywacke turbidites, pure orthoquartzites, impure psammites, and more rarely limestones and dolomites. HARLAND *et al.* (1966) subdivided the Vildadalen Formation into four members. This subdivision is retained, as the four members can be traced throughout the 25 km outcrop of the northern sector, and they are capable of recognition in the central area, and, with further work, it may prove possible to map them further south.

The Flåen Formation, lying beneath the Vildadalen, is transitional to the typical Lower Hecla Hoek lithologies of the Harkerbreen Group below, granular feldspathic psammites with only very occasional interlayers of subpelite (WALLIS *et al.* 1968), quartzite or limestone. However, the feldspathic psammites of the Flåen Formation are quite characteristic and different from those of the Harkerbreen Group, for the former consist of megacrystic feldspars set in a finely laminated matrix, and the latter are typically equigranular granulose rocks.

HARLAND *et al.* (1966) tentatively subdivided the Flåen Formation into three informal divisions. This subdivision is modified and revised, and a complete section is detailed for north Ny Friesland.

The opinion that there are no penecontemporaneous basic igneous rocks in the Planetfjella Group in Ny Friesland as stated by HARLAND and WILSON (1956) BAYLY (1957), HARLAND (1959), and HARLAND *et al.* (1966) is confirmed.

The stratigraphy described below is a lithological succession based on the bulk

[1] The name Vildadalen used in this paper must not be mistaken for Villdalen (=Vilda Dalen, ROSEN 1913). The official name of the valley called Vildadalen by the author is Heikvæven. (Editor's note.)

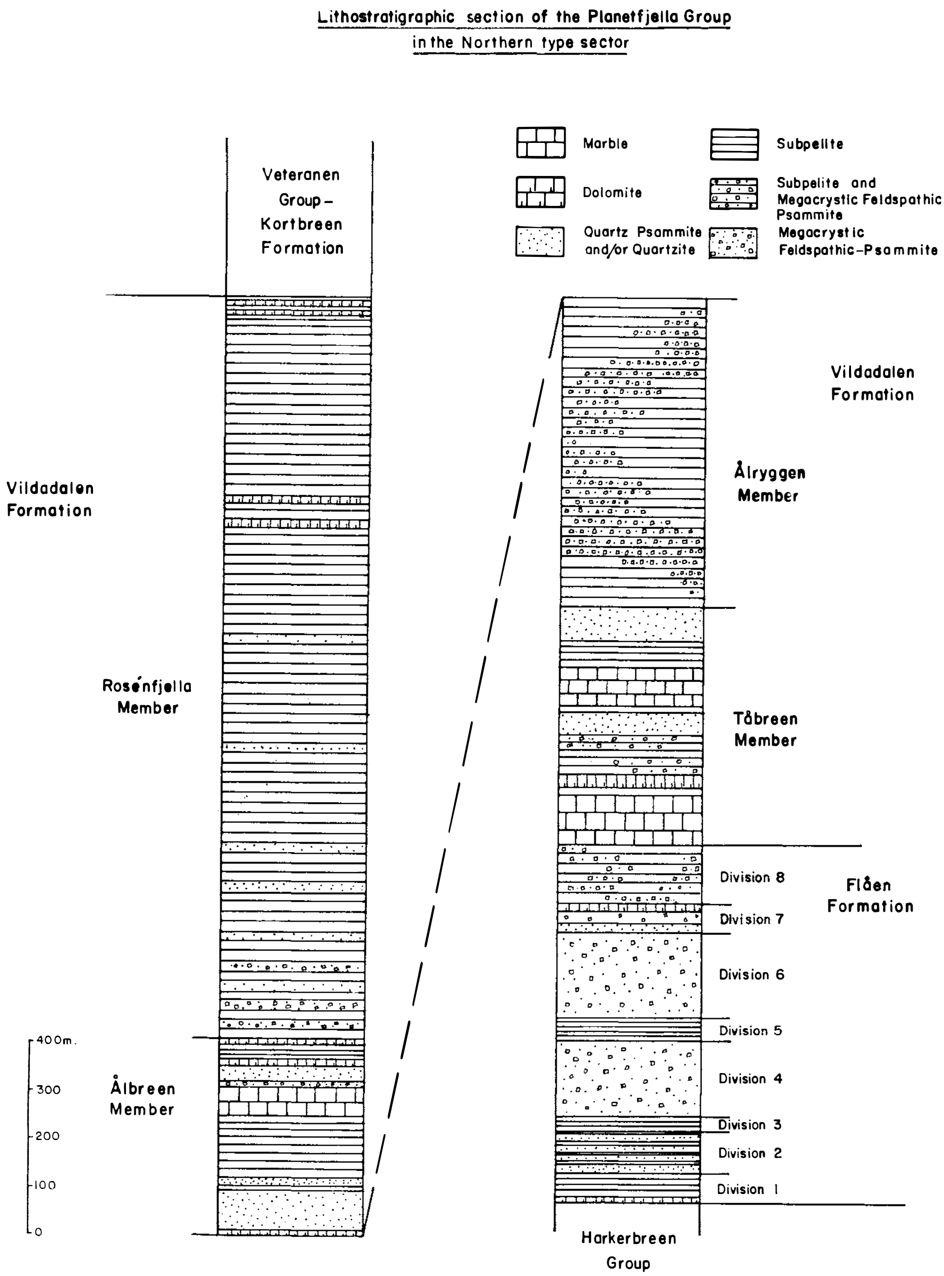

Fig. 2. *Diagrammatic lithostratigraphic section of the Planetfjella Group in the northern sector.*

composition inferred from the mineralogy; limitations of this approach have been fully described in WALLIS *et al.* (1968).

DETAILED STRATIGRAPHIC SUCCESSION IN THE NORTHERN TYPE AREA

In this sector the Planetfjella Group outcrops from Verlegenhuken, on the northernmost coast of Ny Friesland, southwards through the highland interior of Mosselhalvøya, Flåen, and Heia to Mosseldalen, and thence southwards along Dunérbreen and Tåbreen until it is covered by Åsgårdfonna, see Fig. 3.

The Vildadalen Formation

The Vildadalen Formation is the upper of the two formations of the Planetfjella Group, and it consists of four members, which are a repetition of the sequence: 1 and 3 monotonous, finely laminated psammitic-subpelite overlying 2 and 4 massive pure quartzites and marbles, see Fig. 2. The type section is Vildadalen, a steep-sided valley cutting into south Mosselhalvøya. This displays a very well exposed section through the overlying Kortbreen Formation of the Veteranen Group (Middle Hecla Hoek) and most of the Planetfjella Group.

(4) *Rosénfjella Member* (1500 m)

Rosénfjella lies on the south side of Vildadalen, overlooking Dunérbreen. Below the overlying limestone and dolomites of the Kortbreen Formation lies a unit of fine-grained, very dark grey-green subpelites. In the top 20–50 m are occasional chocolatebrown dolomite layers, (up to 5.0 mm thick), interspersed between laminated pelite-psammite or subpelite layers (0.5–2.0 mm). These uppermost rocks have recrystallized to a quartz-chlorite-sericite assemblage ($\pm$ rare plagioclase and tourmaline). This area has suffered intense two-phase deformation, which has produced minor folds up to 1.0 cm in amplitude. In the hinges of the earliest of these folds the fine-grained psammitic interlayers have recrystallized as quartz lenses with a coarser grain size than in the limbs. These quartz fold hinges, or their detached flattened lensoid equivalents, are one of the most characteristic features of the micro-laminated psammitic-subpelitic facies of the Planetfjella Group. The main variation in the Rosénfjella Member in this area is the gradual increase in metamorphic grade down section, which is accompanied by changes in mineralogy, increased grain size, and lightening of colour. There is also an increase in amplitude and complexity of the minor folds. Lithologically there is little variation; the micro-laminated psammitic-subpelite lithology is dominant, but isolated 10 cm thick psammite bands are known in the top 1000 m, and two horizons of interbanded chocolate-brown to orange dolomitic subpelites, 15 m thick, 30 m apart, are found 400 m below the top of the member. Below these dolomite horizons there is a colour contrast between the usual dark grey or black lustrous subpelites and rather more green-coloured strata. However, the latter do not indicate a change in metamorphic grade, but are interpreted as horizons with an original composition relatively higher in FeO and MgO or relatively lower in carbonaceous or pyritic material.

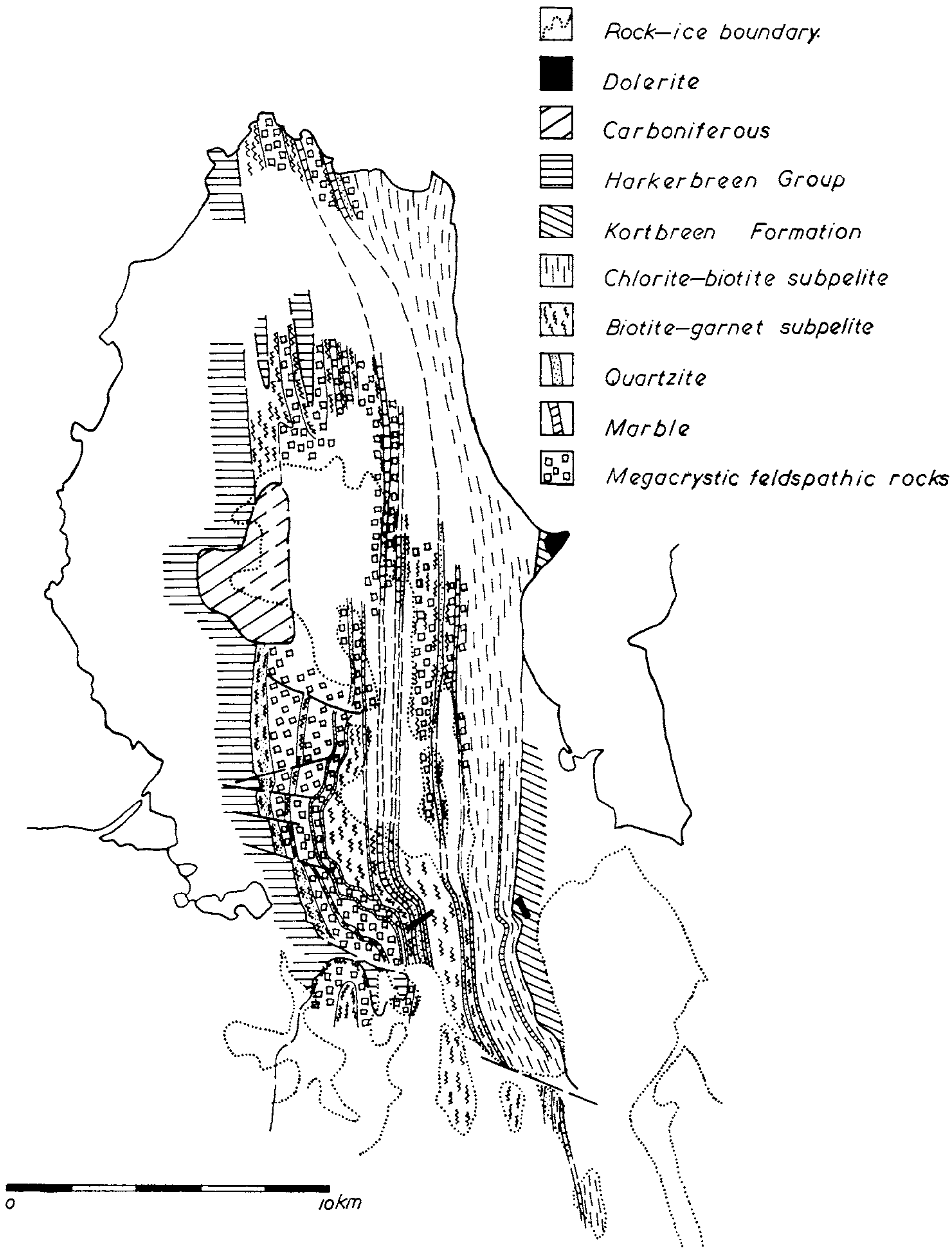

Fig. 3. *Lithological sketch map of the Planetfjella Group in the northern sector.*

Lower in the member the increased grain size, together with the complexity and size of the crenulations and the abundance of quartz lenses, produces a more massive, well jointed rock, which is resistant to erosion and forms a distinctive terrain. At this level biotite and muscovite are the dominant micas present.

Sporadically in the lowest 100 metres of the member are found isolated grains, and/or rare horizons of pale pink feldspar, 2.0–3.0 mm in size, compared to the 0.5 mm groundmass. These megacrysts are often almost euhedral, rather vitreous in appearance and random in distribution; they lie within the foliation and have been affected by the earliest known phase of deformation. In these lower horizons joint faces commonly weather to a distinctive pale pink. These are the highest known horizons in the Planetfjella Group containing feldspar megacrysts.

(3) *Ålbreen Member* (400 m)

Ålbreen runs north-south on the eastern side of Mosselhalvøya in northern Ny Friesland. The member is easily recognisable for 25 km along the strike from the west side of Dunérbreen on Ivorytoppen, and then northwards to the Eolussletta, where it is covered by raised beach material. On the Verlegenhuken shore section similar lithologies have been found at the relevant horizon within the Vildadalen Formation, but with a reduced thickness.

In contrast to the monotony of the overlying Rosénfjella Member, the pure and impure quartzites and carbonates of the Ålbreen Member display rapid alternations both along and across the strike. Because of this rapid lithological variation and the relatively poor exposure of the dolomite/limestone horizons, no one section is typical of the whole outcrop. However, to illustrate the range of variation of rock types, a fairly complete section is given from Magdalenafjellet to Ålryggen below the snout of Ålbreen.

(11) 4 m of yellow dolomitic marble
(10) 30 m of foliated subpelite, micro-laminated with microfolds, quartz hinges and crenulations
(9) 11 m of interbanded yellow dolomite and grey calcareous marble
(8) 5 m of grey psammitic subpelite (as (10))
(7) 30 m of yellow psammite, grading into grey subpelite with characteristic quartz hinges and feldspar megacrysts, and occasional subpelite interbanded with dolomite laminae
(6) 60 m of pure grey marble and interbanded yellow dolomite, a persistent horizon
(5) c. 130 m of medium-grained, interbanded psammite-biotite-subpelite with quartz hinges (as (10))
(4) 13 m of massive quartzites variously coloured white, grey, grey-green, purple, pale pink or yellow; foliation well marked; lineated muscovites rare but prominent

(3) 6 m of coarse-grained micro-laminated psammite-subpelite, with biotite instead of muscovite-chlorite

(2) c. 100 m of massive quartzites, a very pure quartz rock, massively bedded, purple to pink in colour, with the purple quartzite in more massive 10 m units; a persistent horizon

(1) 3 m of yellow dolomitic marble

The most characteristic and persistent horizon is unit (2), the massive purple-pink quartzite, which is exposed for 20 kms from Eolussletta to Ivorytoppen; unit (6) also persists throughout most of this outcrop, in fact, along Dunérbreen and on Ivorytoppen the marble is as conspicuous as the quartzite horizon.

(2) *Ålryggen Member* (500–750 m)

Ålryggen is a well exposed cliff running N–S to the west of Ålbreen. The dominant lithology is uniform and consists of strata similar to the Rosénfjella Member, which have been more intensely metamorphosed at a deeper tectonic level. All the strata are medium- or coarse-grained, and though dark brown, they tend to be lighter in colour than the Rosénfjella Member, and variations in mineralogy are more easily seen. The rocks retain the characteristic micro-laminated psammitic-subpelite lithology, but the psammitic bands have tended to recrystallize as micro-quartzite layers, and the subpelite bands as biotite-muscovite-garnet-quartz-plagioclase assemblages. Biotite is now the dominant mica and garnet is common. The garnets are quite small at the top of the member, being 2.0 mm, but in the lower part they are up to 5.0 mm in size. The garnets apparently distort the ubiquitous microfolds, which have an amplitude of 2.0–4.0 cm with crenulations of 1.0–2.0 cm and detached quartz hinges of 2.0–5.0 cm. This fabric complexity, together with cross-cutting quartz tension gashes, forms a coarsely crystalline, well foliated gneissose rock.

Also present in the Ålryggen Member is a very important and characteristic Planetfjella Group lithology – a crenulated, foliated, megacrystic feldspathic psammite. These feldspathic horizons (c. 10 m thick) appear to be coarse-grained analogues of the feldspar-bearing strata in the lower Rosénfjella Member and locally present in the laminated subpelites of the Ålbreen Member. The megacrystic psammites possess a random and sporadic distribution of distinctively pink weathering, potash feldspar grains, and sometimes less distinctively grey weathering plagioclase grains of deformed subhedral habit. These large feldspars (1.0–5.0 cm) are present in a matrix consisting of equigranular (2.0–5.0 mm) quartz-muscovite $\pm$ plagioclase $\pm$ biotite, which is finely laminated, well foliated, and markedly crenulated. Feldspar sometimes constitutes up to 50% of the rock.

The level at which these horizons of feldspar megacrystic psammite become conspicuous varies along the strike of the Ålryggen Member, see Fig. 5. On Ålryggen they are very conspicuous in the lower part of the member; horizons are common northwards towards Flåen, and very common on the coast section from Lagunepynten to Verlegenhuken. However, southwards from Ålryggen only rare 1.0–5.0 m bands are found on Heifonna, and no horizons have been observed on the Vildadalen–Mosseldalen col or southwards to Åsgårdfonna, see Fig. 5.

(1) *Tåbreen Member* (450–800 m)

Tåbreen is the glacier at the head of Mosseldalen; the member is exposed in the cliffs north of the snout. The Tåbreen Member is analogous to the Ålbreen Member, with horizons of marble and quartzites as well as the characteristic Planetfjella lithologies. There is considerable and rapid variation of rock types along and across the strike, and many individual units are impersistent, thus at Tåbreen:

(5) marble and upper psammites 80 m
(4) pure white quartzite 40 m
(3) impure psammites 160 m
(2) impure quartzites 110 m
(1) basal marble 90 m

On Heifonna the sequence appears as:

(6) marble 50 m
(5) white, ochre, and purple quartzites 130 m
(4) dolomitic interlayer 35 m
(3) psammites 170 m
(2) feldspathic psammite and impure quartzites 140 m
(1) dolomitic marble 80 m

West of Ålryggen the sequence is:

(6) 70 m massively bedded, well jointed, foliated and lineated, coarse-grained, pale purple, pink white, grey orange quartzites; sharp boundary with laminated subpelites above.

(5) 50 m thin bands (10 m) of quartz-lensed garnet biotite, laminated subpelite, marble, and quartzite.

(4) 120 m (but varies in thickness) very massive, compositionally well banded, and internally folded pure marble.

(3) 50 m. After 10 m of schistose garnet biotite subpelite, a massive, well-jointed, pale quartzite.

(2) 400 m. An intermixture of the two characteristic Planetfjella lithologies, the micro-laminated psammite-subpelite with quartz hinges, and the feldspar megacryst psammite, in varying proportions.

(1) 100 m. A narrow marble followed by schistose garnetiferous biotite subpelite, followed by a massive uniform calcium carbonate marble, colour-banded and internally deformed.

To summarize, within the Tåbreen Member there is a prominent and persistent basal marble above which lies a complex sequence of pure and impure psammites and quartzites, and at least one more marble horizon. Northwards from Tåbreen quartzites and feldspathic psammites increase in abundance and the member apparently thickens from 480 m at Tåbreen to almost 800 m at Ålryggen.

The Flåen Formation

The Flåen Formation outcrops extensively on the high plateau of Heia and is well exposed in the northern headland of Flåen, along the north side of Mosseldalen and in the valleys running westwards north of Mosseldalen.

The characteristic component of the Flåen Formation which distinguishes it from the Vildadalen is the extensive occurrence of feldspar. However, the rocks still posses the typical close lamination of the Planetfjella Group which distinguishes them from the Harkerbreen Group below (see Plates I A, I B, and II A).

As mentioned in HARLAND *et al.* (1966), the Flåen Formation is capable of subdivision, and along the 25 kms of the northern sector eight arbitrary divisions can be recognised.

(8) *Upper subpelite division* (120 m)

The division consists of coarse-grained, foliated but massive garnetiferous mica subpelites or subpelite-psammites. The rocks weather to a dark brown with yellowy-grey quartz lenses and streaks standing out in relief giving a gneissose appearance. Garnets are up to 2.0 cm in size and are randomly distributed. They are anhedral, commonly cracked, and the schistosity given by micas and elongate quartz grains flows around them. The rock contains abundant streaks, lenses, and fold hinges of coarse-grained quartz, and the strongly contorted crenulation is cut by boudin necks containing an assemblage of quartz-chlorite-feldspar-calcite. The relative abundance of micas (mainly biotite) gives the rock a well marked foliation, but the continuity of this foliation is destroyed by the garnet megacrysts, which produce a rough undulating surface of biotite-muscovite-quartz-chlorite. A lineation is produced from the crenulation hinges.

This subpelite horizon is extremely uniform across the strike, but northwards from Heia an increasing amount of foliated feldspathic-psammite (see unit 6 below) substitutes for the subpelite, and by Flåen the feldspathic-psammite has become the dominant lithology.

(7) *Upper variable division* (30–45 m).

Below the massive uniform subpelite (or feldspathic-psammite) lies a thin (3–5 m), but in the Heia area, prominent, marble horizon. When well exposed the subpelite is seen to grade into the marble through some interlaminated gneissose garnet-mica-subpelite and impure calcareous pelite with garnet megacrysts up to 3.5 cm in size.

The marble consists of a repetition of a yellow dolomite and grey limestone sequence. The limestone is almost pure $CaCo_3$, but the dolomite is less pure with micaeous layers and quartz lenses.

Below the marble lies another interdigitation of garnet-quartz subpelite and impure dolomite with garnet megacrysts up to 4.0 cm; however, less than 2 m from the dolomite garnets are absent, and the rock is a grey lineated, foliated, psammite-subpelite interlaminated with occasional layers rich in feldspar megacrysts. At Mosseldalen this horizon is 15 m thick, but in north Heia it thickens to almost 30 m.

The unit forms a distinctive craggy terrain in west and south Heia. In some horizons the K-feldspar megacrysts become more numerous and quite large, up to 3.0 cm, and the rock weathers pink and has a distinctly gneissose character.

Below the craggy feldspathite lies the lowest unit of this division – a prominent and highly distinctive colour-banded quartzite horizon, 5–10 m thick. In its lower part the quartzite consists of impure horizons interbanded with psammite, but upwards its purity gradually increases, and it possesses a lustrous aspect with very regular and persistent colour bands in white, yellow, and various greys. These pure equigranular quartzites make a crag feature 4–8 m high. This horizon contains many well displayed folds both of and within the colour-banded foliation. The fold crests produce the dominant lineation (see Plate II B).

(6) *Upper feldspathic-psammite division* (180 m)

This is a major division of the Flåen Formation and consists of grey weathering, massive craggy units of very uniform feldspathic psammites. The rock is well laminated, sometimes highly crenulated on a mm or cm scale. Feldspar megacrysts, of both plagioclase and orthoclase, very rarely microcline, are prominent, and are apparently random in distribution and orientation throughout the division. In some units the megacrysts are abundant, in some very rare, and overall the rock composition varies from impure feldspathic psammite to feldspathic subpelite, with K-feldspar becoming commoner in the upper part.

The megacrysts are almost euhedral or only very slightly flattened, and the foliation flows round them. In the axes of crenulations quartz recrystallizes to produce a rodding along the lineation. Boudinage occurs with quartz-feldspar pegmatites; the boudins are orientated obliquely to both foliation and lineation. The rock units are well jointed on a massive scale.

(5) *Middle subpelite division* (40 m)

With a very sharp junction the feldspathic psammite gives way to **a** horizon of dark brown weathering, gneissose, garnet-quartz-subpelite. The rock is almost equigranular and is little crenulated; the garnets are medium-grained 5.0 mm, often almost euhedral; the foliation either sweeps round them or abuts against them. Variation in lithology is limited to alteration in the percentage of garnets present. Quartz is ubiquitous in fold hinges, lenses and layers up to 20 cms thick and has a dark greenish vitreous lustre. This subpelite division is a valuable marker horizon separating division (4) from division (6).

(4) *Lower feldspathic-psammite division* (150 m)

A unit of pink weathering, massive feldspathic psammite, which is well laminated and foliated, coarsely crenulated with frequent concentrations of pink microcline megacrysts and quartz lenses. The dominant rock type is an equigranular quartz-K-feldspar $\pm$ plagioclase $\pm$ biotite psammite, which is very finely laminated with differential concentrations into quartz-rich and quartz-poor layers.

The foliation is distorted by crenulations and microfolds with amplitudes of 1.0 mm to 5.0 cm. Biotite grains are bent around the hinges rather than lying parallel to the axial surfaces. Quartz is abundant as lenses and contorted streaks up to 10.0 cm wide.

Occasionally there are horizons up to 10.0 m thick, which contain rare to abundant pink weathering K-feldspar megacrysts and white-grey plagioclase megacrysts. These vary in size from 1.0 mm to 2.0 cm. Their shape varies from almost euhedral to generally subhedral to flattened, but all approximate to the common tabular feldspar habit. The megacrysts lie at all angles to the foliation plane with more lying in the plane than across it; some megacrysts are severely flattened in the foliation plane, but this is rare and sporadic. In most cases the foliation, lineation, minor folds, and crenulations are all distorted about the megacrysts.

Boudinage is common, individual necks are up to 10 cm wide and consist of quartz + K-feldspar $\pm$ biotite $\pm$ chlorite. Throughout the unit there are local contorted layers of quartz-feldspar pegmatite with feldspar grains up to 8×4.0 cm. The lower part of the unit contains some horizons of grey weathering, finely laminated psammite; laminae are little contorted and megacrysts are lacking.

The unit as a whole is massive, well foliated, strongly jointed, weathering to a very conspicuous pink red on joint faces, and stands up as crags.

(3) *Lower subpelite division* (30 m)

By transition, division (4) grades downwards with increase of biotite and presence of garnet from feldspathic psammite to subpelite. The subpelite weathers a dark brown, which contrasts with the overall blood red to light pink of division (4) above. The rock is finely foliated with small amplitude crenulations; garnets are ubiquitous and are smaller than in division (5), rarely being greater than 2.0 mm.

(2) *Banded psammite division* (75 m)

The division is built up by the repetition of units usually 0.5–1.0 m thick. Each unit begins with a pure quartz psammite base, weathering pale yellow or pink or light grey, which is openly folded into small folds of up to 20 cm amplitude. The psammite base grades upwards into a more and more closely laminated lithology, with laminae of biotite-rich and biotite-poor psammite. This laminated upper part of each unit is closely crenulated. The rock type is deficient in feldspar and garnet. Boudinage is rare, but large quartz lenses occur.

(1) *Lower variable division* (60 m)

The banded psammite passes downwards into a strongly foliated, more biotitic psammite with a well developed crenulation producing a marked lineation. Few garnets are present, but very biotite-rich and ?pyrite-rich layers weather to a conspicuous ochre.

Below lies a flaggy and easily weathered horizon containing abundant medium size, 5.0 mm, garnets. Underlying this garnetiferous layer is a pink weathering, laminated quartz-mica psammite, which is massive and forms crags. This unit interdigitates with a coarse-grained, massive, highly garnetiferous subpelite, which becomes more dominant below. Boudinage is frequent in northern Heia, and a replacement copper mineral, ?malachite after chalcopyrite, commonly occurs in the boudin necks of the lowest subpelite.

This dark, massive, coarse-grained subpelite is the lowest major unit of the Planetfjella Group in Mosselhalvøya. However, from Mosseldalen for 8 kms northwards towards Flåen the actual junction with the Harkerbreen Group below can be mapped at a 3.0 m horizon of white and grey, internally folded, granular, very pure marble.

CORRELATION OF THE TYPE AREA WITH OTHER AREAS IN NY FRIESLAND

The central sector (see Figs. 1 and 4)

South of Ivorytoppen, in the northern type area, the outcrop of the Planetfjella Group is covered by the highland ice of Valhallfonna and Åsgårdfonna. There is a 20 km gap before the strata reappear in nunataks to the north of Gullfaksebreen, but from here the Group is continuously exposed across the 25 km of the central sector to the southern end of Einherjane and Lokeryggen.

The presence of Planetfjella Group lithologies at the head of Gullfaksebreen and Skinfaksebreen was established by FLEMING and EDMONDS (1941) and WILSON (1958). In 1967 the author measured three detailed sections through the outcrops on Åsgårdsreia, the nunataks lying between Åsgårdfonna ice sheet and the Fakse glaciers[1] (WALLIS and HARLAND 1968). These sections may be briefly compared to those described above for the northern sector, see Fig. 4.

Vildadalen Formation

The Vildadalen Formation lies conformably below the massive reddish and green quartzites, the pale yellow-orange dolomites, and the grey limestones which make up the Kortbreen Formation of the Middle Hecla Hoek (HARLAND *et al.* 1966). This junction is continuously exposed from Rungnekampen, in the north, across Gullfaksebreen and through the valley between Valen and Solkampen to the Skinfaksebreen nunatak, and then along the west side of Lokeryggen southwards to Sigynfjellet and Veteranen. To the west the barren plateau of Valen and Einherjane present a continuous exposure of the Rosénfjella Member of the Vildadalen Formation.

[1] Fakse glaciers is an unofficial name of these glaciers. (Editor's note.)

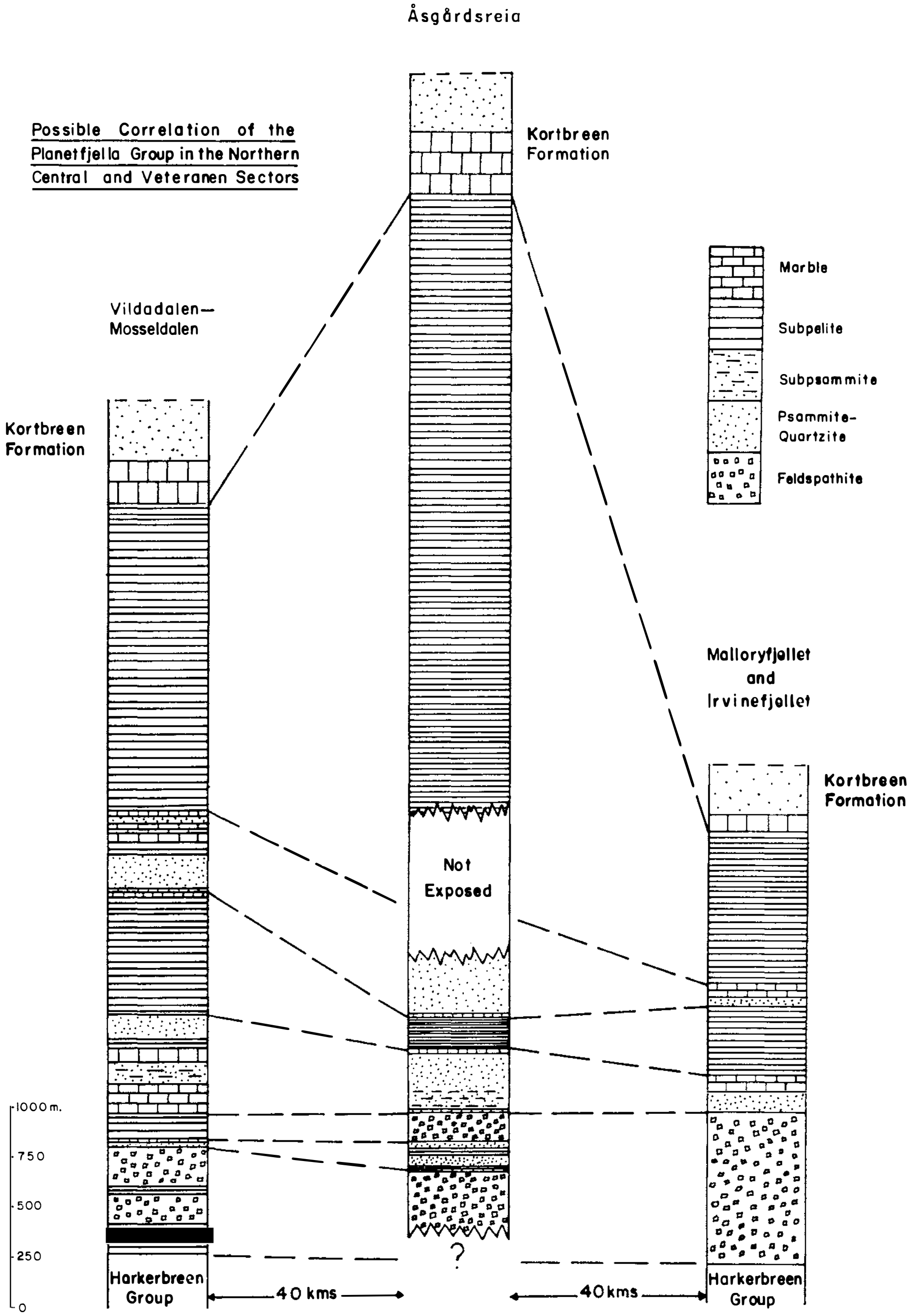

Fig. 4. *Diagrammatic lithostratigraphic sections of the Planetfjella Group in the north, central, and Veteranen sectors, showing possible correlations.*

The Rosénfjella Member (ca. 3000 m). – The member apparently thickens from 1500 m to 3000 m in the 25 km southwards across Valhallfonna. In lithology, however, it is almost identical to exposures in the northern sector, especially if allowance is made for a diminution in metamorphic grade and in tectonic level. On a large scale the member appears as a uniform mass of well cleaved black slates, but in detail the rocks are blue grey or pale grey with repeated rhytmic units of:

sharp interface
(2) fine-grained, dark subpelite (shale), grading downwards to
(1) fine- to medium-grained psammite (sandstone)
sharp interface

This lithology and texture is identical to much of the lower Middle Hecla Hoek (Wilson 1958). Even after careful search, the thin dolomite and quartzite interlayers noted in the northern sector (see above) were not found in the central sector. Rare paler-coloured horizons are found to be large quartz pegmatites (up to 5.0 m in width), and ochre-coloured layers are formed by staining from the weathering of pyrite-rich horizons.

At the junction with the overlying Kortbreen Formation the rocks possess a poorly developed penetrating cleavage and kink bands, and in thin section only rare phyllosilicates are present. However, at the base of the member the rocks possess two penetrative cleavages, microfolding, boudinage, a generation of quartz veins; the psammite layers have commonly recrystallized to give quartz lenses, and the phyllosilicate assemblage is of muscovite and chlorite.

Ålbreen Member (c. 600 m). – Unfortunately erosion has selectively attacked the Rosénfjella–Ålbreen junction, which is not exposed, the minimum width of the snow-ice cover being 800 m. From moraine material there is no evidence of unusual or unexpected lithologies in this gap, which, by analogy with the northern sector, probably consists of marble and impure psammites.

The first exposed rocks to the west are a succession of pure and impure quartzites and psammites, variously coloured purple, pink, white, grey, yellow, and green. These are thinly bedded (less than 20 cm thick) flaggy and rather friable; they are occasionally interbanded with laminated dolomitic psammites. No sedimentary structures were observed, and the rocks have recrystallized often with conspicuous muscovite.

The dominant colour of the outcrop is a greyish yellow, and the base is marked by a prominent crag of grey marble and yellow dolomite (10 m).

Ålryggen Member (225 m). – Below the marble there is an abrupt change in in lithology to dark-coloured impure subpelites with psammite interlayers. The rocks are in massive but well foliated units; biotite-muscovite-chlorite is present in the subpelites. The colour varies with grain size and staining from the weathering of pyrite-rich horizons. Rare feldspathic psammites occur, and feldspar together with quartz recrystallizes in transgressive veins. The lithology is very reminiscent in structural and metamorphic character of the Rosénfjella Member as seen in Vildadalen in the northern sector. In the lower part the beds become more finely foliated with some definite psammite bands.

Tåbreen Member (280 m). – Below the massive dark subpelite-psammite lithology of the Ålryggen Member lies a variable group of rocks beginning with a rythmic sandstone-limestone-dolomite-shale sequence (25 m), which passes down through 10 m of subpelite into a massive uniform purple quartzite. In this quartzite there are some green and yellow horizons, but the purple colour is conspicuous from afar. Chlorite as well as muscovite occurs in these recrystallized and well foliated quartzites. The unit passes down through a thick unit with a mixture of subpelites, impure and pure psammites into 10 m of grey limestones and yellow dolomites.

Flåen Formation

The remaining strata exposed on the Åsgårdsreia are correlated with the Flåen Formation.

Division 8 (150 m). – Below the marbles of the Tåbreen Member lies the first crag-forming lithology of this area, a massive but well foliated feldspathic-megacrystic psammite. The typical rock is a fine-grained, dark-coloured, biotite-plagioclase-quartz subpelitic-psammite, with rare to abundant small megacrysts of pink weathering feldspar, varying in size from 2.0 mm to 2.0 cm.

The megacrysts are usually tabular, equant- or lozenge-shaped but some have been flattened to an augen shape in the foliation plane. The rock is traversed by many streaks and veins of quartz and quartz and feldspar. Though the foliation is pronounced and the lineation is obvious, crenulation is only present on the most minute scale.

Division 7 (120 m). – Below lies a four fold assemblage with first white, grey, and purple quartzites and psammites; then finely foliated and coarsely crenulated subpelites; then massive white and grey quartzites underlain by a unit of grey marble with dolomite layers.

Division 6 (300 m+). – Below the marble lies 25 m of coarse-grained, coarsely crenulated garnetiferous-quartz-subpelite with large quartz veins and with garnets up to 5.0 mm. These are the only visible garnets in the Åsgårdsreia succession. The rest of the division is more or less uniform feldspathic psammite. Small megacrysts of pink weathering feldspar are common, as are veins and pegmatites of quartz and feldspar. The rock is a medium- to coarse-grained biotite-plagioclase -quartz psammite with occasional interlayers of quartz-rich lenses and biotite subpelite. The rock usually weathers to a pale pink, but unweathered it is dark grey. The rock is well foliated and crenulated on a coarse scale.

This massive uniform lithology extends westwards to the Åsgårdsfonna, below which may lie lower divisions of the Flåen Formation.

The Veteranen sector

Although there is no break in exposure between the central and the Veteranen sectors no geologist has yet visited the 10 km of outcrop north of Ydalkampen and Sigynfjellet. However, D. E. T. BIDGOOD (LEWIS 1959) and C. B. WILSON (WILSON 1958) have visited Planetfjella outcrops to both north (Ydalkampen and Sigynfjellet) and south (Svingfjellet) of the lower reaches of the Veteranen glacier. All these outcrops have proved to be composed of strata equivalent to the Rosénfjella Member. To the south of Ydalkampen no detailed geological mapping has been attempted on the 20 km of exposure along Veteranfjella or Breidfjellet. However, the black phyllites of the Rosénfjella Member are clearly visible along the eastern slopes of Veteranfjella, and changes in outcrop colour and weathering character indicate the presence of lower members in the outcrops to the west. Formation boundaries can be interpreted from the work of C. B. WILSON (1958) and M. B. BAYLY (1957) from Trinity Hallbreen to Forsetekollen and about Parisbreen from north Breidfjellet to Reinbukkbreen. WILSON records outcrops of quartzites between strata equivalent to the Rosénfjella Member and the Flåen Formation indicating the presence of lower members of the Vildadalen Formation.

The 30 km of southern Veteranen have been thoroughly explored, and ODELL first recorded the typical feldspar megacrystic lithology of the Flåen Formation from Irvinefjellet in 1923 (ODELL 1927, p. 155). FLEMING and EDMONDS (1941, p. 426) working south from Gullfaksebreen in the central sector (see above) commented on the identical nature of their Gullfaksebreen "quartz-feldspar gneiss" and the Irvinefjellet strata, ODELL's "augenschist", and thus established a link between these two areas.

As mentioned in the Introduction, the Cambridge workers of the early 1950's made southern Veteranen the type area of the Planetfjella Group, and they gave a general description of the lithologies as follows, HARLAND and WILSON (1956, p. 274), "..... The Planetfjella is a distinctive semipelitic facies. It is usually metamorphosed and shows conspicuous pink feldspar augen set in a dark schistose matrix. The rock weathers pink". BAYLY (1957, p. 386–7) gives a more detailed petrographic description. However, HARLAND's 1959 (p. 324) account, "... a distinctive pelitic and semipelitic rock belt. They (the rocks) vary from black mica schists to quartzitic schists with feldspar augen, which rock commonly weather red" and section (p. 327), clearly shows the division into an upper, black, subpelitic unit lying above a lower feldspathic and more quartz rich unit, i. e. the Rosénfjella Member and the Flåen Formation respectively.

The three lower members of the Vildadalen Formation are less obvious, but C. B. WILSON and the author have independently mapped Malloryfjellet, and have shown that the typical variable lower members of the Vildadalen are present with a much reduced thickness. Below the quartzites and the orange- and chocolate-coloured dolomites of the Kortbreen Formation of the Middle Hecla Hoek, lies a thick, uniform, dark grey to black unit of phyllitic subpelites, the Rosénfjella Member. To the west is an outcrop of orange-brown weathering, slightly dolomitic schistose quartzite, below which lies a paler-coloured outcrop of non-dolomitic pink, brown- and white-striped quartzites interbedded with black subpelite layers. This is followed by a unit of uniform, dark, crenulated, and cleaved subpelite, which is underlain by an conspicuous yellow weathering dolomite with some impure psammites, the latter forming the extreme western end of Malloryfjellet and the extreme eastern end of Irvinefjellet. Further west on Irvinefjellet the psammites are replaced by uniform, pink weathering, feldspar megacrystic feldspathic subpsammite – the Flåen Formation.

The Vildadalen Formation as seen on Malloryfjellet still possesses the four divisions and the repetitive nature found further north in the central and northern sectors, but here in the south, the lower members are even more reduced in thickness than they were in Åsgårdsreia. South of Malloryfjellet the Vildadalen Formation outcrops on Neptunfjellet, Marsfjellet, Venusfjellet and on Eddingtonryggen. The Flåen Formation is well exposed across Gallerbreen, Månebreen, Banebotnen and Planetbreen, but no detailed work has been accomplished since BAYLY's 1957 description (p. 386–7).

The southern sector

The outcrop of the Planetfjella Group reappears south of Harkerbreen on Eroshetta and Skotteknausen before being covered on Sentralisen. FAIRBAIRN (1933, p. 448) described from Uranusfjellet, "... a dark grey, medium- to fine-grained rock, characterised by small augen of pink feldspar up to 0.25 inch and a variable amount of white mica, the rock shows a pronounced foliation but is not schistose...", and he commented that the outcrop of this lithology, the Flåen Formation, continued northwards to Irvinefjellet. To the south, ODELL (1927, p. 155) had observed an outcrop of "a hard compact augen schist" striking across Nordenskiöldbreen from Terrierfjellet to Bumerangkammen. Cambridge geological parties in the early 1950's confirmed all these observations, and they also visited the isolated outcrops appearing through Uranusisen and Lomonosovfonna, such as Oberonhamaren and localities south of Sedgwickjøkelen. These isolated outcrops are either of schistose garnet-quartz subpelite or of feldspar megacrystic psammite. However, in the extreme south, on Terrierfjellet, a more continuous exposure at the western end of the mountain reveals a junction from the dark subpelitic Vildadalen Formation to the feldspathic Flåen Formation. This section also shows that there are calcareous and psammitic horizons in the lower Vildadalen. South of Terrierfjellet the Planetfjella Group fails to outcrop from beneath the Carboniferous strata of northern Bünsow Land.

Discussion

UPPER BOUNDARY

The upper boundary of the Planetfjella Group is the division between predominantly metamorphic Lower Hecla Hoek and the relatively unmetamorphosed Middle Hecla Hoek. The interpretation of this junction has been controversial;

see discussion in ODELL (1927), KULLING (1934), and FLEMING and EDMONDS (1941), and three alternatives exist:

(1). The Lower Hecla Hoek is an older complex of rocks metamorphosed before the unconformable deposition of the Middle and Upper Hecla Hoek.

(2). The Lower Hecla Hoek is the metamorphic equivalent of the Middle and Upper Hecla Hoek.

(3). The Lower Hecla Hoek is an older part of an unbroken stratigraphic sequence which continues conformably upwards into the Middle Hecla Hoek.

HARLAND and WILSON (1956, p. 268) stated the evidence and criteria for rejecting hypotheses (1) and (2) and argued in favour of hypothesis (3). WILSON (1957, p. 306–7) restated the position for favouring the third hypothesis and presented detailed evidence of the nature of the boundary throughout Ny Friesland.

WILSON is the only worker to have visited all the relevant exposures in Ny Friesland, but the author has had the opportunity to confirm WILSON's observations of the junction in the northern sector across Rodahlfjellet and Rosénfjella, in the central sector across Gullfaksebreen, Skinfaksebreen, and Lokeryggen to Sigynfjellet, and in the Veteranen sector on Langfjellet and Malloryfjellet. At all these localities, a distance of 90 kms, the same stratigraphic unit of the Middle Hecla Hoek, the Kortbreen Formation of HARLAND *et al.* (1966), rests upon and above the Rosénfjella Member of the Planetfjella Group. Everywhere the junction is a normal stratigraphic boundary, and also, as argued below, the sedimentary facies of the upper Planetfjella Group, the Vildadalen Formation, is identical to that of the lower Middle Hecla Hoek rocks above.

Thus the Lower/Middle Hecla Hoek junction in Ny Friesland is a conformable and arbitrary lithostratigraphic boundary.

LOWER BOUNDARY

The Planetfjella Group was erected by HARLAND and WILSON (1956), and the criteria used to distinguish it were (p. 275) "its distinctive semipelitic facies, and conspicuous pink feldspar set in a dark schistose matrix", and the Harkerbreen Group below consists of "massive psammites... characterised by amphibolite bands". BAYLY (1957) confirmed these criteria and added the following comment, (p. 387) "amphibolites are absent from the Planetfjella". A detailed description of the Harkerbreen Group has been given by GAYER and WALLIS (1966).

The amphibolites characteristic of the Harkerbreen Group are interpreted as metamorphosed basic volcanic pyroclastics, possibly together with some basic lavas, and, as HARLAND *et al.* (1966) commented, in Ny Friesland, BAYLY's claim (op. cit.) seems to be justified, and the uppermost amphibolite unit seems to occur at the same general horizon at which commenced the change from almost pure granular psammites of the Harkerbreen to the more laminated and more pelitic Planetfjella lithologies. However, the junction between these two groups is rarely well exposed and has had very little study.

In the northern sector the junction must occur just west of Verlegenhuken, but it has not been mapped. On the Flåen headland amphibolite-bearing psammites are interfolded with typical Flåen Formation lithologies in a complex anticline, but to the south the junction is obscured by snow and ice and by the Carboniferous outlier on Polhemhøgdene, see Fig. 3. Below the high ground of Heia the junction is very well exposed for 5 km to the northwest corner of Mosseldalen. As described above, the base of the Planetfjella Group has been taken at a thin (3 m) but persistent marble band, below which there is a sudden change to pale grey and pink, equigranular, granulose, slightly feldspathic psammites, which are interbanded with thin amphibolites. This lithology extends across the low ground to the west of Polhem. At the junction both the Planetfjella and the Harkerbreen Group lithologies have identical dip and strike of foliation and plunge and strike of lineation, and the junction appears to the author to be conformable.

Across Mosseldalen on Ingstadegga the junction between the Planetfjella Group and the underlying Harkerbreen lithologies has been interpreted as a thrust (GAYER, in prep.) on which very low divisions of the Flåen Formation lie on different units of the Harkerbreen Group. South of Krongleisen and Åsgårdfonna the junction is not exposed for almost 80 km until it outcrops across Edinburghbreen in southern Veteranen. In the intervening ground garnet-mica-schist boulders of ?Planetfjella Group are found above Sørbreen, and amphibolite and psammite boulders are common at the edge of Åsgårdfonna above Åsgårdsreia. WILSON reports boulders of amphibolite in the eastern moraine of northern Veteranen, emanating perhaps from Trinity Hallbreen or Parisbreen. This meagre information helps to justify the boundary along the length of Åsgårdfonna.

West of southern Veteranen Cambridge parties of the early 1950's mapped the junction southwards from Edinburghbreen for 20 km to Eddingtonryggen. Above Harkerbreen lies the original type locality of the junction but, unfortunately, no details of this exposure have been published. To the south the junction is seen on Eroshetta before the rocks are covered by Sentralisen and Lomonosovfonna.

Thus, there is much less information on the lower junction of the Planetfjella Group than the upper boundary, but independent descriptions of northern Ny Friesland and of southern Veteranen seem very similar; also M. B. BAYLY and W. B. HARLAND, both of whom have had the opportunity to visit these widely separated areas, have not commented on any noteable differences between them.

PRE-METAMORPHIC CHARACTER

Non-feldspathic rocks

BAYLY (1957) and WILSON (1958) have pointed out that in Ny Friesland the trend of the regional metamorphic facies is transverse to the strike of the Hecla Hoek strata. For example, whereas the Planetfjella Group is mainly at biotite-garnet grade in the northern, Veteranen and southern sectors, in the central sector it is only at chlorite-biotite grade. Thus, by tracing one particular lithology along the strike, one can observe the changes in physical characters which occur with increasing metamorphic grade, and, by analogy, one can then interpret the premetamorphic form of rock types found lower in the section, but at similar metamorphic levels.

In the central sector the lower Middle Hecla Hoek is unmetamorphosed, and WILSON (1958) observed that the limestones and dolomites of the lower division of the Kortbreen Formation were oolitic. He also noted ripple drift, oscillation ripples, and desiccation cracks in the upper quartzitic division. All these sedimentary characters are typical of shallow water environments, and the thick uniform dolomites and limestones are presumably of marine deposition. The metamorphic changes observed along the strike to the northern sector are similar in degree to those lower in the section in the central sector and the form and appearance of the limestones, dolomites and quartzites of the Tåbreen and Ålbreen Members in Åsgårdsreia is almost identical to the Kortbreen Formation at Vildadalen in the northern sector. Thus, by analogy, the pure quartzites and limestone/dolomite assemblages of the lower members of the Vildadalen Formation and division (7) of the Flåen Formation are thought to represent shallow water marine deposits.

The Rosénfjella Member, as seen in the central sector, is lithologically almost identical to the upper and lower greywacke divisions of the Glasgowbreen Formation, and very similar to much of the Galoistoppen Member of the Kingbreen Formation (see HARLAND *et al.* 1966 and WILSON 1958) of the lower Middle Hecla Hoek to the east. These strata are the 'slates' of FAIRBAIRN (1933, p. 541–2) and the 'greywackes' of WILSON (1958). Their characteristics are dark colour, fine grain size, graded bedding, silty mud to very fine sand, and endless repetitions on all scales, mainly 1–2 cm with a few more massive flaggy beds. The combination of composition, great lateral extent, excellent grading and multiple units suggests a turbidite depositional environment.

The metamorphic variation seen down through the Rosénfjella Member in the central and northern sectors together with the known variation in lithology of, for example, the Galoistoppen Member of the Kingbreen Formation, allow the Rosénfjella and Ålryggen Members of the Vildadalen Formation and divisions (1), (2), (3), (5), and (6) of the Flåen Formation to be interpreted as well laminated and graded greywackes prior to metamorphism.

Thus, the bulk of the Vildadalen Formation and some of the Flåen Formation is directly comparable in lithology and character to the lower Middle Hecla Hoek of Ny Friesland (as described by WILSON 1958) and it is interpreted as consisting of repetitive assemblages of dolomites, limestones, and quartzites formed in a shallow water, marine environment and turbidite greywackes with some lateral and more obvious vertical, transitional lithologies.

Feldspathic Rocks

In the lower part of the Vildadalen Formation, and especially in the Flåen Formation, feldspar-rich horizons are a notable component of the Planetfjella Group. There are no comparable lithologies in the lower Middle Hecla Hoek of

Ny Friesland, but strata with a similarly high proportion of feldspar exist in the Harkerbreen and Finnlandveggen Groups of the Lower Hecla Hoek, see BAYLY (1957), HARLAND *et al.* (1966), and GAYER and WALLIS (1966).

Historically there has been considerable discussion over the origin of these feldspar rich, "granitic" looking rocks. BLOMSTRAND (1864, p. 11) suggested that they (the Flåen Formation of Mosselhalvøya) might "be volcanic or it could seem to a certain extent to be sedimentary like the rest". However, KULLING (1934, p. 163) and FLEMING and EDMONDS (1941, p. 407) interpreted BLOMSTRAND's sequence of "granite gneisses giving place to veined gneisses, and these, in turn, to a series of mica schists and quartzites" as being the product of syntectonic metamorphism and metasomatism. FAIRBAIRN (1933, p. 448) described the augen feldspathic rocks of Uranusfjellet (Flåen Formation) under his category "rocks of sedimentary origin in the western schists and gneisses". FLEMING and EDMONDS (1941, p. 422–428) interpreted the "quartz-feldspar augen gneisses" of the Åsgårdsreia (Flåen Formation) "as either a metamorphosed igneous rock or an altered arkose". HARLAND and WILSON (1956, p. 269) in a general discussion on "the gneisses of granitic composition" in the Lower Hecla Hoek concluded that "they either inject or transform the original sedimentary quartzites". BAYLY (1957, p. 390–1) made a thorough study of analogous horizons in the Harkerbreen Group, and came to the conclusion "that the rock's last consolidation was probably from a liquid, not detritus... and that the liquid was a product of refusion". For some of the thinner feldspar-rich horizons he concluded that "a process of feldspar enrichment without total refusion is clearly suggested". HARLAND (1959, p. 315) commented that these rocks "with granitic composition may have achieved their present composition by subsequent introduction of material... in some cases at least it is difficult to escape the conclusion that we have a metasomatic diffusion effect... however, it is possible that the large masses are intrusive... an alternative explanation is to invoke a pyroclastic origin... I prefer a metasomatic interpretation".

HARLAND *et al.* (1966, p. 75) reviewed these suggested origins and placed them in five categories:

I. selective metasomatism
II. magmatic intrusive (granitic sills)
III. magmatic volcanic (lavas)
IV. pyroclastic volcanic (agglomerates and tuffs)
V. detrital arkoses

There have been fewer suggestions concerning the origin of the conspicuous feldspar megacrysts, though almost every worker has mentioned them. BLOMSTRAND (1864, p. 13) recognised "a peculiar, compact rock with included feldspar crystals" in what is now the Sørbreen Formation of the Harkerbreen Group. He interpreted the rock as "a sort of feldspar porphyry", thus suggesting the feldspars had originated as phenocrysts. FAIRBAIRN (1933, p. 448) interpreted the large feldspar grains in the Planetfjella of southern Veteranen as being "porphyroblastic augen". KULLING (1934) described, from the possibly stratigraphically equivalent Cape Hansteen Formation in Nordaustlandet, a thick group of feldspar porphyries with phenocrysts of feldspar and quartz. BAYLY (1957, p. 387) described the "augen" of the Planetfjella Group as follows "the dominant textural feature is a lozenge-shaped feldspar clot – but this is not a true auge; that is to say, there is no central crystal which has forced an opening in the foliation and produced vacancies on either side for itself. Instead the clots are roughly homogeneous aggregates"; but he offers no further explanation of their formation. HARLAND (1959, p. 324) describes the Planetfjella schists as containing feldspar augen and the "texture shows a somewhat irregular and wavy foliation suggesting a flaser gneiss", i. e. a cataclastic rock. HARLAND *et al.* (1966, p. 75) concluded that pyroclastic formation of the feldspathic rocks would "provide the subhedral to euhedral feldspar megacrysts".

Thus, to summarize, the following origins have been or could be suggested for the distinctive feldspar megacrysts:

I. phenocrysts from (a) crystal tuffs (volcanic)
(b) porphyritic lavas and sills (volcanic-hypabyssal)
(c) bimodal granites (plutonic)

II. detrital feldspars in arkoses derived from the weathering of porphyritic lavas or granites and any other feldspar-bearing rock

III. porphyroblasts due to metamorphism and/or metasomatism

IV. relic grains from the cataclastic deformation of coarse-grained bimodal granites or gneisses

V. authigenic growths

No chemical or detailed quantitative mineralogical studies have been carried out on these rocks or on the surrounding strata, but observations of the geological and petrographic relationships help to eliminate many of these possibilities. The following data are relevant to this discussion:

(a) On the feldspathic strata as stratigraphical units:

(1) In detail they are concordant and conformable with the other strata with which they are associated.

(2) On a larger scale they can be shown to be variable both in position and in thickness, both along the strike and through the succession, see Fig. 5.

(3) The rocks with which they are interstratified are interpreted as normal sedimentary strata.

(4) In each feldspathic unit there is great variation in overall feldspar content and in megacryst content.

(5) The units contain variable and randomly different proportions of plagioclase to orthoclase.

(6) The units persist throughout the region independently of changes in metamorphic grade or tectonic level.

(b) On the megacrysts:

(1) They vary in composition, being either plagioclase, orthoclase, or both in any particular horizon.

(2) They possess a subhedral, sometimes even euhedral shape, except where particularly deformed in the foliation plane.

(3) Prior to deformation they appear to have been randomly orientated.

(4) FLEMING and EDMONDS (1941) observed, as had BLOMSTRAND (1864) in his Harkerbreen meta-feldspar-porphyry, that the feldspar grains are broken and extended, and there is recrystallization of quartz and calcite in the cracks. Otherwise the rocks do not seem to have suffered from any comminution due to cataclasis, and there is no evidence for the production of 'augen' by the destruction of a pre-existing crystalline fabric.

(5) As FAIRBAIRN (1933) and FLEMING and EDMONDS (1941) observed the mica fabric in these Planetfjella feldspathic rocks is wrapped around the feldspar grains, suggesting that the micas are deformed about pre-existing megacrysts. This mica fabric is the product of the second metamorphism and penetrative deformation. There are no outcrops of Planetfjella feldspathic strata which allow observation of the relationships of the megacrysts to the first metamorphism and penetrative deformation.

(6) The megacrysts do not possess an included fabric such as co-existing garnets display.

(7) Many of them display excellent twinning.

Origins of megacrysts

The fact that many of the megacrysts have suffered an extension phase of deformation, and that they were present before the second phase of deformation and metamorphism, indicates that any metasomatism and porphyroblastic growth must have occurred before or during the first deformation episode. Thus there is time for metasomatic growth, but (i) feldspar megacrysts are of varying composition and proportion and yet are in close proximity, which makes a metasomatic origin difficult to envisage; (ii) no grains have been observed to contain an included fabric, as do the co-existing garnet porphyroblasts; (iii) the feldspars possess obvious twinning, which is unusual in metamorphic/metasomatic feldspars, though common in igneous feldspars; and (iv) their well-defined shapes are unlikely to occur in metasomatic feldspars originating as porphyroblasts. On these grounds a metamorphic/metasomatic origin is rejected for the megacrysts. However, there has been some local movement of feldspar, for example into post-first deformation transgressive veins, and local diffusion has made a contribution to the present appearance of these rocks, e. g. recrystallization in boudin necks.

There seems to be no evidence of a severe cataclastic episode which might have produced a bimodal texture by mortarization during the first deformation, unless all traces of the characteristic groundmass textures have recrystallized to equilibrium textures in a subsequent constructive metamorphic phase. Severe extension and rupture of some of the megacrysts occurred prior to the second deformation, but this extension phase affected megacrysts already present, it did not aid their formation.

Thus, feldspars would seem to be either primary phenocrysts derived from crystal tuffs or porphyritic acid lavas, and/or to be detrital feldspars derived from the weathering of tuffs, lavas or bimodal granites or gneisses. These sources or a combination of them, would provide well-shaped, well-twinned, inclusionless, large feldspar grains, which would vary in composition and in distribution, both relative to the strata and to the secondary foliation. However, even this origin presents difficulties, for if the feldspar megacrysts are detrital, what sedimentary environment would produce large, randomly distributed megacrysts? The sediment would have to be either completely unsorted, yet these horizons seem to possess a marked primary lamination, or very well sorted, with the feldspars belonging to the coarse fraction, in which case why are there no large quartz grains or other more dense minerals present? Also if the feldspars are detrital, why do they possess euhedral or subhedral shapes when a rounded form would seem to be more appropriate? Similarly, if the megacrysts are derived from pyroclastic crystal tuffs, or from lavas, why are feldspars the only phenocrysts present, and why are the grains neither rounded from reworking nor angular from being broken by volcanic activity? Perhaps some of these questions could be answered by a detailed study of each megacryst horizon to determine the variation in shape and grain size through and along each unit, and through and along the feldspathic strata as a whole. Fig. 5 could be interpreted as indicating a source of feldspar to the north, in which case there should be relatively more feldspar megacrysts to the north, and the megacrysts should be relatively larger?

The textural evidence seems to indicate that the megacrysts are original, pre-metamorphic, constituents of rock, and this primary origin agrees well with the overall stratigraphic relationships of the feldspar-rich horizons. For the latter indicate that the feldspar horizons are an integral part of the sedimentary sequence either as pyroclastics deposits and/or as detrital sediments, for the horizons are conformable, yet possess lateral variation (see Fig. 5). Also, as units they were present prior to any metamorphic or tectonic event for their distribution bears no relationship to these.

Therefore, as it appears that the feldspar content as a whole is detrital, and that the megacrysts are pre-metamorphic, it is worth considering the possibility of the megacrysts being products of authigenic growth. PETTIJOHN (1957) figures and discusses the known occurrences of authigenic feldspar (p. 655, and p. 664–667) and comments on the fact that it is wide-spread in feldspathic sandstones and produces large, well-formed grains of both orthoclase and plagioclase sporadically throughout the feldspathic horizons. A detailed study of the distribution and nature of the twinning in the feldspar megacrysts would probably be the most effective approach in judging the significance of this authigenic possibility. HARLAND *et al.* (1966) have calculated that the Planetfjella Group had an overburden of 7.5 km of Middle and Upper Hecla Hoek, and GAYER *et al.* (1966, fig. 4) suggests that the Planetfjella Group may have been deposited c. 750 m.y. ago,

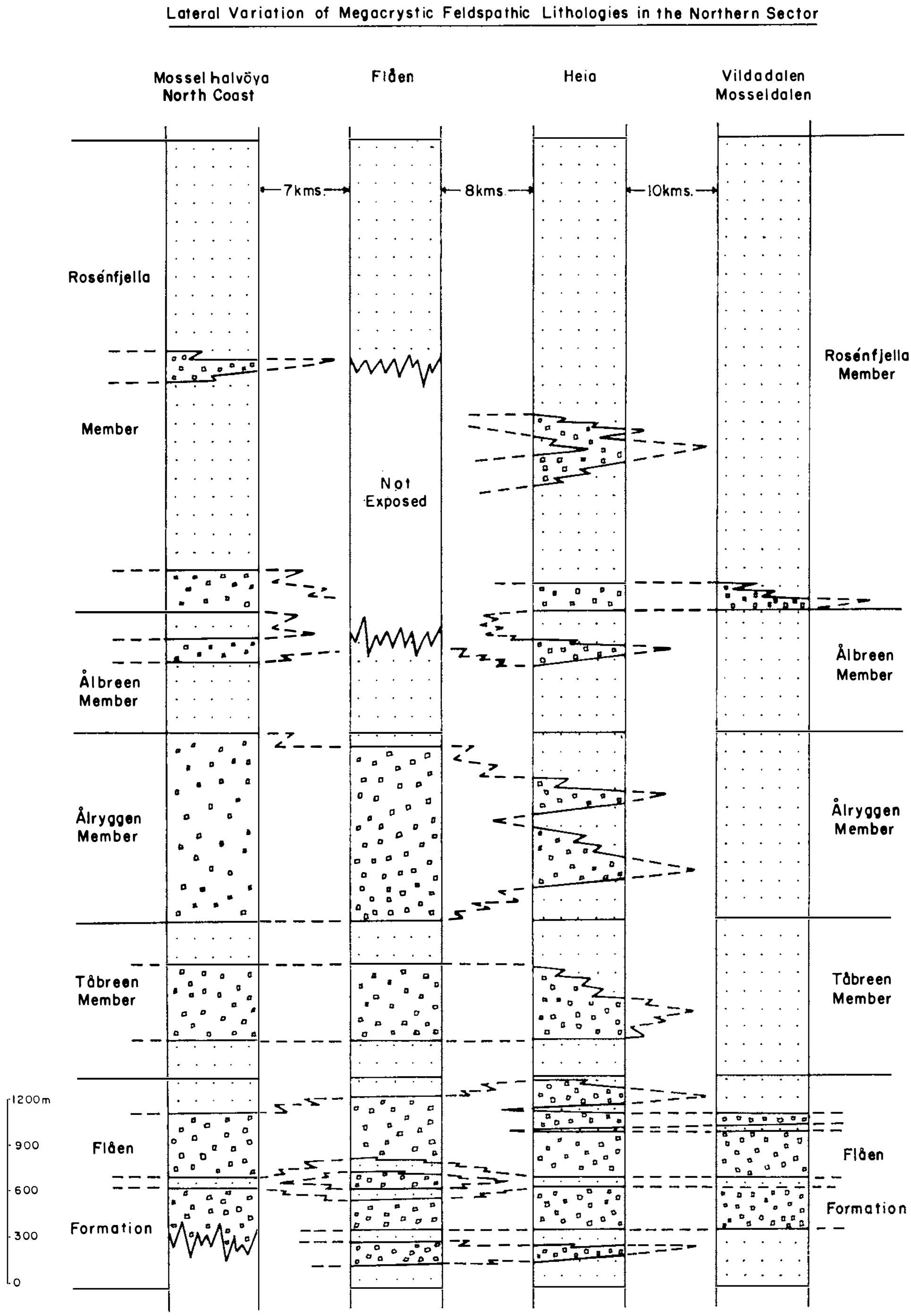

Fig. 5. *Diagrammatic representation of the apparent lateral variation of megacrystic feldspathic lithologies in the Planetfjella Group in the northern sector.*

that is 300 m.y. before the strata underwent tectonic disturbance. With this overburden and this time lag, authigenic growth during prolonged diagenesis cannot be disregarded as a factor contributing to the appearance of these rocks.

THICKNESS

The thicknesses given in the detailed descriptions and in the diagrammatic sections are derived from pacing estimates in the field or from calculations from geological mapping. It is hoped that their accuracy is within 10%. Obviously there is no direct comparison between these figures and the original depositional thickness of the sediments, but the figures do give a relative idea of the ratio of the different rock types. Fig. 4 shows a marked variation in the thickness of the Rosénfjella Member along the outcrop. This variation may well be correlated with the greater deformation and the higher grade of metamorphism observed in the northern and Veteranen sectors compared to the central sector. Thus, the greater thickness seen in the central area may be due to secondary preservation rather than original sedimentary thickening. Unfortunately the strata do not possess suitable lithologies, such as pebbles, oolitites or reduction spots, from which it is possible to calculate the relative amount of deformation along the outcrop.

Conclusions

(1) The Planetfjella Group of HARLAND *et al.* (1966) [the Planetfjella Series of HARLAND and WILSON (1956)], can be divided into the following lithostratigraphic units, which can be mapped throughout Ny Friesland: an upper Vildadalen Formation, comprising the Rosénfjella, Ålbreen, Ålryggen and Tåbreen Members, and a lower Flåen Formation with eight divisions.

(2) The upper boundary of the Planetfjella Group is always found conformably below the Kortbreen Formation of the Middle Hecla Hoek, and there is no evidence for a stratigraphic break at this level in the sedimentary sequence in Ny Friesland.

(3) As far as is known, the Planetfjella Group does in places rest conformably on the Harkerbreen Group.

(4) The assertion that the Planetfjella Group in Ny Friesland does not contain amphibolites is confirmed.

(5) The Vildadalen Formation can be interpreted as a sedimentary analogue of the lower Middle Hecla Hoek, and consists of rhythmic units of fine sand to silty-clay (greywacke), which are probably turbidites, together with pure, shallow-water dolomites and limestones, and pure and impure quartzites and psammites. This succession is thought to represent a repetitive marine sequence whose variations reflect differences in sediment supply and depositional slope. In the lower part of the Vildadalen Formation there are some horizons which are more feldspathic, but these are also thought to be sedimentary in origin.

(6) The subpelitic divisions of the Flåen Formation are analogous to those of the Vildadalen Formation.

(7) The major feldspathic horizons of the Flåen Formation, divisions (4), (6) and part of (7) and (8), contain rare to abundant feldspar megacrysts, and both the high proportion of feldspar in the groundmass and the megacrysts pose distinct problems. However, in the case of the megacrysts the textural evidence, their well-formed shape, variable distribution, and variable composition seem to indicate an early origin. The overall stratigraphic relations of the feldspathic horizons are most easily interpreted as being sedimentary in origin. The feldspathic horizons may have been formed either as derivatives of acid pyroclastics, or as secondary arkoses from acid volcanic or plutonic rocks, but there are no obvious criteria to support either of these alternatives. A primary origin for the feldspar megacrysts raises almost as many difficulties as a secondary origin, and they may be composite features, some being originally large sedimentary grains, some being due to authigenic growth during diagenesis, and some being due to local metasomatism and porphyroblastic growth during the first period of deformation.

Acknowledgments

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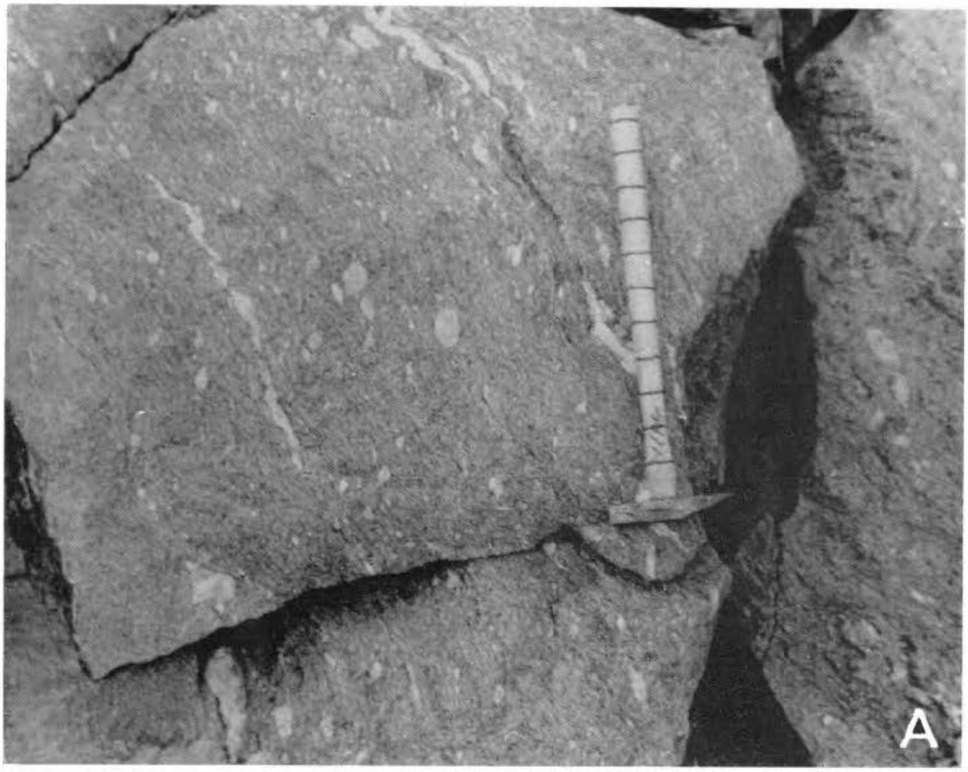

Fig. A. *Typical megacrystic feldspathite. Note the segregation veins lying in the foliation, the random size of the megacrysts, and the more euhedralform of the larger grains. Hammer divisions are 2.5 cm.*

Fig. B. *Well crenulated megacrystic feldspathite. Note the variation in size of the megacrysts, the dominant subhedral form, and their lack of distortion. Hammer divisions are 2.5 cm.*

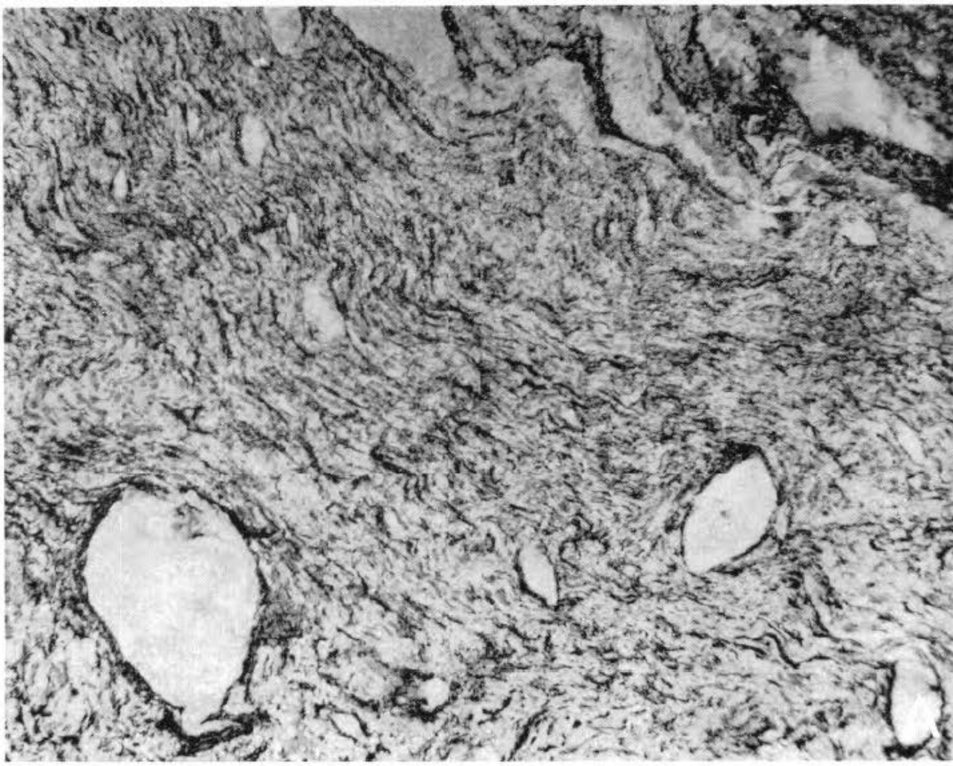

Fig. A. *Detail of two megacrysts to the left of the hammer head in Plate I, Fig. B. Note the well marked compositional foliation (lamination), the quartz segregation veins, and the crenulations abutting against and flowing round the megacrysts. The larger megacryst is 3.5 cm.*

Fig. B. *Well-folded, colour-banded quartzites in division (7) of the Flåen Formation.*

Sulphide mineralizations within the Hecla Hoek complex in Vestspitsbergen and Bjørnøya

BY

BOYE FLOOD

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Abstract

The known sulphide mineralizations in Vestspitsbergen and Bjørnøya occur solely within the Hecla Hoek Complex. The various deposits are described in some detail, and an attempt is made to prove that most of them are related to Caledonian structures; Revdalen, the only one appearing within lithologies of higher metamorphic grade, possibly being older. The others are, owing to structural control, mineral paragenesis, and general geological setting, classified as telethermal mineralizations.

Introduction

No mining of metals occurs in Svalbard today. Nor has such activity taken place previously, except for exploratory mining in a few places.

The first record[1] of sulphide minerals from Svalbard dates back from 1605, when JONAS POOLE, employee of the Muscovy Comp., found galena in Bjørnøya. NORDENSKIÖLD (1875) mentioned the occurrence of pyrite, arsenopyrite, pyrrhotite

[1] If not otherwise stated, historical information refers to HOEL (1966).

and chalcopyrite from within "urformationens bergarter" (the Pre-Cambrian) in Vestspitsbergen. He also recorded galena, sphalerite, silver, barite and witherite from Bjørnøya. As far as the silver is concerned, this must refer to its occurrence within the galena (HORN and ORVIN 1928).

During the 19th century the geological reconnaissance of Svalbard had generally been academic in nature. In the beginning of this century, however, growing economic interest motivated the geological investigations of the islands. The primary reasons were the many finds of coal in Vestspitsbergen, but by degrees prospecting for a large variety of minerals also took place. This led to the founding of many companies of various nationalities, and large areas of Svalbard were taken up by claims. The largest and most active of these companies was the English "Northern Exploration Co. Ltd.",[1] which during its highday had a share capital of £ 1 mill. Although the methods and intentions of this company have aroused discussion, non the less its large share in the activities leading to the finding and closer investigation of a large number of deposits is not disputable. This unique prospecting period in the history of Svalbard ceased when in 1932 the N. E. Co. sold its holdings to the Norwegian government for 100 thousand kroner.

All the sulphide mineralizations in Vestspitsbergen mentioned in this paper (Fig. 1) were either found or explored by the above-mentioned company.

In Bjørnøya the Norwegian company Bjørnøen A/S explored the zinc-lead mineralizations mainly during the period 1925-1930. This company, which was founded in 1915 as I/S Bjørnøens Kulkompani and reorganized to Bjørnøen A/S in 1918, had since 1916 been mining coal at the small mining town Tunheim. Because of this, expeditions supported by the Norwegian government carried out both topographical and geological mapping of the island on a scale of 1:10,000 in the early 1920's. This geological work (HORN and ORVIN 1928) led to a new find of galena and, when the coal mining had to close down in 1925, to the exploration mentioned above.

Details regarding the history of each of the mineralized areas will be mentioned under the separate descriptions of them.

After the mining interest was abandoned in the various localities, little attention was paid to the mineralizations. They were merely noted as copper, lead and zinc deposits. On the geological map of Svalbard (ORVIN 1940), the three sulphide deposits St. Jonsfjorden, Kapp Mineral, and Sinkholmen are marked, all occurring within the Hecla Hoek complex. HJELLE (1962) gave a brief description of the mineralizations within or near to the Hecla Hoek areas between Isfjorden and Bellsund, and suggested that they were of Tertiary age. As a result of the Polish investigations in Hornsund, WOJCIECHOWSKI (1964) and BIRKENMAJER and WOJCIECHOWSKI (1964) gave a short description of the paragenesis and apparent age of the ore-bearing veins of Hornsund and proposed that they were pre-Devonian. This was the first account of sulphide paragenesis given from any locality in Svalbard.

HORN and ORVIN (1928) marked the more significant galena mineralizations on

[1] N. E. Co. later in this paper.

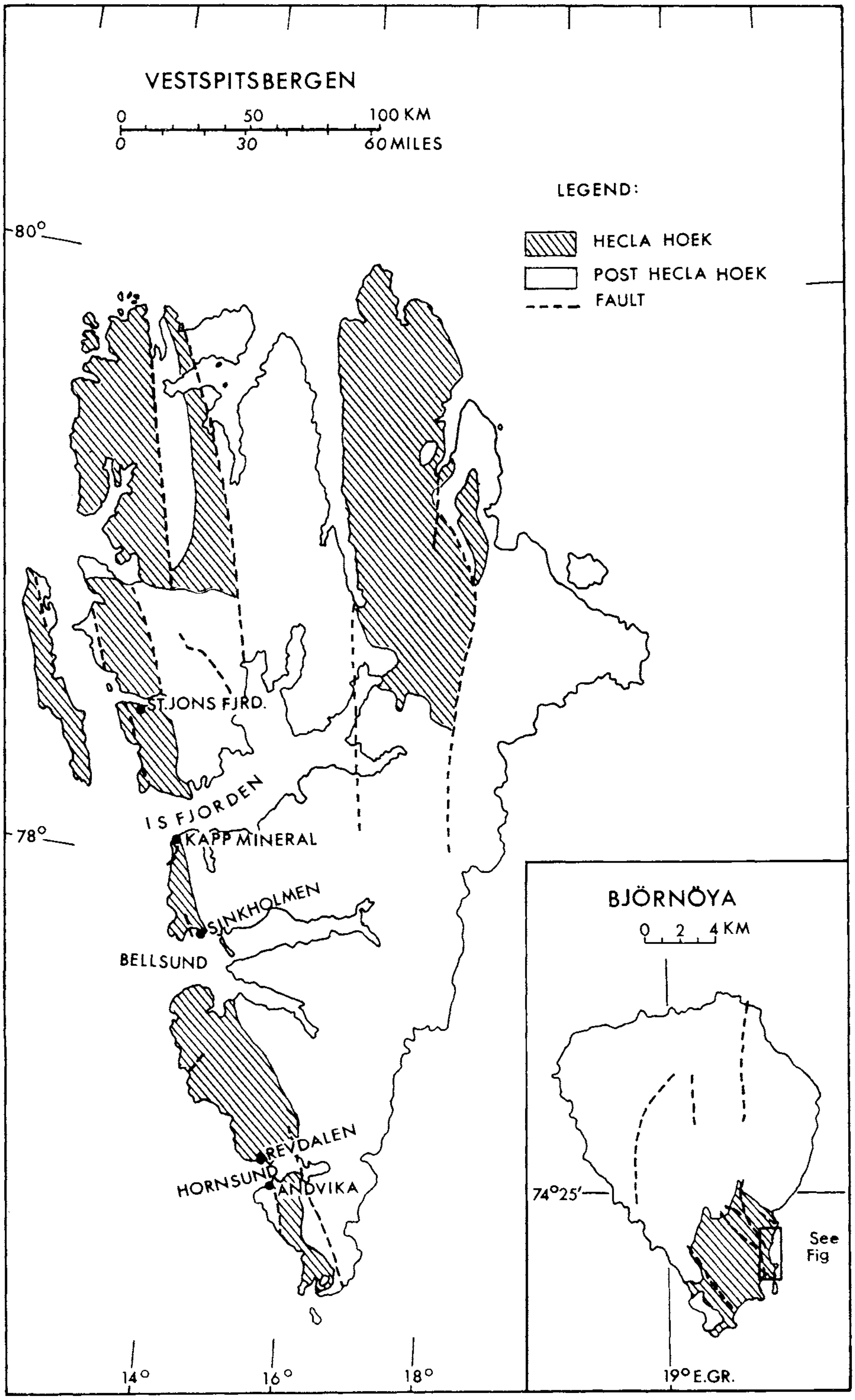

Fig. 1. *Map of Vestspitsbergen and Bjørnøya, showing the mineralized localities.*

their geological map of Bjørnøya, and also gave a short description of their occurrence.

During the summer of 1966 I visited all the localities in Vestspitsbergen shown in Fig. 1, except for St. Jonsfjorden, the most northerly one. The following brief description of St. Jonsfjorden seems convenient, as the deposit is marked on the geological map of Svalbard. Information and samples from this locality were kindly given to me by T. SIGGERUD; neither have I been able to visit Bjørnøya. The information used is taken from HORN and ORVIN (1928) and HOEL (1966), while the relevant samples were obtained from the Norsk Polarinstitutt collections. The reason for including a discussion of these deposits is their resemblance to those of Vestspitsbergen.

My investigations were carried out while Norsk Polarinstitutt was engaged in a combined geochemical-geological investigation around known sulphide-bearing areas in Vestspitsbergen. This work was performed by Dr. BAHNGRELL W. BROWN, U. S. A., and myself, together with W. INGEBRETSEN from Norsk Polarinstitutt, and three assistants. My thanks are due to all of them for their co-operation in the field. W. INGEBRETSEN also prepared the polished sections. The manuscript has been read by director, Dr. TORE GJELSVIK and the language corrected by Dr. ALASDAIR H. NEILSON.

General Geology

As stated in the title, all the mineralizations described here occur within the Hecla Hoek complex. This thick Caledonized sequence consists of young Pre-Cambrian, Eocambrian, and Lower Paleozoic rocks of both igneous and sedimentary origin. The metamorphic grade varies considerably within the complex, which extends along the west coast of Vestspitsbergen (Fig. 1) and also constitutes part of the north-eastern region of the island. In Bjørnøya the Hecla Hoek is exposed in the southern part of the island and covers about one seventh of the total area.

Except for Revdalen, the mineralizations are all located within low grade metamorphic rocks, mainly in carbonates. Revdalen differs from the other localities both in respect of its geological setting and its mineral paragenesis. Because of this, I have in the Hornsund region distinguished between the two localities on the north side and south side of the fjord – Andvika and Revdalen respectively.

Owing to the investigations by MAJOR and WINSNES (1955) and BIRKENMAJER (1959), the stratigraphical position of the mineralized rocks in Andvika is well defined. They consist mainly of oolitic and pisolitic dark grey dolomites of the Höferpynten series belonging to upper Middle Hecla Hoek. A correlation between this lithology and that found on Sinkholmen and its nearby mainland in Bellsund is probable. Regarding the two northernmost localities described here the stratigraphical position is less certain. HJELLE (1962), however, suggests a lower Upper Hecla Hoek age for the rocks around Kapp Mineral.

In Bjørnøya the distribution of the galena-bearing veins is described by HORN and ORVIN (1928) as follows: "The veins of the Older Dolomite series (see geol.

map) appear to be more regular than the deposits in the Younger Dolomite and the Tetradium Limestone, these being of a more patchy nature." Their stratigraphical division of the Hecla Hoek complex was based on HOLTEDAHL (1920), who correlated the oolitic Older Dolomite with the Porsanger Dolomite, and assumed an Upper Cambrian or Basal Ordovician age. Fossil evidence suggested an Ordovician age for the Younger Dolomite and the Tetradium Limestone. Later work by HOLTEDAHL (1931) showed the Porsanger-dolomite to be situated below the fossiliferous Cambro-Silurian sediments, but the correlation of Older Dolomite with Porsanger Dolomite was still valid, and was later extended to the Ryssö-dolomite in Nordaustlandet (KULLING 1934) and the Höferpynten series in Andvika (MAJOR and WINSNES 1955).

The mineralized areas

VESTSPITSBERGEN

The following description will deal with the five localities of mineralization (Fig. 1) in Vestspitsbergen; they will be described successively from north to south. Revdalen will, for reasons already mentioned (p. 112), be described after the other four.

St. Jonsfjorden

During the summer of 1919 prospectors from N. E. Co. traced chalcopyrite on the south side of St. Jonsfjorden. During the following year prospecting went on in this area from late April until early September. A camp, "Copper camp", was erected, but in spite of this promising name the results were not encouraging.

Today some trenches may be found along the contact between dark limestones of varying purity, but evidence of mineralization in this bedrock was not found. Near the shore, however, a heap containing lumps of massive chalcopyrite up to twice the size of a man's fist was found; some lumps consist of a breccia (Fig. 2) with fragments of a grey dolomitic siltstone, noticeably different from the rock in which the trenches were found. This has aroused the suspicion that the ore may have been transported from elsewhere.

Polished sections of this ore show almost solely chalcopyrite, but in a few places clusters or wavy bands up to 0.5 mm long of pyrite grains occur within the chalcopyrite. These grains rarely exceed 0.05 mm in diameter and are mainly seen along or near to the rock fragments. Some of these concentrations of small grains resemble partly replaced cataclastic pyrite crystals observed in some of the other sulphide deposits in Vestspitsbergen. For the present, however, we must question the existence of the mineralization in St. Jonsfjorden. It will not be further discussed in this paper.

Kapp Mineral

This mineralization is situated about 2½ km north-east of Isfjord Radio. Today only some trenches and the remnants of a shaft and two huts are found

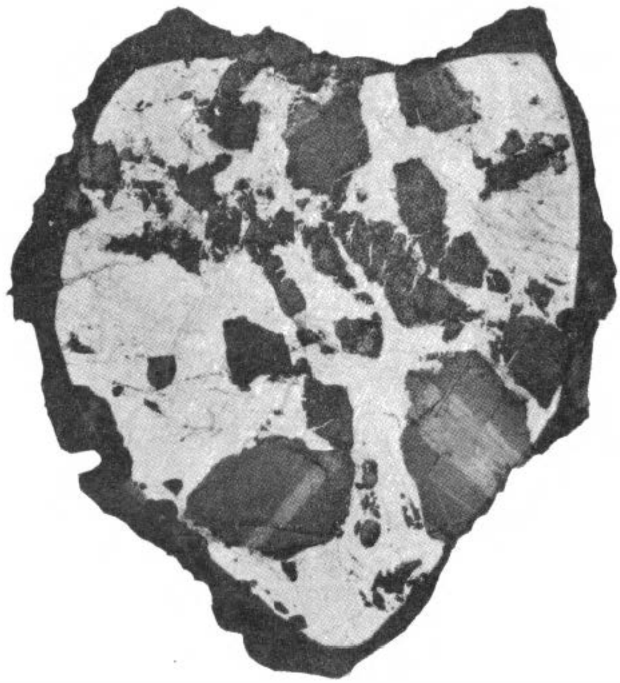

Fig. 2. *Polished hand specimen of ore from St. Jonsfjorden showing chalcopyrite (white) with rock fragments (grey). Nat. size.*

close to the shore line. Galena and a little sphalerite are seen only in a small open pit where the bedrock outcrops between the shore line and the mainly covered "strandflat" above. This locality was found by the mining engineer ARTHUR LEWIN in 1922; during the two following summers LEWIN and his brother worked the claim, and some rich ore was produced. During the summers of 1925 and 1926, and partly also during the intervening winter, N. E. Co. continued the explorative work. A shaft was sunk through the "strandflat" cover a bit further inland, and from a depth of 8 m an adit was worked for c. 25 m towards the north. Thus they reached below the open pit, but no traces of mineralization were found during the underground work. As 1926 was the last year N. E. Co. sent expeditions to Svalbard, no further investigations were carried out.

The sulphide minerals at Kapp Mineral occur in an intensively brecciated dark grey limestone. The breccia zone, a few metres wide, shows a criss-cross pattern of white calcite veins. Associated with these appear veins up to a couple of cm thick of galena and sphalerite, as well as some disseminated ore. This deposit is, according to the geological map of Svalbard (ORVIN 1940), situated near a fault. HJELLE (1962) refers the brecciation and subsequent mineralization to this fault, which follows the strike of the limestone towards the south-west (Fig. 1). Where it outcrops along the shore line south-west of Kapp Mineral, a breccia almost

Fig. 3. *Looking north upon the possible continuation of the Kapp Mineral breccia zone, south of Isfjorden.*

identical to the one described above was observed (Fig. 3), but in spite of good outcrops in this area no sulphide mineralization was found. However, a few pyrite cubes occur in more carbonaceous zones.

Microscopic examination shows the presence of the following minerals from Kapp Mineral:

Galena, sphalerite, pyrite, and chalcopyrite.

The typical appearance of the galena is shown in Pl. I, Fig. 1. The galena displays triangular grooves, which sometimes form a "folded" pattern, possibly due to deformation (Pl. I, Fig. 2). This is also noticed in the material from Andvika. The sphalerite is observed in the galena veins near the carbonate, but also as separate grains both within the galena and in the host rock. Chalcopyrite, which is rare, is seen to form mutual boundaries with galena (Pl. I, Fig. 3). The pyrite, only in accessory amounts, appears more often separately in anhedral to euhedral grains about 0.1–0.2 mm in diameter. They tend, however, to concentrate together with the other sulphides (Pl. I, Fig. 3), a feature also noticed in the other localities described here.

Sinkholmen

This deposit was found on one of Reiniusøyane in Bellsund (Fig. 4) in 1913 by the geologists A. Hoel and A. K. Orvin, both later directors of Norsk Polarinstitutt. The small island, later called Sinkholmen, displays by far the most complex and interesting mineralization of its kind known in Svalbard today.

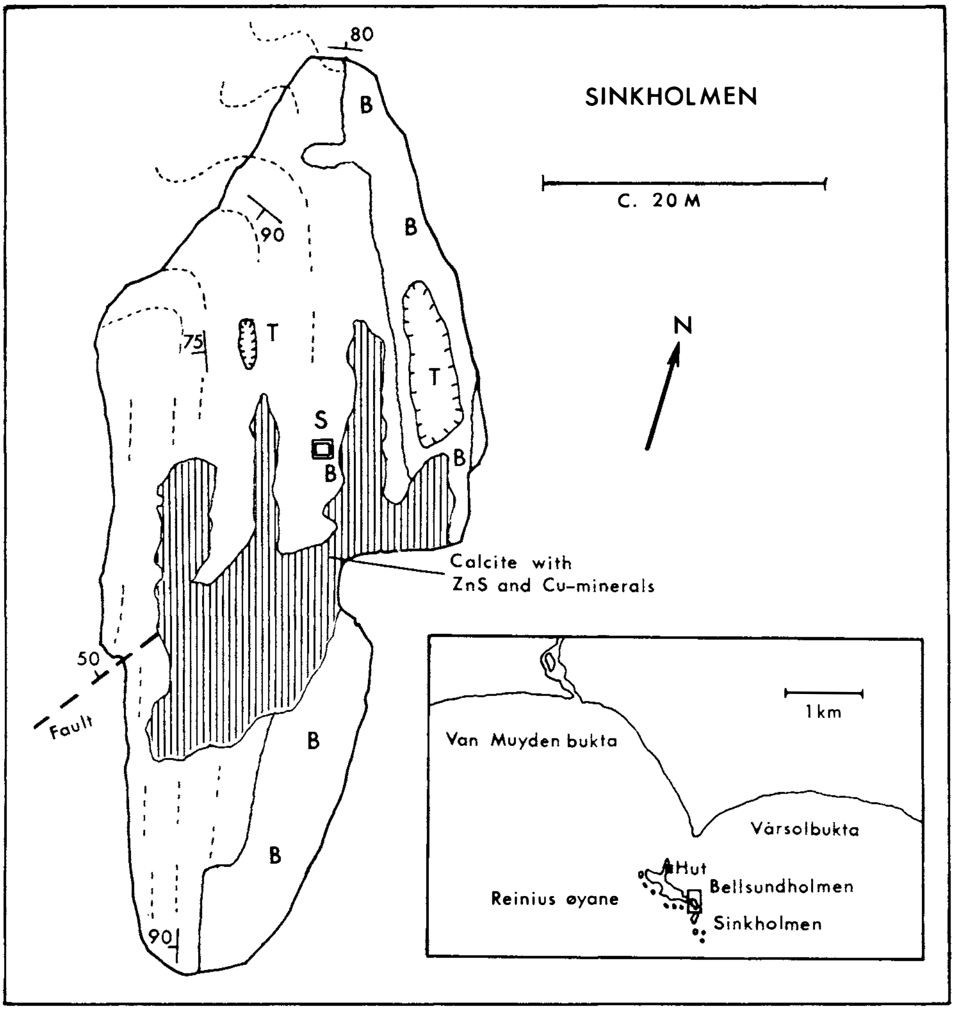

Fig. 4. *Geological sketch of Sinkholmen and a key map of Reiniusøyane. B: Brezzia zones. T: Trenches. S: Shaft. Stipled lines indicate the general strike and folding of the host rocks.*

During the summers 1924–1926, N. E. Co. investigated both the islands and the nearby mainland; a small hut was then built on Bellsundholmen (Fig. 5). The main work carried out on Sinkholmen itself is indicated by the trenches and the shaft shown in Fig. 4. The trench on the east side of the island is reported to have produced c. 240 ton of rich ore, but the bottom of it was then worked down to sea level, and the ore-bearing zone was thinning out downwards. The shaft was sunk down to c. 10 m, but quickly filled with water. Traces of sphalerite were also found on Bellsundholmen, and during the last summer of N. E. Co.'s activity a new shaft was sunk in the south-eastern part of the island. From the bottom of this, almost 3 m down in bedrock, sphalerite was recorded from its western corner.

Fig. 5. *Looking north towards the old prospecting hut on Bellsundholmen. To day its only inhabitants are eiders breeding in the kitchen stove; the hut will soon disappear due to marine erosion.*

Fig. 6. *Looking south on the south part of Sinkholmen with some of the small nameless islands in the background. The white foreground is the central part of the calcite mass.*

Reiniusøyane consist of dark grey dolomitic rocks, partly oolitic and carbonaceous, together with siltstone beds, black limestones, and dark and yellowish shales. The general structure of these lithologies is indicated in Fig. 4. Brecciation of varying intensity is common and thought to be associated with a fault in Van Muydenbukta. This strikes towards the south-east and separates a wedge of Culm sediments to the south-west from Hecla Hoek rocks to the north-east (HJELLE 1962).

Into the central part of Sinkholmen a small fault strikes towards north-east with a horizontal displacement of c. 1 m. Associated with this fault is an extensive replacement of the carbonate and siltstone beds by a mass of coarse crystalline calcite (Fig. 4 and Fig. 6). The strongly brecciated zones along the east side of Sinkholmen and the mass of calcite in the central part appear to be hosts of the sulphide minerals. Brecciation with a little sphalerite and crystals of fluorspar also exists on some of the small islands south of Sinkholmen. A conspicuous breccia zone in the north-west part of Bellsundholmen, however, does not contain any sulphide minerals.

The present microscopical investigation has revealed a notable difference in mineral paragenesis between the calcite mass and breccia mineralizations.

The breccia mineralization is entirely dominated by a light yellowish-brown sphalerite with an iron content of less than 1% (Table I). The brecciation and associated mineralization seem specific to certain beds, this probably being due to difference in competence (Fig. 7). Galena, which occurs only in minor amounts in the ore from Sinkholmen, is shown in Pl. I, Fig. 4. Pyrite appears in a way similar to that noted from Kapp Mineral. The "fahlerts" tetrahedrite[1] is observed in grains up to 4 mm in diameter, closely associated with sphalerite (Pl. I, Fig. 5). The occurrence of copper minerals, possibly chalcopyrite, within this paragenesis was indicated by a minor malachite staining.

	Breccia	Calcite mass
Sulphides	Sphalerite Galena Pyrite	Sphalerite Pyrite Chalcopyrite Bornite Idaite Chalcocite Neodigenite Covelin
Sulphosalts	Tetrahedrite	Tetrahedrite
Gangue	Fluorspar Quartz	Calcite

[1] This mineral has been determined from x-ray powder pattern by Mrs. BRENDA JENSEN, Geologisk Museum, Oslo.

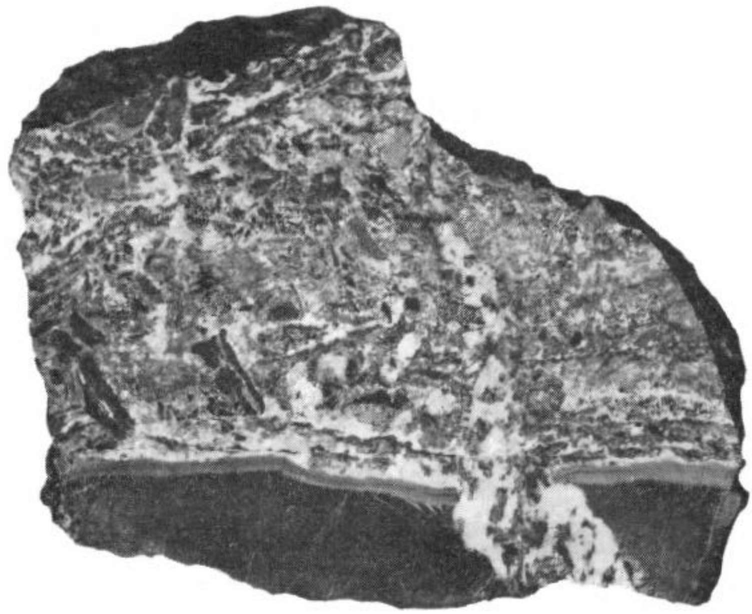

Fig. 7. *Specimen from the large trench on Sinkholmen showing a brecciated layer of dark grey calcareous siltstone. Within the breccia: Siltstone (black), sphalerite (grey), and quartz and fluorspar (white). Half size.*

Field observations from the central part of Sinkholmen show the coarse-crystalline, white calcite with a graphic pattern of dark-weathered sphalerite (Pl. I, Fig. 6); some malachite staining reveals occurrence of copper minerals. None of these, however, are observed within the sphalerite aggregates. Small inclusions of pyrite are frequent within the sphalerite, often in a linear arrangement (Pl. I, Fig. 7), and a few grains of tetrahedrite occur. Between the calcite gangue and the sphalerite there occur border zones a few mm wide of more coarse-grained pyrite and tetrahedrite, the latter with grains up to 1 mm in diameter. The pyrite, by far the more frequent of the two, is often cataclastic and replaced by chalcopyrite, this taking place preferentially along the cracks (Pl. I, Fig. 8).

The other copper minerals listed above are not easily detected in the field, but were observed when big hand specimens of calcite were cut in the laboratory. They appear both as individual and as complex grains, a few mm in diameter, distributed with varying density. Apparently their position is close to the sphalerite aggregates and almost invariably associated with pyrite grains (Pl. II, Figs. 1-4). These figures give a representative impression of the general relationship between the sulphides. An early age of the pyrite, with its fracture-fillings of copper minerals dominated by chalcopyrite and bornite, seems clear. Also a late occurence of the covellite is apparent, as this mineral replaces all the copper sulphides except chalcopyrite, and especially chalcocite and idaite. A general discussion, however, regarding the succession of crystalization of the copper minerals is not within the scope of this paper.

Andvika

Rumours about occurrence of gold and silver led N. E. Co. to send an expedition to Hornsund during the summer of 1920. The expedition worked on both sides of the fjord, but, as stated in a report, without finding deposits of economical significance.

As a result of the Polish investigations in the late 1950's, WOJCIECHOWSKI (1964) published a short account on "Ore-bearing Veins of the Hornsund Area, Vestspitsbergen". The abstract reads as follows: "Quartz-, ankerite-, and ankerite-quartz ore-bearing veins have been found in the Hornsund area, Vestspitsbergen. They contain, pyrite (most important), chalcopyrite, pyrrhotite, galenite and sphalerite, as well as secondary minerals like limonite, cuprite, malachite and azurite. Veins containing haematite and magnetite are less frequent".

Regarding the mineralization in Andvika, WOJCIECHOWSKI's statements are based on observations made by colleagues, not primarily investigating the mineralizations. This explains why my observations from Andvika differ from his general description of the mineralization in Hornsund.

Andvika, situated on the south side of Hornsund, consists of a faulted area of Culm and Hecla Hoek lithologies (Fig. 8), with small mineralizations scattered over a wide area. Along the western shore of Höferpynten the sulphides are mainly found along northerly steep-dipping cross joints, and along joints striking north-north-east with a medium dip to the south-east. The sulphides appear as fissure fillings a few cm wide together with quartz, and may be traced continuously over a distance up to 10 m. Locally where the joints develop into thin breccia zones, and where the two sets of joints cross each other, sulphide veins up to 20 cm thick are seen. On Andskjera galena-bearing veins a few cm thick were found. The mineralization on Kviveodden appears in strongly brecciated quartzite, while Wurmbrandegga shows disseminated sulphides associated with minor breccia zones.

The following sulphide minerals have been observed in Andvika:

Pyrite, arsenopyrite, sphalerite, galena, and chalcopyrite.

Gangue is quartz, which also appears frequently as nicely developed crystals in cavities; these crystals sometimes display amethyst colours or carry rutile needles.

The arsenopyrite, which is typical of this locality, appears mainly together with fine-grained pyrite as the fissure fillings, while sphalerite and galena seem to have a greater affinity for the breccias. Although occurring in highly variable proportions, all the minerals listed above generally appear together (Pl. II, Figs. 5–6).

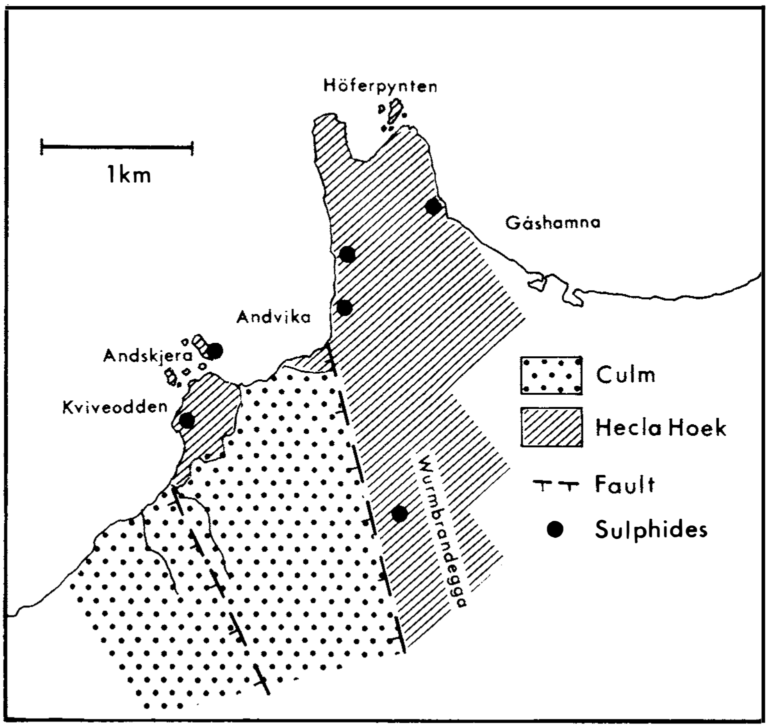

Fig. 8. *Geological sketch map of Andvika and neighbouring areas from* SIEDLECKI and TURNAU *(1964), with the mineralized localities marked.*

Table I

Some analyses of sphalerite from the investigated localities on Vestspitsbergen. Due to lack of material the accuracy of Cd is only ±30%. The elements have been determined at the Chemistry department, Geological Survey of Norway

Sample 66-BF-	Locality	Fe%	Cd%	Mn%
1	Kapp Mineral	<1	0.08	<0.005
71A	Sinkholmen (breccia ore)	<1	0.4	<0.005
74	Sinkholmen (calcite mass)	<1	0.5	<0.005
82	Andvika (east side)	<1	0.15	<0.005
89	Andvika (Kviveodden)	<1	0.35	<0.005
117	Revdalen	7.3	0.1	<0.01

Revdalen

This valley extends c. 6 km in a north-west direction from a point in the fjord a few km west of Isbjørnhamna. The mineralization described in WOJCIECHOWSKI (1964) generally refers to this locality and its surroundings. Others on the north side of Hornsund are, with few exceptions, found as erratics or in moraines.

Geological descriptions of the Revdalen area are given by BIRKENMAJER (1960) and SMULIKOWSKI (1965). The rocks consist of micaschists and carbonates of the Isbjørnhamna Formation, and quartzites and amphibolites of the Eimfjellet Formation, both belonging to the Lower Hecla Hoek. The metamorphic grade of these rocks is within the amphibolite or albite-epidote-amphibolite facies, and their metamorphism possibly pre-dates the Caledonian deformation of the Hecla Hoek (SMULIKOWSKI 1965).

The sulphide-bearing quartz-ankerite veins appear within both the formations mentioned. They may reach 2 m in width, and the largest trends for more than one km along the lower slopes of the south-east side of the valley. Generally, however, they are much smaller, of the order of one or two dm in width. In most cases they intersect the strike of the host rocks at a small angle, also cutting the folds. On account of this BIRKENMAJER and WOJCIECHOWSKI (1964) suggested that the mineralized veins are younger than the main phase of Caledonian orogeny. I have, however, in one case observed in the upper part of Revdalen a thin vein folded together with lithologies of the Eimfjellet Formation. I also assume that if the veins intersect the strike previous to or during the deformation, they would appear to cut the folds of the host rock, although themselves being folded. This may be difficult to observe in the larger veins, as often, owing to vegetation and scree cover, only their general trend is revealed. The frequently fractured appearance of the quartz in the veins also indicates folding.

As already pointed out by WOJCIECHOWSKI (1964), the quartz-ankerite veins do not carry sulphide minerals along their total extensions. Also the positions of the sulphides within the veins seem rather arbitrary. In some of the smaller veins in upper Revdalen a concentration of sulphides along the contacts is apparent. These veins have been best investigated in the screes along the north-east part of the valley.

The sulphide minerals observed in Revdalen are the following:

Pyrite, chalcopyrite, galena, sphalerite, and pyrrhotite.

The paragenesis is distinguished from that of the other localities by occurrence of pyrrhotite and the fact that magnetite is frequently observed together with the sulphides. The magnetite is especially associated with the pyrite, the two sometimes constituting the only opaque minerals. The sphalerite in Revdalen is of a dark brownish colour, containing about 7% of iron (Table I).

The pyrite has two typical modes of occurence. It is seen as fine-grained aggregates, often of a spherical shape with a rim of subhedral and euhedral crystals (Pl. II, Fig. 8). More often, however, the latter texture applies to the whole pyrite grains, as demonstrated in Pl. II, Fig. 7. The chalcopyrite, sphalerite

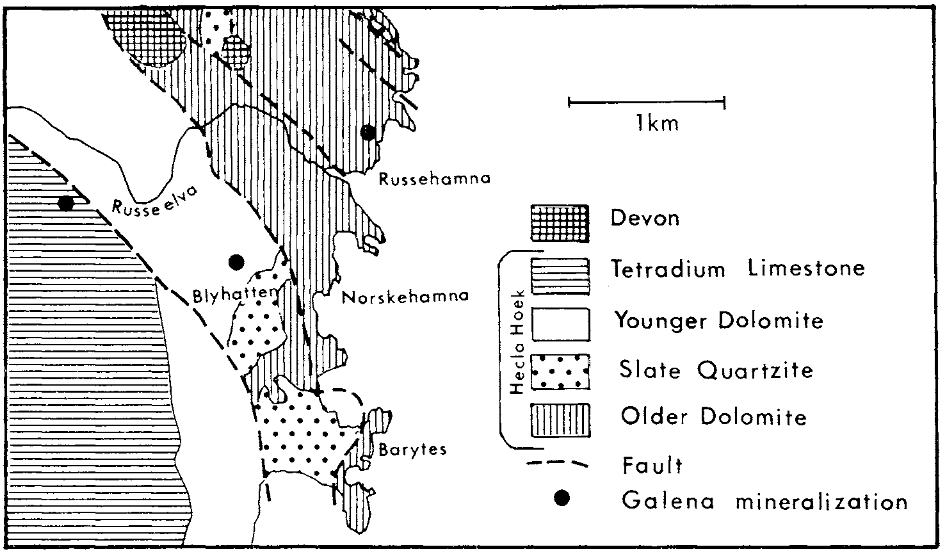

Fig. 9. *Geological map of the south-east coast of Bjørnøya. From* HORN *and* ORVIN (1928).

and galena appear in about equal amounts, but subordinate to pyrite. Pyrrhotite is seen only in a couple of polished sections; the grains rarely exceed 1 mm across.

BJØRNØYA

The long known occurrences of lead mineralizations in Bjørnøya (p. 109) do all appear within the Hecla Hoek (p. 112). The three more significant which have been subjected to closer investigations are marked on the map Fig. 9. For convenience the following names are here used for these deposits, Russehamna, Blyhatten, and Russeelva, from east towards south-west and west respectively.

Russehamna

This locality, situated within the Older Dolomite, was explored already in 1916. It is recorded as galena-bearing barite veins, extending for about 150 m in a direction WNW-ESE. The thickness of the vein varies between 11 and 32 cm. The galena was observed along c. 70 m of its total length, where observed constituting about 50% of the vein.

Blyhatten

While carrying out geological mapping during the summer 1924, A. K. ORVIN found galena in this locality. Further investigations went on until the summer of 1926, when the deposit was abandoned. The mineralization at Blyhatten appears as N-S and E-W striking veins of barite and galena, as well as lenses of galena. The mineralized area occurs in the yonger Dolomite and is about 25 by 15 m.

Trenching outside this area only revealed traces of barite. During the exploration of the deposit a shaft 6 m deep and an adit 25 m long were driven, and c. 75 t of rich ore was produced.

Russeelva

While the work at Blyhatten was suspended in 1926, a careful surveying of the neighbouring area was carried out. This led to a new find of galena and barite c. 1 km further to the west. Prospecting work on this deposit was started during the summer of 1927 and was partly through government support and partly from own income maintained until the summer 1930. C. 260 t of lead ore had then been sold.

Russeelva occurs in the Tetradium Limestone, just south-west of a large fault. It is recorded as a vein of galena and barite 0.5–2 m thick, striking N-S over a distance of 50 m. The mineralized vein appears within a zone of calcite c. 8 m wide, a feature resembling Sinkholmen.

Owing to the grey weathering colour of the galena in Bjørnøya, resembling the colour of the carbonate, it has been reported difficult to distinguish in the field. Generally the mineralized veins are recorded as consisting of coarse galena and barite, with sphalerite sometimes present. This is confirmed by the samples from the Norsk Polarinstitutt collections, mainly showing white barite with coarse lumps of galena with a conspicuous cubic cleavage. Only a couple of polished sections have been investigated, revealing also occurrence of pyrite and chalcopyrite. Thus the following sulphides are observed:

Galena, sphalerite, pyrite, and chalcopyrite.

The two latter occur only in accessory amounts. Pyrite was by HORN and ORVIN (1928) recorded only from Devonian sandstones, but is here observed as small grains, <0.5 mm, together with some yellowish brown sphalerite with grain size a few mm across. Both minerals mainly occur along the borders between barite and the host rock. Chalcopyrite was observed as a few individual grains, <1 mm, within barite.

Apparent age and type of mineralizations

Although I have abcve distinguished between Revdalen and the other deposits, they will, as fas as the discussion of age is concerned, mainly be treated together.

Previous discussions about the age of the mineralizations have arrived at different conclusions. A Tertiary age was proposed for the Isfjorden–Bellsund area (HJELLE 1962), and a probable Silurian age for the Hornsund area (BIRKENMAJER and WOJCIECHOWSKI 1964). HJELLE bases his assumption upon the occurrence of ore minerals near to the Culm rocks and faults assumed to be of a Tertiary age. Also one of his localities (No. 6) displays weak mineralization within an apparent post-Culm breccia including sphalerite, pyrite, and chalcopyrite. The general location of the mineralizations within the Hecla Hoek he ascribes to the overlying Culm sediments acting as a roof against ascending hydrothermal solutions.

Although traces of chalcopyrite, galena, and spalerite are met with also in a couple of other places within the post-Hecla Hoek rocks, they seem incomparable with the mineralizations described here. To our knowledge they solely appear as minor impregnations in sandstones, and are considered insignificant as proof of a younger mineralization in general. It may also be debated whether the Culm sediments, mainly consisting of sandstones and conglomerates, would have the ability to serve as a roof against ore-bearing solutions. The lack of ore-bearing veins in the post–Hecla Hoek rocks also in the Hornsund area, which by BIRKENMAJER and WOJCIECHOWSKI (1964) has been used as a main argument for a pre-Devonian age, seems valid for the whole of Vestspitsbergen. It is admitted that the coastal area, where the mineralized Hecla Hoek rocks occur, is both better exposed and easier accessible than the younger inland rocks, where to our present knowledge no similar deposits exist. In this connection a support for a Hecla Hoek age of the mineralization is found in Bjørnøya, where all the rocks are equally exposed (Fig. 1), but still the mineralizations are found only in the older complex.

Disregarding Revdalen, the described deposits are all located near to fault zones, those adjacent to Sinkholmen and seen in Andvika definitely being of younger age, probably Tertiary. The mineralizations also show a general association with fissures and breccias, which indicates a clear relation between zones of movement and the emplacement of the sulphides. If the mineralizations were contemporaneous with the younger faulting, they should in any case be independent of a pre-fault roof. As the known deposits preferentially occur in carbonates, related mineralizations should then be expected for instance in the carboniferous limestones. According to a general investigation of Alpine, Variscian and Svalbardian faults and thrusts BIRKENMAJER and WOJCIECHOWSKI (1964) claim that none of these served as ways of penetration of ore-bearing hydrothermal solutions. Neither, they say, was any relation found between the fault at Kviveodden (Andvika) and the mineralization, which is older than the fault.

Turning to Bjørnøya, it is by HORN and ORVIN (1928) distinguished between faults being pre-Devonian, older than the Spirifer Limestone, and younger than the Spirifer Limestone. Those appearing on the map (Fig. 9) are all pre-Devonian. Regarding the fault near to Russelva, it is said: "Here galena and blende are quite common in the brecciated rock near the fault. The mineral-bearing solutions have, one is led to believe, especially circulated along the faults, these being the easiest channels of approach." From their map it seems evident that a younger continuation of this fault can be followed also outside the region of Hecla Hoek rocks, but from there no mineralizations are recorded.

I therefore believe the mineralizations in question to be of pre-Devonian age, having taken place along faults and zones of weakness partly rejuvenated during the younger periods of diastrophism. A pre-Devonian structural control of younger faults in Vestspitsbergen is assumed by various authors (ORVIN 1940, MCWHAE 1953, HARLAND 1961).

Although mainly found in the young Pre-Cambrian rocks of Höferpynten series age, related sulphide mineralizations are also recorded from Middle Ordovician rocks (p. 113). Thus, limited within post-Middle Ordovician and pre-Devonian time, a Caledonian origin of the ore-bearing structures seems most likely.

Birkenmajer and Wojciechowski (1964) proposed the mineralizations and an associated epigenetic dolomitizations (in the Höferpynten series and the Cambrian Gnålberget marbles) to be evidences of a late orogenic hydrothermal activity of the main Caledonian orogeny. This conclusion is followed regarding all the localities described, except for Revdalen. The presence of pyrrhotite, although in minor quantities, in this paragenesis and the high percentage of Fe in the sphalerite (Table I), indicate a high temperature of formation for the mineralized veins from this locality. Their typical occurrence seems limited to host rocks of high metamorphic grade (p. 122), and according to my observations they are also, at least partly, folded together with the surrounding lithologies. It is suggested that the Revdalen mineralizations are either contemporaneous with the main Caledonian deformation, or possibly associated with a pre-Caledonian metamorphism of the Lower Hecla Hoek rocks in this region (p. 122).[1]

Although small and scattered as these mineralizations appear to be, some conclusions may be drawn regarding their classification. In contrast to Revdalen, being a single locality of its kind, the results of the investigation of Andvika, Sinkholmen, and Kapp Mineral in Vestspitsbergen and the information obtained from Bjørnøya — a few apparently related deposits in different geological environments — give a better foundation for a more general conclusion.

These deposits have conspicuous common features with regard to mineral paragenesis, common occurrence of sulphide minerals in carbonates, and affinity to fissures and breccias related to faults. In Lindgren (1928) mineralizations with these characteristics, although on a completely different scale of magnitude, are described in the chapter: "Lead and zinc deposits in sedimentary rocks, origin independent of igneous activity." And recently such mineralizations have been classified as telethermal deposits (Greek, tele: far) by Park and Mac Diarmd (1964). To our present knowledge no igneous rocks occur in Bjørnøya, neither are any known in the vicinity of Andvika and Kapp Mineral. In the area northwest of Sinkholmen gabbroic intrusions are recorded, but they are mainly amphibolitized, probably as a result of the Caledonian metamorphism, thus being older than the mineralization.

Also more individual features are in agreement with deposits of the telethermal type, e. g. the occurrence of barite gangue in Bjørnøya and fluorspar on Sinkholmen as well as the associated dolomitization in the Höferpynten series.
These qualifications have been described both from Upper Silesia in Poland (Zwierzycki 1950), and from the Mississippi Valley, U.S.A. (Behre et al. 1950). The deposits in both these regions are regarded as typical representatives of the type of mineralization in question.

[1]*Added in proof.* - According to Birkenmajer (in Polish Spitsbergen Expeditions 1957-60, Pol. Acad. Sci. Warszawa 1968), absolute age determinations are now undertaken in Leningrad on specimens of galena sampled by Wojciechowski. The results of this investigation are awaited with great interest.

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PLATE I

Fig. 1. *Microphoto from Kapp Mineral of a galena vein (white) in calcite (grey). Reflected light.*

Fig. 2. *Microphoto from Kapp Mineral of galena (white) with triangular grooves in a pattern revealing a possible deformation texture. Reflected light.*

Fig. 3. *Microphoto from the ore on Kapp Mineral showing galena (white) with chalcopyrite (cp) encircled. py is pyrite and grey is cabonates. Reflected light.*

Fig. 4. *Microphoto of breccia ore from Sinkholmen showing galena (white), sphalerite (grey) and gangue (dark grey). Reflected light.*

Fig. 5. *Microphoto of breccia ore from Sinkholmen. Light grey is tetrahedrite, grey is sphalerite and black is grooves. Reflected light.*

Fig. 6. *From the mineralized mass of calcite on Sinkholmen. White is calcite and black is sphalerite.*

Fig. 7. *Microphoto from the ore on Sinkholmen showing sphalerite (grey) with inclusions of pyrite (white). Black is grooves and calcite gangue. Reflected light.*

Fig. 8. *Microphoto from the ore on Sinkholmen showing pyrite crystals (white) with beginning replacement of chalcopyrite (light grey). Grey is sphalerite, T is tetrahedrite, and black is calcite gangue. Reflected light.*

PLATE II

Fig. 1. *Microphoto from the ore on Sinkholmen showing pyrite (white) with associated fans and small inclusions of covellite (grey). Dark grey is calcite. Reflected light.*

Fig. 2. *Microphoto from the ore on Sinkholmen showing pyrite (white) in a grain of chalcocite (grey) with fans of covellite (dark grey) to the left. Black is calcite. Reflected light.*

Fig. 3. *Microphoto from the ore on Sinkholmen showing pyrite in a complex grain of neodigenite and bornite (both grey). The neodigenite displays cleavages with a little covellite. Dark grey is calcite. Reflected light.*

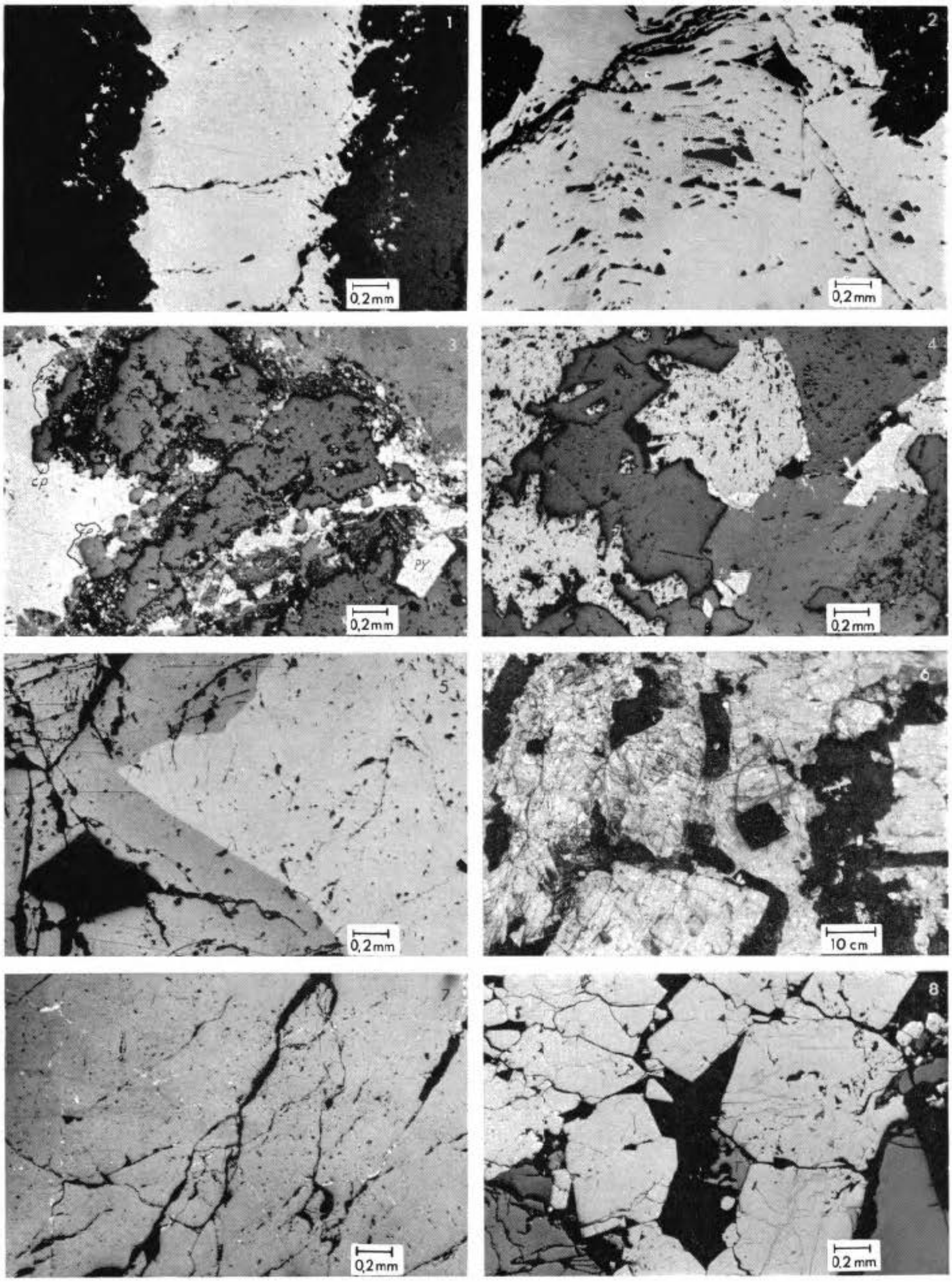
Fig. 4. *Microphoto from the ore on Sinkholmen showing fractured pyrite (white) with an aggregate consisting mainly of idaite (grey) and covellite (black), cp is chalcopyrite. Reflected light, oil.*

Fig. 5. *Microphoto from the ore on Wurmbrandegga, Andvika. White is galena, light grey is sphalerite, py is pyrite and cp is chalcopyrite (encircled). Dark grey is gangue. Reflected light.*

Fig. 6. *Microphoto from the ore on Kviveodden, Andvika. Upper and left half of the fig. shows sphalerite (grey) with an internal borderzone of chalcopyrite (light grey). Lower right half shows an aggregate of pyrite, arsenopyrite and chalcopyrite. Reflected light.*

Fig. 7. *Microphoto of a mineralized vein from Revdalen. White with a higher relief is pyrite, white with triangular grooves is galena, grey is sphalerite and dark grey is gangue. Reflected light.*

Fig. 8. *Microphoto of a mineralized vein from Revdalen: Central part of photo shows two grains of pyrite aggregate with a subhedral rim. Peripheral part displays chalcopyrite grains (white) in gangue (grey). Reflected light.*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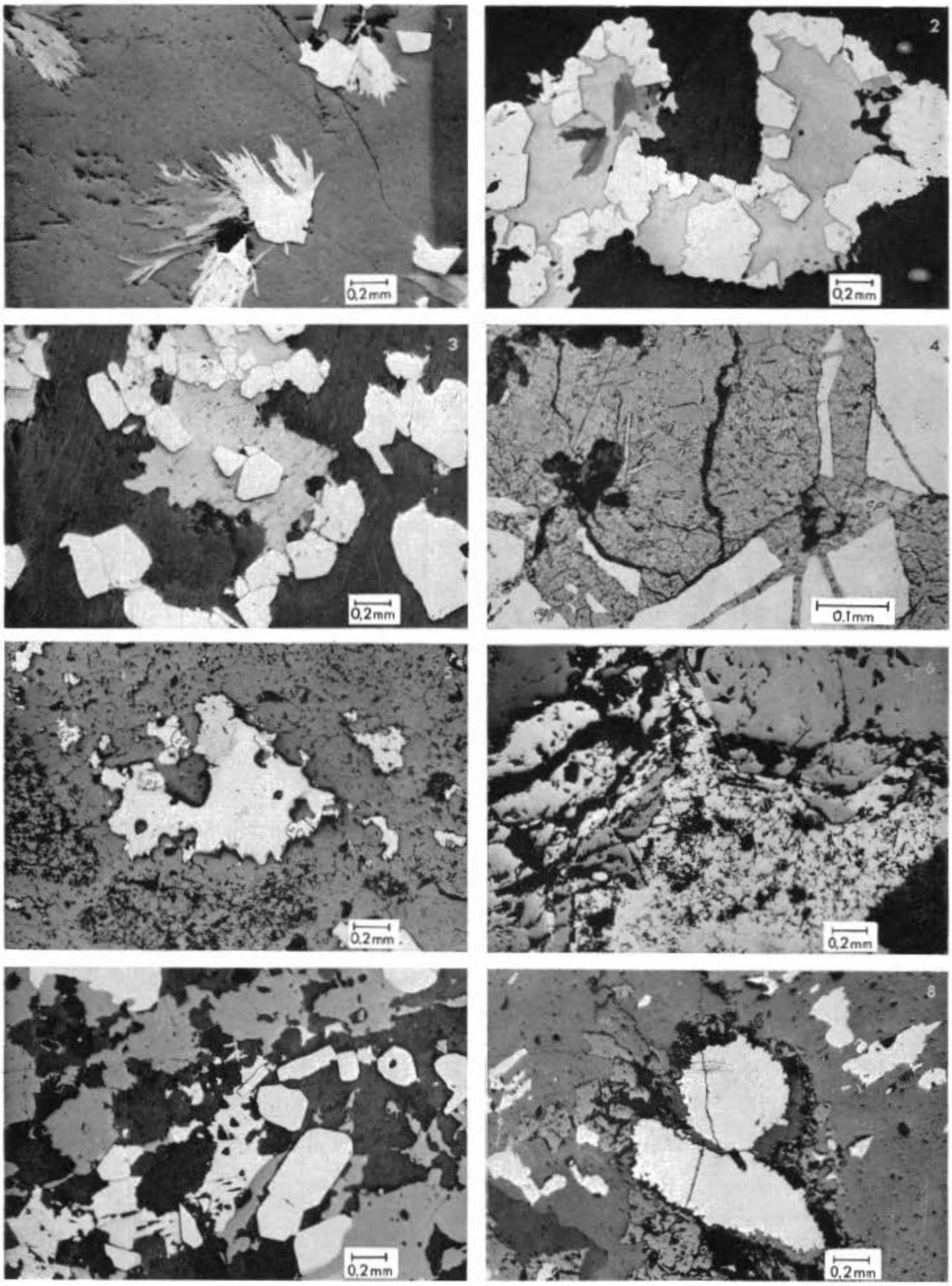
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The character of ice formation on Spitsbergen glaciers

By

Vladimir I. Mikhaliov[1]

Abstract

In the present paper is given a brief description of ice formation zones: the snow zone, the snow-ice zone, the cold and the warm firn zone, the firn-ice zone, and the zone of ice feeding. The data of the Soviet Spitsbergen Expedition 1965 and 1966 and the results of preceding investigations make it possible to ascertain the presence of four ice formation zones on the glaciers of Spitsbergen: the cold and the warm firn zone, the firn-ice zone, and the zone of ice feeding. The existence of the snow-ice zone on the slopes of the highest mountains in the eastern part of Vestspitsbergen is assumed.

Характер льдообразования на ледниках Шпицбергена

Отсутствие до недавнего времени удовлетворительной классификации процессов и зон льдообразования не позволяло систематизировать имеющиеся данные и дать более или менее полную картину изменения характера льдообразования в пределах архипелага Шпицберген. В настоящей работе дано краткое описание зон льдообразования по классификации П. А. Шумского и Е. Н. Цыкина: снежной, снежно-ледяной, холодной и теплой фирновых, фирново-ледяной и зоны ледяного питания. Основными признаками для выделения зон служат морфологические и температурные особенности верхних слоев ледника, которые почти никогда не оставляются гляциологами без внимания. Это позволило, используя данные Советской Шпицбергенской экспедиции 1965 и 1966 гг. и результаты предыдущих исследований, дать общую картину гляциологической зональности на ледниках Шпицбергена. Можно считать установленным наличие на Шпицбергене четырех зон льдообразования: холодной и теплой фирновых, фирново-ледяной и зоны ледяного питания. Причем, на западе архипелага наибольшее распространение имеют теплая фирновая и фирново-ледяная зоны, на востоке - холодная фирновая и фирново-ледяная; в центральных частях Западного Шпицбергена

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представлена, в основном, зона ледяного питания, для южной части острова типична теплая фирновая зона. Предполагается существование снежно-ледяной зоны на склонах наиболее высоких гор Новой Фрисландии северной части Земли Улава Пятого (Западный Шпицберген).

A relatively detailed study of the Spitsbergen glaciers at a sufficiently high level, from a modern point of view, started with the investigations of the Swedish-Norwegian Arctic Expedition to Nordaustlandet in 1931 under the guidance of Professor H. W:son Ahlmann. Since that time much information on various glaciological problems, including peculiarities of ice formation, has been obtained by numerous expeditions. Nevertheless, until now no attempt has been made to systematize the data and to give a relatively complete picture of the change of ice formation peculiarities within the archipelago, i. e. to give a picture of the glacial zones in Spitsbergen. The main reason for this is the lack – until recently – of a satisfactory classification of ice formation processes and zones.

A rather complete classification has been devised by P. A. Shumsky (1955), and by Ye. N. Tsykin (1962); that of Tsykin being a further elaboration of Shumsky's classification. According to this classification, six zones of ice formation are distinguished, the names of which indicate morphological peculiarities of the upper layers of a glacier, and of the ice genesis.

Snow (recrystallization) zone. – No melting takes place even at the warmest time of the year. The upper layers of a glacier consist of snow which turns into firn and then into ice through a gradual recrystallization within the glacier; the temperature of snow, firn, and ice are always negative.

Snow-ice (regelation-recrystallization) zone. – In summer the temperature of the surface layers of the snow can rise to melting point. Slight snow melting, followed by regelation, results in the forming of thin crusts of regelation ice; in other respects this zone is similar to the previous one.

Cold firn (infiltration-recrystallization) zone. – Summer melting is considerable. All the winter snow, saturated with melt water, turns into firn during one summer, the melt water freezes, forming crusts and layers of infiltration ice within the firn. Below the level of the penetration of melt water, which is within the layer of annual temperature fluctuation (active layer), there are always negative temperatures; the final conversion of firn into ice takes place through a gradual recrystallization at a considerable depth.

Warm firn (infiltration-regelation)[1] *zone.* – According to the morphology, this zone does not differ from the cold firn zone, but an abundance of melt water heats the whole firn layer, frozen during the preceding winter, to 0°C. Part of the water forms crusts and layers of infiltration ice within the firn, part of it is retained by the firn after its heating up to melting point, and surplus water flows away. Annual freezing and wetting do not result in complete conversion of firn into infiltration ice, because the great thickness of unmelted firn surplus, derived from

[1] This name was proposed by the author (Mikhaliov 1966) instead of the former, viz.: "warm infiltration-recrystallization" (Tsykin 1962).

abundance of solid precipitation, causes fast immersion of the annual firn layers under the limit of the active layer frozen during the winter. The ice formation process ends in regelational recrystallization into "warm" firn (at melting point).

Firn-ice (*infiltration*) *zone.* – Accumulation is smaller than in the preceding zone, number and thickness of the infiltration ice crusts increase downwards, and at a depth of usually no more than a few metres within the active layer, firn turns completely into infiltration ice. Melt water soaks all the firn, heating it up to 0°C, and, after reaching the surface of the monolithic ice, flows out of the zone. Deeper in the ice there are negative temperatures all the year round. The lower limit of this zone is the firn line.

Zone of ice feeding (*infiltration-congelation*). – At the end of the summer the surface of a glacier becomes free from snow. The layer of infiltration-congelation ice, formed by freezing of melt water on the surface of the monolithic ice which has been greatly cooled during the winter, becomes bare. Since the greater part of the melt water flows out of the zone, taking away the heat spent for melting, low negative temperatures will constantly survive in the ice. The lower limit of this zone is the boundary between the accumulation and the ablation areas, that is, the feeding limit.

The seventh zone is *the ablation zone,* where melting exceeds the amount of solid precipitation. When the snow cover and the newly-formed superimposed ice disappear, the layers of recrystallized glacier ice, which form an angle with the surface of the glacier, become bare.

The morphological and temperature peculiarities of the upper layer of a glacier may be regarded as principal indicators for the division into ice formation zones. By using the data of the Soviet Spitsbergen Expedition 1965 and 1966 and the results of the preceding investigations, it is possible to give a general picture of glacial zones of the Spitsbergen glaciers.

As mentioned before, the Swedish-Norwegian Arctic Expedition, 1931, investigated the glaciers of Nordaustlandet, and the character of ice formation of these glaciers will be treated first. H. W:SON AHLMANN (1933) distinguished, by means of morphological indicators, between an ablation area, an accumulation area, and an intermediate zone. He attributes the ablation area to those parts of the glaciers where seasonal snow rests directly on the surface of the ice. The observations were carried out during the melting period when the snow was saturated with melt water and part of it was used for the formation of a layer of superimposed infiltration-congelation ice. It is quite likely, therefore, that the upper parts of the ablation area, reported by AHLMANN, represented the zone of ice feeding. The intermediate zone occupied the interval from 500–650 m a. s. l. in the central region of the island to 350–450 m on the north-east slope of Austfonna (*1*).[1] This zone is characterized by seasonal snow covering a firn layer up to several decimetres thick, and replaced by ice downwards. The main morphologic indicator of the firn-ice zone is present. AHLMANN attributes to the accumulation area such parts of the glaciers where the depth of the perfect replacement of firn by ice exceeds 3 m, which was the maximum depth of the

[1] Cursive figures in brackets correspond to those marking the glaciers in Fig. 2.

examinations. As the thickness of the firn in the firn-ice zone can reach several metres, this zone stretched above the upper limit of AHLMANN's intermediate zone, and it seems impossible to judge the elevation of its upper limit and the character of the ice formation on the top part of the ice caps.

The existence of the firn-ice zone on the glaciers of Nordaustlandet is confirmed by the data of the Oxford University Arctic Expedition 1935–1936 (GLEN 1939, 1941; MOSS 1938). Firn with ice crusts was found, in the central part of Vestfonna (*2*) at an altitude of 530 m (Central Ice Station), to turn into monolithic ice at a depth of 7.5 m. However, the temperature measurements carried out from December till May testify that during the winter and the spring the temperatures increased with depth to –0.1°C at a depth of 8.5 m. Apparently, at a depth of 9 m the ice was at melting point. This was confirmed by the presence of a pool of water at the bottom of a 20 m deep crevasse. For some time this pool was covered with ice, but was not frozen hard during the winter. This shows that the temperature of the ice could not have been negative. The observed temperature distribution is not characteristic of the firn-ice zone, but of the warm firn zone. We shall return to this question below.

In September 1956 Dr. V. SCHYTT (SCHYTT 1964) observed that, except for 39 cm of fresh snow, the upper 7 m of the top of Vestfonna (Ahlmann Station, 622 m a. s. l.) consisted of firn with ice crusts, which were growing thicker downwards. In the middle of September the cold temperature wave had penetrated the firn down to 1–1.5 m, but under the layer of wet firn there were temperatures of –0.5 and –0.6°C at depths of 7.5 and 10 m respectively. The top of the ice cap therefore belongs to the cold firn zone. However, the rather great depth of the penetration of melt water and the rather high temperatures in the underlying firn indicate that, with comparatively small increase of summer melting, melt water would reach a depth unattainable for the winter cold wave. That would cause a change from the cold to the warm firn feeding type. On the other hand, at an altitude of 530 m infiltrational ice formation ends practically at a depth a little smaller than the depth of the winter cold wave penetration. With comparatively small increase of accumulation the velocity of firn immersion deep into the glacier can surpass the velocity of infiltration ice formation. It would be a transition from the firn-ice zone to the warm firn zone. Hence the existence of the warm firn zone on the slopes of Vestfonna within the interval of 550–600 m a. s. l. may be inferred.

The situation of ice formation zones in the accumulation area of Vestfonna is schematically shown in Fig. 1. This figure also explains the temperature peculiarity of the upper parts of the firn-ice zone. A temperature of 0°C shows that conditions exist for the formation of ice coming from the above-lying warm firn zone. A more or less continuous ring of "warm" ice, being formed in the warm firn zone over the ice coming from the cold firn zone, can exist on the slopes of the ice cap. On its way down the glacier this "warm" ice is buried under the cold ice of the firn-ice zone and is gradually frozen through.

The firn-ice zone has, compared with the other zones, the greatest spreading in altitude (from 450 to 550 m a. s. l.) and, apparently in area, it changes into the

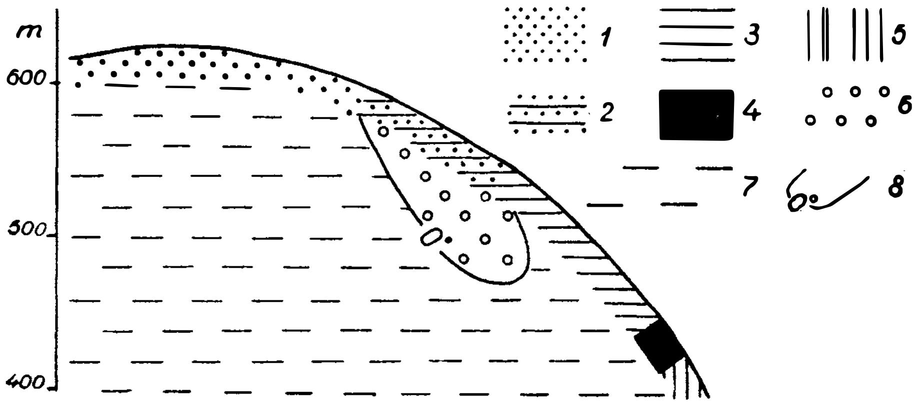

Fig. 1. *Scheme of glacial zones in the accumulation area of Vestfonna (Nordaustlandet). 1 – the cold firn zone; 2 – the warm firn zone; 3 – the firn-ice zone; 4 – the zone of ice feeding; 5 – the ablation zone; 6 – "warm" ice; 7 – cold ice; 8 – 0°C isotherm.*

zone of ice feeding lower down, the extent of which seldom exceeds 20–30 m in altitude judging from our observations in Vestspitsbergen.

Obviously, the same ice formation zones are present in the accumulation area of Sørfonna (*3*), only here the cold firn zone occupies a larger height interval because of the greater height of the ice cap. The amount and thickness of the infiltration ice crusts in the firn cover of Austfonna decrease, as compared with that of Vestfonna (SCHYTT 1964). This proves a smaller melting intensity. Hence it may be assumed that the cold firn zone, occupying the upper part of the ice cap, is replaced at lower altitudes directly by the firn-ice zone, and so avoiding the warm firn zone. The firn-ice zone descends to 300 m, perhaps lower, on the north-east slope of the ice cap, and to only 550 m on the west slope.

The dispersion of the glaciation complicates the picture of glacial zones in Vestspitsbergen. Four regions may be recognized here: western, eastern, southern, and central (Fig. 2). Glaciation of the Spitsbergen type, i. e., transitional from mountain glaciation to glacial cover, is typical of the first three regions. The glaciation of the central region is represented by mountain glaciers.

The presence of a warm firn zone on the glaciers of the western region was determined by the classical investigations of the Norwegian-Swedish Spitsbergen Expedition 1934. On Isachsenfonna (*4*) at an altitude of 850 m, firn predominated down to a depth of 15 m (max. depth of boring). At the beginning of the summer the firn was at melting point under a 10 m thick layer frozen during the winter. At the end of the summer a temperature of 0°C had settled through the whole section (AHLMANN 1935, SVERDRUP 1935).

In July 1966 we carried out some observations on Holtedahlfonna (*5*), 25 km south-east of the headquarters of the Norwegian-Swedish Expedition 1934. At an altitude of 700 m, under seasonal snow, firn with ice crusts was replaced by monolithic ice at a depth of 3.2 m (below the surface of the firn). On July 13 the following distribution of temperatures was observed (SINGER, MIKHALIOV 1967):

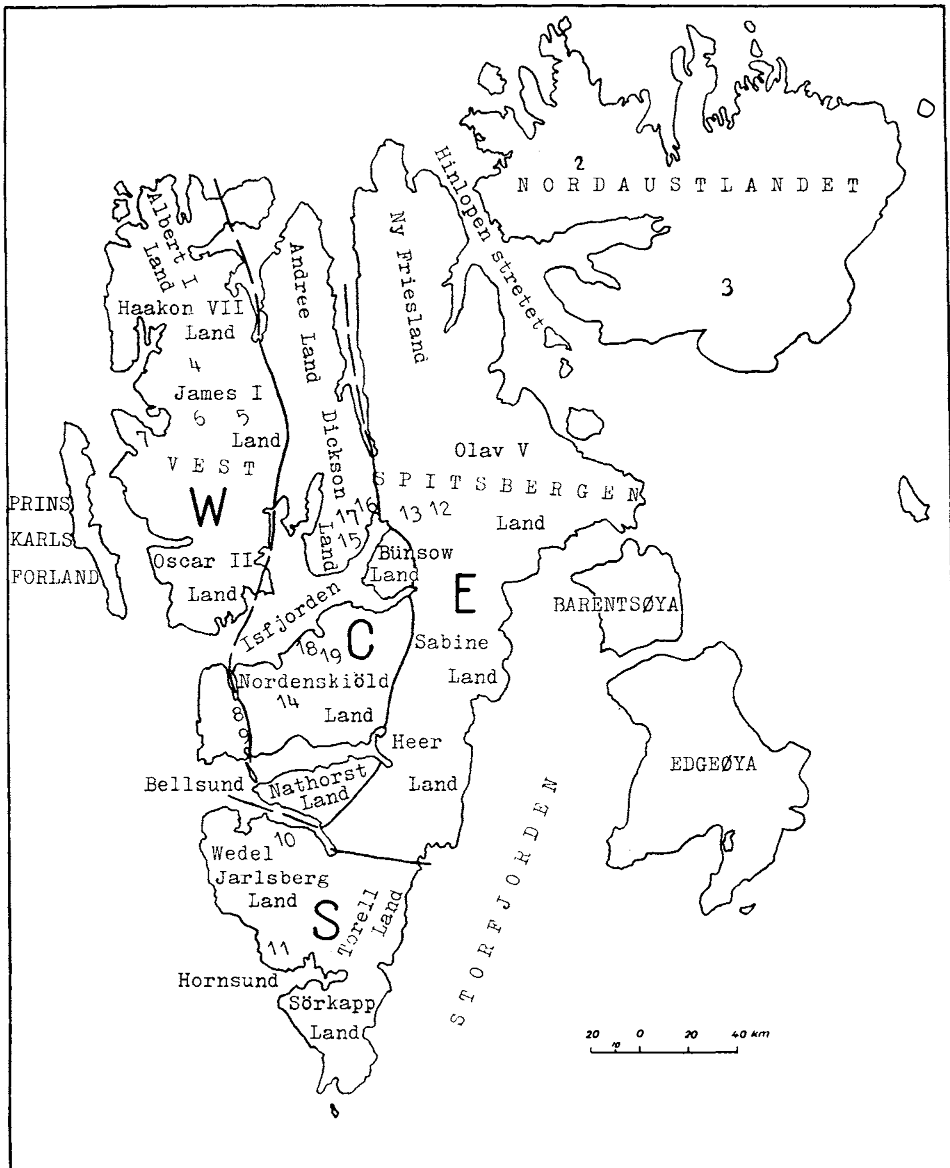

Fig. 2. *Glacial regions of Vestspitsbergen: W – western; E – eastern; S – southern; C – central. Glaciers: 1 – Austfonna; 2 – Vestfonna; 3 – Sørfonna; 4 – Isachsenfonna; 5 – Holtedahlfonna; 6 – Kronebreen; 7 – Lovénbreane; 8 – Grønfjordbreane; 9 – Fridtjovbreen; 10 – Finsterwalderbreen; 11 – Werenskioldbreen; 12 – Lomonosovfonna; 13 – Nordenskiöldbreen; 14 – Tavlebreen; 15 – Jotunfonna; 16 – Ferdinandbreen; 17 – Bertilbreen; 18 – Longyearbreen; 19 – Larsbreen.*

Depth below firn surface, m	1	2.5	5	7.5	10
Temperature, °C	0	–4.4	–4.2	–2.9	–2.0

On July 20 melt water reached the surface of the monolithic ice. This was a typical example of the firn-ice zone.

Different results obtained at different times and at various places may be the result of an alteration of the character of ice formation in the course of time. However, we are not inclined to think that in this region, including Holtedahlfonna and Isachsenfonna, the predominant warm firn feeding type has been replaced by the firn-ice type after 1934. It is most probable that the warm firn zone still exists on Isachsenfonna, and that its lower limit is at an altitude of about 800 m. But this assumption needs to be checked.

The firn line on Kronebreen (*6*), the accumulation area of which includes Holtedahlfonna and Isachsenfonna, is now situated at an altitude of about 600 m. Its elevation decreases towards the west coast of the island, and on Lovénbreane (*7*) on the south coast of Kongsfjorden it is about 500 m.

120 km south of Kongsfjorden on the ice-shed between Austre Grønfjordbreen (*8*) and Fridtjovbreen (*9*) at an altitude of 450 m, the following distribution of temperatures was observed on June 20, 1966, in the firn layer under a 204 cm thick snow layer (SINGER, MIKHALIOV 1967):

Depth below firn surface, m ..	1	2.5	5	7.5	10
Temperature, °C	–3.9	–4.2	–2.5	–1.0	–0.2

The temperature obviously reached 0°C at a depth of about 11 m. As firn predominated in the upper 10 metres of the section, and the value of summer melting (336 mm in water equivalent) was sufficient for heating to melting point the whole active layer, we may attribute this part to the warm firn zone. The firn line lies 380 m a. s. l. on Grønfjordbreane and 340 m on Fridtjovbreen. Apparently the greatest part of the height interval of 380–450 m is occupied by the firn-ice zone, and the lower limit of the warm firn zone lies 400–450 m. Such a considerable descent of the elevation of the limit southwards may be explained by an increase of the solid precipitation. Winter accumulation 1965/66 reached 204 cm of snow (water equivalent 914 mm) on the ice-shed between Austre Grønfjordbreen and Fridtjovbreen, and only 101 cm (water equivalent 485 mm) on Holtedahlfonna. The extent of the zone of ice feeding on Grønfjordbreane is from 30 to 45 m in altitude.

According to O. LIESTØL, glaciologist at Norsk Polarinstitutt (oral communication 1966), there are temperature conditions corresponding to the warm firn zone in the accumulation area of Finsterwalderbreen (*10*) on the south coast of Van Keulenfjorden. Necessary conditions for the existence of a warm firn zone (abundance of solid precipitation, sufficiently intensive melting, great thickness of firn) are also present at altitudes of 400–500 m on Werenskioldbreen (*11*) in the Hornsund region (KOSIBA 1960). It may be assumed, therefore, that the warm firn zone is typical of the southern region of Vestspitsbergen.

The character of ice formation on the glaciers of the eastern region can be judged from the results of our investigations in the summer of 1965 on Lomonosovfonna (*12*) and Nordenskiöldbreen (*13*) (SINGER *et al.* 1966). On Lomonosovfonna (1050 m a. s. l.) the thickness of firn with ice crusts and lenses exceeds at least 24 m (max. depth of boring). On August 13–18, after the end of melting, the distribution of temperatures in the firn was the following:

Depth below snow surface, m	1	2.5	5	7.5	10	12.5	15	17.5	20	24
Temperature, °C	0	–0.4	–3.9	–4.0	–2.6	–1.7	–1.4	–1.2	–1.1	–1.0

This corresponds to the cold firn zone.

Owing to the decrease of accumulation on the upper part of Nordenskiöldbreen, the cold firn zone is replaced by the firn-ice zone at about 900 m. The transition from the cold firn to the firn-ice zone is accompanied by a fall of temperature in the upper layers of the glacier. The following distribution of temperatures was observed on July 4, 1965, at an altitude of 650 m between the nunataks Ekkoknausane and Bumerangkammen, where, under 2.5 m of snow, a 2.4 m thick firn layer was replaced by ice:

Depth below snow surface, m	2.5	7.5	12.5	15	16.5
Temperature, °C	–7.1	–5.6	–4.6	–4.3	–4.2

The temperature at the depth of the dying annual temperature fluctuation (15 m) was 3° lower than that of the cold firn zone. This occurs because in the cold firn zone all the melt water refreezes, while in the firn-ice zone part of the water flows down, taking away the heat.

The elevation of the firn line on Nordenskiöldbreen is 560 m. In 1965 the extent of the zone of ice feeding along the glacier was about 0.5 km, but, as the glacier surface there is almost horizontal, the elevation of the feeding limit practically coincided with that of the firn line.

The increase of accumulation on the glaciers of the east side, compared with the glaciers of the Isfjorden basin (SINGER *et al.* 1966, SINGER, MIKHALIOV 1967), reminds us of the existence of the warm firn zone on the glaciers of the east coast of Vestspitsbergen within the interval of 400–800 m a. s. l. The elevation of the firn line on the glaciers of the east coast is about 200 m (KORYAKIN 1967).

At present, mountain glaciers in the central region of Vestspitsbergen have mainly ice feeding zones, and some glaciers (for example, in Dickson Land) have no accumulation area at all. The elevation of the firn line is rather high: from 580 m on Tavlebreen (*14*) in the upper regions of Grøndalen to 620–640 m on Jotunfonna (*15*), Ferdinandbreen (*16*) and Bertilbreen (*17*) in Dickson Land, and 720–780 m on Longyearbreen (*18*) and Larsbreen (*19*) in the region of Adventfjorden. The firn-ice zone appears in the form of small isolated plots within the zone of ice feeding, mainly on the slopes of the north and east sides. The elevation of the feeding limit on the glaciers in Dickson Land is about 600 m, and in the region of Adventfjorden (Nordenskiöld Land) about 700 m.

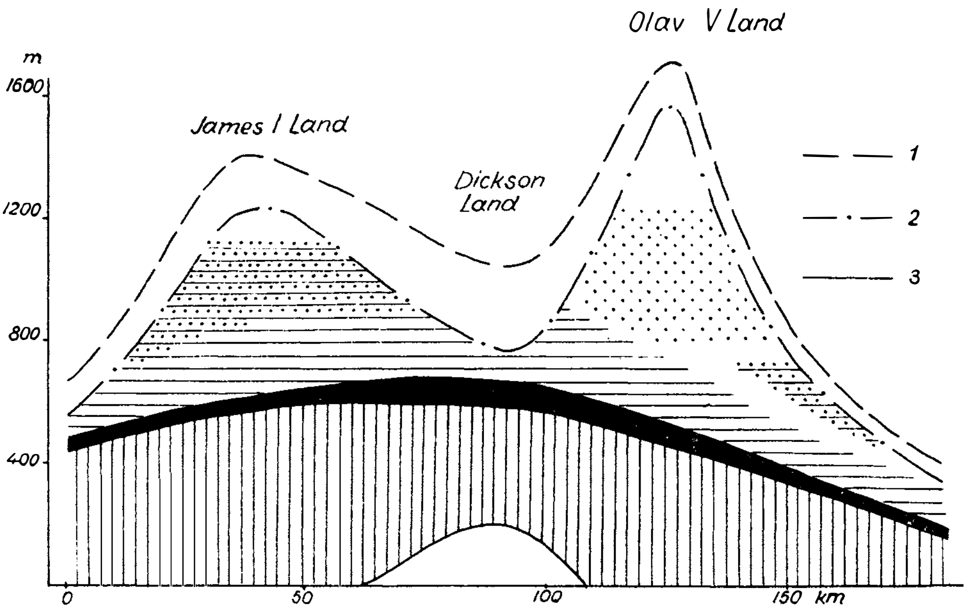

Fig. 3. *Scheme of glacial zones in the profile through Vestspitsbergen along 79°N. 1 – the elevation of mountain tops*; *2 – the elevation of glacier heads*; *3 – the elevation of glacier termini*; *other symbols, see Fig. 1.*

The distribution of ice formation zones in the profile through Vestspitsbergen along 79°N is shown in Fig. 3. Thus, four ice formation zones appear to be present in Spitsbergen: the *cold* and the *warm firn zone,* the *firn-ice zone,* and the *zone of ice feeding.* Most widespread in the west of the archipelago are the warm firn zone and the firn-ice zone; in the east – the cold firn zone and the firn-ice zone; in the central parts of Vestspitsbergen the zone of ice feeding prevails; the warm firn zone is typical of the southern part of the island. There is no information on ice formation conditions above 1050 m. However, on Lomonosovfonna, during the summer of 1965, melt water soaked only the 220 cm thick seasonal snow layer, and did not penetrate the last year's firn. Maybe at higher altitudes seasonal snow does not become wet through, and thus does not turn into firn during one summer, and that on the slopes of the highest mountains in Ny Friesland and in the northern part of Olav V Land, like Newtontoppen (1717 m), Perriertoppen (1717 m), Neptunfjellet (1610 m) and others, there is a snow-ice zone. But at present this is only an assumption.

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"A scheme of petrographic nomenclature" — a reply

BY

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Abstract

A scheme for petrographic nomenclature (*Norsk Polarinstitutt Årbok 1966,* Oslo 1968, pp. 25–37) was followed by a criticism by I. BRYHNI (*Loc. cit.* pp. 38–47). This reply considers these criticisms, rejecting some and inviting wider consideration of others.

We welcome I. BRYHNI's interest in our paper (1968) and would remind readers of our two-fold objective (WALLIS, HARLAND, GEE & GAYER, 1968, p. 26):

A. To explain the system we developed for standardising our descriptions of metamorphic rocks in Spitsbergen, which we have used for some years. This standardisation allowed us to make valid comparisons between rocks described by different workers in different areas at different times.

B. To offer a working scheme for wider criticism as a contribution towards international comparison.

We developed our scheme (*Op. cit.,* p. 27) in the latter part of 1963 whilst attempting to synthesise our studies on the regional metamorphic rocks of north Vestspitsbergen. After consulting others working in metamorphic terrains we failed to discover a practical system that had been adopted widely for the nomenclature of regional metamorphic terrain (rather than a theoretical classification directed to particular interests, of which there are several).

In his criticism, BRYHNI comments (p. 43, footnote) that we made changes in our paper at proof stage which invalidate some of his criticisms. The position is rather as he asserted (p. 43) that we did not alter our paper between original submission and publication. A few clarifications in the wording did not modify the sense of the paper. BRYHNI does not state which of his 'objections' are not relevant.

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In the discussion that follows we concentrate, therefore, on what we think is the basis of his criticism and then discuss his alternative proposal (Ein Symposion 1962).

Judging from the title of BRYHNI's contribution and his comments (p. 46), it appears necessary to re-emphasise that ours is a scheme of petrographic nomenclature for some metamorphic rocks, largely of amphibolite facies. To express an intended pre-metamorphic condition we prefer (p. 27) to use terms prefixed by meta- (e. g. meta-argillite, meta-trondhjemite) as in the first sense given by WINKLER (1965, p. 212).

Comments on Bryhni's criticisms

BRYHNI's criticism of our scheme falls under six headings, two general and four detailed.

General criticisms (1–2)

1. That no scheme of petrographic nomenclature can be based on the rocks of one region but should be erected and discussed in relation to general established systems of nomenclature.
2. That in BRYHNI's view there is no need for our contribution, as there already exists a suitable and more acceptable system in that of Ein Symposion 1960 (1962).

We would agree with BRYHNI that it is certainly more useful to have a widely based scheme, and this discussion is helpful in clarifying objections that we anticipated would arise when applied to the general field. We do not consider the scheme in Ein Symposion to be a satisfactory alternative for our requirements, and doubt its suitability for international usage. It is also a scheme based largely on experience in a single area – the Eastern Alps. We refer to this later.

Detailed criticisms (3–6)

3. That the scheme is intended as a non-genetic nomenclature for metamorphic rocks, but uses terms such as *pelite* and *psammite,* which have a sedimentary origin inferring petrogenesis from a sediment.

For the scheme to be strictly petrographic (non-genetic) it is modally based. To avoid using terms with petrogenetic connotations would have been possible by introducing completely new terms (as we did with feldspathite). However, we thought that to proliferate names would make the scheme less acceptable. We are well aware that the terms *pelite* and *psammite* originated as sedimentary terms, but in our experience they are now restricted to metamorphic rocks having compositions suggested in our scheme. A search of the English language literature on sedimentary rocks will demonstrate their virtual absence. For metamorphic rocks they have been used in a loose genetic way for at least the last fifty years. Our intention was to give the terms a more precise meaning. If, as suggested by BRYHNI, there remains a conflict with sedimentary nomenclature, then we may require new terms to avoid this ambiguity. If, as we suspect, *pelitic* and *psammitic* are in general use to indicate metamorphosed argillites and arenites, we wonder how much evidence of genesis is required before applying these names. How many of the pelitic schists of the literature are meta-argillites, and what criteria have been used to give these names? Judging by the paucity of chemical analyses of sediments and meta-sediments (BROTZEN 1966), chemical composition (directly) is not the basis. It would appear to depend on the alumino-silicate minerals present (what amount?) and unambiguous evidence of a particular sedimentary origin. It appears from the literature that seldom are these criteria considered before the term pelite is applied. Nevertheless we do not object (p. 35) if the name suggests a probable origin. The genesis should not be assumed in the name, but should be considered separately "inviting a distinct exercise in petrogenesis" (p. 35).

4. That the scheme uses terms in a sense distinct from that of their generally accepted usage. Thus in the scheme, *amphibolite* need have no plagioclase and amphibole could be actinolite; *marble* is given a wider sense than an essentially carbonate rock. *Psammite* is restricted to a rock containing a majority of quartz and does not cover sand grade rocks of other compositions.

That some of the terms are used in a sense different from that of some other usages reflects the imprecise way in which these terms have previously been used. The restriction of the term *amphibolite* to rocks containing both hornblende and plagioclase would necessitate additional terms for related rocks of similar composition containing other amphiboles with or without plagioclase. We would add relevant mineral qualifiers to cover these variants (e. g. plagioclase-amphibolite, actinolitic-amphibolite). The term *greenschist* is frequently used in lowgrade metamorphic terrains in association with phyllites. In such areas, where no precise compositional observations have been made, or where texture requires emphasis, or both, we favour the continued use of a semi-modal/textural terminology with the addition of suitable mineral qualifiers. In any event, as BRYHNI has suggested, the term greenschist would require mineral qualification to cover greenschists with chlorite and those with actinolite. In our opinion the term *marble* is not generally restricted to a rock containing essentially carbonate-minerals. We do not refer to limestones as marbles (BRYHNI, p. 42). For WINKLER (p. 211) marble is essentially a carbonate bearing (over 50%) rock thoroughly recrystallised above N.T.P. This also is our definition.

Our use of the term *psammite* has been discussed above.

5. That the scheme would give the same name to different pre-metamorphic rocks. Thus a granite (biotite 5%, quartz 35%, and feldspar 60%) and a trondhjemite (biotite 10%, quartz 40%, and feldspar 50%) are both psammite-feldspathites.

We agree that our scheme would give the same name to a metamorphosed granite and a trondhjemite, as these rocks have essentially similar compositions. If it is intended to express the meaning granite, meta-granite or trondhjemite we recommend this. But we use feldspathite for rocks with more than 50% feldspar when we wish to express no implication as to origin, and we have found many granitic looking rocks to be of sedimentary or volcanic origin.

6. That the scheme would offer more than one name for rocks of the same composition. Thus a rock having a composition quartz 20%, feldspar 40%, and mica 40% could be named e. g. pelitic-subfeldspathite or feldspathic-subpelite.

BRYHNI would appear to have misunderstood our intention. An exceptional rock with the composition postulated has only one name in our scheme, subfeldspathite – subpelite (with or without quartz as qualifier).

Bryhni's alternative scheme (Ein Symposion 1962)

BRYHNI (p. 43) echoes the reservations voiced in Ein Symposion to the effect that nomenclatural schemes useful for regional stratigraphic studies of metamorphic rocks may be impossible to devise without taking into account premetamorphic as well as metamorphic condition. Whilst we agree that the latter must be considered, we think that progress in the study of structure and stratigraphy in metamorphic terrains will be impeded by the continued lack of a workable petrographic scheme. This is not to deny the usefulness of a parallel petrogenetic nomenclature for which we prefix *meta-* to the original rock intended.

In recommending the proposals of Ein Symposion (1962) BRYHNI suggested that WINKLER (1965) and WENK (1963) had "elaborated" on the scheme. In fact, WINKLER summarised the scheme and recommended a modification of it and drew attention to WENK's reservations, whilst WENK, far from recommending the scheme, strongly criticised it, arguing that textural terms are not definable on the basis of composition. This is a conclusion also apparent from our paper and seemingly overlooked by BRYHNI.

The authors of Ein Symposion defined the terms *Phyllite*, *Schist*, *Gneiss* and *Fels* to accommodate both the commonly accepted textural definitions and the particular compositional limits imposed by themselves. They claimed support for their composite definitions from various metamorphic petrologists (p. 169) in stating that the definitions of the majority were accommodated within the composite definitions embodying compositional and textural concepts. To our knowledge only one of those quoted, WENK, published an objection to their use of the terminology. We endorse his objection and WINKLER's reservations.

The Symposion scheme adopts a division of rock types based on the mode. Independently we considered that not only is this the best basis for metamorphic rock nomenclature, but we have also used the same boundaries between limiting compositions (i. e. 50% and 80%). It is encouraging to find agreement with a group of workers in a terrain very different from Spitsbergen and with BRYHNI in this basic approach. However, we have not found it in use elsewhere (or by BRYHNI) and would be interested to see how it works in practice.

We disagree with the way in which Ein Symposion built on this modal foundation.

We have found that in commonly occurring middle grade metamorphic rocks in Spitsbergen five distinct minerals (or groups of minerals) are commonly present. None of these are mutually exclusive. This makes it impracticable to devise schemes based on defining fields within triangular diagrams, tetrahedra, or even parallelograms (chosen by Ein Symposion). WENK (1963) emphasised this point, and we suspect that the problems in Spitsbergen are not so different from those in Central Europe. The Ein Symposion scheme would appear to work only if amphiboles etc. are in small quantity, and if carbonate and feldspar are mutually exclusive. By referring to his studies of the occurrence of plagioclase in metamorphic rocks, WENK emphasised what we have found commonly in Spitsbergen: that carbonate and plagioclase are not mutually exclusive in common metamorphic rocks. This criticism alone is enough to undermine the parallelogram scheme of Ein Symposion.

Having reached this conclusion, after trying out many spatially related schemes, we suggested a division of rock types on the basis of Table 1 in WALLIS *et al.* (1968).

We regard the names used for the modally defined rock groups as less important than the scheme of groups. Nevertheless it appears that the names generate the most feeling. Ein Symposion chose to define the terms Phyllite, Schist, Gneiss and Fels based on particular compositional ranges, and named their modal division accordingly. We are in complete agreement with WENK and WINKLER in considering these terms to be textural and therefore not definable on composition.

If, however, the textural terms are rejected as representing particular modal categories, then other names are required for these divisions, and when these names are used, the textures would be used adjectivally (e. g. schistose amphibolite rather than amphibolitic schist). This in no way reduces the importance of the textural terms. It is a consequence of distinguishing texture and composition, and it serves to enhance the value of the proper use of the textural nouns when emphasis on texture is preferred.

The substantives we used are certainly not without disadvantages, and we are grateful to BRYHNI for underlining some of these. Nevertheless, we feel that there is at present no fully satisfactory alternative set of names to cover strictly petrographic categories. Perhaps not the least advantage of our scheme is that the majority of rocks referred to in the metamorphic literature in the English language as pelitic, psammitic, amphibolitic, or marbles would fall into a modal category with similar names in our scheme.

Summary

In summary our position is this:

I. We are committed to continue using our scheme whilst we complete the present phase of structural/stratigraphical work in Spitsbergen, for much of our work depends on correlation of metamorphic rocks of like composition; but we make no claim that it should have further application.

II. We are at present working on the metamorphic terrains of Canada, Norway, Spitsbergen, and Sweden. We are therefore interested to discover or develop a scheme of general application and look forward to further discussion of this subject. In particular we invite comments on the following propositions:

a) That a modal scheme is useful at least for middle grade metamorphic rocks of wide regional extent, where comparisons between different workers is important.

b) If so, then
   1) five components (groups of mineral phases) are desirable, and
   2) convenient boundary proportions for classes are 50% (and 80%) and approximately 35%.

c) If so, then the names we propose for the classes should
   1) be clearly distinguished from textural terms so that the two can be used independently, and
   2) signify composition in a substantive term to which qualifiers can be attached.

d) If so, we need a suitable choice of names. We did not expect the names proposed to be acceptable to all but could think of no better ones. In particular, we acknowledge that pelite and psammite have sedimentary connotations, especially on the continent of Europe, and thus may be too objectionable; but they are very widely used for metamorphic rocks, and we suggest that alternative terms, which might avoid these objections, would therefore be ignored. We would be grateful to hear of alternative suggestions.

Acknowledgements

One of us (D.G.G.) acknowledges discussion with INGE BRYHNI and members of Norsk Polarinstitutt's geological staff in January 1967, and subsequently with colleagues at Sveriges Geologiska Undersökning particularly T. LUNDQVIST, P. PADGET and E. ZACHRISSON.

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Hvalrossens *(Odobenus rosmarus)* forekomst i Svalbardområdet 1960-1967

(The walrus (Odobenus rosmarus) *in Svalbard 1960–1967)*

(Моржи (Odbenus rosmarus) *на архипелаге Свальбард в 1960-1967 гг)*

BY

MAGNAR NORDERHAUG

Abstract

The total protection of walrus in Svalbard from 1952 has been of less practical importance as the population probably was reduced close to extinction already before the protection was put into force.

In the present paper the observations of walrus in Svalbard 1960–67 are summarized (Fig. 1). Three of the 18 observations indicate that reproduction still may take place in the area.

A re-establishment of the Svalbard population will probably depend partly on an influx from Franz Josef Land, partly on a (small) local reproduction.

A survey of the eastern parts of Svalbard is necessary in order to get a full picture of the present situation of the walrus in this archipelago.

Резюме

Полный запрет охоты на моржей на Свальбарде с 1952 г. имел ничтожное практическое значение, так как популяция этого вида вероятно была сокращена почти до уровня вымирания еще до вступления в силу этого мероприятия.

В настоящей статье приводится обзор наблюдений за моржами в пределах свальбардских вод за 1960-1967 гг. (Рис. 1). Три из восемнадцати наблюдений указывают на то, что прирост в этом районе все еще может иметь место.

Восстановление же прежнего уровня свальбардского моржа вероятно будет зависеть как от вторжения зверей с Земли Франца Иосифа, так и от (незначительного) местного прироста.

Для полной оценки настоящего положения моржей на архипелаге и в его прибрежных водах необходимы наблюдения над восточными частями Свальбарда.

Innledning

Totalfredningen av hvalross i 1952 markerte avslutningen på et kapittel i Svalbards fangsthistorie. Tiltaket kom imidlertid for sent til å få noen større betydning. Selv om bestandsoppgaver mangler fra Svalbardområdet, var hvalrosstammen utvilsomt desimert henimot eksistensminimum allerede på et tidligere tidspunkt. Sluttfasens innledning begynte egentlig ved århundreskiftet. Geværjakt erstattet da den tradisjonelle hvalrossharpunering, noe som førte til en intensivering av jakten og en betydelig økning i tapsprosent i form av sårede og sunkne dyr. Denne uregulerte fangst skjedde i varierende omfang opp til 1950-årene. Den overbeskatning som bestanden har vært utsatt for, og artens begrensede reproduksjonsevne, vil gjøre en eventuell gjenetablering av Svalbards hvalrosstamme til en langvarig prosess.

Selv om vi i dag knapt har noen mulighet til å påvirke utviklingen, bør vi følge den med våkent blikk. Foreliggende arbeid gir en kortfattet oversikt over kjente observasjoner av hvalross på Svalbard i perioden 1960–1967, som et visst sammenligningsgrunnlag for kommende år. Materialet er hovedsakelig innsamlet i sammenheng med den faunistiske kartlegging som Norsk Polarinstitutt foretar på Svalbard.

Instituttet er fortsatt takknemlig for alle opplysninger om hvalross i Svalbardområdet, da de utgjør et viktig grunnlag til å følge den videre utvikling.

I oversikten er observatørens navn for enkelhets skyld angitt uten nærmere referanse, da kildeangivelser fremgår av litteraturlisten.

Takk

Jeg vil få takke alle de personer som har bidradd med opplysninger om hvalrossobservasjoner på Svalbard, enten til de faunistiske oversikter fra Svalbardområdet, eller direkte til dette arbeid.

Observasjoner av hvalross i Svalbardområdet 1960–1967

1960: 1. 1 voksent individ sett i Wahlenbergfjorden, Nordaustlandet, sommeren 1960. (H. GOTLIEBSEN, pers. medd. O. LØNØ.)

1961: Ingen observasjoner.

1962: Ingen observasjoner.

1963: 2. 1 hunn med 1 liten unge sett flere ganger mellom Danskøya og Amsterdamøya i midten av juli. Ungen omkom ved et uhell. (K. Z. LUNDQUIST.)

1964: 3. 1 individ sett ved Isfjordens munning 18. juli. (E. NYHOLM.)
4. 1 dyr, sannsynligvis ungdyr av hvalross, sett ved Moffen 22. august. (W. INGEBRETSEN.)
5. 1 individ sett i Tjuvfjorden, Edgeøya, 16. august. (O. LØNØ.)
6. 1 hann og 1 hunn sett i Tjuvfjorden, Edgeøya, 18. oktober. (O. LØNØ.)

1965: 7. 1 individ sett om våren ved Halvmåneøya. (O. LØNØ.)
8. 1 individ sett i Krossfjorden 3. juni. (U. VOIGT.)
9. 1 individ sett ved Sjuøyane 12. august. (N. GULLESTAD.)

10. 1 ca. 4 meter langt dyr, som ble antatt å være en hvalross, sett ved Rijpfjordens østside, Nordaustlandet, 16. august. (Ø. FÆSTØE.)
11. 1 ungdyr sett ved Ebeltoftlaguna, Kapp Mitra, 22. august. (K. Z. LUNDQUIST.)

1966: 12. 1 individ sett ved Kong Karls Land i juli/august. (H. ÖSTERHOLM.)
13. 2 individer sett ved Blaeuodden, Rijpfjorden, 3. august. (H. ÖSTERHOLM.)
14. 1 individ sett i Lady Franklinfjorden, Nordaustlandet, 25. august. (H. ÖSTERHOLM.)

1967: 15. 1 individ sett øst for Barentsøya 22. juli. (M. NORDERHAUG.)
16. 1 voksent og 1 ungdyr sett ca. 40 naut. mil øst av Edgeøya 16. juli. (T. LARSEN.)
17. 1 voksent og 1 ungdyr sett ca. 40 naut. mil øst av Edgeøya 12. august. Observasjonene 16. og 17. ble antatt å omfatte forskjellige individer. (T. LARSEN.)
18. 1 gammel hann sett i Gåshamna, Hornsund, 23. august. (T. LARSEN.)

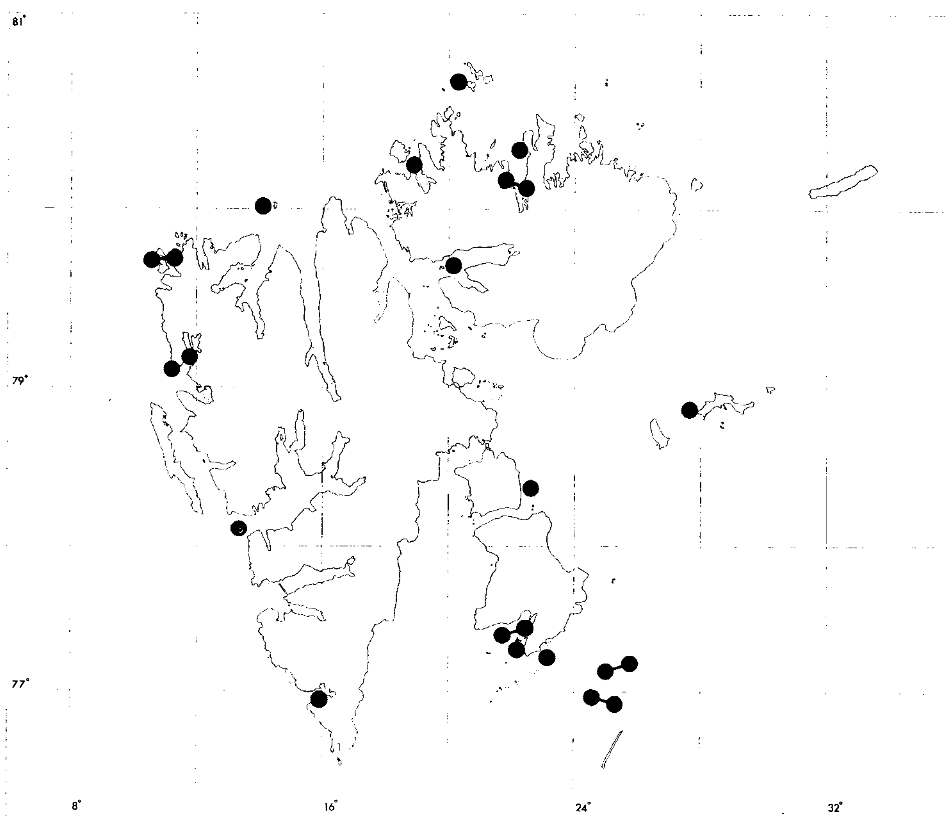

Fig. 1. *Observasjoner av hvalross i Svalbardområdet 1960–1967. Hvert punkt representerer ett dyr. Punkter forbundet med streker representerer individer sett på samme tid.*

Observations of walrus in Svalbard 1960–1967. Each point represents one animal. Points connected with lines represent individuals seen at the same time.

Наблюдения за моржами на Свальбарде в 1960–1967 гг. Каждая точка представляет одного зверя. Точки, соединенные чертой, представляют особей, обнаруженных одновременно.

Diskusjon

Som det framgår av Fig. 1 er hovedmengden av foreliggende hvalrossobservasjoner fra de østlige og nordlige Svalbardfarvann. Tar man i betraktning at dette er de deler av Svalbardområdet som er relativt minst besøkt av mennesker, forsterker det inntrykket av en hyppigere forekomst i disse områder. Dette har rimeligvis sammenheng med to forhold. For det første er de nordlige og østlige deler av Svalbardområdet mindre tilgjengelige på grunn av større drivismengder. Hvalrossen har derfor bedre holdt stand i disse områder i tiden før arten ble totalfredet. For det andre er dette de tilgrensende områder til Frans Josef Land. Ved disse øyene fins fortsatt en hvalrosstamme på noen hundre individer (S. M. USPENSKIJ, pers. medd. 1967). De spredte hvalrosser i Svalbardområdet og stammen ved Frans Josef Land utgjør den nordvestlige utløper av den nåværende østatlantiske hvalrossbestand i Barentshavet og Karahavet. Også i Sovjetunionen er hvalrossen fredet.

Det er rimelig å anta at det har vært en forholdsvis nær kontakt mellom hvalross på Frans Josef Land og Svalbard. I sine dagbøker fra første del av vårt århundre (Norsk Polarinstitutts arkiv) omtaler den kjente ishavsskipper WALDEMAR KRÆMER dette forhold:

> «Spitsbergenstammen holder seg om vinteren og våren fra Hopen og ned til Bjørnøya og langs vestkysten og nordvestkysten, til Moffen. Den trekker opp både på vest- og østkysten av Spitsbergen og går opp til Kvitøya, Viktoriaøya og Frans Josef Land, og holder seg der utover sommeren og høsten. Den kommer sørover i september–oktober.»

Også i dag er nok dette tilfelle, om enn i mindre utpreget grad, og en viss gjenetablering av Svalbards hvalrosstamme vil rimeligvis avhenge av en spredt tilførsel av individer fra de nordvestlige deler av Sovjetisk Arktis, kombinert med en (langsom) tilvekst i de nordøstlige deler av Svalbard.

At enkelte hvalrosser fortsatt formerer seg ved Svalbard, tyder 3 av de 18 foreliggende observasjoner fra 1960-årene på. Vi må videre anta at hvalrossens viktigste tilholdssteder i området i dag er Hinlopenstretet, Nordaustlandets kyster, de små øygruppene nord for Nordaustlandet og farvannene ved Storøya og Kvitøya. Fra disse områder mangler nyere opplysninger. Observasjoner fra disse strøk av Svalbard vil være nødvendig for å fastslå hvalrossens reelle status, og de muligheter som foreligger for en gjenetablering av bestanden.

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Bird life on Bjørnøya 1965

BY

EMIL LÜTKEN[1]

Introduction

In the summer of 1965 the author was leader of a Danish ornithological expedition to Bjørnøya. The participants were: BJARNE BORUP, WEDIGO FERCHLAND, JENS KIRKEBY, JENS PETER LOMHOLT, AKSEL RAVN, and JESPER BOAS THERKILDSEN. The expedition was planned in cooperation with "Norsk Polarinstitutt" and "Statens Viltundersøkelser", Norway, and "Zoologisk Museum", Copenhagen. The aim of the expedition was to study the distribution of breeding birds, and as far as possible to estimate their number; further to collect as much material as possible about the general aspects of the bird life, to collect birds for scientific study, and finally as far as possible to photograph the bird life. Our stay on the island lasted from June 30 to August 11.

During the last centuries Bjørnøya has been an object of ornithological study and attention, and a good deal has been written about its bird life. The best account of the bird life of Bjørnøya can be found in LØVENSKIOLD's treatise, "Avifauna Svalbardensis" (LØVENSKIOLD 1964). The comparisons mentioned in this article with the occurrence of birds on Bjørnøya before 1959 are therefore entirely built on LØVENSKIOLD's treatise, in which is found a list with the titles of all publications about the bird life on Bjørnøya before 1959.

Acknowledgment

I would here like to thank everybody who has helped me to carry out this expedition. A special acknowledgment goes to the participants of the expedition for the great and often difficult work they carried out during our stay on the island. I am most grateful to the people of Bjørnøya for their great helpfulness and hospitality. Finally I am very indebted to ODD MUNKEBYE for information on the bird life on the island.

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The bird life

Most of the interior of the island was examined closely, but a few areas almost extinct of birds were only examined rather loosely. To these areas belong Miseryfjellet and the area west of this mountain and the north-western part of the lake area.

The coastline was examined at least once or twice, but because of bad weather two narrow areas were not examined at all. These areas were the coast along the southern side of Miseryfjellet and the coast between the outlet of Ellasjøen and Hambergfjellet.

Not considering the Little Auk (*Plautus a. alle* (L)) the number of breeding birds in the interior of Bjørnøya – both as far as species and individual birds are concerned – is very scant considering the size of the island. Furthermore, most of the nesting birds occupied a certain limited area or bred in very special localities. Thus six out of twelve species breeding actually inland were partly or wholly associated with islets in the lakes. This was especially true in the case of Great Northern Diver (*Gavia immer* (BRÜNN.)), Red-throated Diver (*Gavia stellata* (PONTOPP.)), Eider (*Somateria m. mollissima* ⋛ *m. borealis*), and Arctic Tern (*Sterna paradisaea* PONTOPP.), and it was to a lesser extent true in the case of Long-tailed Duck (*Clangula hyemalis* (L.)) and Grey Phalarope (*Phalaropus fulicarius* (L.)). Only Purple Sandpiper (*Calidris m. maritima* (BRÜNN.)), Arctic Skua (*Stercorarius parasiticus* (L.)) and Snow Bunting (*Plectrophenax n. nivalis* (L.)) were fairly well spread over most of the island. Two breeding pairs of Common Scoter (*Melanitta n. nigra* (L.)) and one of Ringed Plover (*Charadrius hiaticula* Subsp. ?) were noted. In addition Spitsbergen Ptarmigan (*Lagopus mutus hyperboreus* SUNDEV.) was assumed to be breeding in small numbers, though no proof of this was found.

In the Brettingsdalen on the east side of Miseryfjellet there was a colony of Little Auks, counting 50–100 000 pairs, and in the Jutulsetet valley on the north side of Miseryfjellet, as well as on the mountain side just south of Ellasjøen, a colony with about 100 pairs was seen. On the eastern mountain side near the bottom of Ymerdalen small colonies of Fulmar (*Fulmarus g. glacialis* (L.)), Glaucous Gull (*Larus hyperboreus* GUNN.) and Kittiwake (*Rissa t. tridactyla* (L.)) were nesting. The mentioned mountain side is about 1½ miles from the nearest coast-line.

The coastal ranges are in most places inhabited by one more species. By far most of the seabirds nest in the southern part of the island. Around the southern extremity of the island there is a stretch of 3 miles where the cliffs fall almost vertically c. 1200 ft down to the sea. The cliffs are stratified and shelves protrude the whole way from bottom to top. Incredible numbers of Fulmars, Kittiwakes, Bear Island Guillemots (*Uria aalge hyperborea* SALOM.), and Brünnich's Guillemots (*Uria l. lomvia* (L.)) nest here. This cliff probably houses more birds than any other single mountain on the northern hemisphere. The species found here were also quite numerous in other areas along the coast, and in particular Fulmars were common everywhere.

Other species breeding near the coast, viz. Glaucous Gull and Black Guillemot (*Cepphus grylle mandtii* (MANDT)), were common in many places, while the Little Auk, the Northern Puffin (*Fratercula a. arctica* (L.)) and the Spitsbergen Puffin (*Fratercula arctica naumanni* NORTON) mainly were restricted to the northern part of the island. Great Black-backed Gull (*Larus marinus* L.) nested in small numbers in a few places. Razorbill (*Alca torda pica* L.) was noticed only twice, but was assumed to be breeding in a few places.

Weather conditions

The weather in the summer is usually poor on Bjørnøya, but we were particularly unfortunate as it must have been one of the wettest and coldest summers in this century. The average temperature for the warmest month is normally 4.2°C, but while we were there the average was only 1°C. Frost, snow, rain, and especially fog were very frequent, and this often hampered our study of the birds. As late as August 3 we had snow, but fog was the most annoying and frustrating climatic factor. Almost every day the island was covered with fog for a certain time, and it often lasted several days on end. In particular fog was frequent on the higher areas (Miseryfjellet and the southern part of the island); thus we only once happened to see the mountains of the south coast in clear weather.

The arctic fox

The arctic fox lives on Bjørnøya, but it seems to vary in number from year to year. We saw a few foxes in the northern as well as in the southern part of Bjørnøya, but altogether we saw probably no more than 5 or 6 different animals.

We did not find that they constituted any threat to the bird population as such, but at times they could do great harm to the bird colonies by robbing the nests of eggs and young, and sometimes also by killing old birds. Thus a fox every day roamed the 50 pair big colony of Arctic Terns which was near the radio station, and less than 10 chicks got on their wings. In the colony there were also a few nests of Eiders and Long-tailed Ducks, and all but one of them were robbed. In one case we saw the fox taking a nesting Long-tailed Duck.

On the southern side of the island we saw a fox with a Guillemot in its mouth.

According to ODD MUNKEBYE the foxes will sometimes wade or swim out to the small islets in the lakes. Thus one year a fox robbed and destroyed the Eider-colony on the islet in Haussvatnet.

Systematical account of the species

Great Northern Diver. *Gavia immer* (BRÜNN.)

At least 5 or 6 adult birds lived on the island. On July 14 two juvenile birds were seen over the sea between Kapp Ruth and Kapp Maria.

The Great Northern Divers were mainly noticed in the lake areas: Røyevatnet, Haussvatnet, Laksvatnet, and Holmevatnet. Apart from these lakes, Great Northern Divers were also seen in most of the larger lakes outside this area.

In Holmevatnet a breeding pair was observed on July 23. One of them was seen nesting on the northernmost island. The nest was not examined on this occasion, and when we visited Holmevatnet a week later, the pair had left the area. It is doubtful whether other Great Northern Divers should have attempted to nest, and this was caused by the fact that the waters were not yet completely free from ice towards the middle of July; thus the laying of eggs would be delayed two or three weeks. This supposition is supported by an observation from Bollevatnet on August 4, when four Great Northern Divers were flying around shrieking for about an hour.

LØVENSKIOLD writes that breeding Great Northern Divers remain absolutely silent when their breeding-ground is approached, and that non-breeding birds begin to call as soon as intruders near their lake, and continue calling for a considerable time. This does not at all correspond with our own experiences, for one of the breeding birds in Holmevatnet was shrieking anxiously during our stay there, while non-breeding birds normally remained silent when we approached. But the Divers often screamed when they were flying. The conclusion is that no rules can be made about the behaviour of Great Northern Divers in these situations.

Nobody has ever observed more than two breeding pairs during one year on Bjørnøya, but they are known to have appeared there since 1882, and have been found breeding there since 1923 (LØVENSKIOLD).

Black-throated Diver. *Gavia a. arctica* (L.)

One bird was seen twice together with a Great Northern Diver. Once they flew shrieking over the south-western part of Røyevatnet, and the other time they appeared in Rokotjørna. Their voices were very unlike.

In 1958 Løvenskiold saw a pair consisting of a Black-throated Diver ♀ and a Great Northern Diver ♂. One egg was laid, but it was taken by an arctic fox.

Red-throated Diver. *Gavia stellata* (PONTOPP.)

Only four pairs were found to be breeding, but besides them a few straying birds were also seen; these, however, did not seem to nest at all. Three of the pairs nested on the islets in the lakes, Grautauget, Bollevatnet and Øyangen, while the fourth pair nested in Engelskelva a little more than a mile from its outlet. The pairs in Grautauget and Øyangen each had two chicks, the former on July 28, the latter on August 8. On August 4 the eggs in Bollevatnet hatched, and on August 6 the pair was seen with one young. Probably a Great Skua (*Catharacta s. skua* BRÜNN.) took the other chick. The Diver in Engelskelva was still brooding on its two eggs by our last visit on July 30.

Fulmar. *Fulmarus g. glacialis* (L.)

Widespread breeding bird along most of the coast and on many of the islands around it; often nesting in great numbers. Apart from these localities, a smaller colony was situated on the eastern mountain side near the bottom of Ymerdalen. It was the most widespread bird on the mountain sides, and was often found alone. Especially in the southern part of the island extensive areas were populated with Fulmars.

Numerous variations in colour and plumage were noted, from the light phase to the dark phase. The dark phase dominated, and only about ten per cent of the birds were of the light phase.

Mallard. *Anas p. plathyrhynchos* L.

Single ♂♂ were seen, on July 2 near the radio station, on July 5 at Ellasjøen and on July 28 at Gåsvatna.

Long-tailed Duck. *Clangula hyemalis* (L.)

Breeding in scattered places over much of the lake area. The total population has scarcely exceeded 20–25 pairs. The major part of the nests found were situated on islets in the lake area. The first young were observed on July 12 near the radio station.

Common Scoter. *Melanitta n. nigra* (L.)

Two pairs were known to be breeding, and others which may have been breeding were seen, among other places in Øyangen, where one or two pairs lived permanently.

One of the nests was placed under a large stone a few yards from the edge of a tiny pond about two hundred yards west of the radio station. The nest contained four eggs on July 4, but a few days after it was robbed by an arctic fox. The other nest, which we found on July 23, had six eggs and was placed under a hanging cliff a few yards from the south edge of Røyevatnet. When we last visited the bird on July 30, it still had its six eggs. This was the first time proof was given of the Common Scoter nesting on Bjørnøya.

Eider. *Somateria m. mollissima* $\gtrless$ *mollissima borealis*

On the islet in Haussvatnet and on the biggest islet in Røyevatnet colonies of about 200 and 25 pairs, respectively, were found. On both islets Great Skuas preyed on the eggs and the young and often chased the adult Eiders (see paragraph on Great Skua). Also the Glaucous Gulls were often seen in the colony in Haussvatnet, and one was seen robbing a nest with eggs. On the islet in Røyevatnet we saw a pair of Arctic Skuas robbing and Eider-nest.

On other islets, where the Eider was breeding, we only found one or a few pairs. In addition we found some nests along the coast between the radio station and Tunheim. The total population was estimated to count 300 odd pairs.

In the colonies the distance between the nests was often only a yard. Most of the nests contained three or four eggs, and only two nests with five and one with six eggs were found. The greater part of the eggs did not hatch till the beginning of August.

Lots of males stayed in the colonies or in other places on the island till the end of July, after which they gathered in flocks of 20–50 birds along the coasts to start the moult.

The Latin name of Eider, written above, has been used about the Eiders in Svalbard. LØVENSKIOLD explains this in detail in his treatise.

Spitsbergen Ptarmigan. *Lagopus mutus hyperboreus* SUNDEV.

On July 5 one was heard west of the northern part of Ellasjøen, and on August 7 one was heard for some time a mile north of Ellasjøen.

Northern Golden Plover. *Pluvialis apricaria altifrons* (BREHM)

One lived permanently near the radio station where, in the beginning of July, two were often observed. On July 11 one was seen about 3/4 mile south of the radio station. On July 26 two were seen at Hambergfjellet.

Dotterel. *Charadrius morinellus* L.

On July 29 and 30 one was seen near the drain of Røyevatnet. This was the first time that Dotterel had been seen on Bjørnøya.

From the rest of Svalbard there is only one record of Dotterel. In 1829 a dead Dotterel was found on Edgeøya (LØVENSKIOLD).

Ringed Plover. *Charadrius hiaticula* Subsp.?

One pair was breeding near the coast about 3/4 mile from the radio station. On July 25 we found three newly hatched chicks. This was the first time that Ringed Plover had been known to be breeding on Bjørnøya.

Turnstone. *Arenaria i. interpres* (L.)

One was seen near the radio station on July 2 and one on July 30 near the southern end of the island.

Redshank. *Tringa totanus* Subsp.?

One was seen several times on July 1 and 2 in the vicinity of the radio station.

Ruff. *Philomachus pugnax* (L.)

On July 4 six Ruffs ♂♂ with dark collars were seen fouraging for some time at Mosevatnet about $^3/_4$ mile north-east of Lomvatnet. There is no other record of this bird from the Svalbard area.

Purple Sandpiper. *Calidris m. maritima* (BRÜNN.)

Widespread as breeding bird, but mostly in rather small numbers. In the north-west of the lake area it was not found to be breeding, and on Miseryfjellet it was not seen at all. In the mountains in the southern half of the island only a few pairs seemed to be breeding here and there, but it was quite numerous near the outflow of Ellasjøen. In the rest of the island the number varied in different areas, but even where it was most numerous, there were always a couple of hundred yards or more between the nests.

Grey Phalarope. *Phalaropus fulicarius* (L.)

Common as a breeding bird in an area of only about $^1/_4$ of a square mile south-west of the radio station and on the islets in Laksvatnet. Outside these areas no nests were found. The total population amounted to at least 50 pairs and possibly more. In places the density almost resembled that of colonies. More than 20 nests were found, most of them in the Arctic Tern colony near the radio station and on the islets in Laksvatnet.

In LØVENSKIOLD's treatise it is mentioned that the Grey Phalarope is not found more than one mile from the sea, and not more than 50 ft above sea level. However, the nests in Laksvatnet were found to be more than 2 miles from the coast and almost 100 ft above sea level.

Again according to LØVENSKIOLD, the mating takes place on dry ground as opposed to the Red-necked Phalarope (*Phalaropus lobatus* (L.)), where it takes place in the water. However, we noticed two cases where Grey Phalaropes mated in shallow water.

Most of the young were hatched from the middle of July to the beginning of August, and this is much later than usual. But as an exception we saw, on July 2, a nest containing three newly hatched chicks and one egg.

The greater part of the females left the island before the middle of July and after July 21 no females were seen. There were many non-breeding males. In the first half of July flocks of 10–15 were seen on the biggest islet in Laksvatnet, and out of these flocks two thirds were males; on July 21 a flock of 24 ♂♂ and only 3 ♀♀ was seen.

The males varied much in their plumage. A few were almost as reddish brown over the whole body as the females, but most of them were more light brown. A single male had a pure white breast, which was striking in the otherwise brownish body. Some of the males had strongly parti-coloured bodies, reddish brown, yellowish, greyish, and white nuances. A few had pure white and clearly

Fig. 1. *A Great Skua chasing an Eider.*

Fig. 2. *When chased by Great Skuas, the Eiders often made desperate counterattacks.*

marked cheeks, like the females, but usually they were greyish and without any clear marking against the brownish colours of the neck. The crown of the head might be rather dark with light brownish dots, hut it was never black as in the females. The feathers on the back and wings of the females were black or greyish with white and light yellowish edges, but in males they were blackish brown with yellowish and reddish brown edges. Generally the bills of the females were more pure yellow than those of the males, and the black spot on the tip of the bill tended to be less extensive in the case of the females.

According to ODD MUNKEBYE this was the first year the Grey Phalarope had been breeding in greater numbers on Bjørnøya. LØVENSKIOLD writes that it breeds regularly in small numbers in the north-east part of the island.

Great Skua. *Catharacta s. skua* BRÜNN.

About 10–15 Great Skuas were brushing around mainly over the northern half of the island. They were seen hunting on the birdcliffs and in the Eider colonies. As a rule they foraged alone or in pairs, hut on some occasions 4–6 birds were seen together.

One pair of Great Skuas stayed permanently in the Eider colony in Røyevatnet, another pair settled in the Eider colony in Haussvatnet by the middle of July. Both Eider colonies were at times visited by other Great Skuas, which together with the etablised pairs chased the adult Eiders and took eggs and young. Both on July 16 and 17 the Great Skuas were seen trying to kill adult Eiders in Røyevatnet. They did not succeed on these occasions, but there is no doubt that they now and then kill an adult Eider.

Great Skuas also roamed on the birdcliffs. On the north coast I saw a Great Skua with a newly killed Brünnich's Guillemot. I have observed that they often take adult sea-birds; in 1962 I visited two large Great Skua colonies in the Faroes, and I noticed several remnants, especially of Kittiwakes, Arctic Terns, and Puffins.

One individual was seen north of Bjørnøya in 1910 (LØVENSKIOLD). In 1958 LØVENSKIOLD saw one twice near the radio station. In 1964 Schweitzer saw eight individuales regularly during July and August. It therefore seems that the Great Skua is increasing in number in this area, and it will probably not take long before it is found breeding on Bjørnøya.

Pomarine Skua. *Stercorarius pomarinus* (TEMM.)

On July 26 one was seen about one mile west of the radio station, and on August 4 two were seen near Bollevatnet, and one near Røyevatnet.

Arctic Skua. *Stercorarius parasiticus* (L.)

Rather few in number and isolated as a breeding bird in the interior of the island up to a height of 500 ft above sea level. Only 14 pairs were found breeding, and seven of these bred in the southern part of the island. Besides, some straying birds were seen, but most likely they were not breeding.

All the pairs we found nested in the vicinity of lakes or rivers on moist or swampy grounds, and not as on Nord-Fugløy in North-Norway, where the nests in most cases were situated on completely dry grounds (LÜTKEN 1965).

Altogether four birds of the dark phase were observed, and three of these were mated with birds of the light phase. This means that about 10% of the population belonged to the dark phase and this is a much higher percentage than has been observed on Bjørnøya before. In 1932, 157 pairs bred on the island, and only three of the birds were of the dark phase (i. e. 0.95%); in 1948, 100 pairs bred, and four of the birds were of the dark phase (i. e. 2%) (LØVENSKIOLD).

Long-tailed Skua. *Stercorarius l. longicaudus* VIEILL.

Two were seen from the ship a little south of Bjørnøya on June 30.

Glaucous Gull. *Larus hyperboreus* GUNN.

Common breeding bird along the coast, especially towards the south of the island where the colonies might be 100–200 pairs or more. Towards the north on the eastern side of Miseryfjellet there was a colony of about 200 pairs. Along

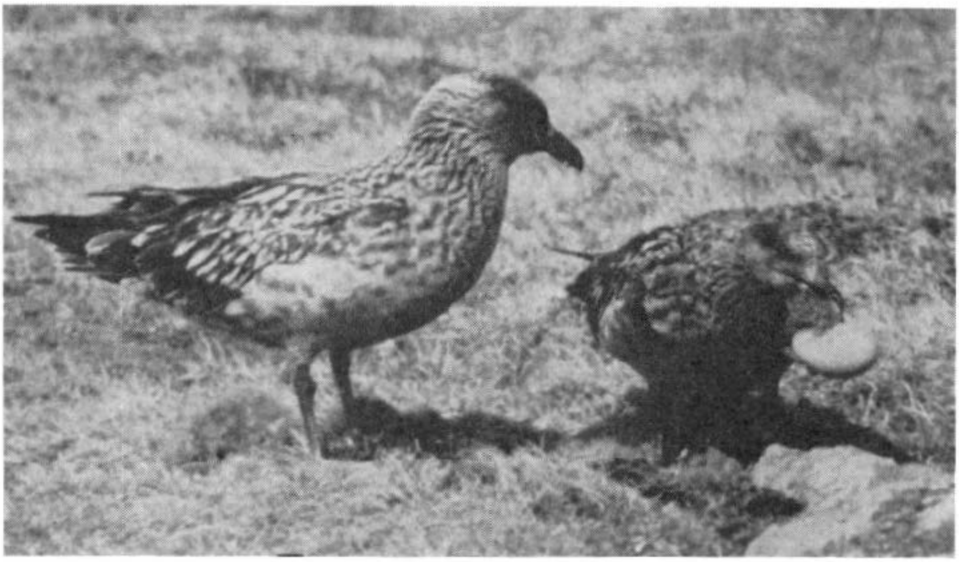

Fig. 3. *Two Great Skuas are about to empty an Eider's nest. Part of the egg was eaten on the spot; then the bird flew away with it in its bill to eat the rest in peace some way off.*

the rest of the coast it nested scattered and in rather small number, often only one or two pairs in each locality and not more than 20-25 pairs. A colony of about 25 pairs was situated on the eastern mountain side near the bottom of Ymerdalen. This colony has not been mentioned by LØVENSKIOLD.

Great Black-backed Gull. *Larus marinus* L.

About 50 birds were seen along the west and east coast, where they nested in colonies of Glaucous Gull. The majority nested in the middle part of the west coast and the middle-southern part of the east coast. On the north coast it was seen only a few times.

Lesser Black-backed Gull. *Larus fuscus* Subsp.?

On July 2, two individuals were seen on the coast about a mile west of the radio station. There is no other record of this bird from Bjørnøya.

Herring Gull. *Larus a. argentatus* PONTOPP.

On July 9 and 10 two adults and one juvenile were seen on the coast near the radio station.

Kittiwake. *Rissa t. tridactyla* (L.)

Very numerous on the bird cliffs in the south. Along the rest of the coast it nested in many places, but in most of the colonies there were only 100–200 pairs or less; the biggest colonies, however, counted from 500 to 1000 pairs and up to a few thousands. On the eastern mountain side in Ymerdalen there was a colony of about 20 pairs.

LØVENSKIOLD does not mention Kittiwake as breeding on the west coast. However, we found some rather big colonies there, and the biggest one had a few thousand pairs.

Arctic Tern. *Sterna paradisaea* PONTOPP.

Breeding in colonies in the north-eastern part of the island. In the area south-west of Røyevatnet there were four pairs. The total population counted 160–180 pairs. A colony near the radio station and one on two islets in Engelskelva, about 2 miles from the outflow, had 50 odd pairs each. Colonies of 10–15 pairs were found on an islet in a little pond north of Lomvatnet, on the biggest islet in Lygna, and in Holmevatnet, as well as on the largest tongue of land in Holmevatnet. On both islands in Laksvatnet colonies of 5–10 pairs were found.

In the area south-west of Røyevatnet two nests were found in Bollevatnet, one nest was found about 500 yards from the nearest lake in a moist terrain south-west of Røyevatnet, and one nest was situated on the edge of a small lake 200 ft above sea level about 1½ mile south of Røyevatnet.

Although the nests in the colony near the radio station were scattered over a big area, an arctic fox managed to take most of the brood, and less than ten young got on their wings.

Norwegian Razorbill. *Alca torda pica* L.

One was seen near the Guillemot colonies both at Taggen and Fugleodden. It probably breeds in small numbers on the island.

Little Auk. *Plautus a. alle* (L.)

In Brettingsdalen on the north-east side of Miseryfjellet there was a colony of 50–100 000 pairs, and on the west coast, south of the outflow of Ellasjøen, there was a colony of 5–10 000 pairs. On the north-eastern side of Miseryfjellet, facing the sea, a few hundred pairs nested. On the north coast and in the northern half of the east coast scattered colonies from a few up to 50–100 pairs were found. On the west coast, north of the outflow of Ellasjøen, there were altogether not much more than 20 pairs. On the upper part of Hambergfjellet and on the southernmost edge of the island there were colonies of about 50 and 25 pairs, respectively. Near Jutulsetet on the northern side of Miseryfjellet and on the mountain side immediately south of Ellasjøen there were colonies of about 100 pairs. LØVENSKIOLD does not mention any of the two large colonies, and the Little Auk is not mentioned at all as a breeding bird on the west coast.

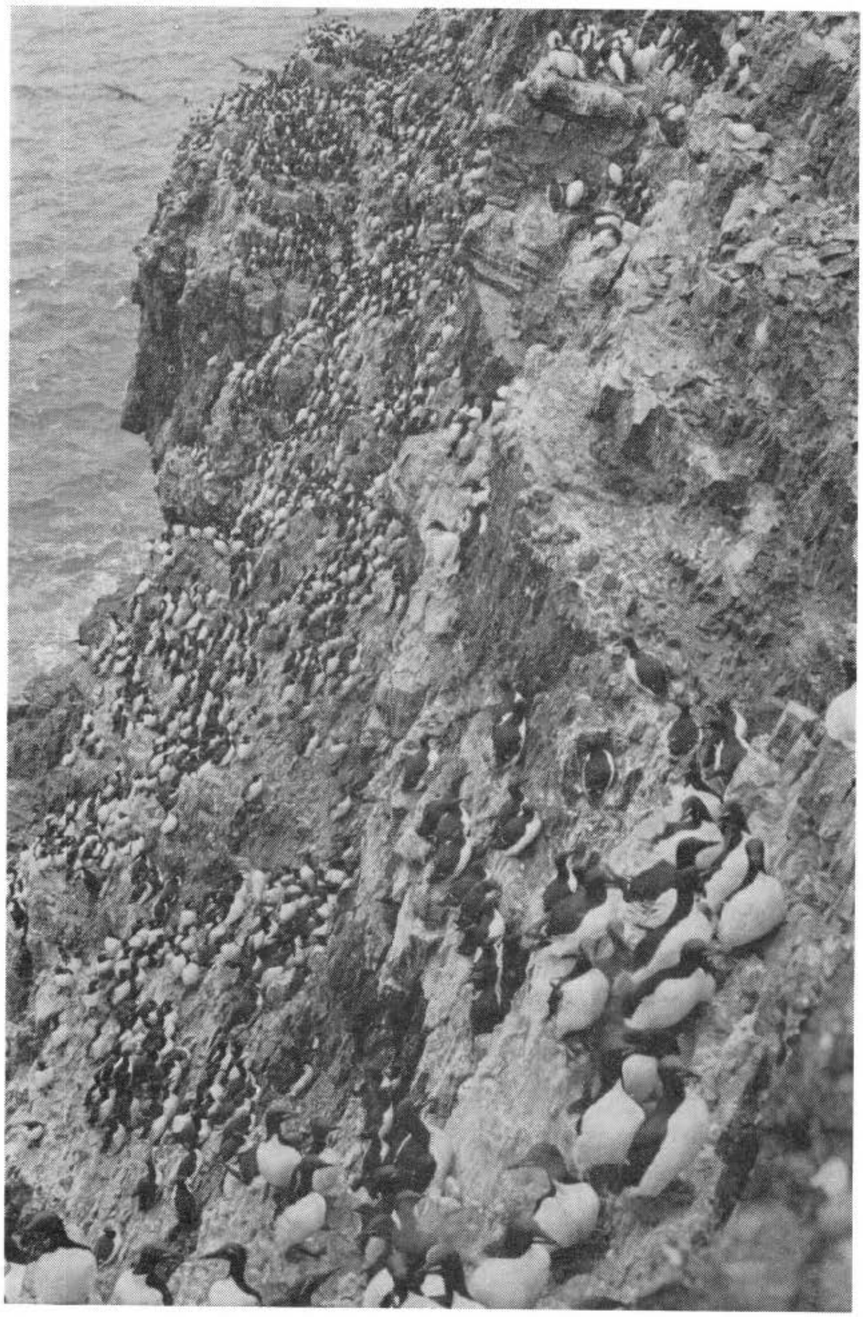

Fig. 4. *Colony of both Bear Island Guillemots and Brünnich's Guillemots on Kapp Kolthoff at the south end of Bjørnøya. More than a thousand guillemots can be seen.*

Bear Island Guillemot. *Uria aalge hyperborea* SALOM. and
Brünnich's Guillemot. *Uria l. lomvia* (L.)

Both species are breeding in enormous numbers on Bjørnøya, and as they almost always nested in the same colonies, they are here treated in the same paragraph.

The Guillemots nested in fantastic numbers in the southern part of the island. They nested continuously from Glupen on the west coast round the south coast to Sørhamna in the east. In places on this long coast-line, however, they only appeared scattered, but it is beyond doubt that the total population of Guillemots has to be counted in millions.

Along the rest of the coast there were few and rather small colonies. The most important of these colonies were: on the east coast – the north-eastern part of Miseryfjellet and Fugleodden; on the north coast – Måkestauren, Taggen and Flisa; on the west coast – Langbukta and Kapp Ruth. Of these, the colony in Langbukta with 5–10 000 pairs was the largest, while the others contained from 500 up to more than 2000 pairs. Apart from these colonies there were a few small colonies of 10–100 pairs. There were also considerable colonies on some of the islands round Bjørnøya.

Though the two species nested together, there was usually a distinct difference in their choice of nesting-site. The Bear Island Guillemot nested mainly on rather broad shelves and ledges, while the Brünnich's Guillemot to a large extent nested on very narrow shelves and smaller projections. They often nested side by side, but in that case, the Bear Island Guillemot nearly always would be more numerous than the Brünnich's Guillemot. However, all in all the Brünnich's Guillemot was more numerous than the Bear Island Guillemot, but this varied much from colony to colony.

The number of "bridled" Guillemots varied from about 30% up to about 75%, but the average was around 50%.

Most of the breeding Guillemots on the south coast left the cliffs between July 30 and August 7. The departure most probably took place on August 6, as the weather then was unusually good. It was quiet and clear, and the sun was shining from an almost cloudless sky most of the day (this was our only day with really good weather). We visited the bird cliffs on the south coast on August 7. The sky was overcast, but visibility was still good, so we managed for the first time to get a very good impression of the bird cliffs in this part of the island, but unfortunately at a time when most of the Guillemots had left the cliffs. Especially on the upper part of the cliff there were still places completely occupied by Guillemots. It was obvious that all the Guillemots in one area had left at the same time.

In the remaining part of the island the departure of the Guillemots must have set in later. There was no sign of departure in any of the colonies we visited on July 6. On Taggen the birds had not yet started to leave when we last visited the colony, on July 9.

Mandt's Guillemot. *Cepphus grylle mandtii* (MANDT)

Nested along most of the coast, but usually in small numbers. In a few places, however, there were small colonies. The nests were usually placed near the edge of the cliff.

Northern Puffin. *Fratercula a. arctica* (L.)

Some small colonies on the north coast, but they hardly ever exceeded 50–100 pairs. On the north-eastern side of Miseryfjellet there was a colony of 75–100 pairs. Along most of the remaining coast line it was extinct, but a few pairs and very small colonies were found here and there.

In places on the north coast the Puffins differed so much in size from each other that some of them probably belonged to the race *Fratercula arctica naumanni.*

Below are given measurements of wings and bills of *Fratercula arctica* subsp. ? shot in different places on the north coast of Bjørnøya at the end of July. The measurements are carried out with sliding gauge, and are given in mm.

No.	Age	Sex	Wing	Height of bill	Length of bill
1	ad.	♂	187.0	45.5	60.0
2	ad.	♂	185.0	42.7	52.4
3	juv.	♀	177.0	35.0	50.0
4	ad.	♀	175.5	41.4	48.8
5	ad.	?	174.0	39.3	50.0
6	ad.	♀	171.0	38.5	47.9
7	ad.	♂	170.0	42.0	50.1
8	ad.	♀	168.5	38.8	49.8
9	ad.	♂	168.0	39.3	50.6
10	ad.	♀	168.0	38.8	44.3
11	ad.	♀	167.0	39.1	50.8
12	ad.	♀	166.0	39.0	49.2
13	ad.	♀	166.0	36.6	46.1
14	ad.	♀	160.0	38,0	51.8
15	ad.	♀	156.0	33.6	43.4

Redwing. *Turdus iliacus* Subsp. ?

Two were regularly seen at the radio station. They may have nested or tried to nest.

Rock-Pipit. *Anthus spinoletta* Subsp. ?

One lived permanently near the radio station. There is no other record of this bird from the Svalbard area.

Meadow-Pipit. *Anthus p. pratensis* (L.)

On July 2 and 26 one was seen a mile west of the radio station. The behaviour of the bird suggested that it was breeding nearby.

Snow-Bunting. *Plectrophenax n. nivalis* (L.)

Very common breeding bird over most of the interior of the island as well as in places along the coast from a little west of the radio station to a little south of Tunheim. It was not found breeding in other places on the coast. In the southern part of the island only a few pairs nested, and in the north-western part of the island it was seen only a few times. In some places in the interior, the occurence of Snow Bunting had the character of colonies, and when the weather was fine, 10–20 males could be heard singing at the same time in these areas. From the end of July we saw the juveniles, and by the beginning of August there was a host of them.

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A recent find of *Pyrolofusus deformis* Reeve (*Prosobranchia*) in Svalbard waters

BY

Finn Aarefjord[1] and Stig Skreslet[2]

Abstract

Twelve species and two egg capsules of the gastropod *Pyrolofusus deformis* Reeve were found in Bjørnhamna at Sørgattet on the north-western coast of Vestspitsbergen.

The depth was 6–15 m where the snails and the capsules were found. No current was observed. Previous recorded findings of *P. deformis* were made at 40–176 m.

The water masses in Sørgattet are weakly stratified, with salinity at 10 m depth between 33.3 and 34‰. The temperature is found to be between 1°C and 6.5°C in the months July and August.

The capsules contained both a white and a yellow component. The last mentioned consisted of eggs, 0.2 mm in diameter. It seems as if *P. deformis* needs one year to develop from egg to juvenile.

In 1966 our SCUBA diving team, participating in the Norsk Polarinstitutt's summer-expedition, came across 12 rather large snails and two egg capsules. They were all found in the bay Bjørnhamna at Sørgattet on the north-western coast of Vestspitsbergen (Fig. 1).

The snails and the capsules (Gonor 1964) all belonged to the *Pyrolofusus deformis* Reeve in the Buccinidae family (Fig. 2). This snail has a circumpolar distribution. It has been found at Point Barrow, Alaska, around the Unimak Islands in the Aleutians and in Spitsbergen. Though the distribution is rather wide, only a few living specimens have been found. Egg capsules have previously been reported found only at Point Barrow.

Habitat

In the Spitsbergen area *P. deformis* has been found on a bottom of mud and clay. Only in one case, viz. in Storfjorden, it has been found on coarse gravel. In Bjørnhamna the bottom consisted, except for an occasional boulder, of fine sand, about 0.5 mm in diameter. Greater parts of the bottom were covered by

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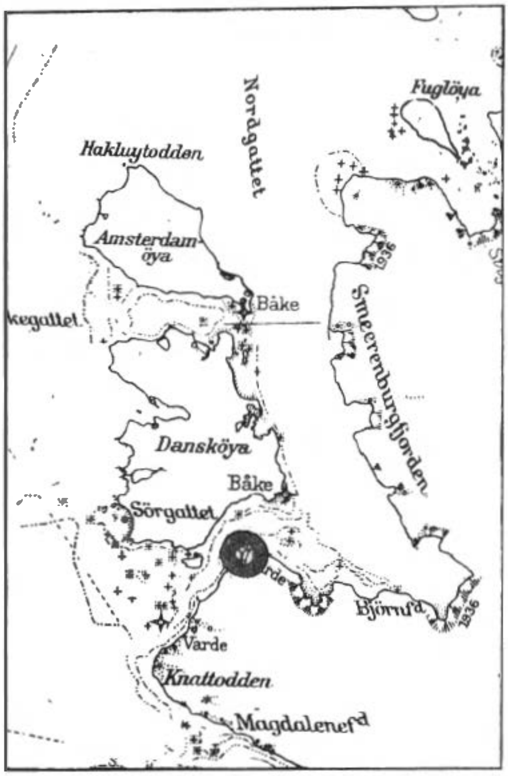

Fig. 1. *The area where P. deformis was found. Bjørnhamna in the circle.*

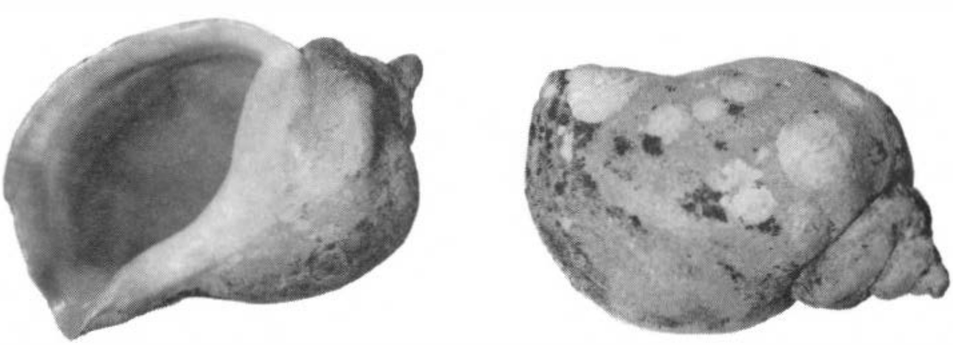

Fig. 2. *P.deformis. Length 12.0 cm.*
Photo: TERJE OLSEN.

loose-lying sea weeds. No current was observed. It seemed as if *P. deformis* had its distribution restricted to this bay, as we found no continuity towards deeper water, that is to about 40 m, or in Sørgattet as a whole. The vertical distribution of the snails (Table I) shows that they, except in Bjørnhamna, prefer deeper water where alterations in hydrographical conditions are supposed to be small.

Table I
Present known localties and number of collected, living *P. deformis*

Locality	Depth m	Number	
Storfjorden, 76°42'N, 17°26'E	139–131.5	1	(KNIPOWITSCH 1902)
» 77°47'N, 19°07'E	102.5	1	» »
Magdalenefjorden, Spitsbergen	112.0	2	(FRIELE 1882)
Bjørnhamna, Sørgattet, Spitsbergen	6–8	11	(1966)
» » »	15.0	1	(1966)
Barrow, Alaska	146.0	1	(McGINITIE 1959)
» »	43.0	1	» »
» »	165.0	2	(GONOR 1964)

Hydrographical conditions

There is no hydrographical data from the exact depth where *P. deformis* and its capsules were found in Bjørnhamna. DIGBY (1960), however, concludes that the water masses are weakly stratified, which is in accordance with our own observations. We therefore apply the temperature from 0 m and 1 m to describe the conditons in 6–8 m depth (Fig. 3). Compared with other available data from localities where *P. deformis* has been found, there is a marked difference in temperature. In Magdalenefjorden the temperature at the bottom was –2.1°C (17/8–78) (FRIELE 1882). In Storfjorden the bottom temperature was –0.7°C (22/7–91) and –1.8°C (16/7–91) at the two stations (KNIPOWITSCH 1901). A direct comparison of these data cannot be made, but they indicate the temperature range in which *P. deformis* may be found. In 1956 the salinity at Sørgattet from July 21 to August 25 varied between 33.3 $^0/_{00}$ and 34.0 $^0/_{00}$ at 10 m (DIGBY 1960). The changes are very small, even at this time of the year when the melting of the glaciers is at its greatest.

The capsules of P. deformis

Until 1966 only two capsules of *P. deformis* have been found. Both were collected at Barrow, Alaska, in August. One was damaged (GONOR 1964). In Bjørnhamna, at 6 m depth, two more capsules were found, one on July 11, the second on August 24. Both were found in the same area as the adult snails.

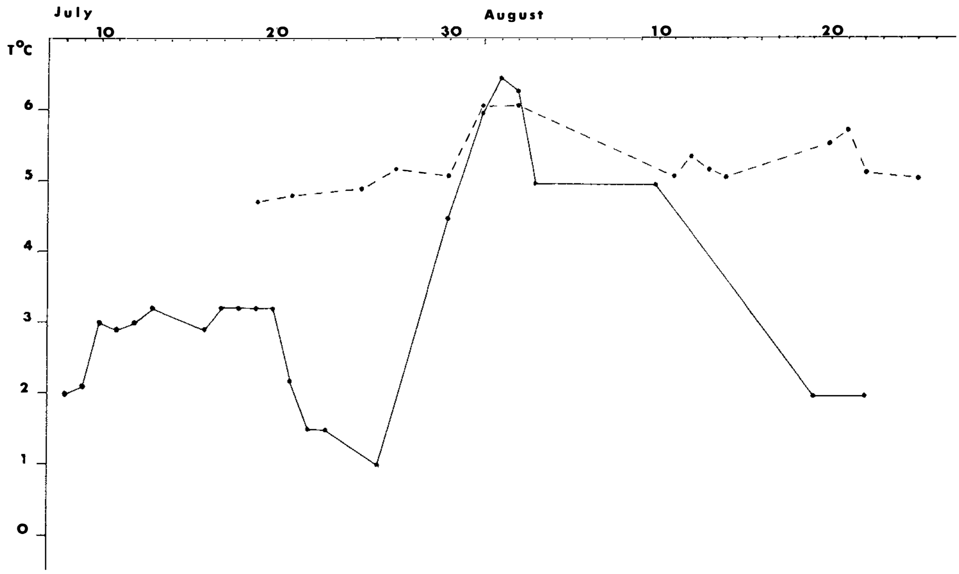

Fig. 3. *The temperature in Sørgattet.* —— 0 m (1966), - - - 1 m (1956).

Both capsules have been measured (Table II) and their contents examined. The capsules contained one white and one yellow component. The white material filled up most of the capsule. The yellow part was found to be composed of globular eggs, 0.2 mm in diameter. No structures could be seen. The lack of structures was reported by GONOR (1964). He suggests that the contents of the damaged capsule were remnants of eggs and embryos, with indications of being attacked by microbial organisms. The two capsules from Bjørnhamna must be considered intact and new, as no embryonal structures were visible.

The second and intact capsule from Barrow, collected in August, contained three juveniles, but nothing else. Prosobranchia with nourishing eggs do not leave the capsule before the nourishing eggs are eaten up (THORSON 1950). This should indicate that *P. deformis* will hatch in the autumn in Alaska. If the same is the case in the Svalbard area, *P. deformis* needs at least one year to develop.

Table II

Measure of capsule of *Pyrolofusus deformis* and depth of finding place

Locality	Diameter mm	Height mm	Depth m
Bjørnhamna	42	33	6
»	36	28	6
Barrow, Alaska	27	24	176

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Polar bear investigations in Svalbard 1967

A progress report. II

BY

THOR LARSEN[1]

Abstract

During a two-month summer expedition to Spitsbergen in 1967, 51 polar bears (*Ursus maritimus*) were successfully trapped, marked and studied. Twenty bears were caught with the morphine-like drug Etorphine (M 99) (Reckitt & Sons Ltd.), and 31 with Sernylan (Phencyclidine hydrocloride) (Parke Davis & Co). Each bear was tagged with nylon and monel metal tags, tattooed in upper right lip, and marked with a big dye number on the hips. The bears were kept in a cage onboard until completely recovered after one day. A 250 cc. blood sample was drawn from each bear, and a 100 cc. milk sample from each lactating sow.

Weather and ice conditions in 1967 were difficult, with only 15 days of satisfactory working conditions. In July, bears were often chased on foot in the pack, while in August most bears were taken from the ship or a small boat.

The field experience from 1966 and 1967 demonstrates that the use of a vessel in the Svalbard pack in the summer is a safe and effective method for large scale live trapping and handling of polar bears. Even better results would be obtained if the vessel could carry a small helicopter.

As in 1966, field work was based on a Norwegian-American collaboration with two participating American scientists.

Introduction

The polar bear investigations in Svalbard were initiated in 1966 in early spring by monthly aerial surveys over the eastern pack ice areas, performed by the Norwegian Air Force. The same summer, four bears were successfully trapped and tagged from the sysselmann's vessel «Nordsyssel» during a five days' effective effort (LARSEN 1967, 1968). From the experience gained in 1966, we found it necessary to alter the original plans. A planned winter expedition to the eastern Svalbard area was postponed one year, and the summer program was repeated in 1967 with a bigger field effort. As in 1966, the expedition was based on participation of American biologists. Dr. A. W. ERICKSON from the University of Minnesota was invited in July, and Mr. J. LENTFER of Alaska Department of Fish and Game participated in August. The plan was first to trap one or two bears for physiological investigations and to put this team ashore. Both groups should cooperate in the ecological program in the last part of the field period.

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Field work

The expedition left Tromsø on July 3. From an aerial survey the day before, the author could bring information on the ice conditions. We sailed to the pack west of Hopen, but the area was soon abandoned because of the ice situation. The expedition moved eastwards, and arrived in the pack east of Hopen on July 10, where we worked for ten days in the direction towards Kong Karls Land. We then sailed to Hopen where specimens and journals from the 1966/67 polar bear catch were collected. The live trapping was continued on the 23rd, and we went to Longyearbyen after a week for supplies and exchange of personnel. On the way we picked up the team on Halvmåneøya and established a base in Hornsund for later physiological investigations.

We left Longyearbyen on August 6, and after a short stop in Hornsund we were back in the same area as the previous month on the 10th. Bear study continued for 12 days. We then returned to Hornsund and later to Tromsø, where we arrived on September 1.

Methods

In addition to the polar bear live trapping in Svalbard, attempts have been made in Alaska (LARSEN 1965, FLYGER 1966, LENTFER 1967) and in Hudson Bay in Canada (JONKEL 1967, 1968). Field work in Alaska demands use of fixed-wing aircrafts and helicopters, and is thus very expensive. Trapping in Hudson Bay has been performed with footsnares, which is an effective method under certain field conditions, but gives less result in relation to time. Work in Svalbard showed that the use of vessels in the pack in the summer period represents an effective way of large scale trapping and handling of bears. Heavy laboratory equipment may be taken into the field, the ship carries storage facilities for biological samples, and bears may be kept onboard in a cage for various studies if necessary. Under certain conditions, physiological investigations and other laboratory work may be performed onboard.

In 1967 a small sealing vessel was rented for two months' polar bear investigations in Svalbard. This ship, «Polarulv», had a length of 83 ft and a 300 h.p. engine. The crew of seven had been reduced to five, which allowed us to take along a group of eight scientists and assistants. A small laboratory was built on the upper aft deck, and a cage for the bears was erected on the main deck. The ship carried a freezer for biological samples and specimens, a kayak, and a plastic boat with outboard motor for the bear trapping.

In 1966, bears were trapped by means of the morphinelike drug Etorphine (M 99) (Reckitt & Sons Ltd.) (LARSEN 1967). Etorphine was to be used also in 1967, but in addition we wanted to test Sernylan (Phencyclidine hydrocloride) (Parke Davis and Co.), which had been used in bear trapping in Alaska (LENTFER 1967) and under laboratory conditions with considerable success. As in 1966,

Fig. 1. *Polar bear sow with two cubs is chased on a small icefloe where they may be immobilized by the syringe gun. «Polarulv» in the background.*

Copyright: HERTA GRØNDAL

syringe guns were both Cap-Chur (Palmer Chemical Co.) and Pax-Arms (Pax Arms Ltd.).

When the bears were immobilized, they were hoisted onboard, weighed, measured and put in the cage. Marking program including tagging with a monel metal and a nylon tag in each ear, tattoo in right upper lip, and a big dye number on both hips. All four tags carried the same number, and the legend "Reward 20 $, Norsk Polarinst. Oslo, Norway". The last two digits on the tags were punched in with the tattoo outfit and dyed in the fur. With some experience, we found that the dye numbers were better if cut with scissors in the fur, and the dye was afterwards rubbed into the underfur with a toothbrush. Bears marked by this method could be distinguished from unmarked bears at a distance of several miles, and the number could be read more than a mile away.

From each bear a blood sample of 250 cc. was drawn from the femoral vein by vacuum bottle, spun, and the serum and hemoglobin fractions were frozen. In some cases heparine was added to prevent clotting. Sows with cubs or yearlings received an injection with Oxytocin (Rio Ramo Drug Co.), and a milk sample of approximately 100 cc. was drawn and frozen.

Two independent estimates of age in adult bears were made from tooth wear. A plan to pull an incisor for age determinations had to be abandoned, but on some occasions a rudimentary premolar was taken.

Bears were normally kept for one day and studied during recovery. Special attention was paid to sows with cubs or yearlings when they were released, and we were careful not to split the family groups.

Results and discussion

Aerial surveys

As in 1966, the aerial survey program was conducted by the 333 Squadron, Norwegian Air Force. The eastern pack ice was surveyed monthly from March to October. The surveys in July and August provided the expedition vessel with information on ice conditions and bear signs, and some equipment was dropped to the vessel. These two surveys made it clear that it would be impossible to sail to Kong Karls Land this summer. An attempt to spot colour marked bears from the plane failed, due to bad weather.

The trapping of polar bears

The ice conditions in the eastern pack were very different from those of the previous year. In July, the ice was very solid, and consisted of big icefloes, several miles across. Most bears had to be stalked on foot, or chased out into open water. Two men worked together, one with a syringe gun, the other with a rifle for protection. They were dressed in white camouflage uniforms and light shoes. It was often difficult to spot the bear between pressure ridges and icebergs, and a third man was therefore watching the operation from the crow's-nest. He could signal to the other two by means of flags or on walkie-talkies. The two hunters tried to get within 15 metres before firing with the syringe gun, but if the bears were frightened, they had to be pushed out into the sea where the vessel could take over. On some occasions the bears had to be run down. It is known that the polar bear has little perseverance, and may be run down by a well trained man under certain conditions (NANSEN 1924). We found this to be difficult with young animals and sows with cubs, but old animals were exhausted after a short time of running.

In August ice conditions improved, and it was possible to hunt the bears with boats as planned. We soon found that the small 14 ft plastic boat with outboard motor was very useful for this work. It could be used for chasing bears in broken ice, and could easily be pulled across an icefloe by two men if necessary. It was quick to manoeuvre, and we found it very easy to push swimming bears on to a small icefloe where they could be shot and later prevented from swimming away. When bears were immobilized on the ice, we did not run the risk of losing them by drowning, and they could then be taken directly onboard the vessel. When working with family groups, we always went for the sow first. The cubs or yearlings would always stay with her, and could easily be taken afterwards.

Fig. 2. *A male polar bear is hoisted onboard for further studies.*
Photo: THOR LARSEN

The weather in July was bad, with much snow and fog. Only 12 days were suitable for surveying from the crow's-nest; 57 bears were spotted, of which 22 were trapped and marked. In August, 8 days were satisfactory for observations; 48 bears were seen, and of these 29 were trapped and marked. The best result was obtained on August 15; 17 bears were seen, and 8 trapped after a five hours' effort. In addition to the 51 bears successfully marked, two died, one probably from a saliva block in the throat caused by Sernylan, the other by drowning.

Twenty bears were taken by means of Etorphine and 31 by Sernylan. Both drugs must be considered to be good in this type of work, and far better than those previously used for immobilization of big game. We found the dose of both drugs to be somewhat higher than what is previously found in carnivores under laboratory conditions. A considerable variance between the dosages from one animal to another may partly be due to ineffective injections by the syringe gun. From our experience in Svalbard, we found that a dose of 30 microgram per kg body weight of Etorphine or 3 mg per kg body weight of Sernylan is required for free-roaming polar bears in the pack. Overdosages of Sernylan would often cause much salivation and convulsions. These secondary effects could be somewhat counteracted by the application of the same amount of Sparine (Promazine hydrocloride) (Wyeth Labs.). Heavy convulsions could sometimes be stopped by a firm pressure by a foot or a knee in the vagus region inside the neck. On the other hand, Etorphine causes a respiratory rate depression and a decrease in heart beat rate. This drug should not therefore be used without an antagonist (ØRITSLAND 1967).

When shot with the syringe gun, bears were normally immobilized after 10 to 15 minutes. With Sernylan they would stay down for 2 to 3 hours, the cubs recovering somewhat faster. With Etorphine they would stay down for almost 12 hours if no antagonist was used, but would recover after 10 to 15 minutes if Nalorphine or Cyprenorphine was given intramuscularly. The polar bears remained calm even when locked up in the cage in the recovery period, and they never made any real effort to break out of the cage. It was odd to note that bears which had been trapped often came up to the ship if we met them later on, and they sometimes followed us for a day or more.

Marking and tagging

Effort has been made to find some means of permanent identification. We believe that ear tags tend to fall off after some years, particularly steel tags, which may cause gangrene due to frost. Some scientists believe ear tags will disappear

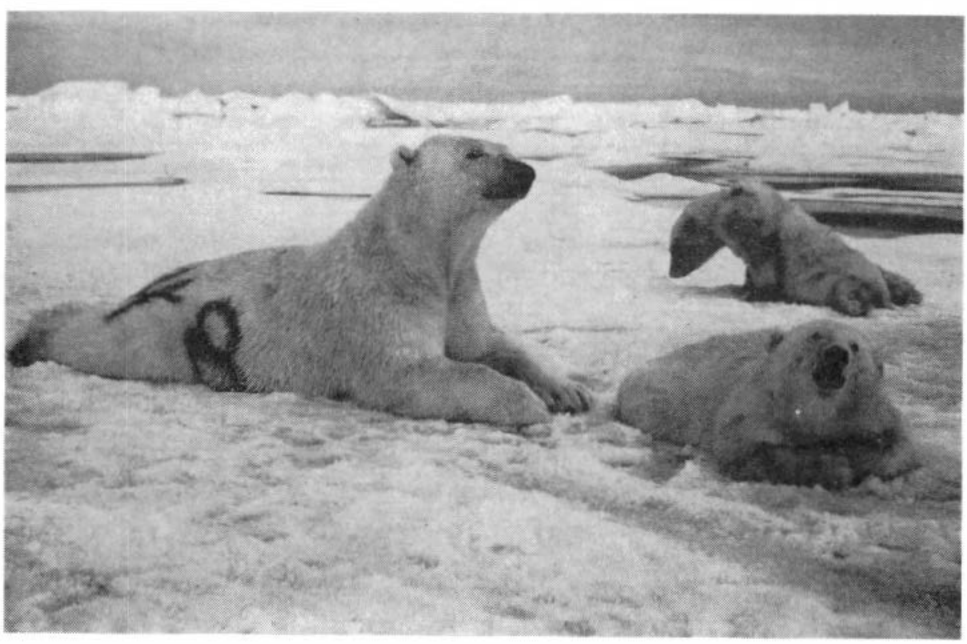

Fig. 3. *Polar bears partly immobilized by Sernylan. The sight is impaired and the hind limbs are affected. At this stage bears may be approached without danger.*

Photo: THOR LARSEN

after 5–10 years. The tattoo in the upper lip should, however, be readable for the rest of the animal's life. A high reward is paid for each bear, because it is important to know when a bear is recovered and to get samples from it. The fur dye was to serve several purposes. It would protect the bear from trophy hunters the same summer, it would enable us to distinguish between marked and unmarked animals, and hence stop another chase of an already marked bear, and it was possible to follow some local movements of the bears during the summer. Some people have criticised this type of marking on the basis that the fur dye will reduce the hunting capabilities of the polar bear. With reference to similar studies of other bear species, and with our knowledge of the polar bears' hunting methods, we do not believe this is of any importance. Some bears which were observed as much as three weeks after they had been marked, were evidently in good shape.

Sampling program

In 1966 an effort was made to draw a small blood sample from the tongue of the bears, the only place where a visible vein could be found (LARSEN 1967). Far better results are, however, obtained by puncture of the femoral vein. Although this vein cannot be palpated, it is easily located, and samples can be taken with only little training. Some samples tended to hemolyze, probably because of the relatively rough treatment of the fragile red cells during the spinning on the centrifuge. Some samples contained lipids, and in these cases blubber and meat were often found between the teeth of the animal, indicating it had just eaten.

It was interesting to note that even sows with yearlings had milk. It has been a lot of discussion between biologists whether the sow is lactating when her young ones leave her at an age of approximately 18 months, and our observations indicate that this is so.

The age estimates based on tooth wear must be treated with care, although the two independent estimates we made differed only slightly. Better results would be obtained if one of the teeth could be extracted, but this is impossible without surgery. A reduced premolar, which in some cases was pulled, is not satisfactory for age determination based on cementum layers.

In addition to the sampling of biological specimens during the summer expedition, some are also collected from the safari vessels and from trappers wintering in Svalbard. Hunting statistics have been collected from trappers and meteorological stations since 1966/67, and are based on a form which has been suggested by Canadian Wildlife Service to be used by all countries undertaking polar bear research. In Svalbard the interest is mainly focused on the Hopen polar bear catches, where hunting activity is relatively constant, and hence a trend in catch data is of greater significance.

Acknowledgments

This study has been sponsored by Industridepartementet, Komitéen til Bevarelse av Polarskibet »FRAM», Nansenfondet, NATO Research Grant, NAVF, Norsk Polarinstitutt, and Roald Amundsens Minnefond. I am in particular grateful to the Norwegian Air Force and to officers and crew at the 333 Squadron, to Generalinspektøren for Hærens Samband, and Generalintendanten. I also wish to thank Mr. A. ALVÆR, Hopen; Mr. E. BRUN, Tromsø Museum; Professor J. JANSEN, Universitetet i Oslo; Mr. T. LANDSVERK, Stavanger; Mr. O. LØNØ, Oslo; Mr. G. NÆVDAL, Fiskeridirektoratets Havforskningsinstitutt; Mr. E. REIMERS, Statens Viltundersøkelser; Mr. C. ROBERTSEN, Tromsø; and Mr. T. ØRITSLAND, Fiskeridirektoratets Havforskningsinstitutt. I have also received considerable help from abroad, and I want to thank Dr. J. CRAIGHEAD, Montana State University; Dr. A. W. ERICKSON, University of Minnesota; Dr. A. M. HARTHOORN, University College Nairobi; Dr. C. JONKEL, Canadian Wildlife Service; Mr. J. LENTFER, Alaska Department of Fish and Game; Mr. T. MANNING, Canadian Wildlife Service; Dr. G. F. SOMERS, Reckitt and Sons Ltd.; and Dr. C. VIBE, University of Copenhagen.

Finally I wish to thank our scientific and logistic advisory panels at Universitetet i Oslo and Norsk Polarinstitutt; my collaborator Mr. N. A. ØRITSLAND; and the crew, and our assistants on «Polarulv» 1967.

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Final remarks

In 1967 it never happened that bears attacked during the live trapping efforts. The main problem for us was to get within a sufficient distance for an adequate shot with the syringe gun, as a rather short distance was required. The polar bear will normally run away from man, and even big males eating a prey would do so when approached. It sometimes happened that bears came up to the ship if everything was quiet on board, and this was in particular the case with young animals.

When approached, the polar bear will behave in a very particular manner. At a distance of 20–30 metres, it will often blow its nose, which thus may be regarded as a first warning. At shorter distances, and in particular when there is little chance to escape, it will smack with its mouth and often lower its head. A sudden move, a hit by the syringe etc., will immediately trigger off a flight reaction. This same behaviour was also observed in polar bears in Hudson Bay, in the fall 1967, by the author, and in other bear species as the black bear (*Ursus americanus*) (JONKEL 1967, pers. comm.). JONKEL (pers. comm. 1967) believes the smacking with the mouth to be the final warning from the bear, and that it is most likely to attack afterwards.

The summer 1967 there were only 15 days with suitable weather and ice conditions for bear trapping. More than three bears were trapped each effective day on an average, indicating the efficiency of the described method. Even better results might have been obtained by cooperation between a vessel and a small helicopter. The ship might serve as a base for the helicopter, and carry fuel and repair outfit, and the helicopter might be able to work under optimal conditions with only little flying out and in of the working area. By this combination, and under satisfactory weather conditions, most of the bears spotted from the crow's-nest could be taken, and five to six bears might be handled each day. The helicopter might also be used in bear counts by the quadrate sampling method, as it has turned out that linear transect flights are not fit for population estimates of polar bears. And finally, the helicopter might guide the vessel through the pack, and take people to areas which otherwise would have been out of range.

In 1967 it turned out that there was a considerable difference in skill between the observes from the crow's-nest. Some were able to spot bears at a distance of more than five miles, while others were unable to observe more than a few hundred metres to both sides. But even so, observation efficiency must be regarded as fairly constant, because of the constant exchange of personnel in the crow's-nest during the day. From the author's personal experience, and from discussions with the two American participants, bear density in the eastern Svalbard waters in the summer of 1967 seems higher than what is normal off the Alaskan coast in early spring months during the trophy hunt of polar bears.

Thor Askheim

AV
SIGURD G. HELLE

Ingeniør THOR ASKHEIM, tidlegare topograf ved Norsk Polarinstitutt, døydde brått og uventa nyårsdagen 1967, nær 78 år gammal.

Topograf THOR ASKHEIM *fotografert om bord i ekspedisjonsfartyet M/S «Minna» i 1947.*

ASKHEIM vart fødd den 18. januar 1889 på Askheim i Eidsvoll. Han tok Kristiania elementærtekniske dagskole med tilleggskurs i 1907–08 og var landmålar ved Ing. Dahls Opmaaling i 1908–16. Seinare arbeidde han i 3 år (1916–19) ved Det Norske Aktieselskab for Elektrokemisk Industri, i 4 år (1919–23) ved Fredrikstad Ingeniørvesen og Havneingeniørvesen og i 1½ år (1923–25) ved Aker opmålingsvesen. Så dreiv han privat oppmålingsforretning i nokre år og hadde ymse gjeremål. Deretter arbeidde han i 2 år (1929–31) i Teknisk Opmaalingsbyraa.

Den 1. juli 1931 vart ASKHEIM fast tilsett som topograf ved Norges Svalbard- og Ishavs-undersøkelser, som var skipa i 1928 for å taka over arbeidet etter De norske statsunderstøttede Spitsbergenekspeditioner, men alt frå 1. februar 1925 hadde han av og til hatt mellombels arbeid for desse to institusjonane, og frå den tid var han på veg inn i den låma som han seinare følgde så trufast så lenge han levde. – Då Norsk Polarinstitutt løyste av Norges Svalbard- og Ishavs-undersøkelser i 1948, vart ASKHEIM naturleg nok tenestemann i den nye institusjonen.

Naturtilhøva i polarstroka set – i minsto av og til – store krav til dei som skal ferdast der. ASKHEIM var fysisk sterk og uthaldande, og attåt det viljesterk og tolsam, så han eigna seg godt til dei mange og ofte slitsame ekspedisjonane. Han var alt i alt med på atten ekspedisjonar til Arktis: tretten til Svalbard, to til Jan Mayen og tre til Aust-Grønland. Dessutan var han med på oppmåling i Finnmark etter krigen i samband med regulering og atterreising av brende byar og tett-bygde strok. – Som lista på slutten viser, la han ikkje inn årane for tidleg. Kvar sommar frå fylte 67 år til fylte 70 år reiste han på ekspedisjonar til Svalbard. Det står respekt av slike prestasjonar, som berre hardhausar med godt mot kan tenkja seg å gjera.

På ekspedisjonane dreiv ASKHEIM fyrst og fremst med triangulering og pass-punktmåling, men han tok òg ymse andre observasjonar i samband med kart-arbeidet, m. a. registrering av tidvatnet.

Det laga seg diverre ikkje slik at eg fekk arbeida saman med ASKHEIM i felten. Vi arbeidde på kvar sin kant, men eg er viss på at han var like blid i telt eller hytte i det kalde nord som på kontoret. Han hadde eit strålande humør og kunne i sanning le og få andre til å le. Han hadde sjølv opplevt mykje og elles høyrt mang ei gammal polarsoge – meir eller mindre sannferdig – på alle ferdene sine, og slike soger og andre skrøner kunne han fortelja att på ein meisterleg og skjemtefull måte og gjerne med ein god lått attåt.

ASKHEIM hadde gått eit fotogrammetrisk kurs i Jena og var med på å konstruera og utarbeida ei mengd med kart frå arktiske og antarktiske strok m. a. ved hjelp av kartkonstruksjonsmaskinar, og han reinteikna og finpussa mangt eit original-kart. Dette arbeidet tok han seg av med stor omsorg. Han var fagmann, ein ekte kartmann, og alt han gjorde – ikkje berre kartarbeidet – vitna om at han hadde uvanleg god ordenssans.

I bortimot 40 år tok ASKHEIM seg meir eller mindre av ekspedisjonsutstyret. Såleis sytte han for at soveposar og ullteppe vart vaska og reinska, at telt og presenningar m. m. vart vølte og haldne i stand, og at det i det heile var nøgda av vanleg utstyr til alle tider. Dessutan hadde han tilsyn med boklageret, som måtte ordnast av og til, for lagerplassen vart ofte for liten når opplagsmassen voks.

ASKHEIM nådde aldersgrensa, som for han var 65 år, i 1954, men vart oppmoda til å stå i tenesta eit år til, og han tok med takk imot oppmodinga. Seinare kom nye tilsvarande oppmodingar, og den siste galdt heilt til fylte 69 år. Så søkte han om å få halda på i stillinga si til han vart 70 år, og søknaden vart imøtekomen. ASKHEIM tyktest vera like frisk både lekamleg og sjeleleg, men etter dei vanlege reglane var det ikkje høve til å etterkoma ein ny søknad seinare om å få stå i stillinga endå lenger. I staden fekk han arbeid som pensjonist, og slik vart han verande ved Norsk Polarinstitutt til han døydde. Siste arbeidsdagen hans var fredag 30. desember 1966. Nyårsaftanen hadde han laurdagsfri. Måndag 2. januar ville han taka som feriedag og så vera attende på kontoret tysdagen. Slik forklåra han meg planane sine då vi skildest siste gongen eg såg han. Det skulle likevel ikkje gå slik. Nyårsdagen seig han saman død i laussnøen i skogen på fedregarden i Eidsvoll, som han kjende seg så sterkt bunden til og vitja så ofte høvet baud seg. – Han vart gravlagd ved Eidsvoll kyrkje den 7. januar.

ASKHEIM var ein uvanleg pliktoppfyllande tenestemann og ein trugen medarbeidar, som på alle måtar var lett å samarbeida med. Han levde gjerne etter prinsippet: Fyrstemann på kontoret om morgonen og sistemann frå kontoret om ettermiddagen. – For det store og verdfulle arbeidet sitt – fyrst og fremst med å kartleggja dei norske utpostane i nord – fekk han i 1960 ei høg påskjøning av H. M. Kongen – fortenestemedaljen i gull.

ASKHEIM har vori med på desse sommarekspedisjonane:

År	Svalbard	Jan Mayen	Aust-Grønland	Finnmark
1925	x			
1928	x			
1931			x	
1932			x	
1933			x	
1936	x			
1939	x			
1945				x
1946	x			
1947	x			
1948	x			
1949		x		
1950		x		
1952	x			
1954	x			
1956	x			
1957	x			
1958	x			
1959	x			

Bremålinger i 1967

AV
OLAV LIESTØL

Abstract

Norsk Polarinstitutt carried out mass balance measurements on four glaciers in the budget year 1966–1967, viz.: Storbreen, Hardangerjøkulen, and Store Supphellebre in southern Norway, and Austre Brøggerbreen in Vestspitsbergen. The results are listed in Table II, together with the results from the glaciers measured by Norges Vassdrags- og Elektrisitetsvesen.

Ice front variations were measured for thirteen glaciers; eitgh were retreating and five were advancing. (See Table III.)

Storbreen 1966-1967

På Storbreen ble akkumulasjonen målt under en tur til breen 10.–15. mai. Alle stenger så nær som 3 var usynlige på grunn av de store snømengder. Etter 17 års målinger av akkumulasjonen har man nå så mange data at man bare ved målinger på et par representative steder på breen kan beregne den samlede akkumulasjon. Det ble allikevel sondert over andre deler av breen, og det er god overensstemmelse mellom den direkte målte (1,8 m) og den beregnede verdi.

På nedre del av Storbreen, under firngrensen, ble det for noen år siden boret ned vaiere til et dyp av ca. 20 m. Dette gjør at man her får kontinuerlige målinger uten avbrudd som følge av omboringer. Ulempen er imidlertid at vaieren nærmest firnlinjen er vanskelig å finne i et år med overskudd. Det er derfor på Storbreen, ved siden av vaierne, satt ned aluminiumsstenger som gjør at vaierne er lettere å finne, samtidig som stengene kan brukes til akkumulasjonsmålinger. I denne ablasjonssesongen var det ikke nødvendig å bore ned noen stang før ved siste besøk på breen, 16. september. Samtlige stenger ble da funnet og målt.

Ablasjonen ble mindre enn i et normalår, nemlig 1,17 m mot normalt 1,68 m. Dette skyldes mindre innstråling og lavere temperatur. At ablasjonen ikke ble enda lavere skyldes den milde september. Luster hadde 1,7° og Fannaråki 2,5° over normalen i september.

Resultatet ble en stor positiv balanse på 0,72 m. Bare året 1962 kan oppvise et like høyt tall i de 18 år målingene har pågått. Se Fig. 1 og 2.

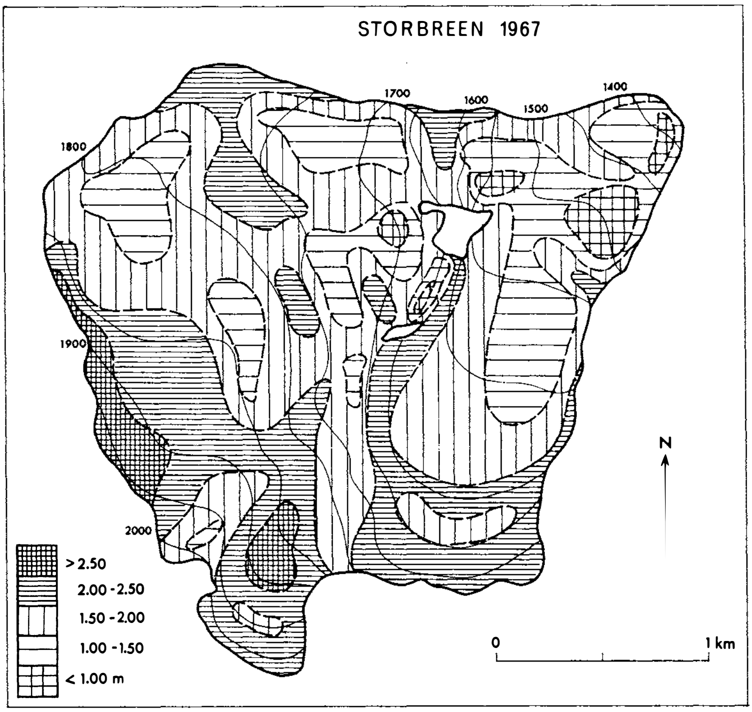

Fig. 1. *Kartet viser akkumulasjonen på Storbreen i 1967.*
Map showing the accumulation on Storbreen in 1967.

Store Supphellebre

Store Suphellebre består av to deler. Nedre del, som er en regenerert bre, ernæres av is som raser fra øvre del. Som i tidligere år ble materialbalansen til den regenererte breen bestemt delvis ved kartlegging av breen ved terrestrisk fotogrammetri, delvis ved meteorologiske beregninger.

Materialbalansen til den øvre og største delen ble målt med liknende metodikk som på Storbreen. Akkumulasjonen ble målt i slutten av mai, men på grunn av de uvanlig store snømengder var bare 7 staker synlige da. I løpet av sommeren kom de fleste nedsnødde staker fram, men stakene øverst i firnområdet ble ikke synlige. Ablasjonen ble målt flere ganger i løpet av sommeren.

Akkumulasjonen på Store Supphellebre var 2,72 m, ablasjonen var 1,50 m, balansen ble derfor sterkt positiv, + 1,22 m.

Fra målingene ble satt i gang på Store Supphellebre i 1963 og fram til 1967, har bare året 1965–1966 vist negativ balanse. Breen har i de fire årene magasinert vel 20.10^6 tonn, svarende til 1,70 m omregnet til vann jevnt fordelt over breen. Den nedre delen har i perioden 1964–1967 lagt på seg 3,5 m, og arealet har økt med 20%.

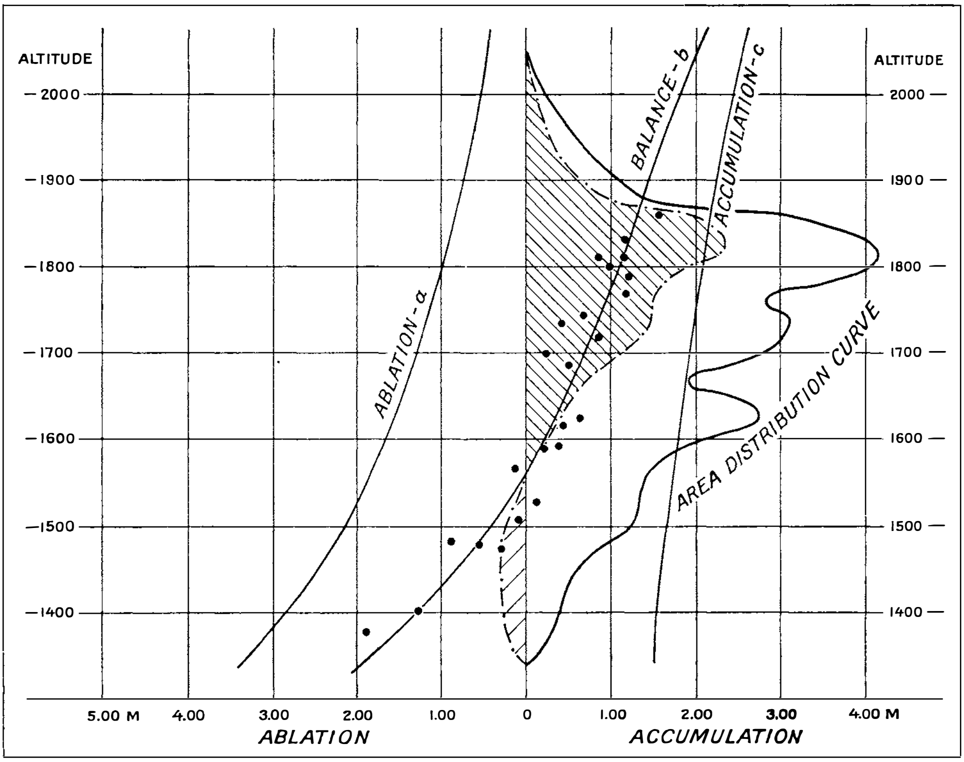

Fig. 2. *Diagrammet viser variasjonen av akkumulasjon, ablasjon og balanse på Storbreen i 1967 i forhold til høyden over havet.*
The diagram shows the variation in accumulation, ablation, and balance on Storbreen in 1967 in relation to height above sea level.

Hardangerjøkulen

Da de siste ablasjonsmålinger ble foretatt på Rembesdalsskåki høsten 1966, var det allerede kommet en god del snø i de øvre områder. Den 12. oktober var det således 0,12 m ved 1 600 m o. h., 0,28 m ved 1 700 m o. h. og 0,35 m ved 1 800 m o. h.. I slutten av februar 1967 ble alle stenger målt og påskjøtt nye lengder. Det skulle imidlertid vise seg at dette ikke var nok. Den usedvanlige store nedbør i mars og april gjorde at bare noen få stenger stakk opp over snøflaten da breen ble besøkt neste gang, 11.–15. mai. Sonderingen av snødybden var relativ enkel i de nedre områder på grunn av fjorårets store ablasjon, men i de øvre områder ble målingen vanskeliggjort av det store snødyp og mangelen på skikkelige referanseflater. I de 4 år målingene har pågått, har det imidlertid vist seg at mønsteret i snøfordelingen i de forskjellige høydenivå er meget likt fra år til år. Det trengs derfor få målepunkter for å få en god bestemmelse av akkumulasjonen. Tilleggsakkumulasjonen ble beregnet ut fra temperaturen på Fannaråki, og nedbøren på Reimegrend. Kartet, Fig. 3, viser akkumulasjonen slik den er beregnet til midten av mai.

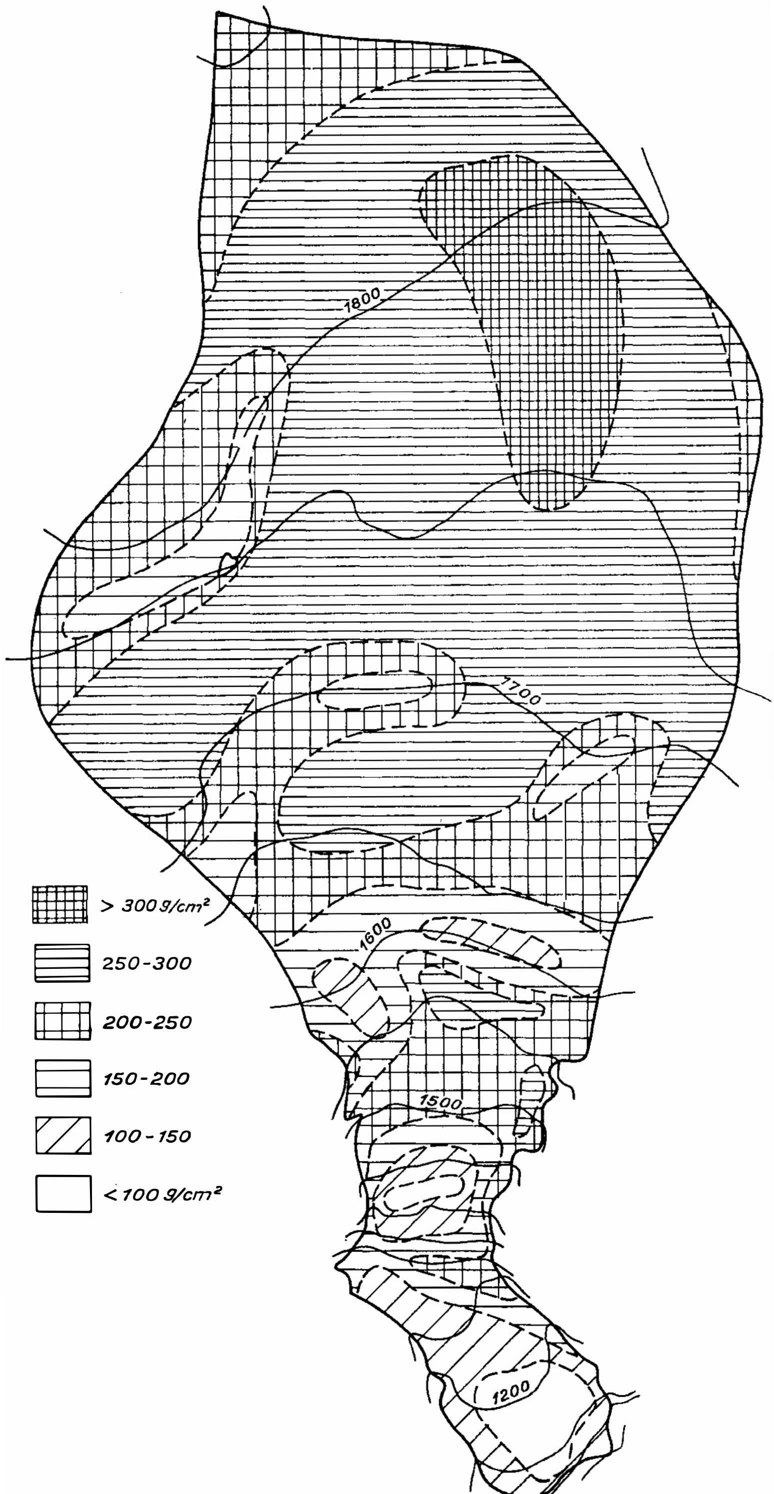

Fig. 3. *Kartet viser akkumulasjonen inntil midten av mai 1967 på den del av Hardangerjøkulen som dreneres til Rembesdalsskåki.*
Map showing the accumulation until the middle of May 1967 on the part of Hardangerjøkulen that flows to Rembesdalsskåki.

Tabell I

Hardangerjøkulen 1967

Høyde-intervall m o. h.	Areal km²	Akkumulasjon			Ablasjon			Balanse		
		10^6m^3	m	l/s.km²	10^6m^3	m	l/s.km²	10^3m^6	m	l/s.km²
1850–1900	0.075	0.17	2.25	71	0.04	0.54	17	+0.13	+1.71	+ 54
1800–1850	3.638	9.28	2.55	81	2.18	0.60	19	+7.10	+1.95	+ 62
1750–1800	3.862	10.74	2.78	88	2.90	0.75	24	+7.84	+2.03	+ 64
1700–1750	3.940	10.48	2.66	84	3.59	0.91	29	+6.89	+1.75	+ 56
1650–1700	2.102	5.26	2.50	79	2.52	1.20	38	+2.74	+1.30	+ 41
1600–1650	0.952	2.19	2.30	73	1.39	1.46	46	+0.80	+0.84	+ 27
1550–1600	0.660	1.39	2.10	67	1.17	1.78	56	+0.22	+0.32	+ 10
1500–1550	0.557	1.07	1.92	61	1.18	2.12	67	—0.11	—0.20	— 6
1450–1500	0.321	0.56	1.75	56	0.77	2.45	77	—0.21	—0.65	— 20
1400–1450	0.191	0.30	1.57	50	0.54	2.84	90	—0.24	—1.27	— 40
1350–1400	0.110	0.16	1.42	45	0.35	3.24	103	—0.19	—1.72	— 54
1300–1350	0.082	0.10	1.27	40	0.30	3.65	116	—0.20	—2.38	— 73
1250–1300	0.270	0.31	1.15	36	1,11	4.12	130	—0.80	—2.97	— 94
1200–1250	0.325	0.34	1.05	33	1.49	4.60	145	—1.15	—3.55	—113
1150–1200	0.324	0.32	1.00	32	1.65	5.10	161	—1.33	—4.10	—130
1100–1150	0.110	0.10	0.95	30	0.62	5.62	178	—0.52	—4.67	—148
1050–1100	0.030	0.03	1.00	32	0.18	6.15	194	—0.15	—5.15	—163
1050–1900	17.55	42.80	2.44	77	21.98	1.25	40	+20.82	+1.19	+ 38

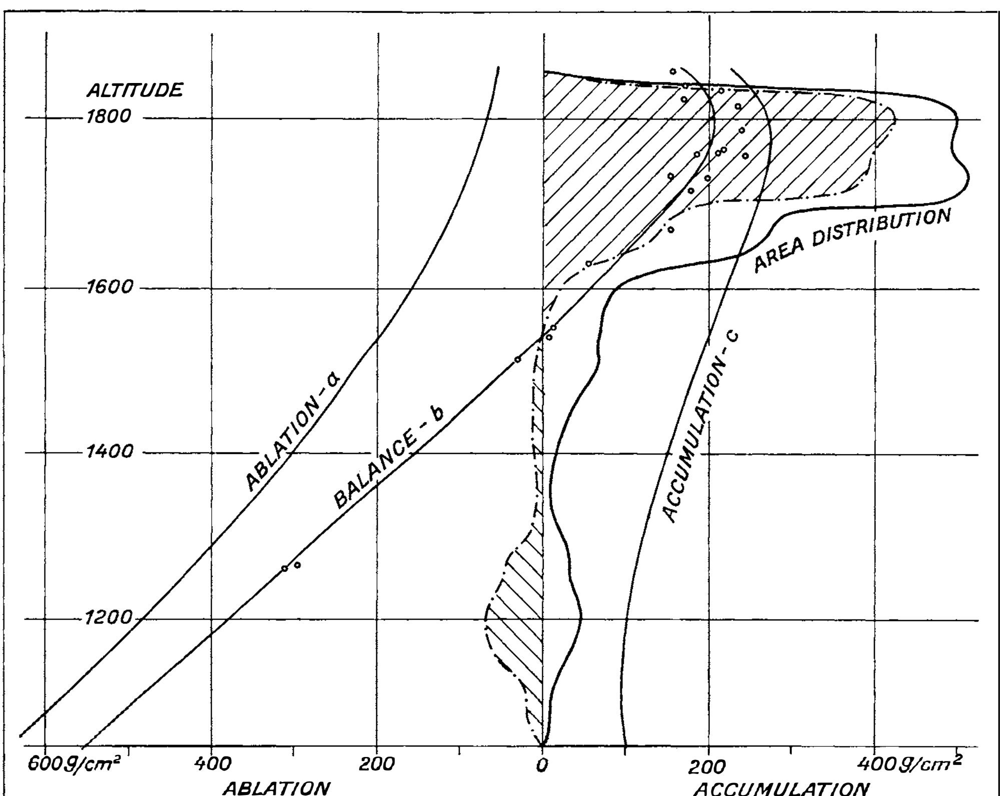

Fig. 4. *Diagrammet viser variasjonen av akkumulasjon, ablasjon og balanse på Hardangerjøkulen i 1967 i forhold til høyden over havet.*

The diagram shows the variation of accumulation, ablation, and balance on Hardangerjøkulen in 1967 in relation to height above sea level.

Ablasjonen ble målt ved 3 besøk på breen, 5.–8. juli, 3.–5. august og 4.–7. september. Alle stengene så nær som tre ble funnet igjen i løpet av sommeren. Ablasjonen etter 7. september er beregnet ut fra målinger på Omnsbreen like nord for Finse, hvor en hovedfagsstudent har begynt massebalanseundersøkelser.

Resultatet av målingene og beregningene er fremstilt i Tabell I og i diagrammet, Fig. 4.

Brøggerbreen (Svalbard) 1966-1967

I 1966 ble det startet massebalanseundersøkelser på Brøggerbreen like sør for Ny-Ålesund. Tolv målestenger ble boret ned i breen i en rekke fra bresnuten og opp til toppen. Den del av Brøggerbreen som ble undersøkt er ca. 8 km² og strekker seg fra ca. 100 til ca. 500 m o. h.. Bare ubetydelige arealer når over 500 m.

Breen er ikke helt ideell for en slik undersøkelse. For det første kan man ikke overkomme å ta med hele breen, og dessuten har den en ganske ujevn overflate, slik at akkumulasjonsmønsteret blir meget komplisert. Det er derfor meningen at man skal legge hovedtyngden av undersøkelsen over på en mer egnet bre. I år ble det derfor satt ut nye stenger på Midre Lovénbreen, som ligger noen kilometer lenger øst. Denne bre er godt avgrenset og har en jevnere overflate. Den har også den fordelen at kartgrunnlaget er usedvanlig godt, siden den østtyske ekspedisjon i 1961 utarbeidet et detaljert fotogrammetrisk kart over hele breen i målestokk 1 : 10 000 med 10 m ekvidistanse.

Tabell II

Massebalansemålinger

Bre	Areal km²	Akkumulasjon m	Ablasjon m	Balanse m	Likevektslinje m o. h.
Ålfotbreen	4.76	4.46	3.18	+1.28	950
Folgefonni	19.74	3.59	2.23	+1.36	1350
Store Supphellebre	11.99	2.72	1.50	+1.22	1190
Tunsbergdalsbreen	43.77	3.31	1.52	+1.79	1160
Nigardsbreen	40.86	3.40	1.24	+2.16	1310
Vesledalsbreen	4.22	2.06	1.71	+0.35	1400
Hardangerjøkulen	17.62	2.44	1.25	+1.19	1540
Storbreen	5.45	1.89	1.17	+0.72	1570
Hellstugubreen	3.38	1.48	0.93	+0.55	1800
Gråsubreen	2.39	1.45	0.74	+0.71	—
Blåisen	2.18	1.38	2.35	—0.97	1175
Storsteinsfjellbreen	5.12	1.37	1.77	—0.40	1450
Cainhavarre	0.68	1.63	1.79	—0.16	1450
Austre Brøggerbreen, Svalbard		0,77	1,42	0,65	400

Målinger av akkumulasjonen på breen ble i alt foretatt 10 ganger i løpet av akkumulasjonssesongen, men bare de siste 4 ganger ble egenvekten bestemt. Ved beregning av akkumulasjonen på denne breen er det meget påkrevet å ta med den påfrosne is, som her får en betydelig tykkelse. I gjennomsnitt får man et tillegg i akkumulasjonen på ca. 0,12 m. I alt ble akkumulasjonen i gjennomsnitt 0,77 m.

Ablasjonen lå langt over det normale og ble beregnet til 1,42 m. Resultatet blir derfor et underskudd i massebalansen på 0,65 m. Man har liten erfaring med massebalansen på breer i dette området, men man bør likevel regne med at dette er et usedvanlig stort underskudd.

Ved siden av undersøkelsene som Norsk Polarinstitutt foretok på Storbreen, Hardangerjøkulen og Store Supphellebre, utførte Norges Vassdrags- og Elektrisitetsvesen målinger på 11 andre breer, 8 i Sør-Norge og 3 i Nord-Norge. Alle undersøkelser i Norge er vist i Tabell II.

For Sør-Norges vedkommende er forholdene ved de forskjellige breer satt opp i diagram, Fig. 5. Til sammenlikning er forholdene i de 4 foregående år, samt en beregnet normal likevektstilstand tegnet inn.

Beregninger av breens fram- og tilbakerykking i meter ble foretatt ved i alt 13 breer, og resultatet er vist i Tabell III.

Tabell III

Enkelte breers lengdeforandring

Jotunheimen		*Folgefonni*	
Storbreen	— 5	Bondhusbreen	— 1
Styggedalsbreen	— 3		
Jostedalsbreen		*Møre*	
Stegholtbreen	—69	Trollkyrkjebreen	+ 5
Lodalsbreen	—93		
Fåbergstølbreen	-101		
Nigardsbreen	—20	*Svartisen*	
Bersetbreen	+10	Engabreen	+10
Austerdalsbreen	— 1		
Store Supphellebre	+ 1		
Briksdalsbreen	+15		

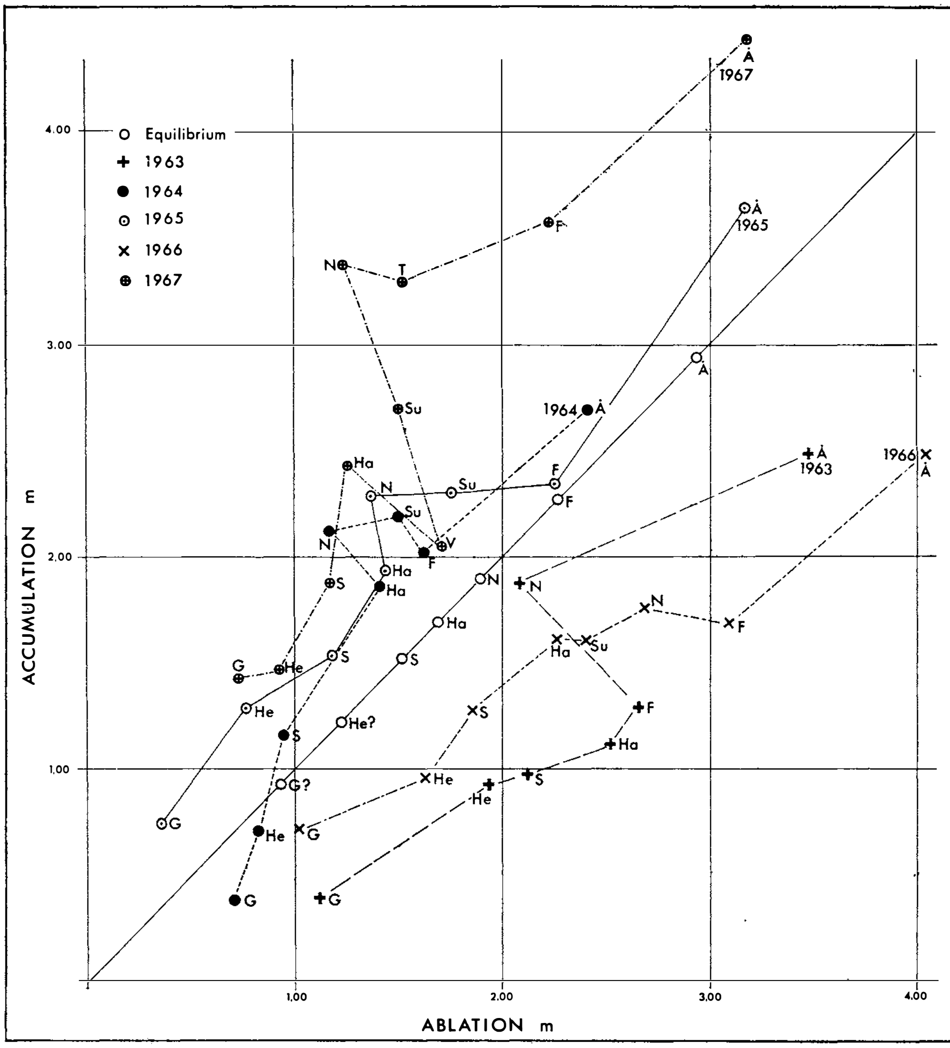

Fig. 5. *Diagrammet viser forholdet mellom akkumulasjon og ablasjon sett i relasjon til forholdene når breene er i likevekt og har «normal» materialomsetning. Å – Ålfotbreen, F – Folgefonni, T – Tunsbergdalsbreen, N – Nigardsbreen, Su – Store Supphellebre, V – Vesledalsbreen, Ha – Hardangerjøkulen, S – Storbreen, He – Hellstugubreen, G – Gråsubreen.*

The diagram shows the relation between accumulation and ablation compared to conditions in a year with balanced budget and "normal" mass exchange.

The weather in Svalbard in 1967

By
Vidar Hisdal

The following description of some salient features of the large scale atmospheric circulation over the Svalbard area is based on a study of the weather maps for 1967. The pressure systems most closely connected with these circulation patterns and the character of the resulting air flow are briefly indicated. Words like cold, cool, normal and mild characterize the temperature conditions in relation to the average conditions for the period 1947–66, the basis of these indications being mainly the temperature observations from Isfjord Radio.

1967	
1–28 Jan.	Most of the period a cold north-easterly air stream between a high-pressure area over Greenland and low-pressure centres moving over northern Europe or between Svalbard and Scandinavia. The lowest temperature of the year at Isfjord Radio (–32.0°C) occurs on 19 Jan.
29 Jan.–3 Feb.	Weak low-pressure systems over Svalbard give southerly winds and considerably higher temperatures.
4–20 Feb.	Cyclones pass just south of, later over the Svalbard area. Mostly easterly to northerly winds, and temperatures varying about the normal for the season.
21–26 Feb.	Advection of cold air from the north between a high-pressure area to the west and depressions to the south and east.
27 Feb.–11 March	Easterly winds in connection with several well-developed cyclones passing near the Svalbard area. Above normal temperatures.
12–18 March	Svalbard is situated near the south-eastern boundary of a high-pressure area. Easterly winds and cold.
19–25 March	A low-pressure system passing just south of the islands gives relatively mild, easterly winds.
26 March–2 Apr.	North-easterly winds to the north of a cyclone that becomes quasi-stationary in the Norwegian Sea. About normal, or somewhat below normal temperatures.
3–12 Apr.	Advection of considerably milder air in connection with cyclones passing over or close to the Svalbard area.
13–23 Apr.	A northerly air stream between a high-pressure area to the west and depressions to the south and east. Temperatures below the average for the season.
24–27 Apr.	A cyclone from the south-west passes the islands. Mild in the front of the cyclone, cool in the rear.
28 Apr.–4 May	A northerly wind between an anticyclone over Greenland and adjacent areas and cyclones moving farther south and east gives temperatures below normal.
5–10 May	Weak depressions approach over Greenland and pass the area. Variable winds and above normal temperatures.

11–15 May	The pressure field over Svalbard is very weak. Calms or weak winds, and temperatures somewhat above the average.
16–23 May	The circulation is governed by cyclones passing over northern Europe and an anticyclone centred north of, later over the Svalbard area. Easterly winds and below normal temperatures.
24–31 May	An anticyclone over Svalbard and adjacent areas gives calms or light, variable winds. Milder.
1–4 June	A very weak depression from the east passes. Temperature slightly above the average.
5–10 June	Easterly to north-easterly winds to the north of cyclones moving over northern Scandinavia. Below normal temperatures.
11–26 June	The cyclones now pass over or close to the Svalbard area. Southerly to easterly winds in the front of the cyclones, northerly to westerly winds in the rear. The temperatures do not differ greatly from the average during the first part of the period. Above average temperatures during the last days.
27 June–2 July	Depressions pass to the east and south. Mostly north-easterly winds and about normal temperatures.
3 July–21 Aug.	The pressure field is weak during practically the whole period. Some depressions, most of them very weak, pass near the Svalbard area. Temperatures somewhat above normal during the first half of July, about normal or below normal temperatures during the rest of the period. The middle of July and most of August are cool.
22 Aug.–5 Sept.	Low-pressure systems approaching from the south-west, later from the south, pass the area. Most of the time moderate easterly to southerly winds with temperatures above the average.
6–10 Sept.	The weather situation is dominated by a cyclonic centre from the south passing the eastern part of the Svalbard area. Westerly winds and below normal temperatures.
11-23 Sept.	Several well-developed cyclones coming from the south-west pass the area. Easterly to southerly winds in the front of the cyclones, westerly winds in the rear, and temperatures varying about the normal for the season.
24–30 Sept.	The cyclones now travel farther to the south and east. Mostly northerly to easterly winds and cool.
1–4 Oct.	An easterly to north-easterly air stream in connection with a depression passing between Svalbard and Norway. Temperatures close to normal.
5–11 Oct.	A trough moving slowly westwards is replaced by a high-pressure ridge. Light winds and temperatures below the average.
12–18 Oct.	Easterly winds to the north of cyclones passing just south of the Svalbard area. Gradually milder.
19 Oct.–2 Nov.	During the larger part of the period a northerly to north-easterly air stream between low-pressure systems moving along the Siberian coast and high-pressure areas to the west. Temperatures below normal. Especially cold during the last half of the period.
3–18 Nov.	Depressions coming from the south, later from the south-west, pass over the area, or between Svalbard and Norway. Generally northerly to easterly winds. The temperature, which is very variable, is on an average a little below normal.
19 Nov.–4 Dec.	Several cyclones with a north-easterly course pass Svalbard. Periods of mild weather alternate with cold spells as the southerly winds in the front of the cyclones give place to northerly winds in the rear.

5–21 Dec. North-easterly winds between high-pressure areas to the west and north, and depressions to the south and east. Gradually colder, and temperatures considerably below normal during most of the period.

22–31 Dec. The air circulation in the front of a well-developed low-pressure system in lower latitudes brings considerably milder air to the Svalbard region during the first half of the period. During the last half of the period the wind turns north-easterly to the north of cyclones moving over the Norwegian Sea, and the temperature again drops to values considerably below normal.

In the table are given the monthly mean temperatures for Isfjord Radio for 1967, as well as their deviation from the means of the period 1947–66.

Temperature data for Isfjord Radio (°C)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1967 means	-18.6	-13.2	-10.6	-8.6	-3.3	+1.5	+4.3	+3.6	+1.1	-5.4	-6.2	-12.4
Deviation of 1967 means from 1947–66 means	-7.3	-1.8	+1.8	+0.1	+0.2	-0.1	-0.3	-0.7	+0.1	-2.6	0.0	-3.4

1967 was, generally speaking, a cool year. The coldest spells are found during the following periods: last half of January, end of February, middle of March, end of October, middle and end of December. During the summer season there were mild periods towards the end of June, in the first half of July, and during the last days of August and the first days of September. The highest temperature of the year at Isfjord Radio, 9.6°C, was observed three times in all: on 24 June, 24 August, and on 1 September.

The sea ice condition in Svalbard in 1967

BY

TORGNY E. VINJE

The charts, Fig. 1a and b, show the extension of drift ice in areas where more than 3/10 are covered with ice. The ice limit based on observations from 1919 to 1943 is also shown for the months April–August. In this connection it should be noted that in the year 1967 satellite pictures made it possible to determine the ice edge in areas from which previously no or few observations have been obtained. This is especially the case for the waters north and east of Svalbard.

The ice cover west of the islands is greater than normal during the first two months of the year. During the spring months a relatively great disintegration occurs, and this entails that a nearly normal ice condition is achieved at the end of April. In May Vesterisen (cfr. chart for June) has a normal extension. In Østisen we remark the very broad flaw lead on the south-eastern side of the islands. In June a broad flaw lead is found north of the archipelago. Vesterisen extends, at the end of this month, somewhat less towards south-east than normal, while Østisen has a nearly normal extension except for the relatively great areas of open waters south-east of Vestspitsbergen. In July Vesterisen and Nordisen have a nearly normal extension, while Storfjorden, which normally is ice-covered, now is completely ice-free. In August both Vesterisen, Nordisen, and Østisen are more extensive than normal. In September open water stretches quite far north of Svalbard, but refreezing takes place during the rest of the year, and results at the end of the year in an assumed greater extension of the ice than normal.

The ice charts have been compiled from observations received at Norsk Polarinstitutt, and from monthly ice charts edited by the Meteorological Office, London. The ice limits for 1919–1943 have been taken from the publication of the Danish Meteorological Institute: "The state of the ice in the Arctic seas".

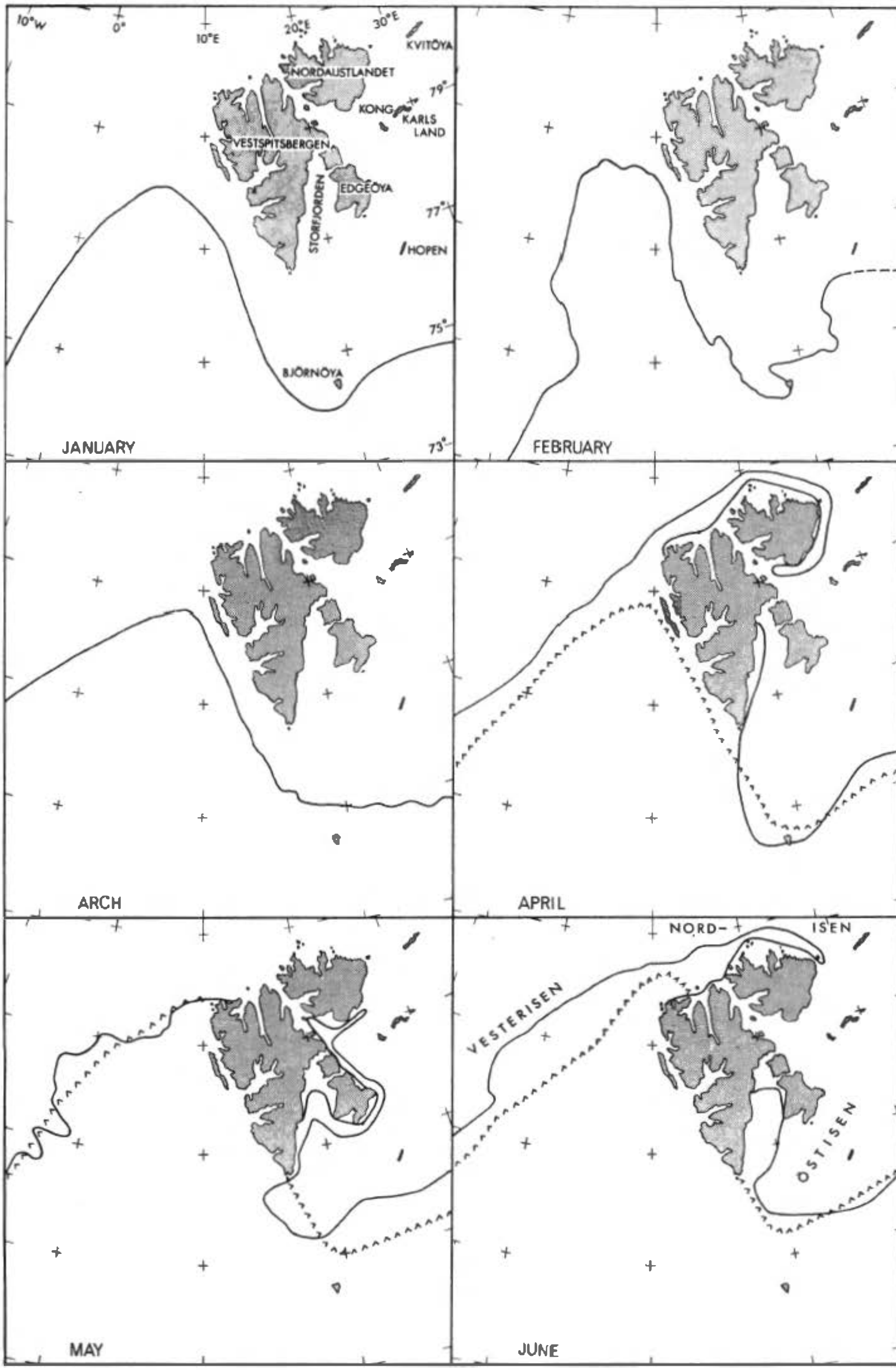

Fig. 1a. —— *Observed extension of sea ice with concentration greater than 3/10 at the end of the month.*

- - - *Assumed boundary at the end of the month.*

^^^^^^ *Monthly mean ice limit based on observations from 1919 to 1943.*

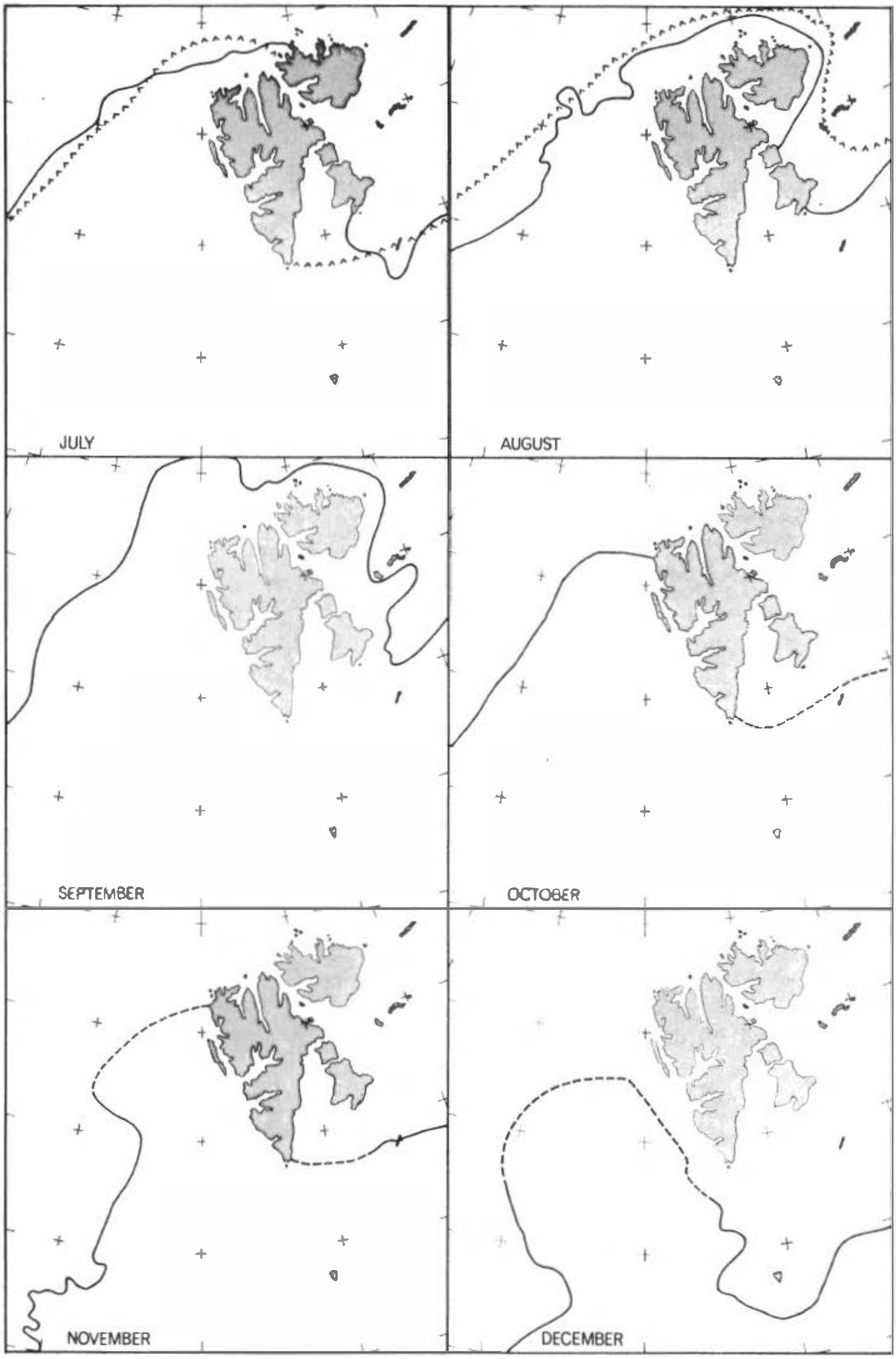

Fig. 1b. —— *Observed extension of sea ice with concentration greater than 3/10 at the end of the month.*
- - - *Assumed boundary at the end of the month.*
^^^^^^ *Monthly mean ice limit based on observations from 1919 to 1943.*

Iakttagelser over dyrelivet på Svalbard 1967

(Observations of the animal life in Svalbard 1967)

AV

MAGNAR NORDERHAUG

Abstract

The present observations of animal life in Svalbard are based on records from Norsk Polarinstitutt's field parties, the meteorological stations on Hopen and Bjørnøya, and information received from persons visiting Svalbard during 1967.

Observations of reindeer (*Rangifer tarandus*) are given in Table I, most of them from the eastern parts. There are four observations of walruses (*Odobenus rosmarus*).

Table II and III give observations of Pinkfooted geese (*Anser fabalis brachyrhynchus*) and Brent geese (*Branta bernicla hrota*). The first breeding record of Barnacle geese (*Branta leucopsis*) from Barentsøya is reported.

Observations of some Passerines are given in Table IV.

Резюме

Приведенные здесь результаты наблюдений за свальбардской фауной основаны на отчетах, представленных полевыми группами экспедиции Норвежского Полярного Института (Norsk Polarinstitutt) за 1967 год, и на сведениях, полученных от метеорологических станций на о-вах Hopen (Надежды) и Bjørnøya (Медвежьем) и от лиц, посетивших Свальбард в 1967 г.

Результаты наблюдений за северными оленями *(Rangifer tarandus)*, преимущественно относящиеся к восточным частям архипелага, даются в таблице I. Сообщается о четырех моржах (*Odobenus rosmarus*), которые послужили объектом для наблюдений.

В таблицах II и III даются результаты наблюдений за короткоклювыми гуменниками (*Anser fabalis brachyrhynchus*) и черными казарками (светлобрюхими) (*Branta bernicla hrota*). Приводится первое сообщение о гнездовании белощеких казарок (*Branta leucopsis*) на острове Barentsøya (Баренца).

Результаты наблюдений за некоторыми птицами из отряда воробьиных даются в таблице IV.

Innledning

Det biologiske observasjonsmaterialet fra Svalbard i 1967 stammer fra en rekke kilder. Norsk Polarinstitutt sender årlig observasjonsskjemaer med til sine ekspedisjonspartier. Videre inngår dette år materiale fra de meteorologiske stasjoner på Hopen og Bjørnøya og fra utenlandske ekspedisjonsgrupper.

Materialet blir i sin helhet arkivert ved Norsk Polarinstitutt med henblikk på en sentralisering av faunistiske data fra Svalbard. Foreliggende arbeid gir en kortfattet oversikt over de mest aktuelle observasjoner.

Den stadig økende tilstrømning av turister og ekspedisjonsgrupper til Svalbardområdet gjør spørsmål innen naturvernsektoren stadig mer aktuelle, også i disse strøk. Vi bør i denne sammenheng vie dyrelivet og de ømfintlige arktiske livssystemene større oppmerksomhet. I dette arbeid er en bedre viten om utbredelse og mengdeforhold hos Svalbards dyrearter nødvendig. Den faunistiske kartlegging vil fortsette, og det er ønskelig at flest mulig også i årene framover vil bidra med opplysninger. I tillegg til observasjonene fra 1967 er noen data fra tidligere år tatt med, da de først nå er blitt kjent. Når intet årstall er angitt, stammer observasjonene fra 1967.

For bidragsyterne er følgende initialer brukt: A. ALVÆR (AA), K. BRATLIEN (KB), R. BØCKMANN (RB), B. FLOOD (BF), A. HJELLE (AH), K. de KORTE (KK), T. LARSEN (TL), J. NAGY (JN), A. NEILSON (AN), D. NORBERG (DN), G. RÜPPEL (GR), T. WINSNES (TW), samt egne observasjoner (MN).

Takk

Jeg vil gjerne få takke alle som har bidradd med observasjoner. Det gjelder så vel Norsk Polarinstitutts partiledere og assistenter som enkeltpersoner og ekspedisjonsgrupper for øvrig. En særlig takk går til ALV ALVÆR og RAGNAR BØCKMANN for verdifulle observasjoner fra henholdsvis Hopen og Bjørnøya.

Pattedyr

Rein (*Rangifer tarandus*). I 1967 ble en rekke reinobservasjoner gjort i de østlige deler av Svalbard, dvs. fra områder der observasjoner har vært sparsomme i de senere år.

De fleste reinobservasjonene (av tilsammen ca. 250 dyr) foreligger fra Edgeøya i tidsrommet 28/7–19/8. De gir et grovt bilde av forholdene i kystområdene fra Tjuvfjorden til Kapp Heuglin på sensommeren, selv om visse dobbeltregistreringer kan ha funnet sted når flere personer observerer i ulike tidsrom. Forøvrig foreligger flere observasjoner fra Barentsøya. En kuriositet er observasjonen av en reinbukk på Svenskøya (Kong Karls Land) i august, adskilt fra de nærmeste faste reinforekomster på Edgeøya av det ca. 95 km brede Olgastretet. Se Tabell I. Reinsdyr forekom imidlertid på Kong Karls Land i forrige århundre.

Polarrev (*Alopex lagopus*). Noen observasjoner fra Bjørnøya skal nevnes: I juli 1966 ble et hi med minst to unger funnet ovenfor Vesalstranda. For øvrig er den sjelden å se (oftest på øyas østside). Tre individer såes i mars 1967 (to hvite, en blå). I juni samme år såes en skadet rev ved Nordkapp (RB).

Isbjørn (*Thalarctos maritimus*). Fra Bjørnøya foreligger følgende informasjoner: De første ferske spor ble sett på øya i slutten av januar. I tidsrommet 7/2–9/3 ble 10 individer skutt. Av disse 10 ble 5 individer kjønnsbestemt: 4 ♂♂ og 1 ♀. Det største individet målte 304 cm fra snute til hale. Av 9 undersøkte hadde 3 trikiner (RB). I områdene mellom Edgeøya og Hopen ble det i tidsrommet 6–30 juli gjort 57 isbjørnobservasjoner, og i tidsrommet 10–22 august 48 observasjoner (TL). For øvrig foreligger observasjoner av isbjørn fra Edgeøya og Barentsøya, bl. a. observasjoner av to binner, hver med to unger (JN).

Tabell I
Observasjoner av rein (*Rangifer tarandus*) i 1967.
Observations of reindeer (Rangifer tarandus) in 1967.

Lokalitet *Locality*	Dato *Date*	Antall *Number*	Observatør *Observer*	Anmerkn. *Remarks*
Chamberlindalens n. del	juli/aug.	1♂, 1♀	BF/AH	
Heimfjellhumpane, Van Keulenfd.	18/7	2 ad.	AN	
Forkastningsdalen– Van Keulenhamna	6–9/7	4 ♂♂, 2 ♀♀	»	
Van Keulenhamna–Ulladalen	10/7	ca. 15 dyr	»	minst 4 juv.
Ulladalen	11/7	40–45 dyr	»	minst 10 juv.
Davisdalen	14–15/7	3 ♂♂, 1 ♀	»	
Lågnesbukta, Bellsund N.	9/7	2 ♂♂	KB	
Ø. for Kuhrbreen, Tjuvfd.	8/8	1 ad.	JN	
Keilhaustranda, Tjuvfd.	2/8	13 dyr	AN	6 simler, hver m/en kalv, +1♂
Vogelberget, Kvalpt.	7/8	7 ad., 1 juv.	JN	
Kvalpynten	medio aug.	ca. 30 dyr	KB	
Kvalpt.–Siegelfjellet	1–9/8	ca. 20 dyr	AN	minst 2 juv.
Jungfernstieg, nær Siegelfjellet	13/8	4 ad.	KB	
Mudalen v/Diskobkt.	1–2/8	9 ad., 1 juv.	JN	
Diskobkt. søndre del	19/8	71 dyr	AN	minst 10 juv.
Visdalen, S. Kapp Lee	20/8	2 ad.	»	
Rosenbergdalen, S. Kapp Lee	28/7	7 ad.	JN	
Kapp Lee	22/8	4 ad.	DN	
Åsneset–Kapp Heuglin	13/8	7 ad.	JN	
Raundalen–Kapp Geyer	medio aug.	70–90 dyr	»	ca. 1/3 juv.
Barkhamodden S, Barentsøya	14/8	1♀, 1 juv.	»	
Krefftberget, Barentsøya	19/7	1♀, 1 juv.	»	
Helisberget, Barentsøya	13/7	11 ad.	»	
Helisberget, Barentsøya	17/7	6 ad. 2 juv.	»	
Mistakodden, Barentsøya	10/8	6 ad.	MN	
Svenskøya, Kong Karls Ld.	10/8	1 ♂	»	

Ringsel (snadd) (*Phoca hispida*). Ett individ ble sett i Nordhamna, Bjørnøya, i august 1966 (RB). Arten var meget vanlig i juli/august øst for Edgeøya (TL).

Grønlandssel (*Phoca groenlandica*). Ved Kvitfiskpynten sør for Bellsund ble 20–25 individer sett 29/7 (KB). I områdene øst for Edgeøya var arten meget vanlig, særlig nær iskanten, i juli/august. Flokker på 20–50 individer ble stadig observert (TL).

Storkobbe (blåsel) (*Erignathus barbatus*). Ett individ ble skutt på Bjørnøya i august 1966, og flere ble sett på øya i løpet av sommeren (RB). Arten var vanlig på grunt vann (80–100 m) øst for Edgeøya i juli/august, 1967 (TL).

Hvalross (*Odobenus rosmarus*). En gammel hann ble sett i Gåshamna, Hornsund 28/8 (TL). Ca. 40 naut. mil øst av Edgeøya såes to individer (hvorav et ungdyr) 16/7 og 12/8. Det er grunn til å tro at forskjellige individer ble observert i de to tilfeller (TL). Ett individ ble sett fra fly øst for Barentsøya 22/7 (MN).

Knølhval (*Megaptera nodosa*). Ca. 30 naut. mil øst av Hopen ble to individer immobilisert og merket 29/7 (TL).

Fugl

Smålom (*Gavia stellata*). Fra de østlige Svalbardfarvann kan observasjoner nevnes fra Kvalvågen, Bölscheøya, Lurøya, Thomas Smithøyane, Barentsøya og Ryke Yseøyane i juli/august 1967 (KB, JN, TW).

Havhest (Fulmarus glacialis). I 1967 ble egg første gang funnet på Bjørnøya 25/5. Arten sees der hele året (RB). På Hopen såes arten første gang 4/2 (AA).

Krikkand (*Anas crecca*). Observasjoner fra Bjørnøya: 1 ♂ såes ved stasjonen 26/5. Ett par sett ved Herwighamna ca. 28/5 (RB).

Toppand (*Aythya fuligula*). Sett på Hopen sommeren 1962 og 1963 (AA).

Havelle (*Clangula hyemalis*). På Bjørnøya ble arten sett hele året. Hekker spredt på nordsiden av øya ved småvann. Egg funnet midt i juni (RB). Fra Vestspitsbergen foreligger hekkefunn eller kullobservasjoner fra Reinodden (BF), Kapp Martin (KB) og Rubypynten (AH).

Ærfugl (*Somateria mollissima*). På Bjørnøya sees arten hele året (RB). Første observasjon på Hopen var 15/2 (AA). Fra øyene i den vestlige munning av Freemansundet foreligger følgende data: Ureinskagen, ca. 10 tomme reir, 30/7. Ca. 150 voksne individer såes ved øya. På Thomas Smithøyane såes ca. 300 reir som hadde vært i bruk (14/8). På øya mellom Thomas Smithøyane og Ureinskagen såes ca. 50 reir som hadde vært benyttet (14/8). (K. Torvsik, pers. medd. JN.) En flokk ærfugl ble sett ved Abeløya (Kong Karls Land) fra fly 10/8 (MN).

Praktærfugl (*Somateria spectabilis*). Arten ble sett ved Bjørnøya om vinteren og til ut i mai/juni. Den opptrådte ganske tallrikt vinteren 1966/67 (RB). På Hopen ble den sett sommeren 1960 og 1961 (AA). Et reirfunn (2 egg) ble gjort på vestsiden av Chamberlindalen (120 m o. h. i 1967) (BF). Fem individer sett utenfor Siegelfjellet, Edgeøya, i august (AN).

Kortnebbgås (*Anser fabalis brachyrhynchus*). To flokker (en på 50–60, en på 10–15 individer) ble sett flygende mot Bjørnøya, 80 naut. mil sørvest av øya 24/5 (TW). Dette er en av de få direkte observasjoner av gåsetrekket mellom Norge og Svalbard. På Bjørnøya ble den første sett 23/5 (RB). Førsteobservasjonen fra Hopen i 1967 var 4 individer 12/6 (AA). Se for øvrig Tabell II.

Tabell II
Observasjoner av kortnebbgjess (*Anser fabalis brachyrhynchus*) i 1967.
Observations of Pink-footed geese (Anser fabalis brachyrhynchus) in 1967.

Lokalitet *Locality*	Dato *Date*	Antall *Number*	Observatør *Observer*
Revvatnet, Hornsund	25/8	83	KK
Isbjørnhamna–Hyttevika	25/8	150–200	TL
Dunderdalen	27/7	40 ad.	BF
Chamberlindalen	4–12/7	flere kull (1–6)	»
Renardbreen, Recherchefd.	25/7	3 ad., 4 pull.	»
Calypsobyen	17/8	5 ad.	»
Calypsobyen–Dunderbukta	19–22/8	flokker (4–25)	»
Calypsobyen–Klokkefj.	23/8	ca. 100	AH
Kapp Lyell	juli	et par m/ 5 pull.	BF
Reinodden	16/8	42 ad.	»
Vestvågen	6–13/7	10–43 ad.	»
Ulladalen, Van Keulenfd.	13/7	3–4 ad., 7–10 pull.	AN
Neset, Malbukta	28/7	ca. 15	»
Van Muydenbukta	9/8	20–25 ad., 15–20 pull.	KB
Flosjøen, Nordenskiöldkyst.	9/7	5 ad.	»
Straumsjøen, Erdmanflya	20/7	15–20 ad., 25–30 pull.	»
Fuglehuken, Forl.	16/7	1 par	»
Ossian Sarsfj., Kongsfj.	27/5	5 ad.	TW
Sarsøyra	4/7	15–20 ad.	»
N. Sarsøyra	9/7	4 ad. (hekkepl.)	»
Bolscheøya, Tusenøyane	1/8	20–25 ad.	KB
Øy V. av Lurøya, Tusenøyane	16/8	22 ad.	»
Ryke Yseøyane	19/8	2 ad.	JN

Ringgås (*Branta bernicla hrota*). Arten ble sett på Bjørnøya under høsttrekket i 1966. Ved Nordvestbukta (Bjørnøya) såes 17 stk. 23/5–67 (RB). På Store Dunøya såes 38 ad. 16/8, og på Nordre Dunøya såes 17 ad. 16/8 og 21 ad. 27/8 (KK). Fra de østlige Svalbardfarvann foreligger disse observasjonene: Strongbreens front (Kvalvågen) 1/8, 28 ad.; Kvalvågen 3/8, 9 ad., og 11/8 ca. 40 ad. samme sted (TW). På Bjørnholmane nord for Kvalpynten 3/8, 6 ad.; Diskobukta 22/8, 3 ad.; Dianabukta 4/8 minst 10 ad.; Andréetangen 12/8, 10 ad. (AN).

Hvitkinngås (*Branta leucopsis*). Arten ble sett i stort antall under høsttrekket på Bjørnøya i 1966. Under vårtrekket (1967) ble de første (8 individer) sett ved Nordhamna 24/5. Hvitkinngåsa ble anført som den vanligst forekommende gåseart under trekket (RB). I Chamberlindalen sør for Bellsund såes 300 individer i den nordre del av dalen 21/7 (AH). Ved Reinodden (Recherchefjorden) såes 11 individer 15/8 (BF). Fra de østlige områder foreligger følgende observasjoner av arten i 1967: På Kong Ludvigøyane, 15/8, såes flere individer, men kun voksne (KB); på Barentsøya såes 24 ad. og 6 pull. ved Andsjøen, Talveraflya, 18/7 (JN). Disse to observasjoner viser den fortsatte ekspansjon av artens utbredelse på Svalbard. Hekkefunnet fra Barentsøya er for øvrig det første fra Storfjordområdet. I området Diskobukta–Kvalpynten (Edgeøya) ble arten ikke registrert (AN).

Svane (*Cygnus sp.*). En svane ble sett på Erdmannflya 20/7 (KB). Nærmere artskarakterer mangler.

Spitsbergenrype (*Lagopus mutus*). Observasjonene er vist i Tabell III.

Tabell III
Observasjoner av spitsbergenrype (*Lagopus mutus*) i 1967.
Observations of Spitsbergen ptarmigan (Lagopus mutus) in 1967.

Lokalitet *Locality*	Dato *Date*	Antall *Number*	Observatør *Observer*
Konglomeratfj., Dunderd.	26/7	1 ad.	AH
Chamberlindalen	11–12/7	1–3 ad	BF
Chamberlinpasset	26–27/7	1–3 ad.	BF/AH
Observatoriefj., Recherchefd.	19/7	2 ad.	BF
Observatoriefj., Recherchefd.	13/7	ett par m/9 pull.	»
Jarnfjellet, Recherchefd.	15/8	ca. 16 (mest pull.)	AH
Jarnfjellet, Recherchefd.	16/8	1 ad., 1 pull.	»
Engelskbukta	5/7	2 ad.	TW
Ny-Ålesund	26/5	1 ad.	»
Oss. Sarsfj., Kongsfd.	27/5	2 ad.	»
Kongsvegen, Kongsfd.	26/6	1 ad.	»
Ringertzbreen, S. Bockfd.	8/6	1 ad.	»
Kvalvågen, Storfd.	13/7	1 ad., 3 pull.	»
Uvdalen, Diskobukta	aug.	1 ad., 10 pull.	AN
Krefftberget, Barentsøya	19/7	1 ad.	JN
Hopen	høst 1966	flere skutt	AA

Tjeld (*Haematopus ostralegus*). Ett individ ble sett ved Nordkapp, Bjørnøya 3/6. (N. Elfarvik pers. medd. RB.)

Sandlo (*Charadrius hiaticula*). På Bjørnøya ble arten første gang sett 9/6 (RB). To såes på Nordre Dunøya 27/8, og ett individ med en unge på Kapp Linné 6/8 (KK). Ett individ såes i Longyearbyen 6/8 (TL). På Hopen såes 5 + 2 18/6 (AA).

Heilo (*Pluvialis apricaria*). På Bjørnøya ble ett individ sett ved Laksvatnet, juli 1966 (RB).

Steinvender (*Arenaria interpres*). I 1967 ble arten første gang sett på Bjørnøya 10/6 (RB). Tre stk. ble sett på Nordre Dunøya 27/8, og 2 ved Kapp Linné 6/8 (KK).

Småspove (*Numenius phaeopus*). En småspove ble sett ved Kvalvågen 29/7 (TW).

Rødstilk (*Tringa totanus*). To individer såes ved Herwighamna, Bjørnøya, 10/5 (RB).

Fjæreplytt (*Calidris maritima*). På Bjørnøya ble arten første gang sett 5/5. De første eggene ble funnet i begynnelsen av juni (RB). På Hopen såes arten første gang 15/6 (AA). På Snøfjella, Holtedahlfonna (ca. 800 m o. h.), ble en fjæreplytt sett 30/5 (TW).

Myrsnipe (*Calidris alpina*). Arten ble første gang sett på Bjørnøya 6/6 (RB). I Longyeardalen ble et reir funnet 16/7. Det var dessuten minst to andre par i området (GR).

Sandløper (*Crocethia alba*). Arten ble sett første gang 6/6 på Bjørnøya, og flere ganger senere sammen med fjæreplytt og myrsnipe (RB). Arten ble også registrert på Hopen i juni (AA).

Polarsvømmesnipe (*Phalaropus fulicarius*). På Bjørnøya ble arten første gang registrert 4/6 (RB). Et hekkefunn ble gjort på Kapp Martin, Bellsund, 6/7 (2 egg) (KB). På Thomas Smithøyane (Freemansundet) ble 8 stk. sett 14/8. (K. Torsvik, pers. medd. JN.)

Tyvjo (*Stercorarius parasiticus*). Noen observasjoner av mørke og lyse faser i Svalbardområdet, 1967, skal nevnes:

12 individer, Bjørnøya, juni: 4 mørke, 8 lyse (RB)
28 individer, Hornsund, august: 1 mørk , 27 lyse (KK)
19 individer, Nordenskiöldkysten, august: 4 mørke, 15 lyse (KK)

Polarjo (*Stercorarius pomarinus*). To individer sett i Ymerdalen, Bjørnøya, august 1966 (RB). På Hopen sett ett individ 12/6 (1967) (AA). I drivisområdene øst for Edgeøya såes arten daglig (2–20 stk.) i juli/august (TL). Kapp Martin 13/8, 4 stk.; Kapp Linné 11/8, 2 stk. (KK).

Storjo (*Catharacta skua*). To individer såes ved Røyevatnet, Bjørnøya, 6/5. Sommeren igjennom ble arten alltid sett på turer langs vestsiden av øya. I juli ble 20 eksemplarer sett samtidig ved Grunningen. Ingen reir ble funnet (RB).

Ismåke (*Pagophila eburnea*). På Bjørnøya ble arten sett fra januar til april (RB). To individer ble sett på Hopen 7/4 (AA). I drivisområdene øst for Edgeøya såes opptil 50 individer daglig i juli/august (TL).

Svartbak (*Larus marinus*). På Bjørnøya ble de første individer sett i mars. Arten hekker på øyas vestside, særlig nord for Kapp Dunér (RB). På Hopen såes en svartbak 1/10–66 og en 7/4–67 (AA). På Dunøyane ble 1–3 stk. sett 16–20/8 (KK). To individer såes ved Klokkebekken mellom Kapp Lyell og Dunderbukta 20–22/8 (BF). Ved Calypsostranda såes en svartbak 25–26/8 (AH). I Kraussbukta såes 2 stk. 3/8 (AN).

Gråmåke (*Larus argentatus*). På Hopen ble 5 stk. sett 1/10, 1966 (AA).

Polarmåke (*Larus hyperboreus*). På Bjørnøya ble det første egg av polarmåke funnet 13/5 (RB). Noen observasjoner av polarmåke fra Tusenøyane og Edgeøya skal nevnes: Bölscheøya 1/8, 25–30 ad., 10–15 pull. Lurøya 2/8, 10–15 ad., 5–10 pull. Kvaløya 16/8, 50–100 ad., 5–10 pull. Øy øst for Lurøya 16/8, 50–100 ad., 5–10 pull. Siegelfjellet (Edgeøya) 13/8, 3 ad. (KB).

Krykkje (*Rissa tridactyla*). Arten ble første gang sett ved Bjørnøya i midten av mars. De første eggene ble funnet ved Taggen 18/5 (RB). På Hopen ble arten første gang sett 31/3 (AA).

Rødnebbterne (*Sterna macrura*). Arten ble første gang sett på Bjørnøya 27/5. De første egg ble funnet 17/6 (RB). Kolonier med 20–200 individer ble sett i Recherchefjorden (Rubypynten, Reinholmen, Renardbreen og Calypsobyen). (BF/AH). Noen få ble funnet hekkende på Thomas Smithøyane, Freemansundet 14/8. (K. Torsvik, pers. medd. JN.) På Abeløya ble en større koloni sett fra fly 10/8 (MN).

Alkekonge (*Plautus alle*). På Bjørnøya ble arten første gang sett i midten av april. Kolonier fins ved Emmaholmane, Kapp Posadowsky, Tunheim og i store kolonier mellom Brettingsdalen og Skrekkjuvet (RB).

Polarlomvi (*Uria lomvia*). Til Hopen ankom de første (i store flokker) 18/2 (AA).

Teist (*Cepphus grylle*). De første ble sett på Hopen 8/3 (AA).

Snøspurv (*Plectrophenax nivalis*). På Bjørnøya ble arten første gang sett 3/4 (RB). På Hopen ble arten første gang sett 7/4 (AA).

Diverse spurvefugler (*Passeriformes*). Se Tabell IV.

Tabell IV
Observasjoner av noen spurvefugler (*Passeriformes*) i 1967.[1]
Observations of some Passerines (Passeriformes) in 1967.[2]

Art *Species*	Lok./dato *Loc./date*	Anmerkning *Remarks*	Observatør *Observer*
Låvesvale (*Hirundo rustica*)	Bjørnøya 25/5–67	Ett eksempl.	RB
— » —	Hopen 1955	Ett »	AA
— » —	» 19/6–67	Ett »	»
Taksvale (*Delichon urbica*)	Bjørnøya juni –67	Ett »	RB
Rødv.trost (*Turdus iliacus*)	Bjørnøya 10/6–67	Flere	»
— » —	Hopen 27/4–67	Ett »	AA
Steinskvett (*Oenanthe oenanthe*)	» 7/6–65	Ett »	»
Linerle (*Motacilla alba*)	Bjørnøya 1966	Ett »	RB
Varsler (*Lanius excubitor*)	Hopen 28/4–67	Ett »	AA
Stær (*Sturnus vulgaris*)	Bjørnøya 30/3–67	Flere	RB
— » —	» sommer –67	Flere	»
— » —	Hopen 13/4–67	Ett »	AA
Bjerkefink (*Fringilla montifringilla*)	Bjørnøya 26/5–67	Flere	RB

Anmerkninger

Det begrensede artsantall i Svalbardområdet og den forholdsvis store interesse for dyrelivet blant de som ferdes der nord, gjør de fleste observasjonene tilstrekkelig pålitelige. Visse tvilstilfeller oppstår imidlertid, og noen observasjoner av denne type skal nevnes:

Ved Kvalpynten på Edgeøya såes, 8/8, 4 voksne sjøorrer (*Melanitta fusca*), og dagen etter såes 6 ♂♂, 8 ♀♀ og ca. 15 unger av samme art i Kraussbukta (Edgeøya), Observatøren (S. Krogdahl) mener det ikke foreligger feilbestemmelse. På Hopen såes sommeren 1963 flere ganger en fugl angitt som «kongeørn» (AA). Det er rimelig at det har vært tale om en ørn, men det er usikkert hvilken art. Fra Hopen angis også observasjoner av «hettemåker» i 1956 og i 1961. Uten nærmere detaljer er det ikke mulig å avgjøre med sikkerhet om det der (som i flere andre tilfeller i Svalbardområdet) var tale om sabinemåke eller hettemåke.

[1] Noen observasjoner fra tidligere år er inkludert.
[2] *Some observations from previous years have been included.*

Norsk Polarinstitutts virksomhet i 1967

AV

TORE GJELSVIK

Organisasjon og administrasjon

Personale

Norsk Polarinstitutt fikk i 1967 opprettet ny stilling for biolog. Stilling for underdirektør ble godkjent gjenopprettet mot at den ubesatte sekretærstillingen ble inndratt. Forslag om nye stillinger for fotograf og 2 geologer ble avslått. Til underdirektør ble utnevnt førstehydrograf og ekspedisjonsleder K. Z. LUNDQUIST. Ny ekspedisjonsleder for Svalbard er operasjonssjef THOR SIGGERUD.

Den faste staben ser slik ut:

Direktør:	TORE GJELSVIK, dr. philos.
Underdirektør:	KAARE Z. LUNDQUIST, o/kapt. Fra 24. februar.
Kontorsjef:	MAGNE BOTNEN, cand. jur.
Operasjonssjef:	THOR SIGGERUD, cand. real.
Geolog I:	HARALD MAJOR, cand. real.
Geolog I:	THORE S. WINSNES, cand. real.
Geolog II:	AUDUN HJELLE, cand. real.
Geolog II:	JENÖ NAGY, cand. mag. Ansatt som vitenskapelig assistent.
Geolog II:	BOYE JOAKIM FLOOD, cand. real.
Glasiolog I:	OLAV LIESTØL, cand. real.
Meteorolog I:	VIDAR HISDAL, cand. real.
Geofysiker II:	TORGNY EMIL VINJE, cand. real.
Førstehydrograf:	K. Z. LUNDQUIST. Til 24. februar.
Hydrograf I:	HELGE HORNBÆK, høyere skipsførereks.
Hydrograf I:	JOHAN HENRIK CHRISTIANSEN, kapteinløytnant. Fra 6. august.
Førstetopograf:	SIGURD G. HELLE, cand. mag.
Topograf i særklasse:	HÅKON HILL, jordskiftekandidat.
Topograf I:	DAG NORBERG, siv.ing.
Geodet I:	OLA STEINE, jordskiftekandidat. Fra 8. mai.
Biolog:	MAGNAR NORDERHAUG, cand. real. Fra 21. april.
Konsulent:	PETER HAGEVOLD, cand. mag. Fra 1. august.
Bibliotekar:	SØREN RICHTER, mag. art.

Konstruktør I:	EINAR NETELAND, tekniker.
Materialforvalter:	KÅRE MONRAD BRATLIEN, radiotelegrafist.
Karttegner I:	BJØRN ARNESEN
Karttegner I:	BJARNE EVENSEN
Karttegner II:	MAGNE GALÅEN. Permisjon fra 1. september.
Laborant i særklasse:	WILLY INGEBRETSEN. Permisjon fra 10. april til 31. august. Fratrådte 18. desember.
Fullmektig I:	EVA ANDERSEN
Fullmektig I:	SIGNE ØVERLAND
Fullmektig II:	GUDRUN EDWARDSEN
Fullmektig II:	KIRSTEN DANIELSEN
Kontorassistent I:	KJELL JOHANSEN

Midlertidig engasjerte:

Fullmektig ELI HOLMSEN
Assistentbibliotekar VIBEKE EEG-HENRIKSEN
Assistentbibliotekar INGRID DEVOR
Cand. real. ØRNULF FJELLDAL
Cand. mag. LEIF-EGIL LØRUM
Cand. mag. OLAV ORHEIM
Cand. real. YNGVAR GJESSING
Stud. real. TOR ERIK LYNNEBERG
Tegner RUNE ANDERSSON
Assistent SIDSEL PAASKE

Stipend og forskningsbidrag er ytt til:

Meteorolog BEATRICE TAYLOR, Canada, stipend til glasiometeorologiske undersøkelser (av Hardangerjøkulen).

Lektor ODD LØNØ, stipend til bearbeidelse av innsamlet materiale vedrørende isbjørn.

Cand. real. THOR LARSEN, bidrag til studier ved Havforskningsinstituttet i Bergen og ved University of Minnesota i forbindelse med aldersbestemmelser og raseundersøkelser av isbjørn.

Geolog DAVID G. GEE, bidrag til fortsatt bearbeidelse av innsamlet materiale fra Nordaustlandet.

Vitenskapelig assistentlege ved Åsgård sykehus, Tromsø, cand. med. TOM ANDERSEN, bidrag til deltakelse i symposium ved University of Alaska om helseproblemer i cirkumpolare strøk.

Universitetslektor HELGE KLEIVAN, bidrag til opphold ved Memorial University of Newfoundland, Canada, i forbindelse med studier av etnografiske forhold på Vest-Grønland.

Følgende gjesteforskere hadde arbeidsplass ved Norsk Polarinstitutt i ca. 2 måneder:

Dr. STANISLAW SIEDLECKI, Geologisk Laboratorium, Det Polske Vitenskapsakademi, Kraków.

Geolog ANNA SIEDLECKA, Geologisk Laboratorium, Det Polske Vitenskapsakademi, Kraków.

Oppnevnelser:

MAGNAR NORDERHAUG ble oppnevnt til formann i "Arbeidsgruppen for viltstell og naturvern på Svalbard" i august 1967.

REGNSKAPET FOR 1967

Kap. 950, Poster:	*Bevilget*	*Medgått*
1. Lønninger	kr. 1 285 400	kr. 1 249 856
9. Deltakelse i Antarktisekspedisjonen 1964/67	» 30 000	» 34 242
10. Kjøp av utstry	» 22 000	» 24 223
15. Vedlikehold	» 18 700	» 16 660
20. Ekspedisjoner til Svalbard og Jan Mayen	« 675 000	» 526 770
29. Andre driftsutgifter	» 277 400	» 289 675
70. Stipend	» 40 000	» 36 732
	kr. 2 348 500	kr. 2 178 158
Kap. 31. Fyr og radiofyr på Svalbard	kr. 25 000	kr. 25 528
	Budsjettert	*Innkommet*
Kap. 3950. Salgsinntekter	kr. 21 000	kr. 35 465

Kommentar til regnskapet:

Kap. 950.

Post 20. Ekspedisjoner til Svalbard og Jan Mayen. – Mindreforbruket skyldes at Luftforsvaret ikke kunne påta seg helikoptertjenesten på Svalbard. Til dette formål var bevilget kr. 150 000.

I høstsesjonen vedtok Stortinget at det skal opprettes en helårs vitenskapelig stasjon i Ny-Ålesund. Myndighetene har gitt Norsk Polarinstitutt i oppdrag å forestå bygging og drift av stasjonen. Dermed er en sak som instituttet har arbeidet med helt siden 1962, brakt vel i havn.

Ekspedisjonsvirksomheten

Svalbardekspedisjonen

Med små avvik ble Svalbardekspedisjonen gjennomført etter programmet. Fordelt på 16 partier deltok i alt 46 personer, hvorav 14 av det faste personalet, 6 engasjerte partiledere og 26 assistenter. Siden ekspedisjonen ikke kunne få leid helikopter, ble programmet omlagt til mer bruk av ekspedisjonsfartøyet M/S «Signalhorn» som base.

Ett geologparti drog til Svalbard over en måned før vanlig feltsesong for å undersøke om avsmeltningen av berggrunnen var kommet langt nok til at man kunne utnytte de bedre vær- og føreforhold til geologiske undersøkelser. Resultatet var meget positivt, men kan skyldes spesielt gunstige forhold dette år, og det er nødvendig med flere års forsøk før man kan trekke konklusjoner på lengre sikt.

Vær og isforhold. – Været var svært dårlig store deler av sommeren med stadig nedbør, ofte i form av snø, og med lavt skydekke. Ikke sjelden blåste det kraftig vind. På Vestspitsbergen var det ingen isproblemer, men ved Tusenøyane, Edgeøya og omkring Kong Karls Land var det store ishindringer.

Fyr og radio. – Som vanlig ble gassbeholdere og batterier på lysfyr og radiofyr skiftet. Fyrene ble ettersett og overhalt, og på Kapp Martin og Fuglehuken ble de grundig oppusset og malt. Dette arbeidet ble utført av BRATLIEN og NETELAND. Radiofyrene ble straks satt i gang, og de ble kontrollert flere ganger utover sommeren. Lysfyrene ble tent da «Signalhorn» utpå høsten gikk hjemover. «H. U. Sverdrup» tente Fuglehuken senere på grunn av dårlig vær da «Signalhorn» passerte.

Ekspedisjonsfartøyene. – M/S «Signalhorn» med BJARTE BRANDAL som fører ble overtatt av ekspedisjonslederen THOR SIGGERUD 29. juni. Den 30. juni forlot fartøyet Åndalsnes etter innlasting av ekspedisjonsutstyret. Det returnerte til Åndalsnes 4. september.

I løpet av sesongen satte fartøyet ut de fleste partiene, forflyttet, forsynte og hentet dem inn for hjemreise. De ekspedisjonsdeltakere som ikke fikk plass med «Signalhorn», reiste med kullbåter.

Ettersyn av fyr og radiofyr ble utført, og SIGGERUD gjorde undersøkelser av havbunnen i utvalgte områder, når dette passet.

Fra 27/7 til 25/8 var «Signalhorn» base for de kombinerte undersøkelser i Storfjorden, Edgeøya, Barentsøya og Tusenøyane.

M/S «H. U. Sverdrup» var utleid til Norsk Polarinstitutt av Forsvarets Forskningsinstitutt. Fartøyet ble overtatt av LUNDQUIST 8. august i Bodø og kom tilbake dit 15. september. Det ble vesentlig brukt i det hydrografiske oppioddingsarbeidet nord for Hinlopenstretet. Den 26. august fulgte fartøyet iskanten fra vest mot øst og nådde 81°13'N og 18°20'Ø. LUNDQUIST gikk fra borde i Longyearbyen 30. august, og ledelsen ble overtatt av CHRISTIANSEN og HORNBÆK. På sin vei nordover 1. september ble skipet heftet et par dager i Forlandsundet, da det ble bedt om å delta i letingen etter et havarert fransk militærfly. Etter anmodning av sysselmannen holdt det vakt ved ulykkestedet inntil «Nordsyssel» kom.

Skipet ble ført av OLAV NORDHUS og hadde 8 manns besetning.

Samarbeid med andre. – Norsk Polarinstitutt var på forskjellig vis en ekspedisjon fra Geographisches Institut, Würzburg, under ledelse av professor BÜDEL, behjelpelig med planlegging og gjennomføring. En av Polarinstituttets geologer ble stilt til rådighet for den tyske ekspedisjonen, og kunne til gjengjeld utføre undersøkelser av interesse for Polarinstituttet. Ved et par anledninger fikk våre topografer nytte et helikopter som den tyske ekspedisjonen disponerte.

To svenske kvartærgeologer, KNAPE og BJÖRKLUND fra Naturgeografiska Institutionen i Stockholm, fikk skipsleilighet med ekspedisjonsfartøyet M/S «Signalhorn» til og fra Edgeøya.

Hydrografparti 1 med HELGE HORNBÆK som leder og SIVERT UTHEIM, DANIEL DAVIDSEN og MARTIN BJØRNDAL som assistenter detaljloddet med M/B «Svalis» i Krossfjorden, rundt Kapp Mitra og nordover til Fjerdebreen fra 10. juli til 26. august. Partiet, som hadde sin leir i Ebeltofthamna, var sterkt hindret i å utføre sitt arbeid av uvær med nedbør og sterkt redusert sikt.

Hydrografparti 2 og *3* om bord på M/S «H. U. Sverdrup» med KAARE Z. LUNDQUIST og JOHAN HENRIK CHRISTIANSEN som ledere, løytnant KJELL OLAV PETTERSEN som assisterende hydrograf og EINAR NETELAND som teknisk leder loddet i området nord for Hinlopenstretet (Verlegenhuken og Lågøya) med slavestasjoner på Biskayerhuken og Verlegenhuken i tiden 16. august–10. september. Slavestasjonene ble betjent av JON OLA FRANKPLADS, PER WILLY GUSTAVSON, KAY PETTER LINDBRÅTEN og FRIDTJOV THORKILDSEN. Ved månedsskiftet august–september gikk «H. U. Sverdrup» til Longyearbyen, der LUNDQUIST debarkerte. HELGE HORNBÆK, som etter å ha avsluttet sitt arbeid i Krossfjordområdet var kommet til Longyearbyen, embarkerte her og deltok i det videre hydrograferingsarbeid etter at skipet kom tilbake til området nord for Hinlopenstretet.

Det ble loddet ca. 2000 naut. mil i linjer med ekkogrammer over et område på omkring 875 naut. mil^2. Virksomheten ble lagt til dette nordlige område, hvor loddingen kunne foregå i forholdsvis godt vær med ubetydelige ishindringer, fordi forskningsskipet ikke slapp til i Storfjordområdet på grunn av drivisen.

De to *topografpartiene* med DAG NORBERG og OLA STEINE som ledere og STEIN KÅRE ULSTEIN, SVEIN EIRIK PAULSEN, TERJE ANDERSEN og HARALD WOLD som assistenter opererte vesentlig på Edgeøya (Negerpynten, Kvalpynten og Tjuvfjorden) og Tusenøyane. Den primære oppgave var å bestemme et hjelpepunkt for hydrografene på Lurøya (i Tiholmane). Dessuten målte de inn passpunkter og utvidet triangelnettet øst- og sørover fra Kvalpynten til Negerpynten og Tusenøyane. Trianguleringen ble fullført som kombinasjon av vinkel- og elektronisk avstandsmåling (tellurometer). Vinkelmålingene ble noe svake enkelte steder på grunn av drivisen, som iblant hindret adkomsten og nødvendiggjorde en forsering av arbeidet. Til sist foretok de noen kontroll- og depresjonsmålinger i den svensk-russiske gradmålingsrekke langs Edgeøya og Barentsøya.

Geologparti 1, ledet av direktør TORE GJELSVIK og THORE S. WINSNES med assistentene ODD ELIASSEN og ALV ORHEIM reiste til Svalbard 21. mai med første båt til Ny-Ålesund. På grunn av isvansker og forsinkelser ved lossing kom partiet av gårde fra Ny-Ålesund først 29. mai. Fram til midten av juni arbeidet partiet i Snøfjella–Dovrefjell–Wergelandfjella, ofte plaget av tåke og "whiteout", men ellers med godt vær og føre. Geologene fant til sin overraskelse at berggrunnen var nesten like meget blottet som ved høysommerstid i 1966, da vertikalfotograferingen av området fant sted. Det geologiske utbytte av ekspedisjonen ble meget godt.

Den 14. juni returnerte GJELSVIK til Ny-Ålesund, mens WINSNES flyttet sørover og fortsatte kartleggingen i området mellom Kongsfjorden og St. Jonsfjorden (se kartet, Fig. 1).

Geologparti 2. – WINSNES ble i begynnelsen av juli hentet av ekspedisjonsfartøyet, og fra 12. juli til 23. august fortsatte han å kartlegge i Heer Land med assistentene ARILD HEM og ARNE DALLAND. Fossiler fra kritt ble innsamlet.

Geologparti 3. – HARALD MAJOR og PER BRANDVOL (fra SNSK) med assistent FREDRIK MAJOR tok i tiden 23. juli–11. august en rekke prøver i snitt gjennom kullfløtsene i gruve 3, 4, 5 og 7 ved Longyearbyen for senere undersøkelser. Dessuten ble målinger og detaljundersøkelser foretatt i gruvene.

Geologparti 4 og *5.* – AUDUN HJELLE med assistentene ARILD ANDRESEN og MORTEN LAAKE og BOYE FLOOD med assistentene TERJE ANDRESEN og TORMOD SÆTHER arbeidet hovedsakelig innenfor området Dunderdalen–Bellsund–Recherchebreen. I en kortere periode arbeidet dessuten FLOOD i Hornsund, og HJELLE sammen med EINAR TVETEN (se under) vest for Kongsfjorden. Formålet med arbeidet i Bellsundområdet var kartlegging og stratigrafiske undersøkelser av Hecla Hoekbergarter.

Geologparti 6. – EINAR TVETEN med assistentene OLAV TJØNNETVEIT og ERIK E. SOLBU fortsatte de geologiske undersøkelser i området vest for Krossfjorden som ledd i sin hovedfagsoppgave til embetseksamen.

Geologparti 7. – JENÖ NAGY deltok i den tyske ekspedisjon som under professor BÜDELS ledelse arbeidet på Barentsøya og Edgeøya. På forskjellige lokaliteter undersøkte NAGY kvartæravsetninger og innsamlet materiale med henblikk på mikropaleontologiske undersøkelser. Dessuten utførte han geologisk kartlegging og stratigrafiske undersøkelser i triasformasjonen på Barentsøya og Edgeøya innenfor den ramme ekspedisjonsopplegget gav.

Geologparti 8. – Fra M/S «Signalhorn» studerte ekspedisjonsleder THOR SIGGERUD den submarine geomorfologi med ekkolodd både inne i fjordene og på kanten av shelfen (se kart, Fig. 1). Videre gjorde han geologiske iakttakelser på en del av Tusenøyane.

Geofysikerparti. – OLAV ORHEIM, assistert av BEATRICE TAYLOR, satte i gang målinger på midre Lovénbreen ved Ny-Ålesund og utførte rutinemålinger av austre Brøggerbreen. Assistert av NILS-MARTIN HANKEN fortsatte han de rutinemessige målinger av Finsterwalderbreen i Van Keulenfjorden.

Målingene av massebalansen på austre Brøggerbreen ved Ny-Ålesund ble igangsatt sommeren 1966, og avlesninger ble foretatt med et par ukers mellomrom hele vinteren og sommeren. Det arbeidet ble utført av JENS ANGARD. Resultatet viste en negativ massebalanse på 65 g/cm^2.

Biologparti. – ALASDAIR H. NEILSON med assistenter STEIN KROGDAHL og PER DYRHAUG fortsatte sine botaniske undersøkelser i tidsrommet 6. juli–23. august, dels på Vestspitsbergen, dels på Edgeøya.

I området Van Keulenfjorden–Recherchefjorden ble 30 lokaliteter undersøkt og ca. 90 plantearter påvist, hvorav en ny for Vestspitsbergen.

På Edgeøya ble 22 lokaliteter undersøkt og 80 plantearter påvist.

Dessuten ble en rekke jordprøver innsamlet for mikrobiologiske undersøkelser.

Arkeologparti. – Stud. mag. art. JOHAN CHRISTIAN KELLER med assistentene JON AAENG og NILS-MARTIN HANKEN arbeidet i Bellsundområdet (Recherchefjorden, Van Keulenfjorden og ytre deler av Van Mijenfjorden). Arbeidet tok sikte på å registrere og lokalisere tufter etter vesteuropeiske hvalfangere fra 1600-tallet og russiske fangstmenn fra 1700-tallet. På ca. 10 undersøkte lokaliteter ble det funnet rester etter i alt ca. 40 hus.

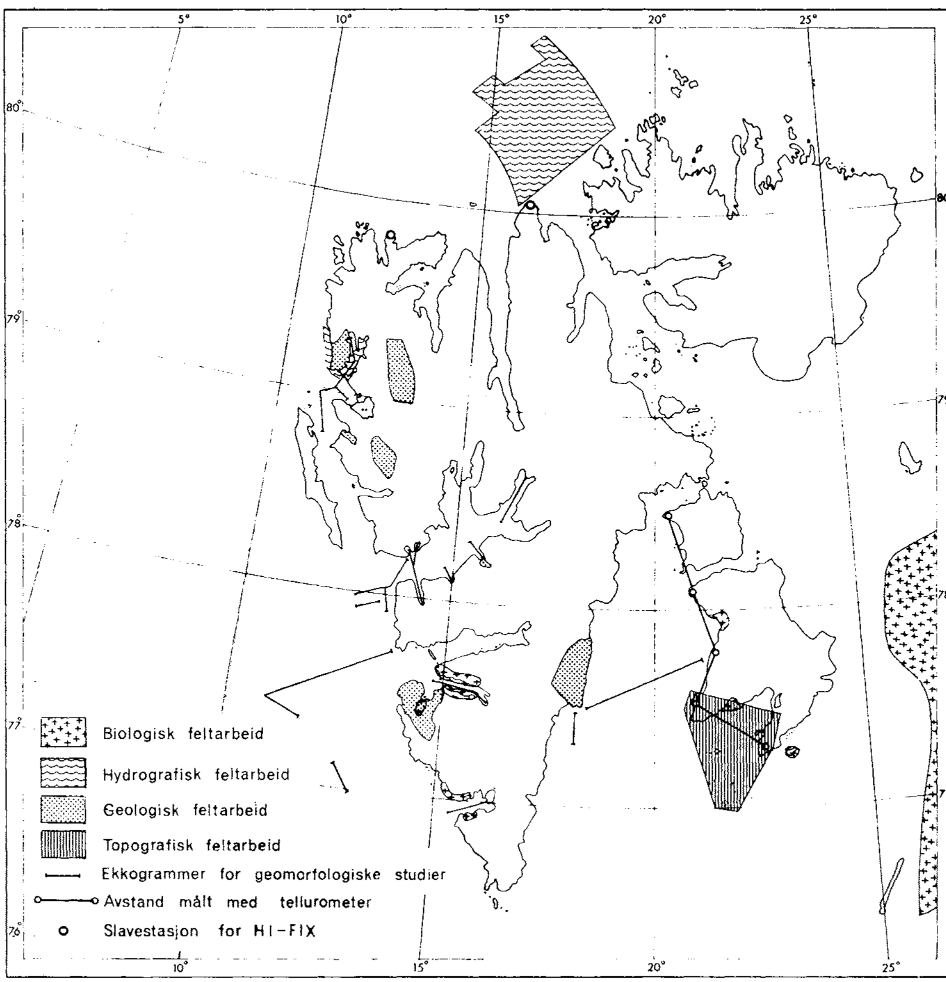

Fig. 1. *Kartet viser hvor Norsk Polarinstitutts feltpartier arbeidet sommeren 1967.*

Andre norske ekspedisjoner til Svalbard

Norsk Polar Navigasjon A/S fortsatte med 5–10 mann under ledelse av oberstløytnant GUNNAR SVERRE PEDERSEN oljeundersøkelsen i Grønfjorden, hvor virksomheten ble avsluttet og deretter flyttet til området ved Bellsund. Av geologer fra Cambridge-ekspedisjonen ble det for selskapet utført geologiske undersøkelser og funnsøkning i Hornsundområdet.

En zoologisk ekspedisjon til de østlige Svalbardfarvann fant sted i tidsrommet 3. juli–1. september. Den ble ledet av cand. real. THOR LARSEN og cand. mag. NILS ARE ØRITSLAND. Formålet var å utføre økologiske og zoofysiologiske studier av isbjørn. I arbeidet deltok også professor ALBERT W. ERICKSSON, University of Minnesota, og dr. JACK LENTFER, Alaska Department of Fish and Game, samt veterinær TORE HÅSTEIN fra VETERINÆRINSTITUTTET i Oslo som observatør. Undersøkelsene er ledd i et flerårig forskningsprosjekt som utføres i samarbeid mellom Universitetet i Oslo og Norsk Polarinstitutt. Ekspedisjonen arbeidet fra M/S «Polarulv», som var chartret for dette formål. Det ble merket 51 isbjørner ved hjelp av muskellammende midler, og data vedrørende isbjørnens biologi ble innsamlet. De zoofysiologiske undersøkelser pågikk dels på ekspedisjonsfartøyet, dels i Hornsund. Et levendebehandlingssystem for isbjørn uten bruk av muskellammende midler ble utarbeidet, og en del zoofysiologiske målinger utført. Ekspedisjonen ble i det vesentlige finansiert av NATO Research Grants Programme med støtte fra Norsk Polarinstitutt til gjennomføringen.

Utenlandske ekspedisjoner til Svalbard

En svensk gruppe på 3 deltakere, ledet av dosent INGEMAR AHLÉN fra Zoologiska Institutionen ved Lunds Universitet, gjorde zoologiske undersøkelser i områdene Prins Karls Forland og Ny-Ålesund.

To svenske kvartærgeologer, PEDER KNAPE og PEDER BJÖRKLUND fra Geografiska Institutionen i Stockholm, studerte marine grenser og strandvoller på Edgeøya.

En finsk gruppe med to deltakere, ledet av dr. ERIK NYHOLM fra Kuusamo, foretok zoologiske undersøkelser på Bjørnøya, og ved Longyearbyen og Ny-Ålesund.

En annen finsk gruppe på to deltakere, ledet av botaniker LASSE VELMALA fra Turku, foretok botaniske undersøkelser i området ved Longyearbyen.

Cambridge Spitsbergen Expedition 1967 med 19 deltakere, ledet av dr. A. CHALLINOR, utførte geologiske undersøkelser i områdene Ny-Ålesund, Grønfjorden og Hornsund. En del av ekspedisjonen arbeidet for Norsk Polar Navigasjon A/S.

En fransk ekspedisjon fra Centre National de la Recherche Scientifique på 10 deltakere, med professor JEAN CORBEL fra Lyon som leder, studerte geologi, glasiologi og botanikk i områdene Ny-Ålesund, Virgohamna, Grønfjorden, Billefjorden og Tempelfjorden.

En nederlandsk gruppe på 3 deltakere, med student ERIC FLIPSE fra Rozendaal som leder, utførte zoologiske og botaniske undersøkelser i områdene Kapp Linné og Hornsund.

En sovjetisk geologisk ekspedisjon med 18 deltakere fra Vitenskapelig forskningsinstitutt for Arktis' geologi i Leningrad undersøkte i samarbeid med trusten Arktikugol' områdene Nordenskiöld Land, Isfjorden, Van Mijenfjorden, Dicksonfjorden, Ekmanfjorden, Billefjorden, Wichebukta og Agardhbukta. Ekspedisjonen, som ble ledet av dr. D. V. SEMEVSKIJ med dr. V. N. SOKOLOV som vitenskapelig leder, hadde 5 geologiske partier og ett geofysisk parti.

Dessuten arbeidet tre mindre grupper fra Sovjetunionens vitenskapsakademi også på Svalbard: En gruppe på 6 personer, ledet av dr. JU. A. LAVRUŠIN fra Geologisk Institutt i Moskva, opererte i områdene Billefjorden, Van Mijenfjorden, Linnévatnet og Brøggerhalvøya. En annen gruppe på 4 personer, med dr. E. M. ZINGER fra Geografisk Institutt i Moskva som leder, foretok glasiologiske undersøkelser på Grønfjordbreane, Nordenskiöld Land og i Adventdalen. Endelig utførte to botanikere, L. JU. BUDANCEV og I. N. SVEŠNIKOVA, fra Botanisk Institutt i Leningrad paleobotaniske undersøkelser i områdene Sveagruva, Grumant og Colesbukta.

I alt tre tyske ekspedisjoner arbeidet på Svalbard denne sesongen. I samarbeid med Norsk Polarinstitutt utførte en ekspedisjon på 14 deltakere, ledet av professor JULIUS BÜDEL, rektor ved universitetet i Würzburg, geomorfologiske undersøkelser på Barentsøya og Edgeøya. Ekspedisjonen opererte fra M/S «Norvarg» med ett helikopter og hadde skips- og helikoptermannskap i tillegg til sine ordinære deltakere.

Student DIETER HAARHAUS fra Kiel drev, som leder for en gruppe på 4 deltakere, zoologiske studier i Sassendalen, og i Sassenfjordområdet foretok museumstekniker HEINZ-OTTO REHAGE fra Dortmund-Brackel botaniske undersøkelser med to medhjelpere.

Österreichische Spitsbergen-Expedition med 6 deltakere, ledet av professor EBERHARD STÜBER fra Salzburg, drev biologiske undersøkelser i området Magdalenefjorden.

I tillegg til de nevnte ekspedisjoner besøkte 15 andre ekspedisjoner Svalbard for opptak av film (bl. a. til fjernsyn), radioprogrammer etc.

Antarktis

Dronning Maud Land

Sommersesongen 1966–67 deltok cand. mag. OLAV ORHEIM i et amerikansk forskningsprosjekt på Plateau Station, hvor han studerte snøens metamorfose. Han avsluttet undersøkelsene i slutten av januar og var tilbake i Oslo en måned senere.

Cand. real. YNGVAR GJESSING reiste i oktober 1967 som deltaker i den amerikanske "South Pole – Queen Maud Land Traverse III", som startet på Plateau Station, for å ta seg av de meteorologiske observasjonene og studere overflatesnøens struktur.

Utenlandske overvintringsekspedisjoner

Belgia–Nederland la ned sin stasjon, Roi Baudouin, i februar etter tre års sammenhengende drift.

Følgende fire overvintringsstasjoner var i drift med til dels utvidet forskningsprogram om sommeren:

Stasjon	*Geogr.br.*	*Geogr. l.*	*Overvintrere*	*Nasjon*
SANAE	70°19'S	2°22'V	16	Sør-Afrika
Novolazarevskaja	70°46' »	11°50'Ø	14	SSSR
Syowa	69°00' »	39°35' »	24	Japan
Plateau Station	79°15' »	40°30' »	8	USA

Breundersøkelser i Norge

Undersøkelsen av Hardangerjøkulen (for N.V.E.) og Storbreen ble fortsatt, men det ble ikke, slik som de to foregående år, foretatt kontinuerlige observasjoner. Breene ble besøkt en rekke ganger fra februar til oktober, og massebalansen ble bestemt og viste i år stort overskudd på begge breer: 72 g/cm^2 på Storbreen og 119 g/cm^2 på Hardangerjøkulen. Fra de faste observatørene fikk instituttet inn måleresultater fra 13 breer. Virkningen av de senere års overskudd begynner nå å gjøre seg gjeldende, idet fem av breene har rykket fram.

Med støtte fra instituttet undersøkte hovedfagsstudentene OLAV ORHEIM og SIGMUND MESSEL henholdsvis Store Supphellebre i Fjærland og Omnsbreen ved Finse.

Flyrekognosering

I mars deltok LUNDQUIST og VINJE i isrekognosering fra fly omkring Svalbard og over Barentshavet i forbindelse med "Birds Eye-prosjektet" etter innbydelse fra US Naval Oceanographic Office.

333 Skvadron av det norske luftforsvar foretok seks tokter på østsiden av Svalbard for isrekognosering og telling av isbjørn.

Arbeidet ved avdelingene

Hydrografisk avdeling

En del forberedende arbeid i forbindelse med sommerens målinger, som opplegg av målebord osv., ble utført. I arbeidet med det nye sjøkart 521 "Fra Femtebreen til Gråhuken" i målestokk 1:100 000 ble de siste Hi-Fix-loddinger i området redigert. Rettelser av brefrontene etter de siste flyfotografier ble påført kartet, som ble korrekturlest, ferdigtrykt og utgitt. Sjøkart 503, som er under omarbeidelse, ble påført rettede brefronter etter de siste flyfotografier. Videre ble det nedlagt en del arbeid på å forberede nytt opplag av sjøkart 504 og 505 til trykning.

Topografisk-geodetisk avdeling

Det ble foretatt beregninger av målinger på *Svalbard* fra de to siste somrer. Spesielt for hydrografisk avdeling ble det utført en del kystkonstruksjon i målestokk 1:50 000 i området Krossfjorden–Kongsfjorden. Arbeidet med å konstruere og rentegne grunnlagsplatene (1:50 000) til kartblad C10 Braganzavågen og C11 Kvalvågen i serien Svalbard 1:100 000 ble fullført. Det ble arbeidet videre med navnekart Svalbard 1:100 000 og med stedsnavn for øvrig. Blad 2 og 4 i kartserien Svalbard 1:500 000 var i arbeid, og i den anledning ble det konstruert noe i området Hinlopenstretet–Wahlenbergfjorden i målestokk 1:200 000. Det nye kartet Svalbard 1:1 000 000 ble utgitt.

For *Dronning Maud Land* ble det utført en del tilleggskonstruksjon i Sør-Rondane i målestokk 1:100 000. Dette er et ledd i et norsk-belgisk samarbeid.

Geologisk avdeling

HARALD MAJOR fortsatte arbeidet med kartbeskrivelse av geologisk kartblad Adventdalen, drev kullgeologiske og petrologiske studier særlig av prøver fra Statens Longyear-gruve 7, og vurderte Statens utmål og funnpunkter og andre spørsmål vedrørende bergrettigheter på Svalbard.

THORE S. WINSNES fullførte en beskrivelse av Nordaustlandets sedimentære lagrekke og begynte på forarbeidet til et oversiktskart 1:500 000 over geologien i den sørlige del av Vestspitsbergen. Høsten 1967 bearbeidet han observasjoner fra sommerens ekspedisjon, katalogiserte det innsamlede materiale og utarbeidet kart over de undersøkte områder. Til bergmesteren anmeldte han 7 kullfunn og redigerte en langtidsplan for avdelingen.

AUDUN HJELLE bearbeidet materiale fra Nordaustlandet og Bellsundområdet. Kjemiske analyser av materiale fra Nordaustlandet og nordvestre del av Vestspitsbergen ble databehandlet.

BOYE FLOOD fortsatte og avsluttet bearbeidelsen av sitt materiale fra Nordaustlandet. I Årbok 1966 offentliggjorde han artikkelen "On the contact between the Hecla Hoek and the Culm, Vestspitsbergen". Han ledet arbeidet med typesamling av bergarter og en ordning av det geologiske kartmaterialet.

THOR SIGGERUD deltok i arbeidet med en publikasjon om Nordaustlandets geologi og studerte submarin geomorfologi i Svalbardfarvann, særlig etter ekkogrammer som ble opptatt under sommerekspedisjonen.

HJELLE, FLODD og SIGGERUD utarbeidet dessuten hvert sitt foredrag til Det 8. nordiske geologiske vintermøte.

JENÖ NAGY fortsatte sitt arbeid med stratigrafi og ammonittfaunaer innen undre kritt på Vestspitsbergen. Han utarbeidet også strukturkart i forbindelse med undersøkelser av oljemuligheter.

Geofysisk avdeling

VIDAR HISDAL overtok arbeidet med å fullføre dr. G. DE Q. ROBINS analyse av høydevinden over Maudheim, fortsatte en undersøkelse av sol- og himmelstrålingens spektralfordeling og utførte i den forbindelse et omfattende kalibreringsarbeid. For Årbok 1966 utarbeidet han en beskrivelse av værforholdene på Svalbard i 1966.

TORGNY VINJE fullførte bearbeidelsen av målingene fra tårnet på Norway Station og beregnet den turbulente varmetransport samt vindens friksjon mot bakken. Ellers stod han for innsamling av isobservasjoner fra de tre faste stasjonene Bjørnøya, Hopen og Isfjord Radio, og fra fly og skip som passerer disse farvann mer eller mindre regelmessig. Observasjonene formidlet han videre til norske og utenlandske interessenter.

OLAV LIESTØL bearbeidet det innsamlede glasiologiske materiale fra Norge og Svalbard, offentliggjorde kortere oversikter og utarbeidet en rapport for Norges Vassdrags- og Elektrisitetsvesen i forbindelse med undersøkelser på Hardangerjøkulen. I Årbok 1966 publiserte han artikkelen «Bremålinger i Norge i 1966».

OLAV ORHEIM arbeidet videre med støtte fra Norsk Polarinstitutt med sin hovedoppgave, en undersøkelse av Store Supphellebre i Fjærland. Han bearbeidet også glasiologisk materiale, innsamlet på ekspedisjonen "Queen Maud Land Traverse II" og på Plateau Station. I Årbok 1966 publiserte han en artikkel: "Surface snow metamorphosis on the Antarctic Plateau".

BEATRICE TAYLOR bearbeidet materiale fra Hardangerjøkulen fra årene 1965–1966.

Biologisk avdeling

MAGNAR NORDERHAUG tiltrådte som biolog ved instituttet i april. Hans arbeid tok først og fremst sikte på å føre den biologiske virksomhet ved instituttet inn i fastere former. En vesentlig del av tiden gikk i 1967 med til arbeidet med isbjørnproblemene. Videre fortsatte han studiet av svalbardgjessene, sendte ut biologiske observasjonsskjemaer og bearbeidet observasjonsmaterialet som var innsamlet under feltgruppenes virksomhet på Svalbard i 1966. Han besvarte en rekke henvendelser om biologisk ekspedisjonsvirksomhet, arktisk dyreliv m. v. I sammenheng med de pågående isbjørnundersøkelser deltok han i to flyrekognoseringer til Svalbard i juli–august. I Årbok 1966 offentliggjorde han «Iakttagelser over dyrelivet på Svalbard 1966» og «Trekk av snøspurv (*Plectrophenax nivalis*) fra Svalbard til Kvitsjøen».

Arbeidsgruppen for viltstell og naturvern på Svalbard», hvor NORDERHAUG fungerte som formann, og som sorterer under Svalbardutvalget, begynte sitt arbeid høsten 1967. Gruppens mandat er å utrede aktuelle problemer innen viltstell og naturvern på Svalbard. De øvrige medlemmer er: konsulent IVAR BLEKE STED, Landbruksdepartementet; konsulent SIGMUND HUSE, Administrasjonen for friluftsliv og naturvern; konsulent SVEIN MYRBERGET, Statens viltundersøkelser og konsulent HAAKON ASKILDSEN, Justisdepartementet (observatør).

Det viktigste av instituttets biologiske utredningsarbeid vil bli fremmet gjennom arbeidsgruppen, som hittil vesentlig har utredet forslag til nye jaktbestemmelser for isbjørn.

Biblioteket

Tilveksten i årets løp har vært ca. 380 bind. En rekke trykksaker er mottatt som gave.

Registreringen av småskriftene, som det er 5 000 av, er avsluttet, men katalogiseringen og klassifikasjonen av boksamlingen etter UDC-systemet fortsetter. Dette arbeid beregnes avsluttet i 1968.

Det er blitt luket i samlingen, og en del serier som ikke har interesse for instituttet, er sjaltet ut og overlatt andre institusjoner.

Heller ikke i 1967 har man kunnet avse tid og arbeidskraft til å ordne og katalogisere den stadig voksende kartsamlingen.

Konsulent- og informasjonstjeneste

Administrasjonen og de forskjellige fagavdelinger for øvrig tok seg av konsulent- og informasjonstjenesten innenfor sine fagområder.

Konsulentstillingen, som ble ledig fra 1. januar, ble besatt ved PETER HAGEVOLD fra 1. august. Han gjennomgikk russisk faglitteratur, informerte medarbeidere ved instituttet om innholdet og oversatte en del til norsk.

SØREN RICHTER ble konsultert i spørsmål om polaregnenes arkeologi, etnografi, geografi og historie.

Direktør GJELSVIK måtte i løpet av året avse megen tid til å utarbeide betenkninger for Svalbardutvalget om spørsmål i forbindelse med bergverksordningen for Svalbard.

Forelesnings- og foredragsvirksomhet

TORE GJELSVIK holdt en rekke foredrag om Svalbard i forskjellige foreninger i Oslo og Østlandsområdet.

OLAV LIESTØL holdt i vårsemesteret en forelesningsrekke i glasiologi ved Universitetet i Oslo for hovedfagsstudenter i geofysikk, foruten at han veiledet hovedfagsstudenter i glasiologi. Han ledet en glasiologisk ekskursjon til Hardangerjøkulen og holdt 10. november et foredrag om emnet «Breens erosjon» i Den norske turistforenings bregruppe.

MAGNAR NORDERHAUG holdt høsten 1967 foredrag på trekkfuglsymposiet i Lund om «Trekkforhold hos hvitkinngås og alkekonge på Svalbard», og i Norsk ornitologisk forening i Oslo om «Hekkeforhold hos arktiske fuglearter».

Reiser, kongress-, møte- og kursvirksomhet

Boye Flood oppholdt seg i Stockholm 23.–25. april, hvor han bl. a. studerte arkiveringen av geologisk materiale ved Sveriges Geologiska Undersökning.

TORE GJELSVIK deltok, ved siden av sine to reiser til Svalbard, i den nordiske geografekskursjon til Island 18. juli–1. august, i møtet mellom de nordiske geologdirektører i Ålborg i slutten av august og i et malmgeologisk symposium, arrangert av «International Association of the Study of Genesis of Ore Deposits (IAGOD)» ved University of St. Andrews, Skottland, i begynnelsen av september.

OLAV LIESTØL deltok i IUGG's kongress i Bern 2.–6. oktober og samtidig i «SCAR Working Group of Glaciology».

DAG NORBERG deltok i «31. Photogrammetrische Wochen 1967» i Karlsruhe, Vest-Tyskland 24. september–8. oktober.

MAGNAR NORDERHAUG gjorde to reiser til Jylland, i mai og desember, for studier av trekkforhold og næringsområder for svalbardgjess. I august deltok han i «Den 8. internasjonale viltbiologkongress» i Helsinki, og i oktober deltok han i et symposium ved Lunds Universitet om nyere problemer og metoder i trekkfuglforskning. Reisene til Jylland og Lund ble dekket av Nordisk Kollegium for Terr. Økologi.

THOR SIGGERUD gjennomgikk i løpet av våren et kurs i flyteori.

Publikasjoner

Skrifter:

Nr. 141 – OLAV LIESTØL: Storbreen glacier in Jotunheimen, Norway.

Nr. 142 – JERZY FEDOROWSKI: The lower Permian tetracoralla and tabulata from Treskelodden, Vestspitsbergen.

Meddelelser:

Nr. 94 – VIDAR HISDAL: On the analysis of non-equidistant observations of the tide. (Særtrykk av International Hydrographic Review. Vol. XLIV, No. 1.)

Nr. 95 – NILS GULLESTAD og MAGNAR NORDERHAUG: Undersøkelser av produksjon og hekkeforløp hos rødnebbterne i Svalbardområdet i 1965. (Særtrykk av Fauna, Årgang 20, 1967, hefte 3.)

Publikasjonsliste:

Publikasjoner (Publications). 1967.

Sjøkart:

521 Femtebreen – Gråhuken, 1:100 000.

Landkart:

Svalbard 1:1 000 000.

Instituttets medarbeidere har utenom instituttets serier publisert:

TORE GJELSVIK: Prospekteringsmuligheter på Svalbard. Tidsskrift for kjemi, bergvesen og metallurgi, nr. 10, Oslo 1966.

OLAV LIESTØL, medarbeider i "Glasio-hydrologiske undersøkelser i Norge 1966". Rapport nr. 2/67. Vassdragsdirektoratet, Hydrologisk avdeling, Oslo 1967.

JENÖ NAGY: Oil exploration in Spitsbergen 1965 and 1966. Polar Record, Jan. 1967, vol. 13, number 85.

MAGNAR NORDERHAUG: Trekkforhold, stedstrohet og pardannelse hos alkekonge på Svalbard. Fauna, nr. 4: 236–244, 1967.

SØREN RICHTER, bidrag til Norsk Biografisk Leksikon, Gyldendals konversasjonsleksikon og Norway Year Book.

TORGNY VINJE: Some results of micrometeorological measurements in Antarctica. Arch. Met., Geoph. Bioklim., 16 (1), Wien 1967.

The activities of Norsk Polarinstitutt in 1967

Extract of the annual report

BY

TORE GJELSVIK

The staff of the institute increased in 1967 from 31 to 32, as a new post for a wildlife biologist was established. In addition, ten persons were employed on short-term contracts. The office of deputy director, removed ten years ago, was re-established, and first hydrographer and expedition leader K. Z. LUNDQUIST was appointed deputy director. Chief of operations T. SIGGERUD is now expedition leader for Svalbard. The following persons started work at the institute: Captain lieutenant J. H. CHRISTIANSEN (hydrographer), cand. mag. P. HAGEVOLD (consultant in translation and documentation), cand. real. M. NORDERHAUG (wildlife biologist), and cand. geod. O. STEINE (geodesist).

In its autumn session the Storting (parliament) passed a resolution to establish a new all-year scientific station at Ny-Ålesund. Norsk Polarinstitutt was entrusted with the task of building and running the station. A committee appointed by the Royal Norwegian Council for Scientific and Industrial Research is to advise on research projects.

Field activity in Svalbard

The first participants of the summer expedition arrived in Svalbard on May 25, and the last ones left the archipelago on September 12. Sixteen field parties with altogether forty-six expedition members and two ships with a crew consisting of seventeen persons took part in the expedition. Since helicopter service could not be provided this year, the expedition vessel M/S «Signalhorn» was more extensively used as a base, especially for submarine geomorphological investigations and topographical surveying.

One geological party went to Svalbard more than a month before ordinary field season. The task was to find out whether snow conditions allowed geological investigations at this time, when the weather conditions usually are very good. The result was positive, but it may be due to particularly favourable conditions this year, and more experience is needed before safe conclusions can be drawn.

In most parts of Svalbard the weather during the summer was extremely bad, with frequent strong winds and precipitation, often as snow. Ice conditions on the western and northern coast were good, but in the eastern regions the ice often interfered with and even prevented the work of the topographers and hydrographers.

Hydrography

Onboard the M/S «H. U. Sverdrup» K. Z. LUNDQUIST, J. H. CHRISTIANSEN, K. O. PETTERSEN, and E. NETELAND sounded an area of 875 nautical sq. miles to the north of Hinlopenstretet from August 16 to September 10, since the Storfjorden area, which originally had been selected for hydrographical work, was filled with drift-ice. By the end of August LUNDQUIST disembarked, and HORNBÆK, having finished his work on the western coast, joined the parties onboard the research ship and participated in the sounding during the last few days of the season.

H. HORNBÆK, using the small surveying-boat «Svalis», surveyed in the Krossfjorden area, round Kapp Mitra and northwards to Fjerdebreen in the period July 10–August 26. The work was often delayed by bad weather and low visibility.

Topography–Geodesy

D. NORBERG and O. STEINE, working in Edgeøya and the Tusenøyane area, determined an auxiliary point for the hydrographers on Lurøya, measured control points, and extended the triangulation net to the east and south from Kvalpynten to Negerpynten and Tusenøyane. The triangulation was carried out as a combination of angular and electronic distance measurements (tellurometer). The angular measurements were not quite satisfactory in some places because of drift-ice, which hindered access to some stations or necessitated a forced pace of work at other stations. Finally the topographers took a few control and depression measurements in the Swedish-Russian Arc-of-Meridian in Edgeøya and Barentsøya.

Geology

By the end of May T. GJELSVIK and T. S. WINSNES set out for the mountains Snøfjella-Dovrefjell-Wergelandfjella, where the weather was fairly good, but sometimes fog and whiteout were a nuisance. The geologists were surprised to find that the ground was nearly as free from snow as it was at midsummer 1966, when the vertical photographs of the area were taken. The geological investigations, as anticipated, benefited greatly by the easy access to outcrops and the safe crossing of glaciers.

In the middle of June GJELSVIK left the party, while WINSNES moved southwards and continued mapping in the area between Kongsfjorden and St. Jonsfjorden (see map, p. 212).

From July 12 to August 23 WINSNES mapped in Heer Land. Cretaceous fossils were collected.

H. MAJOR collected samples from sections of coal beds in the mines 3, 4, 5, and 7 at Longyearbyen for later analysis. Measurements and detailed studies were made in the mines.

A. HJELLE and B. FLOOD worked cheifly in the Dunderdalen–Bellsund–Recherchebreen area, where they mapped and made stratigraphical investigations of Hecla Hoek rocks. For a short period HJELLE collaborated with E. TVETEN (see below), while FLOOD worked in Hornsund.

E. TVETEN continued his studies in the area west of Kongsfjorden.

J. NAGY participated in a German expedition under the leadership of Professor BÜDEL (Würzburg University) to Barentsøya and Edgeøya. In different localities he examined Quaternary deposits and collected material for micropaleontological analysis. Besides he carried out geological mapping and studied parts of the Triassic formation of the two islands.

Onboard M/S «Signalhorn» expedition leader T. SIGGERUD studied submarine geomorphology with an echo sounder both in the fjords and on the edge of the shelf (see map, p. 212). Besides he made geological observations on several of the small islands of Tusenøyane.

Geophysics

O. ORHEIM and B. TAYLOR made measurements on Midre Lovénbreen and routine measurements on Austre Brøggerbreen. Afterwards ORHEIM took routine measurements on Finsterwalderbreen in Van Keulenfjorden.

Mass balance measurements on Austre Brøggerbreen at Ny-Ålesund were started in the summer 1966 by O. LIESTØL, and the instruments have been read by J. ANGARD at two-weekly intervals the whole year round. The results showed a negative balance of 65 g/cm^2.

Biology

A. H. NEILSON continued his botanical investigations in the period July 6–August 23, partly in Vestspitsbergen, partly in Edgeøya. Thirty localities in the Van Keulenfjorden–Recherchefjorden area were examined, and about ninety species were found. In Edgeøya twenty-two localities were examined, and eighty species were found.

A number of soil samples were collected for microbiological analyses.

Archaeology

J. CHR. KELLER searched the Bellsund area (Recherchefjorden, Van Keulenfjorden, and outer parts of Van Mijenfjorden) to localize and register sites used by western European whalers in the XVII century and by Russian sealers and hunters in the XVIII century. Remains of approximately forty houses were found in about ten localities.

Aerial reconnaissance

In March K. Z. LUNDQUIST and T. E. VINJE participated in aerial ice reconnaissances around Svalbard and over the Barents Sea in connection with the «Birds Eye» project at the invitation of US Naval Oceanographic Office.

333 Skvadron made six flights to the eastern parts of Svalbard for ice reconnaissances and counting of polar bears.

Other Norwegian expeditions to Svalbard

A zoological expedition from the University of Oslo, headed by T. LARSEN and N. A. ØRITSLAND, to the eastern Svalbard waters carried out ecological and zoophysiological studies of the polar bear in the period July 3–September 1. Professor A. W. ERICKSON, University of Minnesota, Dr. J. LENTFER, Alaska Department of Fish and Game, and veterinary T. HÅSTEIN (observer), Oslo Veterinary Institute, took part in the expedition. The expedition is part of a joint Polar Bear Programme drawn up by the University of Oslo and Norsk Polarinstitutt. Report on this expedition is printed on pp. 171–179 in this volume.

Norsk Polar Navigasjon A/S continued oil exploration in Grønfjorden, where the activity after some time was interrupted and transferred to the Bellsund area. Geologists from the Cambridge Spitsbergen Expedition carried out geological investigations for the company in the Hornsund area.

Foreign expeditions to Svalbard

A Swedish group of three participants headed by I. AHLÉN from Zoologiska Institutionen, University of Lund, carried out zoological investigations in the environments of Ny-Ålesund.

Another Swedish expedition of quaternary geologists, P. KNAPE and P. BJÖRKLUND from Geografiska Institutionen in Stockholm, studied marine boundaries and beach ridges in Edgeøya.

Two Finnish groups, each of them consisting of two participants, headed by Dr. E. NYHOLM, Kuusamo, and L. VELMALA, Turku, carried out zoological (Bjørnøya, Longyearbyen, Ny-Ålesund) and botanical (Longyearbyen) investigations, respectively.

Cambridge Spitsbergen Expedition 1967 with nineteen participants, headed by Dr. A. CHALLINOR, carried out geological investigations in Ny-Ålesund, Grønfjorden, and Hornsund. Part of the expedition worked for Norsk Polar Navigasjon A/S.

A French expedition from Centre National de la Recherche Scientifique, consisting of ten participants, with Professor J. CORBEL from Lyon as leader, studied geology, glaciology, and botany in Ny-Ålesund, Virgohamna, Grønfjorden, and Tempelfjorden.

A Dutch group of three persons, headed by student E. FLIPSE from Rozendaal, conducted zoological and botanical studies at Kapp Linné and in Hornsund.

A Soviet geological expedition, counting eighteen participants, distributed on four geological groups and one geophysical group, all from Scientific Research Institute of Geology of the Arctic (Leningrad), in cooperation with the trust Arktikugol', under the leadership of Dr. V. N. SOKOLOV and with Dr. D. V. SEMEVSKIJ as expedition leader, examined and surveyed areas in Nordenskiöld Land, Isfjorden, Van Mijenfjorden, Dicksonfjorden, Ekmanfjorden, Billefjorden, Wichebukta, and Agardhbukta.

Besides three groups from the Academy of Sciences of the USSR also did field work in Svalbard: one group of six persons headed by Dr. JU. A. LAVRUŠIN (Geological Institute, Moscow) made investigations in Billefjorden, Van Mijenfjorden, Linnévatnet, and Brøggerhalvøya; another group of four persons, with Dr. E. M. ZINGER (Institute of Geography, Moscow) as leader, carried out glaciological investigations on Grønfjordbreane, in Nordenskiöld Land, and in Adventdalen; finally, two botanists, L. JU. BUDANCEV and I. N. SVEŠNIKOVA (Botanical Institute, Leningrad), carried out paleobotanical studies in Sveagruva, Grumant, and Colesbukta.

Three German expeditions did field work in Svalbard this season. In cooperation with Norsk Polarinstitutt an expedition of fourteen members under the leadership of Professor J. BÜDEL, rector of the University of Würzburg, carried out geomorphological investigations in Barentsøya and Edgeøya. The expedition used M/S «Norvarg» with one helicopter for transportation.

Student D. HAARHAUS from Kiel conducted, as leader of a group of four members, zoological studies in Sassendalen, and in the area of Sassenfjorden museum technician H.-O. REHAGE from Dortmund-Brackel, accompanied by two assistents, carried out botanical investigations.

Österreichische Spitsbergen-Expedition, counting six participants, headed by Professor E. STÜBER (Salzburg), carried out biological investigations in Magdalenefjorden.

In addition to the expeditions mentioned, fifteen other expeditionary groups (Norwegian and foreign) visited Svalbard for other, non-scientific and non-economical purposes.

Expeditions to Antarctica

During the 1966–1967 austral summer O. ORHEIM participated in an American research project at Plateau Station, where he studied the metamorphosis of the surface snow. He finished his investigations by the end of January and returned to Oslo a month later.

Y. GJESSING went to Antarctica in October 1967 to participate in the American "South Pole–Queen Maud Land Traverse III", whitch started from Plateau Station. He carried out meteorological observations and stuied the structure of the surface snow.

Glaciological studies in Norway

The investigations of Hardangerjøkulen (for The Norwegian Water Resources and Electricity Board) and Storbreen were carried on. Continuous observations, as in the two previous years, were not made, but both the glaciers were visited several times from February to October. The mass balance was determined and proved to be positive: 72 g/cm² on Storbreen and 119 g/cm² on Hardangerjøkulen. The institute received results of measurements of thirteen glaciers from regular observers. The effect of positive mass balance in recent years had begun to tell, as five glaciers had advanced.

O. ORHEIM and S. MESSEL examined respectively Store Supphellebre in Fjærland and Omnsbreen at Finse with support from the institute.

Preparations of data

Hydrography

A new Svalbard chart 521 "Fra Femtebreen til Gråhuken" on the scale of 1 : 100 000 was published. Another chart (503), which is being revised, was corrected as to glacier fronts according to the aerial photographs of 1966, and preparatory work on a new impression of charts 504 and 505 was initiated.

Topography

Calculations of measurements taken during the two previous summers in Svalbard were made. Some coastal compilation on the scale of 1 : 50 000 in the Kongsfjorden–Krossfjorden area was performed for the hydrographers. Compilation and drawing of the originals (1 : 50 000) of the map sheets C10 Braganzavågen and C11 Kvalvågen in the series Svalbard 1 : 100 000 were finished. The work at placename maps of Svalbard 1 : 100 000 continued, sheet 2 and 4 in the map series Svalbard 1 : 500 000 was under preparation, and for that purpose some compilation was made in the area Hinlopenstretet–Wahlenbergfjorden on the scale of 1 : 200 000. A new map Svalbard 1 : 1 000 000 was published.

For Dronning Maud Land (Antarctica) additional compilation in the Sør-Rondane area was carried out on the scale of 1 : 100 000 as part of Norwegian-Belgian cartographic cooperation.

Geology

H. MAJOR continued the description of the 1 : 100 000 geological map of Adventdalen. He carried out petrographical studies of coal deposits, particularly of mine 7 at Longyearbyen, and evaluated government claims and other problems concerning mining rights in Svalbard.

T. S. WINSNES worked on a description of the sedimentary succession of Nordaustlandet, and started preparatory work on a synoptical 1 : 500 000 map of the geology of the southern part of Vestspitsbergen. In the autumn he prepared a map of the areas investigated during the summer expedition, and worked out a long-term plan for the geological work of the institute.

A. HJELLE prepared materials from Nordaustlandet and the Bellsund area. Chemical analyses of rocks from Nordaustlandet and the north-western part of Vestspitsbergen were computer processed. He prepared a lecture: "Recent investigations on the metasupracrustal migmatite complex in north-west Svalbard" for the VIII Nordic Geological Winter Meeting.

B. FLOOD finished his part of the description of the geological map of Nordaustlandet. In Årbok 1966 he published a paper entitled "On the contact between the Hecla Hoek and the Culm, Vestspitsbergen". He supervised the work at a type collection of rocks and an arrangement of the geological map material of the institute. For the VIII Nordic Geological Winter Meeting he prepared a lecture: "Sulphide mineralization within the Hecla Hoek complex in Vestspitsbergen".

T. SIGGERUD participated in the work at a publication on the geology of Nordaustlandet. By means of echograms taken during the summer expedition he studied submarine geomorphology in the Svalbard waters. On this theme he worked out a lecture for the VIII Nordic Geological Winter Meeting: "On the fjords of Svalbard and their formation".

J. NAGY continued his work on stratigraphy and ammonite faunas whithin the Lower Cretaceous of Vestspitsbergen. He also prepared structure maps in relation to oil possibilities.

Geophysics

V. HISDAL undertook the completion of the analysis of the upper wind observations from Maudheim (Antarctica). In connection with an investigation of the spectral distribution of radiation from sun and sky a careful calibration of the instruments was carried out. An account of the weather conditions in Svalbard in 1966 was prepared for Årbok 1966.

T. VINJE continued the collection of information on the extension and character of the sea ice in the Svalbard area, and completed an investigation of the turbulent transfer of heat and momentum over an Antarctic ice shelf.

O. LIESTØL prepared glaciological data collected from Norway and Svalbard, published brief surveys, and worked out a report for The Norwegian Water Resources and Electricity Board in connection with a study of the glacier Hardangerjøkulen. In Årbok 1966 he published an article entitled "Bremålinger i Norge i 1966" (Glacier measurements in Norway in 1966).

O. ORHEIM continued his work at the investigation of Store Supphellebre in Fjærland (Norway), and prepared material collected during the expedition "Queen Maud Land Traverse II" and at Plateau Station (Antarctica). In Årbok 1966 he published an article entitled "Surface snow metamorphosis on the Antarctic Plateau".

B. TAYLOR prepared data from Hardangerjøkulen collected in 1965–1966.

Biology

M. NORDERHAUG took up his new post as a wildlife biologist in April. Much time was spent on the polar bear problem and a continued study of the present status of the geese in Svalbard. He also started work on a committee for wildlife management and conservation in Svalbard, which was established in August. In Årbok 1966 he published "Iakttagelser over dyrelivet på Svalbard 1966" (Observations of the animal life in Svalbard 1966) and "Trekk av snøspurv (*Plectrophenax nivalis*) fra Svalbard til Kvitsjøen" (Migration of snow buntings (*Plectrophenax nivalis*) from Svalbard to the White Sea).

Notiser

What is "Mumiyo" from Antarctica?

The substance called mumiyo has in recent years aroused new and considerable interest among scientists in the U.S.S.R. as a possible medicine. In former times healing properties have been attributed to this balsam; it has been mentioned and described far back in the history of science and medicine (Aristotle, Avicenna, al-Biruni and others), and is still well-known in oriental (folk) medicine. The name was in the early Middle Ages used for different wax-like bituminous substances (pitch, natural asphalt). Later is has been restricted to a special wax-like substance found in the mountains of Iran, India and China.

In the U.S.S.R. several articles on the substance have recently appeared; a symposium was held in Tadžikstan in 1965, and several medical institutions have started a closer investigation of it. Mumiyo is usually found as a thin layer on the surface of rocks, but has now been reported found in Antarctica in thicker masses.

The occurrence of mumiyo in Antarctica was first described from western Dronning Maud Land by Ardus (1964) and an analysis of it was given by Jones and Walker (1964). It was concluded that the unidentified substance was probably a modification of the excreta of Snow Petrels, as these were the only animals on the spot where the substance was found – some 320 km from the coast.

Then Konovalov and Michajlova (1966) report finds of mumiyo on rocks in eastern Antarctica, from Dronning Maud Land to Wilkes Land. The wax-like substance was found at a distance of 250 km from the coast and at an altitude of up to 1500 m. The Antarctic samples were described and analysed together with two samples from the Caucasian mountains by Korotkevič, Konovalov and Michajlova (1967). While the Antarctic samples attain a thickness of up to 5 cm, the Caucasian samples are only a few mm thick. The similarity of the samples is shown by their infra-red and ultra-violet spectra, and the contents of C, H, and N is also close to the same in all samples, the ratio being $C:H:N \sim 10:15:1$.

It is concluded that mumiyo is not a product of the rocks and has no connection with mineral oil. It is stated that the most probable solution of the problem of its origin is that mumiyo is a product of organic life or metamorphosed relics of it. In Antarctica mumiyo is formed from the residue of the life cyclus of the petrels.

During an expedition to the mountains of Dronning Maud Land in January 1959 the author of this paper observed Snow Petrels (*Pagodroma nivea*) nesting in many places in the mountains. Several nests contained a chick, and also some eggs were seen. The nesting places were usually found in scree-covered hillsides facing north. The nests were mostly well hidden in crevices or between the rocks of the scree. The nest itself was formed as a weak depression in sand or gravel. Near the colonies of Snow Petrels, nesting Antarctic Skuas (*Catharacta skua mccormici*) were also always present, living as parasites on the petrels. The colonies were some 250 km from the sea and at an altitude of 1650 m.

A common habit among the Arctic Fulmar Petrels (*Fulmarus glacialis*) is spitting in self-defence, and in Spitsbergen the author has several times observed this habit. The spittle can be expelled with great force, reaching 1–2 m away. It is very oily and probably consists of the stomach contents. In a similar manner

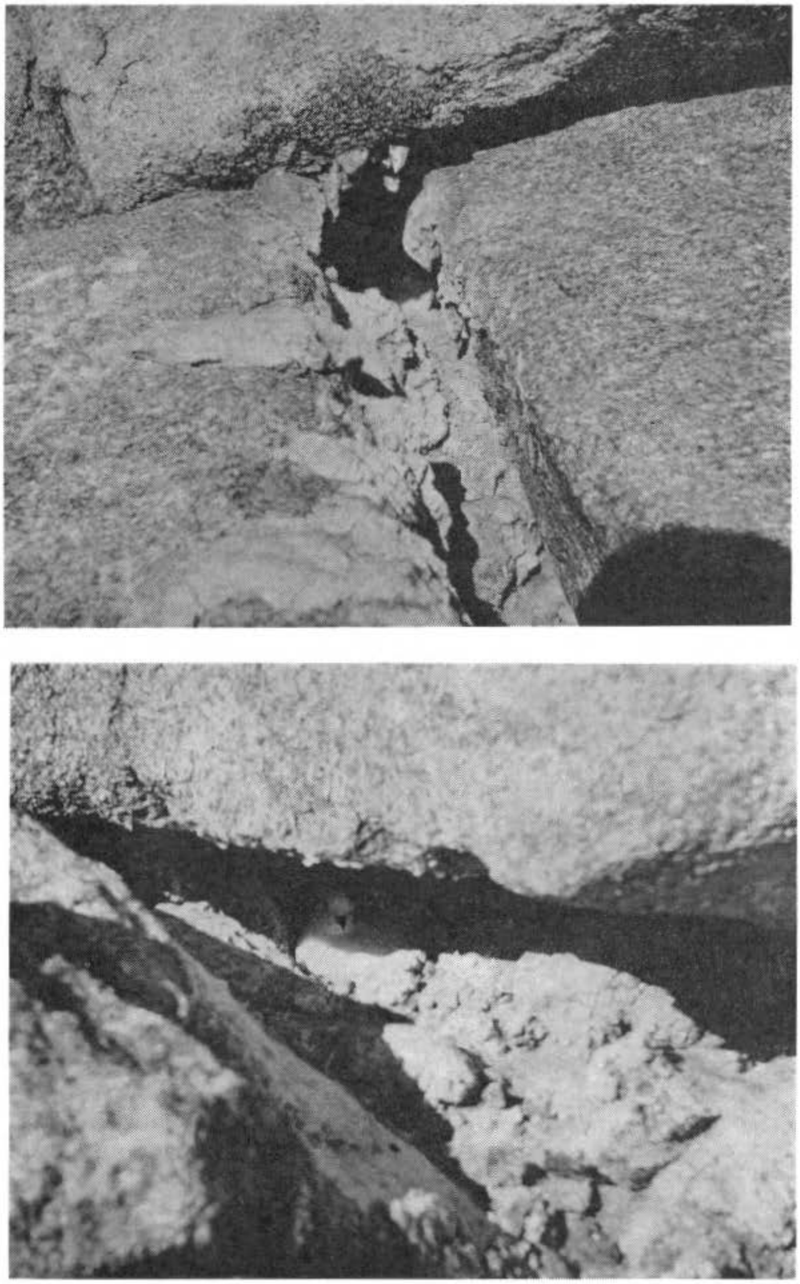

Fig. 1. *Snow Petrels (Pagodroma nivea) nesting in the mountains of Dronning Maud Land, Antarctica. Round the openings of the nests is accumulated wax, which is formed by the hardened oily spittle, delivered in self-defence.*

the Snow Petrel spits in defence. The spittle is a pink and very oily substance, and is delivered when the bird is disturbed on the nest. The colour is no doubt caused by crustaceans, which constitute the main diet of the bird. As seen in Fig. 1, which shows two birds on the nest, the spittle accumulates round the nest in the form of wax. In the lower picture the wax is seen in the front to the right of the bird. A few "drops" of wax can also be seen above the birds head. In the upper picture the wax can be seen hanging down from the "roof" in a stalactite-like manner, and it also sticks as lumps to both sides and in the front of the nest. The amount of wax is here estimated at several kilos.

In the bird colony several old, abandoned nests were also seen, and in some of them the wax had taken on a weathered form, much like the specimens described by ARDUS (1964, Fig. 3).

It is my belief that the so-called mumiyo from Antarctica is the result of this spitting habit of the Snow Petrel. Whether a similar origin can be ascribed to mumiyo from Asia, I am unable to tell.

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Comparison of chemical and modal analyses of granitic rocks from Svalbard

Approximate chemical compositions of 48 samples were computed from modal analyses (HJELLE 1966). Later, 10 of the samples were analysed chemically, and in Table 1 the two sets of analyses are listed together for comparison. Coarse-grained rocks were counted both in slabs and thin sections. Quartz, potassium feldspar, plagioclase, and "other minerals" were distinguished in the slabs, and the relative amounts of the "other minerals" determined by counting in the thin sections.

The SiO_2 values are generally slightly lower in the computed analyses than in the chemical analyses, especially in the relatively coarse-grained rocks (Nos. 22, 29, 33, and 34). This is probably due to errors in point counting, especially of the slabs. The computed values for Al_2O_3 and K_2O are slightly higher than the chemically determined values. (Nos. 29, 33, and 34 show the largest discrepancies.) This indicates that by point counting potassium feldspar was slightly overestimated at the expense of quartz. The TiO_2, Fe_2O_3 and FeO values show no significant trend of deviation, except in the case of the grey granitic rocks from north-west Svalbard (Nos. 2, 4, and 5). These have relatively low computed values for FeO, which may be due to a difference in composition between the biotite of these rocks and the average biotite (19.15% FeO) used in the computation (DIETRICH and SHEENAN 1964). Errors in point counting must also be taken into account, as small variations in the modal percentage of the common ore minerals may cause considerable variations in the TiO_2, Fe_2O_3 and FeO values. The MgO values show relatively small deviations, except for the Laponiahalvøya – Sjuøyane

Table I

	2		4		5		12		22		29		33		34		41		46	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
SiO_2	74.2	75.5	71.8	69.99	71.5	71.9	70.6	69.93	70.0	71.3	68.3	71.9	74.4	76.6	74.3	78.4	72.2	72.9	74.8	73.6
TiO_2	0.1	0.19	0.3	0.40	0.2	0.24	0.4	0.38	0.8	0.37	0.6	0.46	0.1	0.10	0.2	0.08	0.2	0.22	0.0	0.12
Al_2O_3	14.2	13.0	15.1	15.24	15.2	14.4	14.5	15.31	14.4	14.4	15.2	13.8	14.1	12.6	13.5	12.2	14.5	14.5	14.6	15.0
Fe_2O_3	0.1	0.2	0.3	0.09	0.2	0.1	0.8	1.20	0.4	0.4	0.5	0.5	0.2	0.5	1.4	0.5	1.5	0.4	0.7	0.4
FeO	1.0	1.6	1.7	2.79	1.4	1.6	2.4	1.56	2.9	1.9	2.9	2.4	1.2	1.1	1.2	0.7	0.9	0.9	0.4	0.5
MnO	—	0.07	—	0.05	—	0.03	—	0.01	—	0.02	—	0.04	—	0.03	—	0.02	—	0.02	—	0.02
MgO	0.3	0.4	0.8	0.87	0.7	0.5	1.0	0.81	1.1	0.6	1.3	0.7	0.4	0.2	0.5	0.1	0.4	0.3	0.2	0.1
CaO	1.4	1.1	2.5	2.57	1.7	1.4	2.4	2.45	1.5	0.9	1.8	1.6	0.5	0.4	0.2	0.2	0.7	0.7	0.4	0.5
Na_2O	2.9	2.7	3.0	3.44	3.2	3.0	3.0	3.31	2.8	2.7	2.5	2.6	2.7	2.8	2.8	2.6	2.9	3.1	3.6	3.8
K_2O	5.6	4.6	4.1	3.49	5.5	5.2	4.3	3.90	5.4	5.8	5.9	5.3	5.8	5.2	5.1	4.6	5.9	5.6	4.7	4.7
H_2O^+	0.2	0.6	0.4	0.79	0.3	0.8	0.5	0.74	0.5	1.1	0.6	0.7	0.5	0.8	0.7	0.9	0.6	0.9	0.7	1.0
H_2O^-	—	(0.2)	—	(0.03)	—	(0.2)	—	(0.04)	—	(0.3)	—	(0.3)	—	(0.0)	—	(0.2)	—	(0.3)	—	(0.2)
P_2O_5	0.0	0.06	0.0	0.08	0.0	0.09	0.1	0.05	0.1	0.13	0.2	0.12	0.0	0.11	0.0	0.17	0.1	0.20	0.1	0.27
CO_2	0.0	0.03	0.0	0.08	0.0	0.02	0.0	0.10	0.0	0.02	0.0	0.02	0.0	0.02	0.0	0.01	0.0	0.06	0.0	0.02
BaO	—	0.14	—	—	—	0.10	—	—	—	0.08	—	0.08	—	0.01	—	<0.01	—	0.03	—	0.02
	100.0	100.19	100.0	99.88	99.9	99.38	100.0	99.75	99.9	99.72	99.8	100.22	99.9	100.47	99.9	100.48	99.9	99.83	100.2	100.05
al	47.4	46.1	44.7	42.8	45.3	46.3	40.9	44.3	41.2	45.8	41.0	42.4	49.3	48.1	46.8	51.4	46.4	49.2	51.8	52.2
fm	7.8	12.9	14.6	17.7	12.1	11.6	19.7	16.7	21.1	15.0	21.4	17.6	10.4	10.2	16.7	7.8	13.6	8.7	6.6	5.0
c	8.4	7.2	13.2	13.1	9.2	8.2	12.5	12.7	7.9	5.1	9.0	9.1	3.2	2.7	1.4	1.7	4.3	4.1	2.5	3.2
alk	36.4	33.7	27.5	26.5	33.4	34.0	26.8	27.3	29.8	34.1	28.5	30.9	37.1	39.0	35.1	39.1	35.7	38.0	39.1	39.6
si	421	454	360	334	362	391	339	336	340	384	312	374	440	496	439	561	392	420	451	434
k	0.56	0.57	0.48	0.40	0.53	0.53	0.49	0.44	0.56	0.59	0.61	0.58	0.59	0.55	0.55	0.54	0.58	0.54	0.46	0.45
mg	0.33	0.28	0.43	0.35	0.42	0.34	0.37	0.35	0.38	0.32	0.41	0.30	0.34	0.19	0.28	0.11	0.25	0.28	0.24	0.14

a: Composition computed from modal analyses (A. HJELLE 1966).
b: Chemical analyses by P. R. GRAFF, Norges geologiske undersøkelse, geologisk avd. (Nos. 4 and 12), and B. ÅKERLUND, Sveriges Geologiska Undersökning (all other analyses).
For locations se table II.

quartz monzonite and the Brennevinsfjorden granite (Nos. 22, 29, 33, and 34) in which computed figures for MgO and FeO are higher than those determined by chemical analyses. This suggests an overestimation of biotite in the mode. The Na_2O and the CaO percentages generally compare fairly well. This is in contrast to the earlier mentioned high figures for the computed K_2O values, which may be related to an overestimation in the mode of potassium feldspar compared to quartz. It is also possible that the albite content of the potassium feldspar was underestimated because of loss of perthite material by the grinding and separation processes of the potassium feldspar.

Concluding remarks. - In general it can be concluded that the modal method, used by the author (1966) for obtaining approximate chemical analyses of granitic rocks is subject to only small errors for most of the oxides concerned. However, some oxide percentages (FeO and K_2O) may show moderate to considerable differences compared to the new chemical analyses. The computed analyses may, however, be improved by better methods and/or more careful point counting, especially of the slabs.

Acknowledgements. - The chemical analyses were carried out in Stockholm and Trondheim by the geochemical departments of Sveriges Geologiska Undersökning and Norges geologiske undersøkelse, geologisk avd. The directors of these departments are thanked for the assistance in this project.

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Table II

No. in Table I	N.P. specimen No.	°N	°E	Location	Regional division
2	63 Gj 20	79°44.4′	10°14.6′	S Amsterdamøya	Grey granitic dyke rocks
4	64 Hj 230A	79°38.9′	10°47.9′	SW Danskøya	of
5	63 Gj 1	79°38.5′	11°0.2′	Bjørnhamna	north-west Vestspitsbergen
12	64 G 118	79°39.2′	11°39.1′	S Vasahalvøya	Hornemantoppen quartz monzonite, north-west Vestspitsbergen
22	65 Hj 111	80°37.7′	19°0.5′	Nelsonøya	Laponiahalvøya–Sjuøyane
29	65 Hj 99	80°19.7′	20°2.6′	Dornier Walflya	quartz monzonite, Nordaustlandet
33	62 Gj 114	80°17.2′	19°46.6′	Amundsenodden	Brennevinsfjorden granite,
34	65 Hj 100	80°10.8′	19°52.5′	E of Gottwaldt-høgda	Nordaustlandet
41	65 Hj 166A	80°0.1′	22°41.3′	Stegdalen	Rijpfjorden granite,
46	57 Ws 71	79°48.1′	22°9.9′	S Helvetesflya	Nordaustlandet

Audun Hjelle

Norsk vitenskapelig helårsstasjon på Svalbard

Etter forslag fra Kirke- og undervisningsdepartementet vedtok Stortinget i høstsesjonen å opprette en helårs vitenskapelig stasjon i Ny-Ålesund og bevilget kr. 300 000 til bygge- og innredningsformål og drift første halvår. Et forslag om en slik stasjon ble fremsatt av Norsk Polarinstitutt i 1965, etter at instituttet siden 1962 ved henvendelser til en rekke institusjoner hadde undersøkt om interessen og betingelser for en helårsstasjon var til stede, og etter at situasjonen i Ny-Ålesund var blitt avklaret etter gruveulykken. Norges almenvitenskapelige forskningsråd (NAVF) oppnevnte i 1966 et utvalg til å utrede saken og fremmet deretter et forslag til departementet i overensstemmelse med utvalgets innstilling.

Stasjonen skal bygges og administreres av Norsk Polarinstitutt. Et rådgivende utvalg oppnevnt av NAVF skal vurdere og prioritere de forskningsprosjekter som blir foreslått.

Etter forhandlinger med Kings Bay Kull Comp. A/S som eier grunnen og bygningen i Ny-Ålesund, er det bestemt at den tidligere kontorsjefbygning skal innredes til stasjonsbygning.

Norsk Institutt for Kosmisk Fysikk opprettet i 1964 en stasjon for ionosfæriske og jordmagnetiske registreringer på Kapp Linné, og den ble i 1966 flyttet til Ny-Ålesund. NAVF har i 1967 forskuttert et beløp slik at den seismiske stasjon, drevet av Jordskjelvstasjonen, Geologisk Institutt, Bergen Universitet, er blitt installert i Ny-Ålesund. Disse virksomheter vil inngå i helårsstasjonen. I første omgang vil stasjonen få en fast besetning på bare 2 mann, og Norges teknisk-naturvitenskapelige forskningsråd (NTNF) har gått med på at disse kan innlosjeres i NTNF's messe. Det er å håpe at norske vitenskapelige institusjoner vil slutte opp om stasjonen, slik at aktiviteten etter hvert kan økes. Særlig i sommertiden ventes at mange norske forskere vil bruke stasjonen som utgangspunkt for sine prosjekter. Det kan komme på tale å la også utenlandske forskere arbeide ved stasjonen når driften er kommet godt i gang.

Operasjonssjef THOR SIGGERUD som har stått for Norsk Polarinstitutts forarbeid i saken, fungerer som administrativ leder for stasjonen.

Tore Gjelsvik

Tredje etappe av Dronning Maud Land Traversen

Abstract. During the Antarctic summer of 1967–68 the writer served as visiting scientist on the third stage of the American "Queen Maud Land Traverse". The traverse started from Plateau Station (79°14′S, 40°30′E) Dec. 5, 1967, and the nine members of the expedition were picked up by plane Jan. 30, 1968, on the position 78°42′S, 6°52′W. The writer was responsible for the meteorological observations and the studies of the snow surface.

Som ved de to tidligere etappene av den amerikanske Dronning Maud Land Traversen innbød National Science Foundation Norge til å sende en deltager også til tredje etappe. Sydsommeren 1964–65 foregikk første etappe fra Sydpolen til Utilgjengelighetens Pol. Året etter fortsatte traversen frem til Plateau Station (79°14′S, 40°30′Ø). Sommeren 1967–68 skulle traversen nå fjellene i Dronning Maud Land og så dreie sydover igjen. Norsk Polarinstitutts Årbok for 1964 og for 1965 inneholder beretninger fra OLAV DYBVADSKOG og OLAV ORHEIM om første og annen etappe av traversen. Jeg vil derfor i første rekke ta for meg det som var spesielt for tredje etappe, hvor jeg var med som norsk deltager.

Jeg ankom med fly til McMurdo Station 31. oktober 1967 sammen med de fleste av deltagerne på traversen. McMurdo Station er den største basen i Antarktis og ligger på Ross Island i Rosshavet. Vi fortsatte til Amundsen–Scott

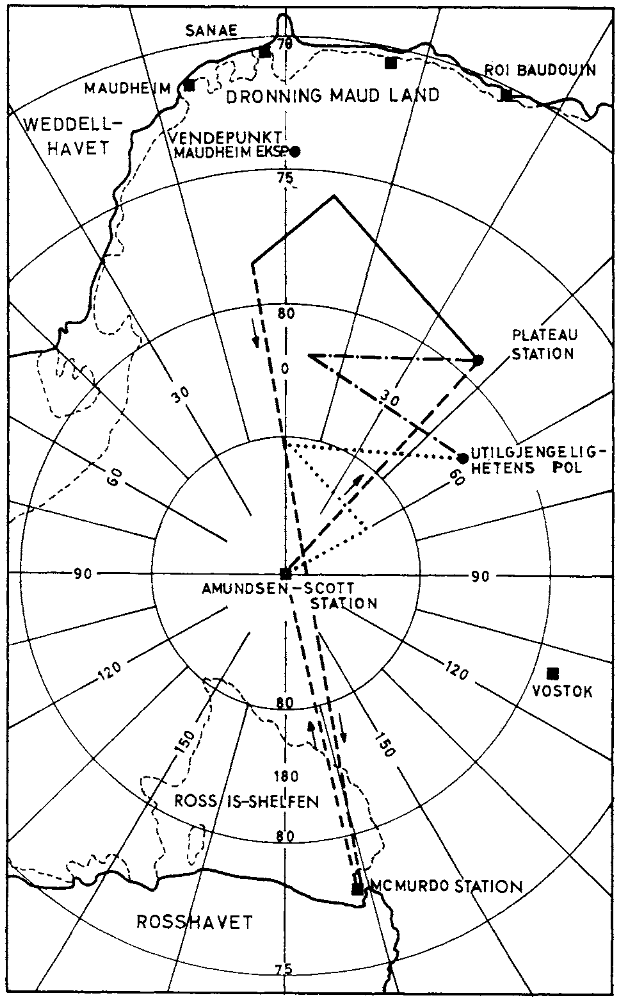

Fig. 1. *Kart over Antarktis der rutene for de tre etappene av den amerikanske "Queen Maud Land Traverse" er inntegnet. Den prikkete og strek-prikkete linjen angir etappene gjennomført henholdsvis sydsommeren 1964–65 og 1965–66. Den fullt opptrukne linjen viser tredje etappe av traversen, og den stiplete angir flyruten.*

Map of Antarctica showing the route of the American "Queen Maud Land Traverse". The dotted and the dash-dotted lines indicate the parts of the traverse covered during the south summer of 1964–65 and 1965–66 respectively. The full drawn line indicates the third stage of the traverse and the broken line shows the distance travelled by air.

Station på Sydpolen 19. november, etter å ha brukt tiden i McMurdo til å klargjøre instrumenter og utstyr. Sydpolen ligger ca. 2800 m o. h., og vi tilbrakte 5 dager der for å akklimatisere oss til det lave lufttrykket, slik at overgangen ikke skulle bli alt for stor når vi kom til Plateau Station. Denne basen ligger nemlig ca. 3 600 m o. h. med lufttrykk omkring 600 mb.

Da vi kom til Plateau Station 23. november, hadde basen vært isolert siden midten av februar. Flyet hadde gjort et forgjeves forsøk på å finne frem til stasjonen dagen før. Plateau Station må kunne betegnes som den vanskeligst tilgjengelige basen i Antarktis. Den har forbindelse med omverdenen bare ca. 2½ måned i året. Basen ble tatt i bruk i januar 1966 og skal etter planen legges ned i februar 1969. Den er bemannet med 4 vitenskapsmenn og 4 mann fra U. S. Navy. Hovedtyngden av forskningen er lagt på meteorologi. Foruten rutinemessige observasjoner hver 6. time, registreres stråling og transport av varme i sneen. Det mest imponerende på stasjonen var kanskje det 40 m høye tårnet, der temperatur, vindhastighet og vindretning ble registrert i 12 forskjellige nivåer. Dessuten ble temperaturen i sneen registrert i forskjellige nivåer ned til en dybde av 2 m. Ettersom stasjonen ligger på en nær sagt endeløs flate med en forholdsvis jevn sneoverflate, skulle dette tårnet gi muligheter til interessante studier av den vertikale variasjon av temperatur og vind. Det ble dessuten foretatt registreringer av den magnetiske feltstyrken og fotografering av sydlys. Videre ble den høyere atmosfære undersøkt ved hjelp av V.L.F. (very low frequency) samband med stasjoner i California og Alaska.

Værforholdene i dette området av Antarktis er dominert av et nokså stasjonært høytrykk. Dette kan resultere i kraftige inversjoner. I det før omtalte meteorologiske tårnet ble det målt temperaturdifferanser mellom bakkenivået og 40 m nivået på opp til 39°C. Nedbøren er meget liten og kommer i form av "fall out", det vil si direkte sublimasjon av vanndamp. En av mine oppgaver på Plateau Station var å måle siste års akkumulasjon ved hjelp av et nett av 99 bambusstaker, som var satt opp i februar 1966. Akkumulasjonen tilsvarte ca. 25 mm vann pr. år.

Vi tilbrakte 10 dager på Plateau Station og brukte tiden til å montere og prøve instrumentene, samt pakke de 13 sledene og tilhengerne som weaslene skulle ha på slep. Bare verktøy og reservedeler til weaslene veide 4 tonn, og drivstoffet nærmere 15 tonn.

Vi var i alt 10 deltagere. Lederen, NORMANN PEDDIE, var navigatør og tok seg dessuten av de magnetiske målingene. Et team på 3 mann fra Wisconsin State University hadde som hovedoppgave å måle istykkelsen ved forskjellige metoder og utførte dessuten gravimetriske målinger og barometriske høydemålinger. De 3 glasiologene undersøkte sneens skiktning og tetthet og tok sneprøver for hver 10 cm ned til en dybde av 3–5 m. I alt ble det samlet inn nærmere 1 tonn sne, som i frosset tilstand ble transportert til Belgia for kjemisk analyse. Ut fra analysen kan de forskjellige lags alder beregnes og dermed også den årlige akkumulasjon. Ved hver hovedstopp ble det boret et ca. 40 m dypt hull, som først ble brukt av glasiologene til å måle temperatur og tetthet av sneen som en funksjon av dybden. Etterpå ble så hullet fylt med sprengstoff til bruk for seismologenes målinger av istykkelsen. Mine oppgaver var stort sett de samme som mine forgjengeres, DYBVADSKOG og ORHEIM. Det var i første rekke meteorologiske observasjoner hver 6. time og overflatestudier av sneen. To av deltagerne var mekanikere. Foruten å kjøre de to største weaslene, utførte de mirakler hver gang noe gikk i stykker.

Vi startet 5. desember. Etter planen skulle vi ha korte stopp for hver 5. nautiske mil, og etter 50 mil stoppe ca. 1 døgn for å utføre mer tidkrevende feltarbeid. Det tok oss vanligvis mellom 15 og 20 timer å tilbakelegge 50 nautiske mil. I praksis ble dette opplegget ofte forandret på grunn av uhell med kjøretøyene. To dager etter at vi hadde startet, ble en av deltagerne syk og måtte kjøres tilbake. Planen var å kjøre i rett linje frem til vendepunktet til et av Maudheimekspedisjonens partier og deretter dreie mot sør-sørvest. Denne ruten ville også passere vendepunktet for Den Russiske Transantarktiske Ekspedisjonen i 1963–64. Jeg ble meget imponert over vår navigatør da vi en dag oppdaget noe svart rett i kursen vår. Det viste seg å være en stabel av tomme oljefat, som russerne hadde satt opp for å markere dette vendepunktet.

Vi fikk flyslipp med drivstoff, reservedeler og post tre ganger. På grunn av en del uhell med kjøretøyene måtte ruten kortes noe inn. I alt kjørte vi ca. 1400 km.

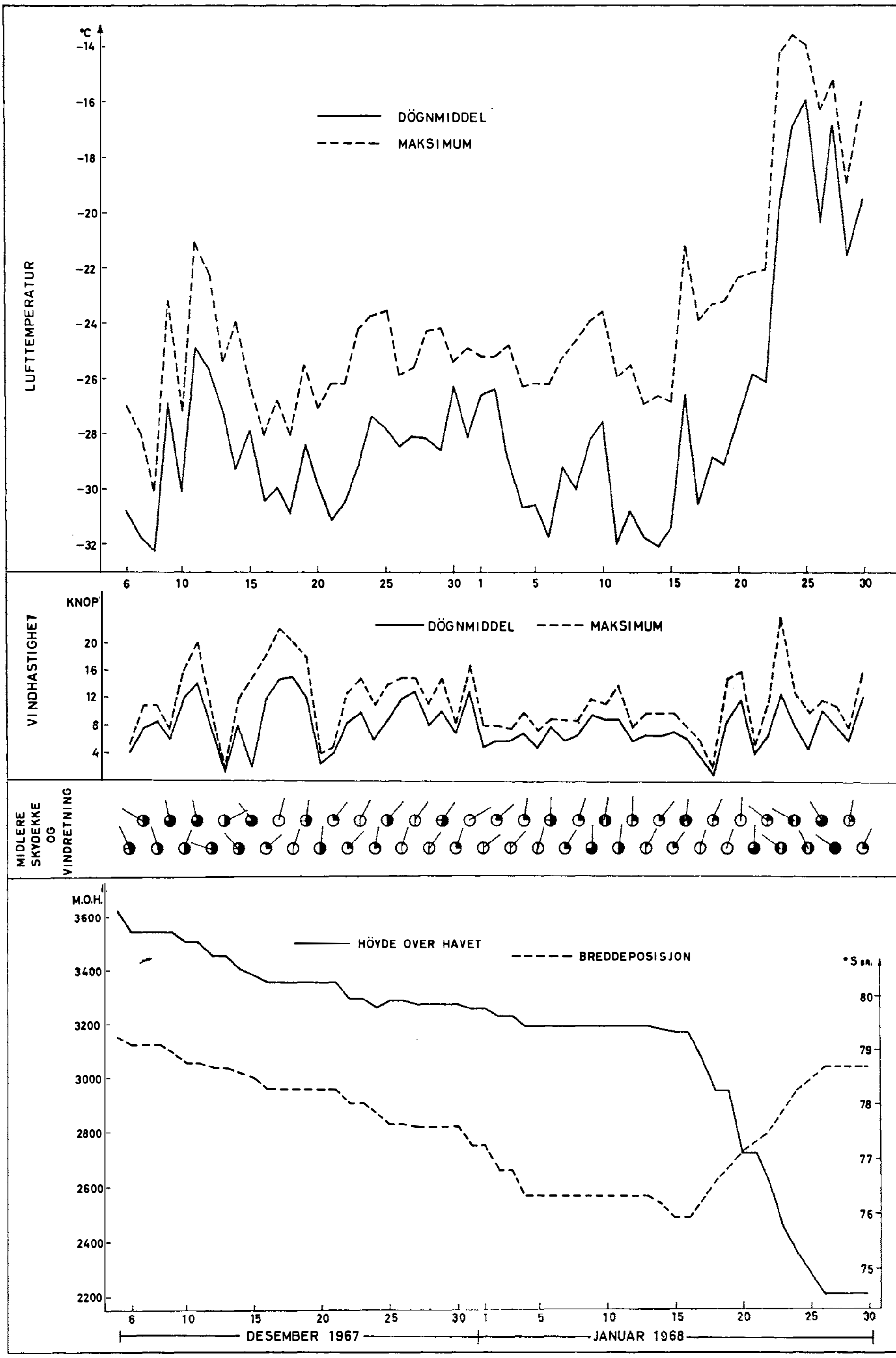

Fig. 2. *Døgnmidler og maksimumsverdier for temperatur og vindhastighet, samt midlere skydekke og vindretning. Kurvene nederst på figuren viser observasjonsstedenes høyde over havet og breddeposisjon.*

Diurnal averages and maximum values for temperature and wind speed, and averages for cloudiness and wind direction. The altitude and latitude of the places where the observations were carried out are shown on lower part of the diagram.

Etter planen skulle vi plukkes opp av fly ca. 1. februar. Vi stoppet et par dager før for å planere en landingsstripe for flyet, samt demontere instrumentene og en del av utstyret. Weaslene og det meste av utstyret skulle settes igjen for å brukes neste år på fjerde etappe tilbake til Sydpolen. Alt den 29. januar hadde vi radiokontakt med Amundsen–Scott Station, som kunne fortelle at et fly var i ferd med å starte derfra for å plukke oss opp 4 timer senere. Etter en hektisk innspurt kom vi oss av gårde.

I løpet av den tiden vi var underveis, ble det gjort forsøk med radiosondering fra fly for å bestemme istykkelsen. Denne metoden viste seg å være meget nøyaktig og effektiv og førte til at fjerde etappe av Dronning Maud Land Traversen, som neste år skulle fortsette frem til Sydpolen, ble utsatt og muligens blir skrinlagt.

Det var en stor opplevelse å få anledning til å besøke Antarktis og få et innblikk i U.S.A.'s forskningsinnsats der. En kunne ikke unngå å bli imponert over det store opplegget og hvor effektivt alt virket. U.S. Navy besørger all transport, utrustning og teknisk assistanse. Ved helårsstasjonene er over halvparten av mannskapsstyrken militært personell. Denne gigantiske forskningsinnsats koster U.S.A. ca. 28 millioner dollar i året, hvorav ca. 3/4 tas over forsvarsbudsjettet.

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Recovery of polar bears marked in Svalbard

During two years of studies of the biology of the polar bear (*Ursus maritimus*), 55 bears have been marked in the Svalbard area. Four of these were trapped in 1966 and the rest in the following summer (LARSEN 1967, 1968). All bears have been trapped in the waters between Kong Karls Land, Edgeøya, and Hopen. They were marked with a nylon and a monel metal tag in both ears, a tattoo in the right upper lip, and a dye number on the hips. The fur marks were applied partly for the protection of the bear from trophy hunters the same summer.

One bear (No. 315) was shot from M/S «Fortuna» in 1967, only two weeks after it was marked in the same waters. The crew were not able to see the fur mark on the bear, which was shot while swimming (ARNESEN 1967, pers. comm). There have been rumors about another marked bear killed the summer 1967, but I have not been able to confirm this.

One young male (No. 351) was killed in Longyearbyen on February 11, 1968. This was the last bear which was marked the previous summer on the edge of the pack ice north of Hopen. When shot with the syringe gun, one of the syringes went rather deep in behind the abdomen on the right side. It had to be removed through a small cut which afterwards was sutured. The bear received 2 mill. units of Penicillin, and was observed during recovery. Evidently this little accident was not dangerous to the bear, which was in good shape when shot the following winter.

The recovery of the last bear, together with other data obtained during the polar bear study, indicates that the polar bear does not belong to one circumpolar stock as suggested by some biologists (PEDERSEN 1945). More probably, there are several discrete populations with little exchange of gene material between them.

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Isbjørnundersøkelser i Canada høsten 1967

Abstract. The Canadian Wildlife Service initiated polar bear (*Ursus maritimus*) studies in 1961. Effort has been made to find methods for live trapping and handling of polar bears. In 1966, four bears were trapped by foot-snares.

The author had the opportunity to participate in the Canadian polar bear investigations in October 1967. In nine days, five bears were trapped without any accident.

Foot-snares seems to be a safe method for polar bear trapping, and can probably also be used in Svalbard during winter. The traps should then be combined with an alarm system which may enable the scientist to be on the spot shortly after the trapping, and hence avoid possible frostbite.

I det nordlige Canada er isbjørnen (*Ursus maritimus*) et viktig fangstobjekt for eskimoene. Ca. 600 dyr skytes hvert år, og det har vært en viss bekymring for en overbeskatning av bestanden. Bl. a. av denne grunn startet Canadian Wildlife Service et forskningsprogram for isbjørn i 1961. Undersøkelsene har i første rekke vært konsentrert om de sørligste bestandene i Hudson Bay og i James Bay. I likhet med biologer i U.S.A. og Norge har canadiske forskere forsøkt å komme frem til effektive levendefangst- og merkemetoder for isbjørn. Høsten 1966 ble fire bjørner fanget med fotsnarer, injeksjonsgevær og bedøvende midler ved Cape Churchill (JONKEL 1967).

Isbjørnene i Hudson Bay har et levesett som er ganske forskjellig fra deres stammefrenders i resten av Arktis. De søker sin næring langs kysten og innover i landet, og kan enkelte ganger påtreffes langt inne i de nord-canadiske barskogene, opptil 250 km fra kysten. Enkelte dyr søker til eskimolandsbyer og anlegg, hvor de kan oppholde seg i lange tider. Isbjørn kan stadig sees like opp til husene på Cape Churchill, og man kan være sikker på å se bjørn rundt avfallshaugene i distriktet. Enkelte biologer mener at Hudson Bay-stammen av isbjørn er adskilt fra dyrene på de nord-canadiske øyene og østover mot Grønland.

Høsten 1967 fikk jeg anledning til å delta i isbjørnundersøkelsene ved Cape Churchill, som ble ledet av Dr. CHARLES JONKEL ved Canadian Wildlife Service. I begynnelsen av oktober drev vi isbjørnfangst med fotsnarer langs kysten ca. 30 km øst for basen. Vi satte opp 15–20 fotsnarer i en "trapline" langs kyststripen og innover i landet, med et par kilometers avstand mellom hver felle. Snarene ble forankret i en stor drivvedstokk, en stubbe eller et oljefat fylt med grus. Som åte brukte vi kjøttstykker eller hermetikk. Ved hver felle reiste vi en stor stake. Erfaringen har vist at isbjørnen gjerne tiltrekkes av slike landemerker. Dessuten ville en fanget bjørn rive ned staken under forsøkene på å komme seg løs. Fra hyttetaket kunne vi således lett kontrollere om det var fangst i snarene etter som stakene sto oppe eller ikke.

Under mitt ni dagers opphold tok vi fem isbjørner i fotsnarene, og Dr. JONKEL fanget ytterligere femten de følgende tre uker. I motsetning til svartbjørnen

Fig. 1. *Hanbjørn fanget med fotsnare. Legg merke til snaren like over venstre pote.*
Male polar bear trapped by foot-snare. Note the snare right above the left paw.
Photo: T. LARSEN

(*Ursus americanus*) og grizzlybjørnen (*Ursus horribilis*) tar isbjørnen det relativt rolig når den blir fanget, og den gir opp å komme løs etter en times tid. Snaren vil meget sjelden volde skade. Løkken strammer som regel til like over labben, og hindrer ikke blodsirkulasjonen nevneverdig. Selv hos bjørn som hadde stått lenge i fellene kunne vi ikke konstatere åpne sår eller brudd. I et par tilfeller var labben litt hoven, men dyrene haltet aldri når de ble sluppet.

Isbjørnfangst med fotsnarer kan sikkert benyttes på Svalbard vinterstid for merkinger og biologiske undersøkelser. Man bør imidlertid utvise spesiell forsiktighet for å hindre forfrysninger. Fellene kan eventuelt koples til et alarmsystem som varsler så snart en bjørn er fanget. Dermed har man muligheter for å være på pletten kort etter og avverge skader som kan forårsakes av den strenge kulden.

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Frozen up *Littorina saxatilis* OLIVI in the icefoot in Spitsbergen

The authors were members of a team participating in Norsk Polarinstitutt's summer expedition 1966. Our main camp was established in Sørgattet, at the north-western coast of Vestspitsbergen. Here the ice cover was still present in the littoral zone at the beginning of July. From the icefoot and downwards there was an even distribution of *Littorina saxatilis* (OLIVI).

The species of Littorina are known to behave differently in the winter. According to BLEGVAD (1929) *Littorina littorea*, just before an ice period, migrates to deeper water and returns again when the ice disappears. In northern West-Greenland *Littorina saxatilis* winters partly frozen up in the ice (HØPNER PETERSEN 1962).

In order to study the behaviour of *L. saxatilis* in Sørgattet, we marked all snails of this species with a yellow varnish within an area of 1 by 3 m horizontally beneath the icefoot. The position of the icefoot was marked with a nylon line. The position of the snails was not changed.

After three days the ice had retreated about 50 cm, but none of the marked snails had passed the nylon line. On the other hand, new unmarked snails had turned up between the icefoot and the line. When parts of the ice were chopped loose, snails were found lying in between small stones, loose ice and fine sand, which had a temperature of 1°C. See Fig. 1.

It seemed as if the margin of the operculum was fixed to the shell with mucus. When brought into a temperate room, the snails after some minutes crept about.

We cannot predict what minimum temperature the snails frozen up in the ice will be exposed to during winter time. Both *L. littorea* and *L. saxatilis* are well known cold-resisting animals, surviving for several days in –15°C (CANWISHER 1955). SØMME (1966) found the same species in the Oslofjord to be less cold-resistent than those found by CANWISHER. The combination of the cover of ice and snow and the relatively warm sea will probably give a higher temperature below the ice than in the air. The frozen up *L. saxatilis* in the icefoot at Sørgattet should indicate that these specimens will live under the cover of ice for 8–9 months, viz. from Setpember/October to July.

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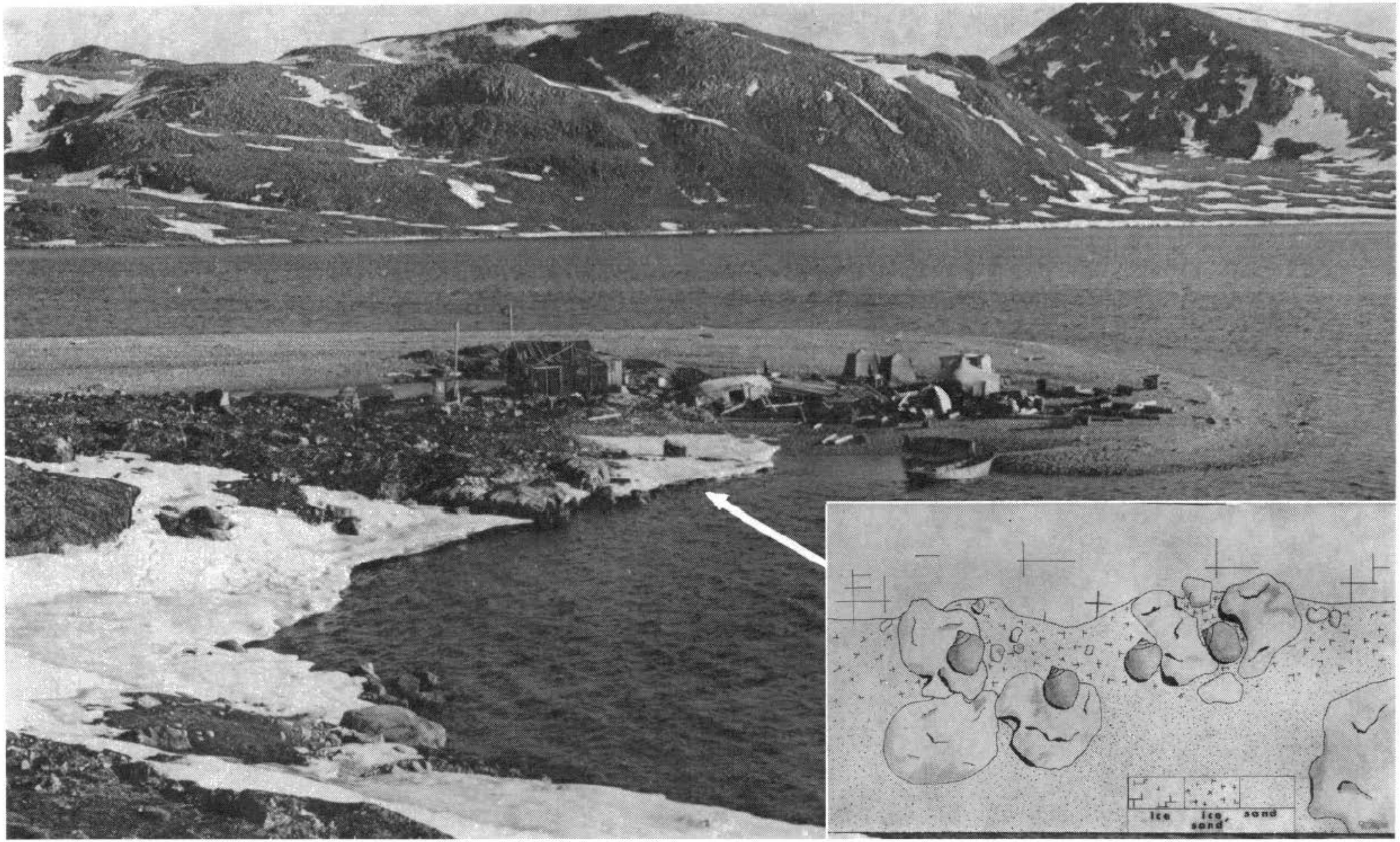
Fig. 1. *Sørgattet, Vestspitsbergen. The place where the snails were studied is shown by the arrow. Sketch of snails, ice, and sand inserted.*
Photo: T. OLSEN Sketch: F. AAREFJORD.


Ice
Ice sand
sand

A. W. BRØGGERS BOKTRYKKERI A/S - OSLO