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ÅRBOK 1961

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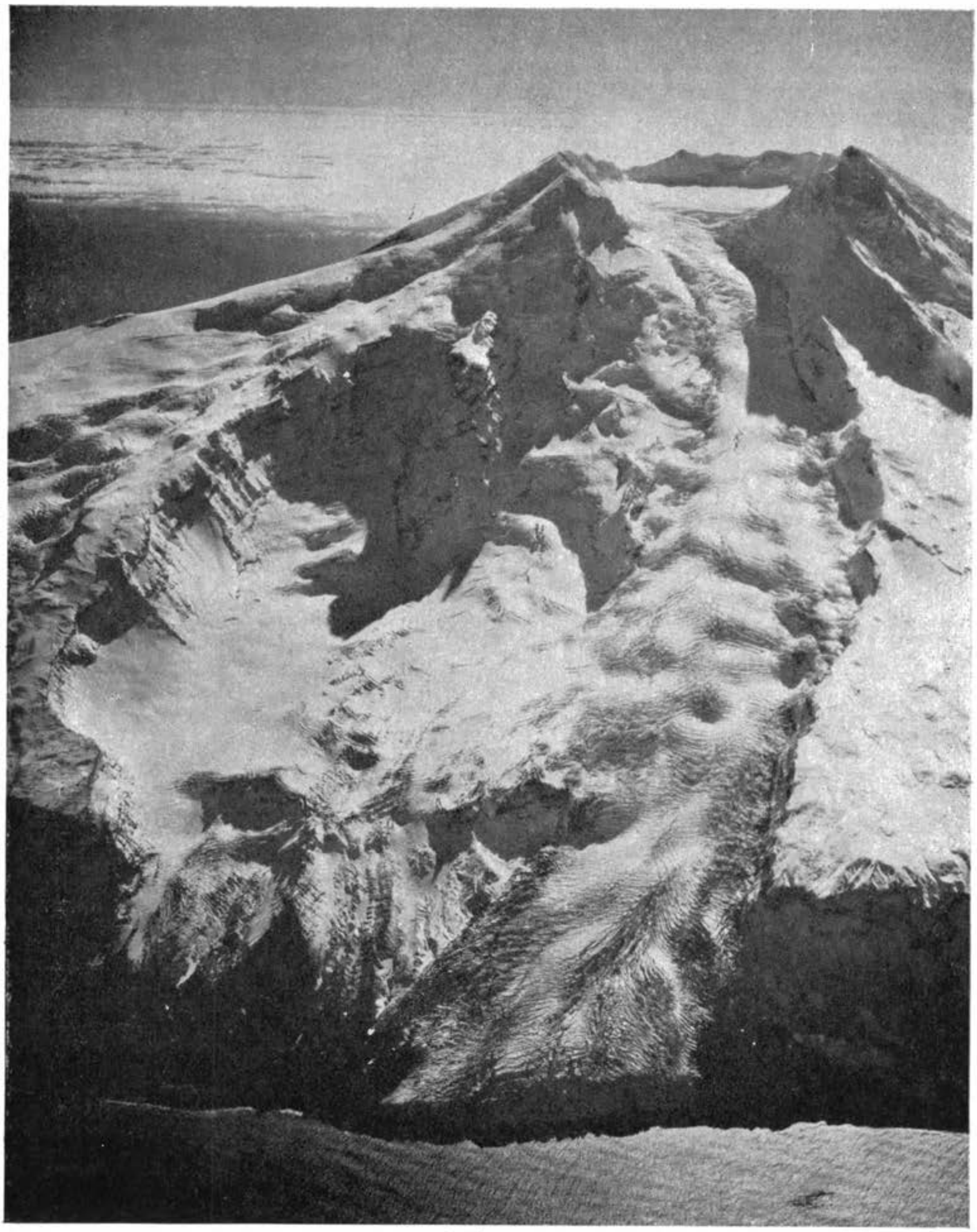

Beerenberg på Jan Mayen sett fra nordvest med Haakon VII Topp (2277 m. o. h.) til høyre. Weyprechtbreen bryter seg veg gjennom kraterrenden og ender i havet. Foto: B. LUNCKE.

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SCIENTIFIC RESULTS NO. 4

The cooling power in Antarctica

BY

TORGNY E. VINJE

Contents

Abstract

We have measured the cooling power at Norway Station (70°.5 S, 2°.5 W) with kata-thermometers for air-temperature (Ta) between +1 and —41° C, and for wind speeds (v) at 10 m level up to 27 m sec^{-1}. The linear proportionality of the cooling power (H) to (36.5–Ta), for a constant wind speed, is shown to hold in this temperature-interval for a wind speed less than about 12 m sec^{-1}.

We used four kata-thermometers, and it turned out that they gave systematic different values of the cooling power for equal meteorological conditions. Comparing the individual values with their mean we find a maximum deviation of about ± 20 %. We have supposed that this is due to errors in the calibration, subjective errors plus dissimilarities in the shape of the bulbs. The latter will cause differences in the turbulence around the bulbs, and consequently in the effective cooling of the wind. The possible difference in the cooling power of the air due to differences in the shape will probably not emerge during calibrations in a still air chamber.

In spite of the dissimilar climatic conditions in Antarctica and Europe we found that a formula based upon two of our Katas, with which we have taken by far the most measurements, corresponds fairly well to the mean of the Kata-formulae found in Europe. The maximum deviation of the values given by European formulae from those derived by the Norway Station formula is about ± 20 %. We have here omitted the formula of HILL (1919), as it reveals a fairly large deviation from the other formulae.

The Kata-formula can be written in the form $H = (a+bv^m)\,\theta$, where a, b and m are constants and $\theta = (36.5\text{–}Ta)$. LEHMANN found that m decreases with increasing vertical stability in the air-mass. We obtained $m = 0.42$, which is lower than any of his values, and this should be due to the relatively high vertical stability in Antarctica.

We found little or no effect of the short-wave radiation on the cooling power when this exceeded 40 mcal cm^{-2} sec^{-1}, so our formulae should give an expression of the cooling effect of the air and long-wave radiation only. The formula based on the wind speed at the 10 m level is

$$H = (0.46 + 0.08v)\,\theta \qquad \text{for } v < 12 \text{ m sec}^{-1},$$

and the formula based on the wind speed at the Kata-level is

$$H = 0.57\, v_0^{0.42}\, \theta \qquad \text{for } 1 < v_0 < 12 \text{ m sec}^{-1}.$$

Monthly and annual means of the cooling power have been calculated for most stations in Antarctica and for some stations in Europe.

We found that for $H < 25$ sun-bathing is possible in mid-summer, for $H > 65$ there is risk of freezing of exposed human skin, and for $H > 110$ mcal cm^{-2}sec^{-1} there is risk of quick freezing of exposed human skin.

Acknowledgements

The author is indebted to Mr. BJØRN GRYTØYR and Mr. HANS MARTIN HENRIKSEN for their great interest and valuable assistance at Norway Station.

The measurements were planned by Mr. VIDAR HISDAL, and the author wishes to express his gratitude to him and Mr. NILS JØRGEN SCHUMACHER for valuable discussions and suggestions.

Thanks are also extended to Mr. BJARNE EVENSEN, who drew the figures.

Instruments

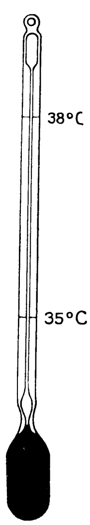


Fig. 1. *The kata-thermometer.*

The cooling power as measured with the kata-thermometer (short: Kata) is the mean loss of heat per sec from a dry kata-thermometer when the mean temperature in the fluid of the Kata sinks from 38° to 35° C (see Fig. 1). The four Katas we used at Norway Station (70°.5 S, 2°.5 W) were delivered from R. Fuess, Berlin, and calibrated at fixed room temperatures between 16° and 18° C in calm air at Bergakademie, Clausthal-Zellerfeld, Germany. The calibration constant for each Kata divided by the number of seconds which it takes for the fluid in the kata-thermometer to sink from 38° to 35° C, the Kata-value, gives us the cooling power expressed in mcal cm^{-2}sec^{-1}.

We used four Katas. Two of them broke due to great temperature differences between the glass and the air, and the other two because of the specially troublesome conditions.

The first Kata we used will be referred to as K_1, the second K_2, and so on. The calibration constant for K_1 was 540, for K_2 558, for K_3 544, and for K_4 546 mcal cm^{-2}. We made altogether 346 measurements with an air-temperature ranging from +1 to —41° C, and a wind speed between calm and 27 m sec^{-1} at the 10 m level.

Measuring technique

We used a thermos-flask with hot water for heating of the Kata to temperatures well above 38° C. The bulb of the Kata was dried very carefully with a wash-leather to be sure there was no water left, when exposing it to the air. The Kata-value we measured with a stop-watch to the nearest 1/10 of a second. We generally took series of four consecutive measurements of the Kata-value, and made a mean out of the three last ones to find the cooling power.

The Kata was exposed in open air by holding it vertically in the hand, as far as possible from oneself, and always so that the air passing the bulb was not hindered by one's own body or other nearby obstacles. In sunny weather the exposure was made in the shadow.

We made the measurements around noon once a day, and noted the prevailing weather conditions.

At and above a wind speed of about 12 m sec^{-1} we observed that some drifting snow melted on the bulb. To reduce the amount of melted water, the heating and drying were done underneath the hatch of the vertical exit. When the fluid was on the point of leaving the upper enlargement of the stem, the Kata was quickly handed over to a man outside, who measured the Kata-value.

Radiation influence

From the registrations of the global radiation (G) we observed that for a clouding-over G was generally not very much reduced compared with temperate regions. LILJEQUIST (1957) found that G was reduced to between 55 and 65 % of its original value at Maudheim, which lies near the coast. The sky above Norway Station, which lies 34 km inland, should not be influenced by the water-sky[1] to the same extent as above Maudheim, so we should expect less reduction here. We will use 65 % as an average, and for the value of the diffuse radiation from the sky in clear weather we will, according to our measurements, use 15 % of G.

The albedo of the snow surface we measured to be about 90 % in cloudy to overcast weather, and about 85 % in clear weather. Short-wave radiation, which can affect the bulb, is the diffuse one (D) from the sky and clouds, and the reflected one (R) from the snow surface. For the mean of the short-wave radiation, which hits an arbitrary orientated square centimeter on both sides, we then have:

In cloudy to overcast: $R + D = (0.9 \cdot G + G)0.65 = 1.24\ G$

In clear weather: $R + D = 0.85 \cdot G + 0.15\ G = 1.00\ G$

where G is the global radiation if there were no clouds. We see that the short-wave radiation, which can affect the bulb, should be greater in overcast than in clear weather, as we measured the cooling power in the shadow when we had sunshine.

[1] The term "water-sky" refers to the dark appearance of the clouds above open water.

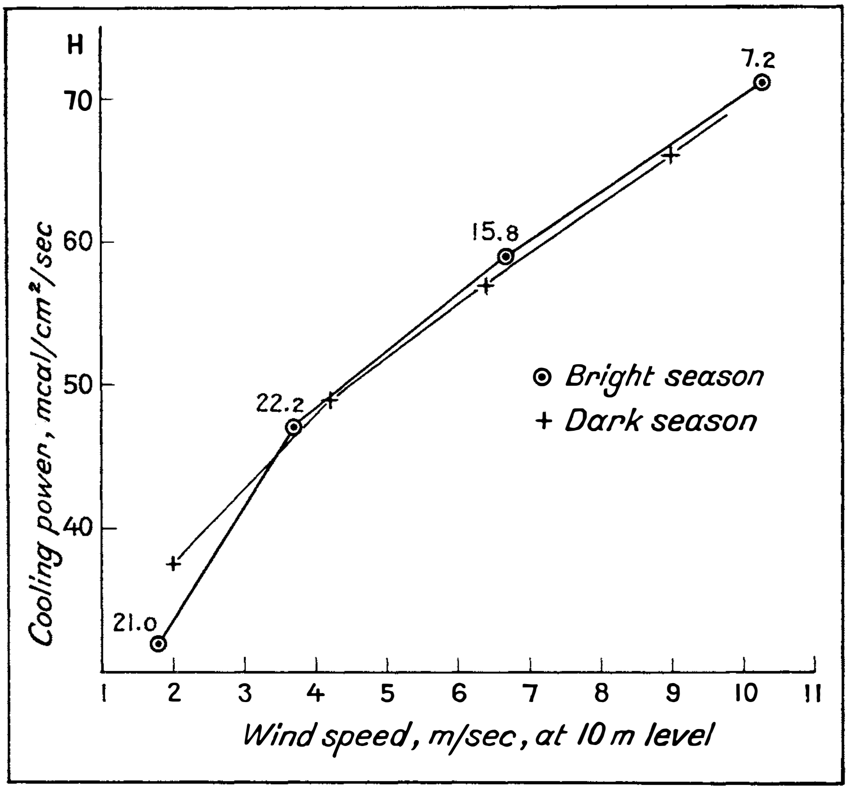


Fig. 2. *The connection between the cooling power and the wind speed at the 10 m level. The values are reduced to –20° C with the aid of Fig. 3. The numbers at the points are the mean short-wave radiation in mcal cm^{-2} sec^{-1} hitting the bulb.*

For K_3 we have chosen 32 measurements in the dark season, and compared them with 32 measurements in the bright season. In order to keep conditions as equal as possible, and to include the cases when we probably have most diffuse short-wave radiation, the total cloudiness is 6–8/8 for all measurements. The means of the observations are represented in Fig. 2, where all measurements are reduced to —20° C by aid of Fig. 3 (p. 12). According to Fig. 2 it seems that the short-wave radiation influence for cooling power above 45 mcal cm^{-2} sec^{-1} is negligible or even negative. A possible explanation for this could be as follows:

The long-wave radiation affects mainly the outer surface of the glass bulb, but the short-wave radiation affects the dark fluid just inside the glass. An expression for the cooling power could be written $H = \frac{\lambda}{x}(t_1 - t_2)$, where λ is the thermal conductivity of glass, x is its thickness, and t_1 and t_2 are the temperatures of the inner and outer side of the glass bulb. The long-wave net radiation reduces at first the temperature t_2, and should therefore increase the cooling power (for Ta< 36.5° C) which is natural, but the short-wave radiation energy will mostly raise the temperature t_1, having too little time, due to the small Kata-value, to be spread to the rest of the bulb, this will cause a greater temperature gradient, and consequently a greater cooling power. According to Fig. 2 it seems that for cooling power above 45 mcal cm^{-2} sec^{-1}, this latter effect is nearly equal to the expanding effect caused by the heating of the fluid. For lower cooling power it is possible that the short-wave radiation energy will have time enough to be spread to the rest of the bulb, and consequently lower the cooling power.

From Fig. 2 we find that for cooling power above 40 mcal cm^{-2} sec^{-1} the deviation of the two curves from their mean is less than $\pm$ 3 %.

Cooling power formulae

Proportionality of H to (36.5–Ta)

From Kata-measurements in Europe, with relatively high air-temperatures, formulae have been constructed of the form $H = (a + bv^m)\,\theta$, where a, b and m are constants and $\theta = (36.5\text{–}Ta)$. It is of interest to see if the proportionality between H and θ also holds for the relatively low temperatures at Norway Station.

For K_3, with which Kata we took most of the measurements, we have made a selection of the measurements with wind speeds of 27, 18, 12, 8 and 4 knots, i. e.: 14.0, 9.2, 6.2, 4.1 and 2.1 m sec^{-1}. We have chosen the mentioned wind speeds because these comprise the greatest number of measurements. For the different wind speeds we have formed group means with respect to the temperature. The results are represented in Fig. 3.

We see that for $v \leqslant 9.2$ m sec^{-1} the extension of the lines (for equal wind speed) intersects the abscissa near +36.5° C, which should mean that for a fixed wind speed H is very nearly proportional to (36.5–Ta). The group means in Fig. 3 for $\leqslant 9.2$ m sec^{-1} can be represented by the equation:

$$H = (0.42 + 0.09\,v)\,(36.5\text{–}Ta).$$

The maximum deviation of the group means from the values given by the formula is $\pm$ 2.9 %. From Fig. 3 we see that the deviation would have been less if we had used a somewhat lower temperature than +36°.5 C, but as the deviation is small, and moreover, as in nearly all other formulae constructed from Kata-measurements + 36.5 is used, we will keep to this.

We see from the figure that the proportion mentioned above does not hold for v = 14 m sec^{-1}. This is supposed to be due to melted snow on the bulb, which occurs for wind speeds higher than about 12 m sec^{-1}.

Differences between the kata-thermometers

The cooling rate, H/(36.5–Ta), will later on be represented with respect to the wind speed at the 10 m level and at the Kata-level. It is therefore important that these wind speeds are correct.

The anemometers used were constructed at the Meteorological Institute, Oslo, and they were calibrated before and after the expedition in two different wind-tunnels. The deviation from the mean of the two calibrations is less than $\pm$4.6 %.

As the height to the reference anemometer (see Fig. 4) decreased during our series of cooling power measurements, we have to reduce the noted wind speed to the 10 m level. This is done by aid of the investigations made by LILJEQUIST

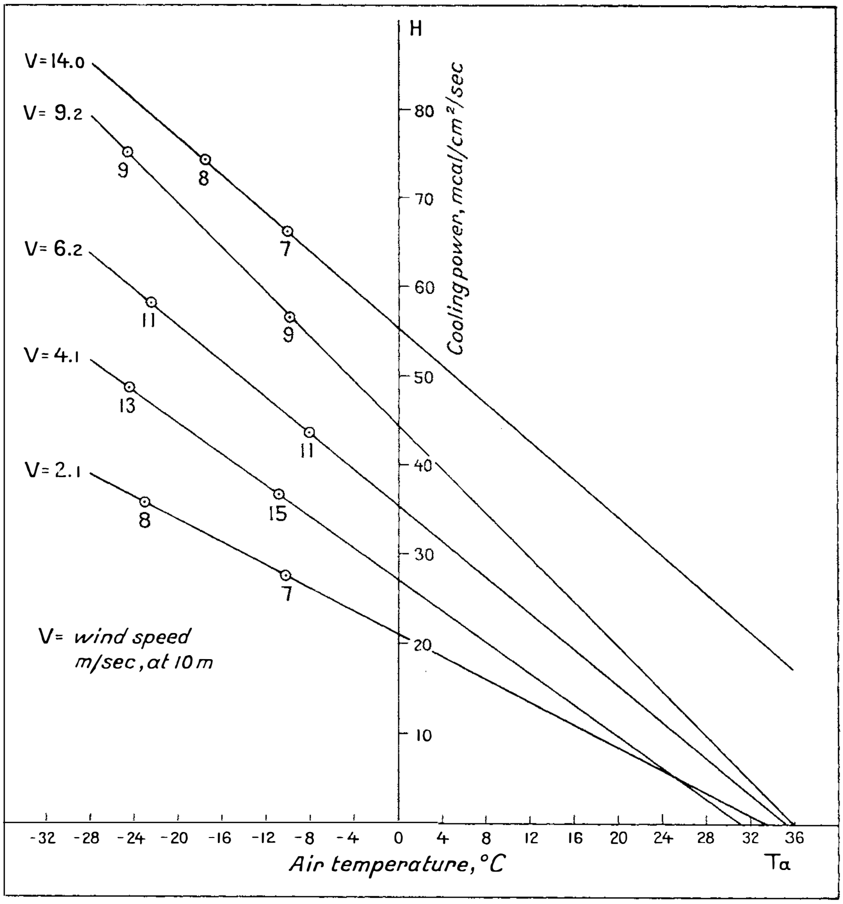


Fig. 3. *Relation between the cooling power and the air-temperature for different wind speeds.*

(1957) at Maudheim. For wind speeds above 8 m sec^{-1}, or for totally overcast, we have made the reduction by aid of the logarithmic wind-law for neutral stability. For wind speeds less than 8 m sec^{-1}, and a broken sky, the total cloud-cover has been taken as a probable indication of the vertical stability, as the latter is neutral, or very nearly so, in totally overcast weather, and has its highest value when the sky is clear. The reductions for the different groups are noted in Table I.

In Table I we have presented our measurements of the cooling power. We have omitted all observations with snowfall for wind speeds less than 8 m sec^{-1}. For higher wind speeds we have considered all measurements, as we then can expect drifting snow to hit the bulb whether is snows or not. At and above 12 m sec^{-1} we observed that the drifting snow generally melted on the bulb, the groupings of the measurements with respect to the wind speed in knots have therefore been made within the following limits: 0–1, 2–5, 6–10, 11–15. 16–20, 21–23, 24–30, 31–35 and so on.

Table I is represented in Fig. 5 a for v less than 12 m sec^{-1} for each kata-thermometer separately. We see that for a given wind speed the corresponding

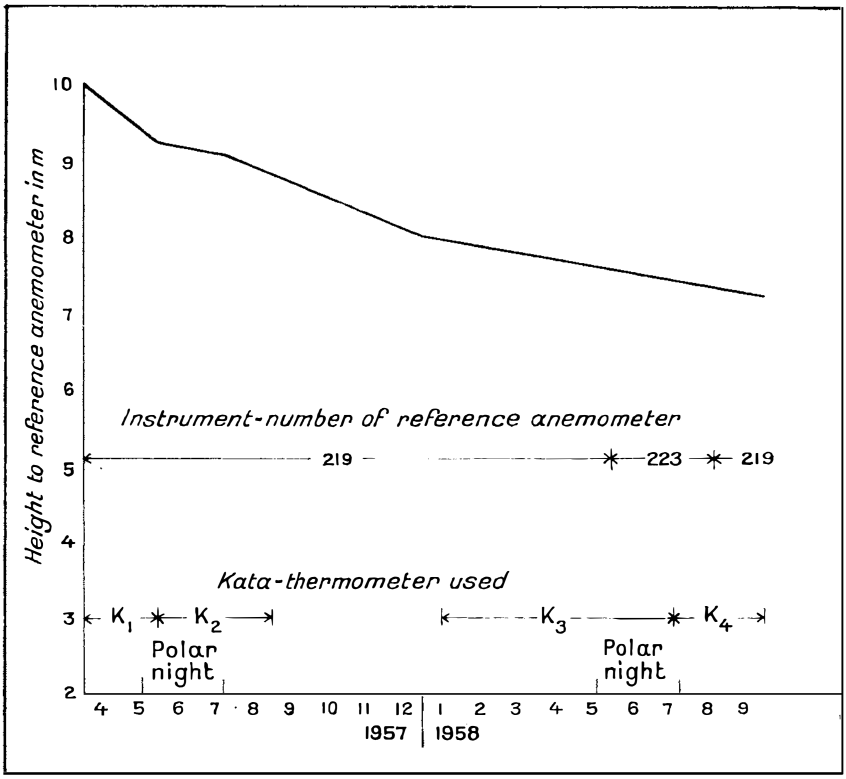


Fig. 4. *Number and height of the different reference anemometers.*

values of the cooling rate can differ very much from Kata to Kata.[1] At first we thought that this differences could be due to differences of the reference anemometers which sometimes were replaced (see Fig. 4). (Even though the anemometers were calibrated, this is done under far different meteorological conditions.) When using K_2 and K_3 we have some registrations of the wind speed also at the Kata-level, i. e. for another anemometer, and with respect to this wind speed we have represented the cooling rate for K_2 and K_3 in Fig. 5 b. Wi find for the Katas in question that the mean difference in the cooling rate is very near the same in the two cases, 17 and 18 % respectively. This indicates that the differences between the Katas should not be due to uncertain wind measurements. The cause of the differences should be sought elsewhere.

We consider the group means represented in Fig. 5 a, and find that the deviation of the cooling rate values for K_2 and K_3 from their mutual mean is maximum $\pm 9\%$. Taking all four Katas into account, we find that the maximum deviation is as high as $\pm 20\%$. In all probability this great difference is not caused by calibration plus subjective errors alone. It may indicate that there exists an additional source of error depending upon differences in the shape of the Kata-bulbs.

[1] Unfortunately, we were not aware of this difference when taking the measurements, so we have no simultaneous readings for our Katas.

Table I.

K_1

H	Ta	v	H/θ	Δv	n	N
30.1	19.9	0.4	0.53	0.0	4	6
40.3	23.0	2.1	0.68	0.0	1	7
47.5	16.8	4.2	0.89	0.0	5	6
64.1	16.8	9.2	1.20	0.0	3	
68.0	13.5	14.6	1.36	0.1	2	
77.1	6.8	17.7	1.78	0.1	1	

K_2

H	Ta	v	H/θ	Δv	n	N
38.7	29.6	0.3	0.59	0.0	5	3
50.3	31.8	2.1	0.74	0.1	19	4
61.0	29.4	4.3	0.93	0.2	14	4
68.6	24.7	7.3	1.12	0.3	18	6
72.6	18.3	9.3	1.33	0.1	13	
81.2	18.3	11.3	1.48	0.1	7	
78.0	15.2	13.9	1.51	0.2	11	
90.6	13.8	17.2	1.80	0.2	6	
105.5	13.5	20.3	2.11	0.2	3	
157.5	13.6	26.5	3.14	0.3	4	

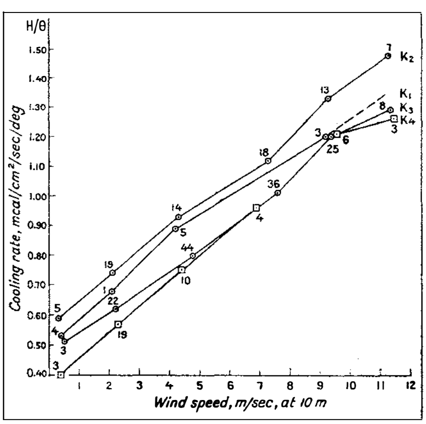
K_3

H	Ta	v	H/θ	Δv	n	N
30.0	22.7	0.5	0.51	0.1	3	5
34.5	18.8	2.2	0.62	0.3	22	5
44.3	19.2	4.8	0.80	0.6	44	5
52.5	15.3	7.6	1.01	0.9	36	5
65.7	18.4	9.4	1.20	0.2	25	
62.9	12.4	11.4	1.29	0.3	8	
70.1	14.1	13.9	1.39	0.3	24	
70.2	7.2	17.4	1.61	0.4	4	
99.7	13.5	19.8	1.99	0.4	7	
116.5	9.1	22.5	2.56	0.5	1	

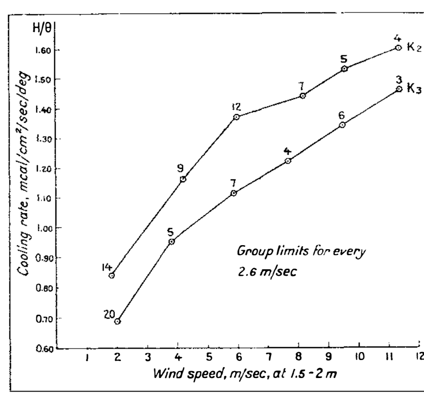
K_4

H	Ta	v	H/θ	Δv	n	N
26.3	29.0	0.4	0.40	0.1	3	3
37.9	30.0	2.3	0.57	0.3	19	5
50.0	30.6	4.4	0.75	0.6	10	5
60.7	27.1	6.9	0.96	1.0	4	4
74.7	25.4	9.6	1.21	0.3	6	
77.3	25.1	11.5	1.26	0.3	3	
70.5	19.3	14.5	1.26	0.4	3	
88.9	23.0	17.1	1.49	0.5	2	
111.0	19.4	20.3	1.99	0.6	3	
127.0	14.6	27.7	2.49	0.8	1	

In Table I is H the cooling power in mcal cm^{-2} sec^{-1}, Ta negative temperature in °C, v wind speed reduced to 10 m level in m sec^{-1}, $\theta = (36.5 - Ta)$, Δv correction of v due to change in the height to the reference anemometer, n number of observations, and N mean total cloudiness.



a



b

Fig. 5a and b. *Variation of the cooling rate with wind speed at 10 m level (a) and at Kata-level (b).*

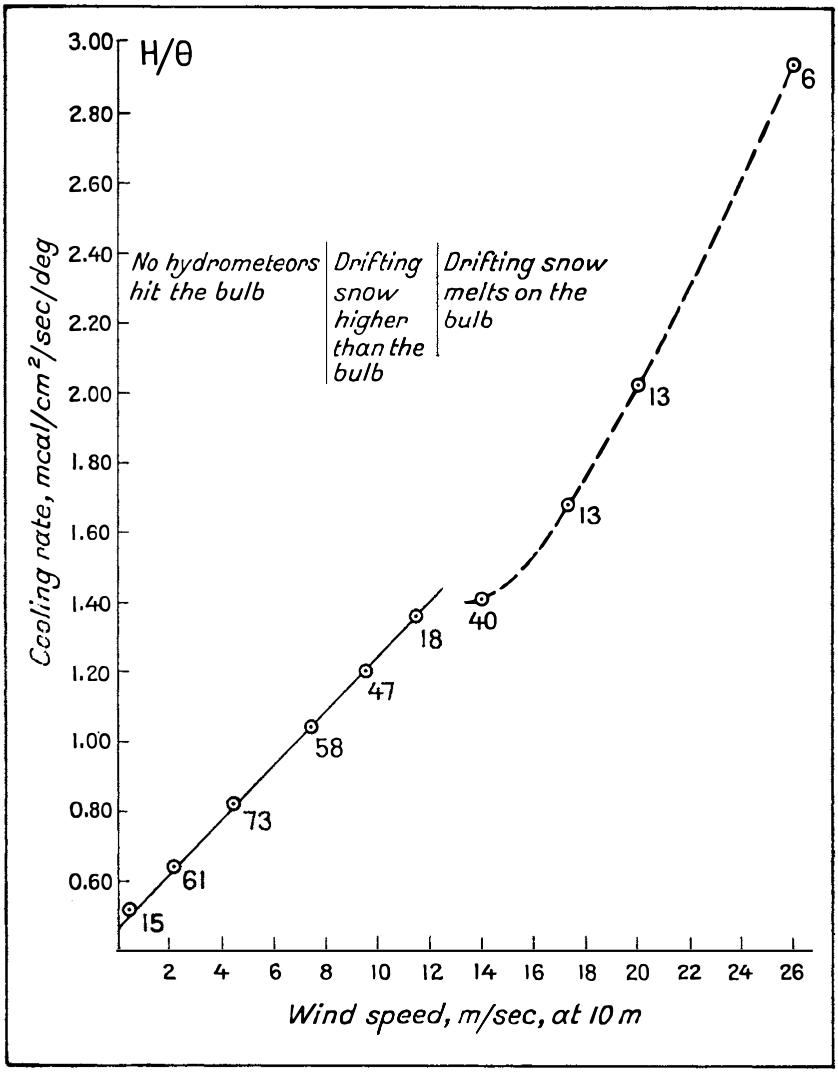


Fig. 6. *Variation of the cooling rate with the wind speed at 10 m. Mean for all four Katas.*

As the wind has the greatest effect upon the cooling power, it is reasonable that small dissimilarities in the form of the Kata-bulbs will lead to marked differences in the cooling powers measured, as the effective turbulence around the bulb is dependent on its shape. A difference in the effective cooling of the wind cannot be found in a still-air chamber, and will therefore not be involved in the instrument factor.

To make no preference of any instrument, we have formed the arithmetic mean of the group means to construct a formula. The group means of the cooling rates are represented with respect to wind speed at 10 m level in Fig. 6. For wind speeds at and above 12 m sec^{-1}, the drifting snow melts on the bulb, and we can no longer expect the found cooling rates to be relevant to dry air cooling power measurements.[1] The curve above 12 m sec^{-1} is therefore indicated by a broken line. For wind speeds below 12 m sec^{-1} we see that the group means lie very nearly on a straight line, which can be expressed by the equation

$$\text{I.} \quad H = (0.46 + 0.08v)(36.5 - Ta)$$

The maximum deviation of the groups in Fig. 5 a, from the respective values derived from this equation, is ± 20 % around 0.5 m sec^{-1}, decreasing to ± 8 % at about 12 m sec^{-1}.

Comparison of formulae

For the comparison with other formulae, where the wind at the height of the kata-thermometer (v_0) is referred to, we have used a mean formula for K_2 and K_3 based on wind measurements taken at this height (see Fig. 5 b). By the method of least squares we get

$$\text{II.} \quad H = 0.57 v_0^{0.42} (36.5 - Ta) \qquad v_0 > 1 \text{ m sec}^{-1}$$

Other formulae which have been formed from kata-thermometer measurements in Europe are as follows:

$H = (0.27 + 0.49 \sqrt{v})\theta$	HILL 1919
$H = (0.14 + 0.49 \sqrt{v})(33 - Ta)$	HILL
$H = (0.13 + 0.47 \sqrt{v})\theta$	HILL 1923
$H = (0.14 + 0.49 \sqrt{v})\theta$	WEISS 1925
$H = (0.10 + 0.40 \sqrt{v})\theta$	BRADTKE 1926
$H = \sqrt{0.29 (0.26 + v)}\theta$	ANGUS, HILL, SOPER 1930
$H = (0.123 + 0.465 \sqrt{v})\theta$	BEDFORD, WARNER 1933
$H = (0.113 + 0.34 v^{0.622})\theta$	LEHMANN 1936
$H = (0.375 + 0.316 \sqrt{v})\theta$	JORANGER 1955[2]

Some of these formulae are represented in Fig. 7.

There is a wide spreading of the curves. This makes the differences which have been found between our four kata-thermometers more understandable. We see that our curve, as the mean of two Katas, is approximately central. If we omit the formula of HILL 1919, which deviates quite markedly from the others, the deviation of the cooling rates evaluated from our formula is less than about ± 20% from those evaluated with help of the other formulae for $v_0 > 1$ m sec^{-1}. This should be compared with the maximum deviation found between our Katas, namely ± 20 %.

Most of the formulae are written as a function of the form $H = (a + bv^m)\,\theta$. LEHMANN found a marked variation of m with respect to the air-masses.

[1] The melting of the snow could possibly be due to better contact between the snow and the bulb as it is reasonable to expect that the snow grains will be pulverized when colliding with the bulb above a certain speed.

[2] Personal communication.

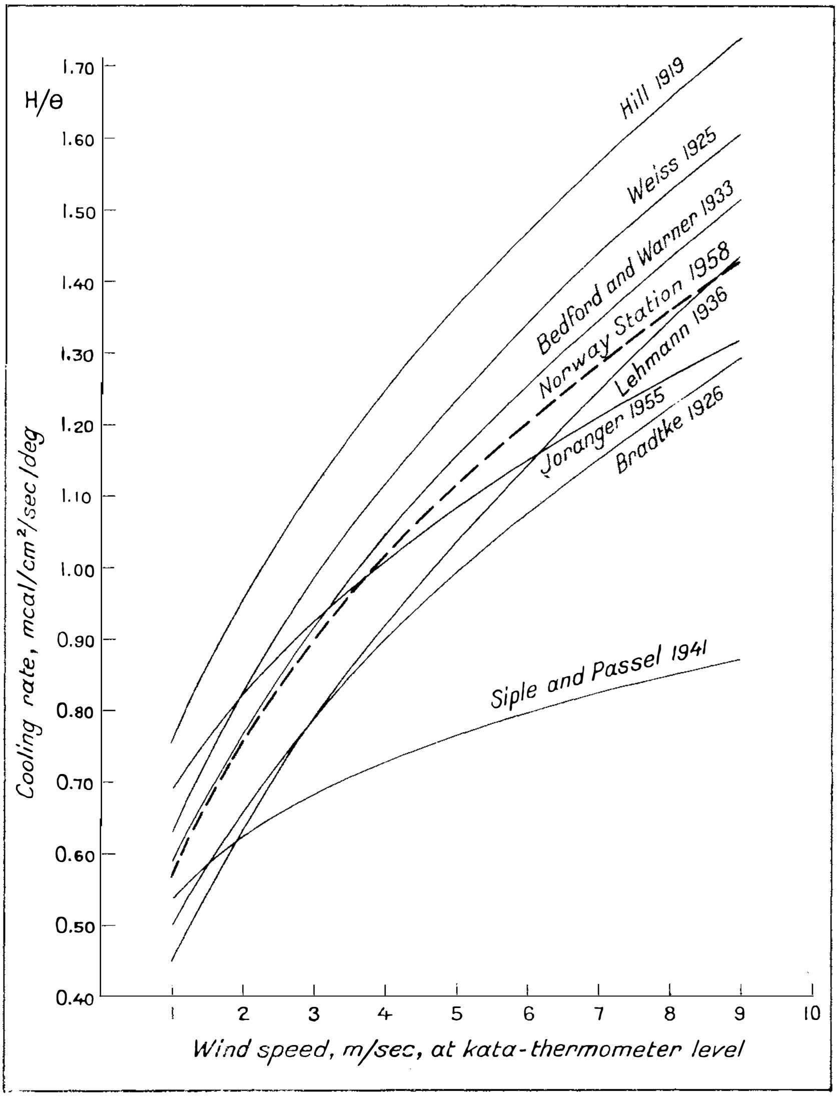


Fig. 7. *Graphical representation of different Kata-formulae. The Siple and Passel curve is based on theirs special relative comfort thermometer constructed in Antarctica.*

He arrived at the following results:

Airmass	m	mean wind m sec^{-1}	number of observations
mAC	0.727	4.20	189
mPC	0.685	3.00	243
mPW	0.552	2.89	189
mTW	0.514	4.75	114

LEHMANN says: «Je kälter das Ursprungsgebiet der Luftmasse ist, desto steiler ist die Steigung der Windabhängigkeitskurve. Die Erklärung für diese Erscheinung liegt wieder in der Struktur des Windes begründet. Die arktischen und polaren

Luftmassen weisen in unseren Breiten während der warmen Jahreszeit naturgemäss eine höhere Instabilität auf und sind viel turbulenter als die tropischen.» In other words the less the stability the greater the value of the exponent m. We found m = 0.42, and this relatively low value could then be explained by the great stability prevailing in Antarctica.

SIPLE and PASSEL (1945) measured the atmospheric cooling of 250 gr of water during freezing period in their special relative comfort thermometer at Little America in 1941. As this method of finding the cooling power is quite different from ours, the two results cannot be directly compared, but the graphical representation of their formula, $H = \frac{1}{36}(\sqrt{100v} + 10.45 - v)(33 - Ta)$, in Fig. 7, will give information of the difference between them. It is natural that their formula gives lower values than a kata-thermometer as the conductive loss of heat from the water at zero °C must be less than that from a kata-thermometer with temperature about +36° C, and in addition the effective turbulence around the smaller Kata bulb is probably greater.

Cooling power at Norway Station

We will compare the cooling power with the stage of relative human comfort as observed at Norway Station.

On sunny, calm days in mid-summer the air temperature could rise to about zero ° C. Under such conditions sun-bathing was possible, and the calculated cooling power is about 17 mcal cm^{-2} sec^{-1} in the shade. When it started to blow under such conditions, a wind speed of about 2–3 m sec^{-1} at 10 m level, made sun-bathing unpleasant or impossible, i.e. the heat balance of the human body becomes negative. This increase of wind-speed implies a raise in the cooling power to about 25 mcal cm^{-2} sec^{-1}. (We see from the formula that this value of the cooling power would also have been reached if, in calm weather, the air-temperature had been decreased from zero to about —18° C.)

When the cooling power exceeded 65 mcal cm^{-2} sec^{-1} the skin in the face was often lightly frost-bitten when doing work outdoor. FRAZIER (SIPLE and PASSEL, 1945) made measurements of the freezing time for exposed human flesh at Little America in 1941. The air-temperature and wind speed is given for only one of his series, viz. —32.5° C and 7 m sec^{-1}. This corresponds to a cooling power of 70 mcal cm^{-2} sec^{-1} according to our formula. In this case FRAZIER finds that the freezing time varies from 6.3 minutes down to 20 seconds from person to person.

For as high cooling power as 110 mcal cm^{-2} sec^{-1} we once found that exposing the face to the wind caused very quick freezing of the skin.

Relating the cooling power to the stage of relative human comfort we get:

Cooling power, mcal cm^{-2} sec^{-1}	Description
<25	Sun-bathing possible in mid-summer.
>65	Risk of freezing of exposed human skin.
>110	Risk of quick freezing of exposed human skin.

An interesting phenomenon in mid-summer is the rapid change in the human comfort due to change in the wind speed. This can be illustrated by the change in the cooling power. If, for instance, we have 0° C, and calm, the cooling power will be about 17 mcal cm^{-2} sec^{-1}. If now the wind speed increases to 20 m sec^{-1} the cooling power will raise to 75 mcal cm^{-2} sec^{-1}; and thus the situation is changed from that when we could take sun-bath to that where there is risk of dangerous cooling of the exposed human skin.

In Fig. 8 we see the variation of the monthly mean cooling power (calculated, formula I) from year to year for Norway Station. The highest value is 78 and the lowest is 39 mcal cm^{-2} sec^{-1}. Out of 32 months we have 9 months with a mean cooling power higher than 65 mcal cm^{-2} sec^{-1}.

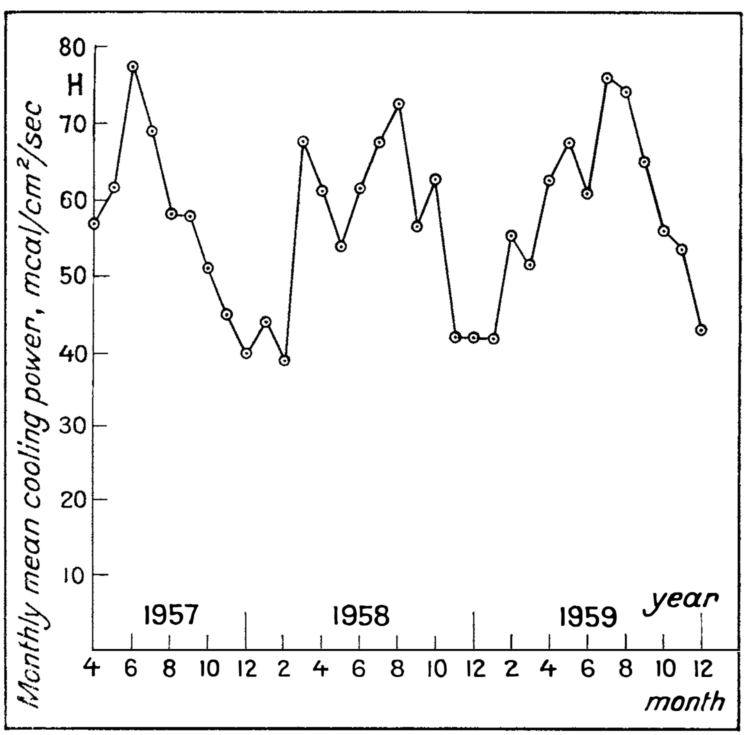


Fig. 8. *Annual variation of the calculated monthly mean cooling power at Norway Station.*

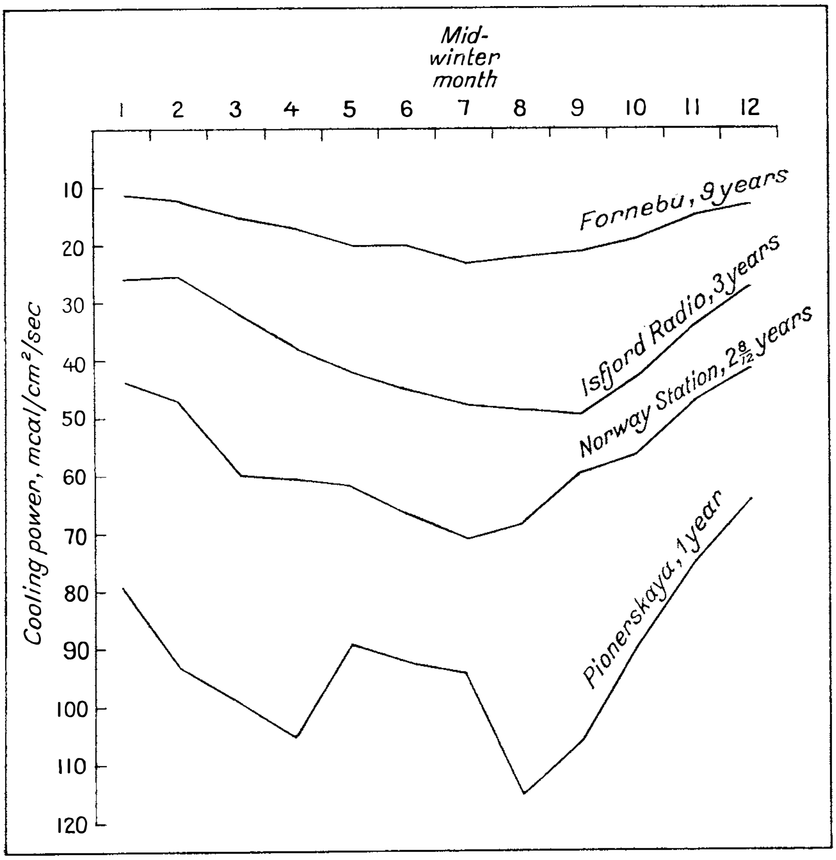


Fig. 9. *Annual variation of the monthly mean cooling power for selected stations in Antarctica and Europe.*

In Fig. 9 we have represented the calculated values of the monthly mean cooling power for stations in different climatic regions. We have chosen Oslo (Fornebu airport), Isfjord Radio (Spitsbergen), Norway Station, and Pionerskaya — the station on the Antarctic inland plateau which has highest cooling power.

Cooling power at Antarctic and Sub-Antarctic stations

In Fig. 10 we have represented the annual mean, highest and lowest monthly mean cooling power of some stations, as calculated from our formula I and the ordinary meteorological means of temperatures and wind speeds. All stations represent one year or more. The values given represent different periods, which are listed on the figure. The cooling power for the inland stations are reduced according to HILL's experimental formula $H_1 = \frac{H_0}{2}\sqrt{1 + \frac{p_1}{p_0}}$ where H_1 is the cooling power at air-pressure p_1 and H_0 is the calculated cooling power at sea-level pressure p_0. The reduction amounts to 16–20 %.

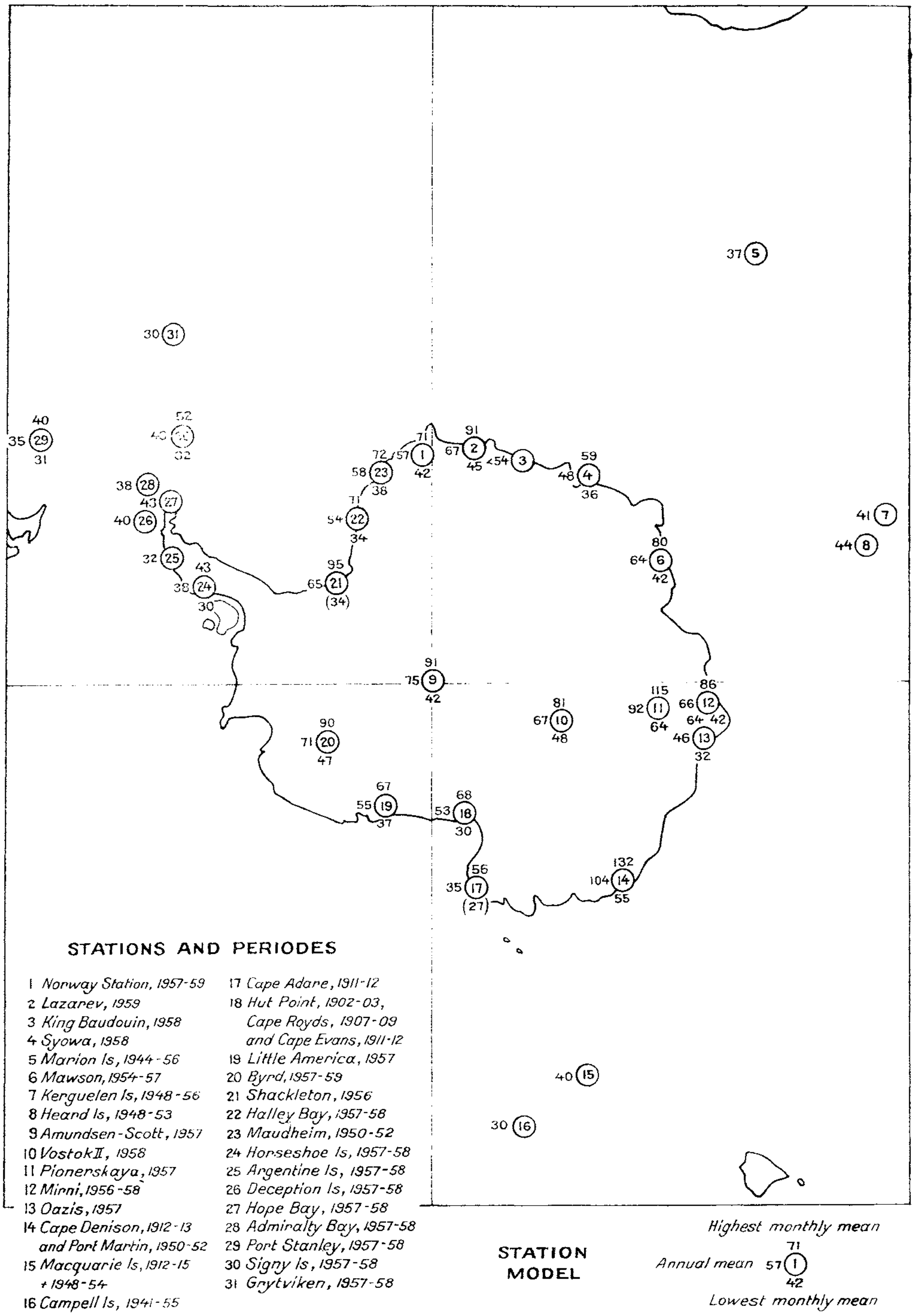


Fig. 10. *Cooling power chart for the Antarctic.*

We see that for the coldest season most stations in Antarctica have a maximum monthly mean cooling power higher than 65 mcal cm^{-2} sec^{-1}, i. e. values which involve risk of freezing of exposed human skin, and Pionerskaya and the Adélie Land coast stations have a maximum monthly mean cooling power higher than 110 mcal cm^{-2} sec^{-1}, when there is a risk of quick freezing of exposed human skin. Even for the "warm" season the lowest monthly mean cooling power for Pionerskaya is as high as 64 mcal cm^{-2} sec^{-1}. We see that, except Cape Adare and the stations on Palmer Peninsula, the annual mean cooling power is higher than about 45 mcal cm^{-2} sec^{-1} for the stations in Antarctica.

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New investigation on the structure of Arctolepis from the Devonian of Spitsbergen

BY

ANATOL HEINTZ

Contents

Abstract

Some well preserved specimens of *Arctolepis decipiens* (WD) collected in Spitsbergen in 1960 are described. The rostral plate in these forms, and probably in the majority of other Arctolepida, are very broad and compose the front part of the dermal head-roof – from one preorbital process to the other. The postnasal in the described form does not compose a part of the head-roof, but probably a minute more or less independent plate, situated between the suborbital, the preorbital and the rostral – in the same way as in the Brachythoraci. In my opinion the "postnasal" described in some Arctolepida by BRYANT (1934), DENISON (1958) and STENSIØ (1942, 1945) is, probably, not an independent plate at all, but only a part of the rostral.

The large suborbital, the small postsuborbital and the sclerotic ossifications are described from *Arctolepis decipiens.* The comparatively large sclerotic ossifications consisted of four plates and protecting almost the entire eye-ball, leave only a fairly narrow oval (?) opening at the front and a small round one at the bottom – the latter probably for the optical nerve.

No traces of the gnathal elements have been discovered in the described complete and well preserved forms, which indicate that they were composed of the cartilage only.

Introduction

During two brief visits to the innermost part of Dicksonfjorden in 1959 and 1960 (in connection with the preparation for and the actual excursion of the XXI International Geological Congress (N. HEINTZ, 1962)) some interesting new remains of Arctolepida were collected by THORE S. WINSNES, NATASCHA HEINTZ, and myself.

The following is only a short account of some new features in *Arctolepis,* as a more detailed and complete description will be given by Dr. TOR ØRVIG, Stockholm, in a paper on the Arthrodira from the Devonian of Spitsbergen.

Head-shields of Arctolepida are not abundant in the Devonian deposits of Spitsbergen, and they are only occasionally found together with the body-carapaces, which means that it very often is difficult to determine with certainty which types of headshields and body-carapaces belong to one another. I have therefore (HEINTZ, 1929, a, b) introduced the name "*Svalbardaspis*" to the isolated heads, which could not with certainty be correlated to the body-carapaces.

In material previously described from Spitsbergen, no traces of cheek-plates have been discovered in Arctolepida. This also applies to the majority of the forms described from other parts of the world (BRYANT, 1932, 1934; DENISON, 1958; HEINTZ, 1933; STENSIØ, 1942, 1945).

In 1959 WINSNES found two very large slabs of red Devonian sandstone on the SE slope of the mountain Lykta about 300 m above the bottom of Nathorstdalen. These slabs obviously had not been moved far from the original beds, as the entire slope in the vicinity was covered with very coarse debris. In several places, too, rocks of approximately the same appearance were seen in situ.

These slabs contained an unusually large amount of well preserved fossils – *Doryaspis* and *Arctolepis* being predominant. By using dynamite one slab was blasted in 1959 and the other in 1960. Especially the latter contained a great number of exceptionally well preserved fossils – mostly the two species, *Doryaspis nathorsti* (LANK.) and *Arctolepis decipiens* (WD.). The fossils, however, were not isolated plates or shields, but more or less complete specimens. The *Doryaspis* shows all the smaller plates in the frontal region in natural position and all the tail-scales are well preserved. In four of the *Arctolepis* specimens the head-shields were found in the natural position to the body-carapaces and some of the cheek-plates were also preserved in situ. However, no traces of fin-skeletons, body-coverings or fragments of the vertebral column have been discovered. This very probably indicates that the skeleton of the fins and the vertebral column was purely cartilaginous and that the posterior part of the body has not been protected by any kind of solid bony scales. Since the minute cheek- and sclerotic plates of *Arctolepis* and the very fine scales and plates of *Doryaspis* were so well preserved and undisturbed, it seems highly improbable that the calcified or ossified parts of the inner skeleton or the body scales, if present, should completely disappear.

The rostral region

The development of the rostral region can be seen in four of the new specimens (P.M.O. A 28629, A 28639, A 28637 and A 28603). Especially two of them are well preserved. The first represents a weathered head-shield with clearly developed ossification radiations and distinct sutures between the plates (Fig. 5). The second – a well weathered minute slab containing only one head-shield – also distinctly shows the ossification radiations, but the sutures between the plates are not so pronounced (Pl. I, 3, 4. Fig. 1).

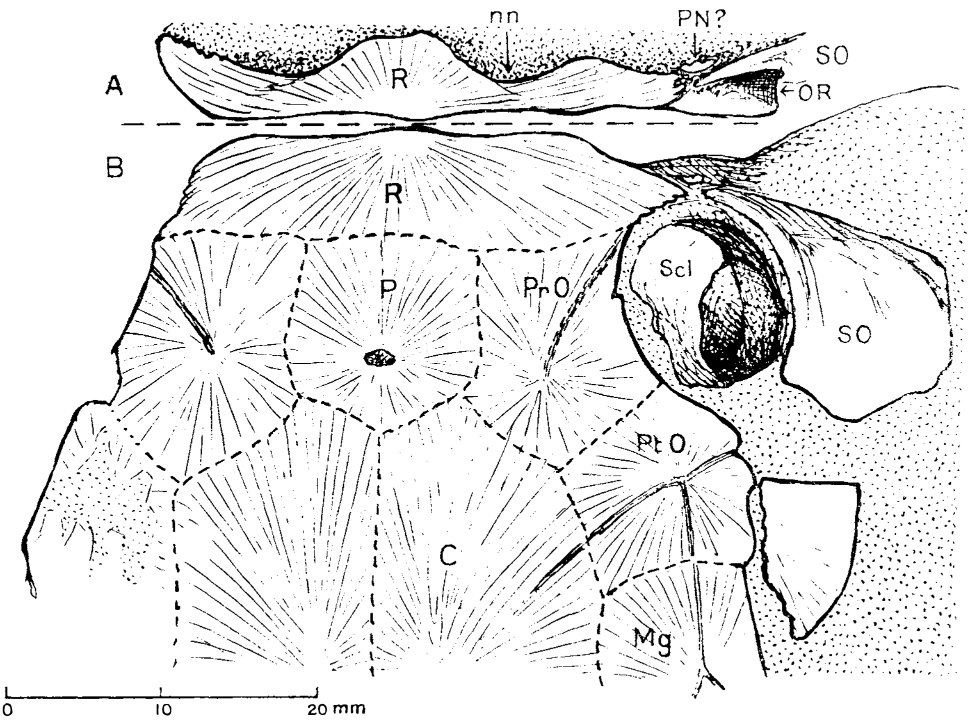

Fig. 1. *Arctolepis decipiens* (WD). (P.M.O. A 28637). Front part of a weathered head-shield. A – front view; B – seen from above. Explanation to the letters see p. 40.

As may be seen from the figures, the rostral plate in the specimens are short but broad, forming the entire front part of the head-shield between both the preorbital processes. The pineal plate is of medium size, well limited both from the rostral, the preorbital and the central plates. The moderately sized preorbitals are separated from one another by the pineal plate. The frontal region of the head-shield shows a characteristical pattern – the rostral plate composing the anterior border, followed backwards by two preorbitals between which the pineal plate is situated (Fig. 1, 2, 3c, 4, 5, 8).

In my description of *Arctolepis* (=*Jaekelaspis*) *solnørdali* (HEINTZ, 1929 b) I gave a somewhat different reconstruction of this region (Fig. 3 A). The preorbitals continue to the front margin of the head, composing the preorbital processes, while the rostral plate narrows and becomes more rounded. The pineal plate is more triangular and relatively minute. DENISON proposed (1958) yet another reconstruction of the same head (Fig. 3 B). The anterior part of the preorbital in my reconstruction is now separated as an independent "postnasal", through which the orbital canal runs to the very front of the head.

A more thorough investigation of the original has, however, proved that DENISON's as well as my own interpretation were incorrect and that the development of the anterior part of the head-shield of *A. solnørdali* (Fig. 3 C) completely corresponds to that described here in *A. decipiens* (Fig. 1, 2, 4, 5, 8). The difference, however, between the old and the new reconstructions does not refer only

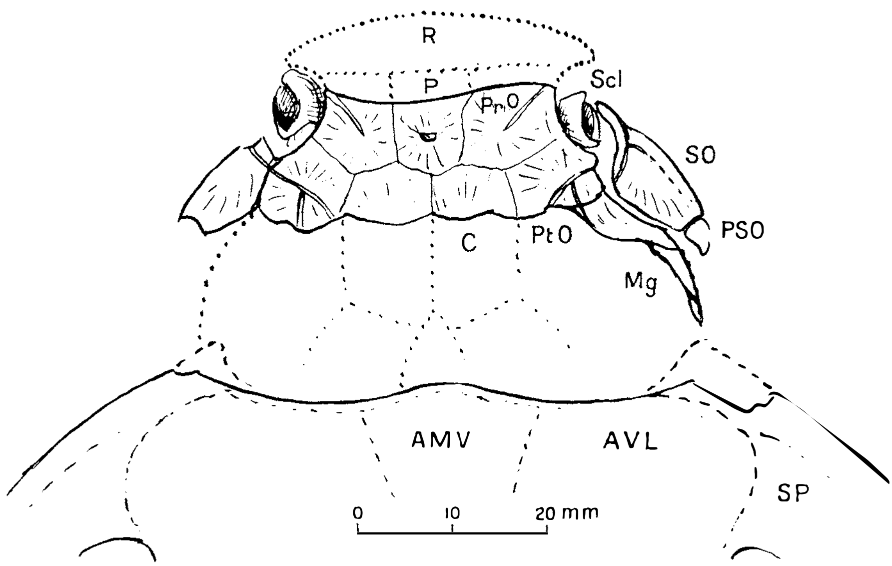

Fig. 2. Parts of the head-shield and body-carapace of *Arctolepis decipiens* (WD). (P.M.O. A 28603). The head-shield seen from the dorsal side, the body-carapace seen from the ventral side. Explanation to the letters see p. 40.

to the boundaries between the plates, but also to the absence of the "postnasal" (DENISON) and to the course of the supraorbital canal. This actually stops close to the orbital notch and does not continue on to the lateral corners of the rostral (regarded by DENISON as the postnasal). In two of the new specimens (A 28639, A 28629) and in some specimens which I have seen in Stockholm, the uppermost part of the supraorbital canal curves strongly in an anterio-median direction and continues for a short distance on to the rostral plate, running in the direction of its ossification centre (Fig. 4, 5).

Apparently, therefore, the postnasal of *Arctolepis* does not exist as a part of the head-roof and DENISON's reconstruction (1958) cannot be correct. This is quite obvious after having examined the rostral region of all the new *Arctolepis* from Svalbard as well as that of the best preserved older specimens. In none of them there is any sign of independent ossifications near the preorbital processes. On the contrary, the ossification rays from the rostral continue uninterrupted to the very lateral point of the preorbital processes and no traces of any sutures or intersection of the ossification rays at any angle can be seen (Pl. I, 4. Fig. 1, 3c, 5, 8). This is especially important as the sutures between the rostral, the pineal and the preorbital plates as a rule are very clearly indicated by the course of the ossification rays (Pl. I, 4. Fig. 1).

Owing to the kindness of Dr. ØRVIG, I had the opportunity during a visit to Stockholm in May 1962 to study a large number of head-shields of different Arctolepids, many of which were excellently prepared. These had been collected in Spitsbergen, mostly by the English–Norwegian–Swedish expedition in 1939. This material will later be described by ØRVIG. In all the more or less well preserved specimens, where either the ossification rays or the sutures between the

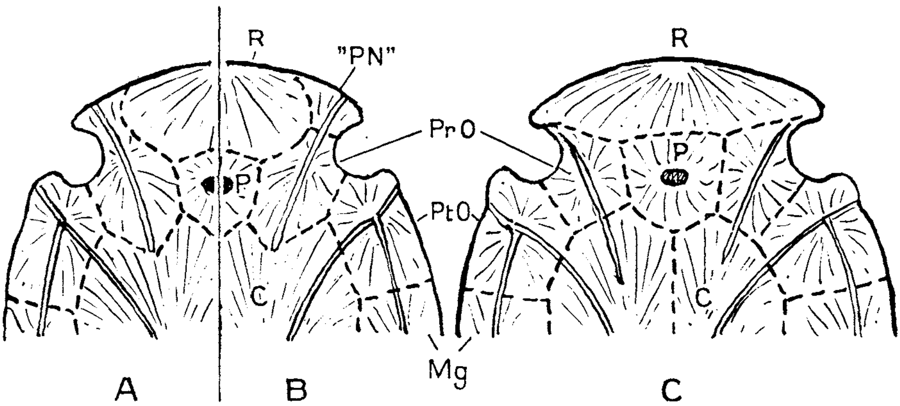

Fig. 3. *Arctolepis solnørdali* (HTZ) (P.M.O. B 099). Reconstruction of the front part of the head-shield. A – according to HEINTZ, 1929 b; B – according to DENISON, 1958; C – new reconstruction. Explanation to the letters see p. 40.

plates could be seen, (more than 20) the rostrals were developed in the same way as in the species described in this paper. No trace of postnasal could be discovered, except in one rather badly preserved specimen with fragments of the suborbital. Here, however, a minute plate or plate-fragment was situated between the front part of the suborbital and the lateral corner of the rostral (preorbital process). These fragments are, however, so badly preserved, that at the moment it is difficult to state if they actually are parts of postnasals. But at any rate in none of the examined specimens does the postnasal constitute a part of the preorbital processes as assumed by DENISON.

Very often the rostral region of the *Arctolepis*-forms from Spitsbergen is strongly compressed dorso-ventrally and consequently does not give any clear idea of its configuration. In the specimen A 28637, however, the shape of the frontal part of the rostral region can clearly be seen and the rostral plate is only moderately compressed[1] (Pl. I, 3, 4. Fig. 1, 9). Seen from the front, the rostral in this specimen is considerably thicker in the median part, becoming thinner towards both sides and thickening again on both the lateral corners (preorbital processes). Two not very deep "nostril notches" (nn) (Pl. I, 3. Fig. 1, 9) are thus developed on the underside of the rostral. In the configuration of the front part of the rostral the *Arctolepis* strongly brings to mind the development of the same region in *Kujdanowiaspis* (STENSIØ, 1942, Fig. 3). *Arctolepis*, however, does not have anything as such deep "nostril notches" and no ossifications limiting them from the ventral and lateral sides. Apparently these parts were in *Arctolepis* wholly cartilaginous. But there can hardly be any doubt that fairly large wholly cartilaginous, or to some extent ossified nasal sacs, were developed immediately below the rostral in these forms too. They were protected from the sides by the thickened median parts of the rostral, but not by the postnasal, as STENSIØ believes to be the case in *Kujdanowiaspis*.

[1] This is also the case in a number of ØRVIG's specimens.

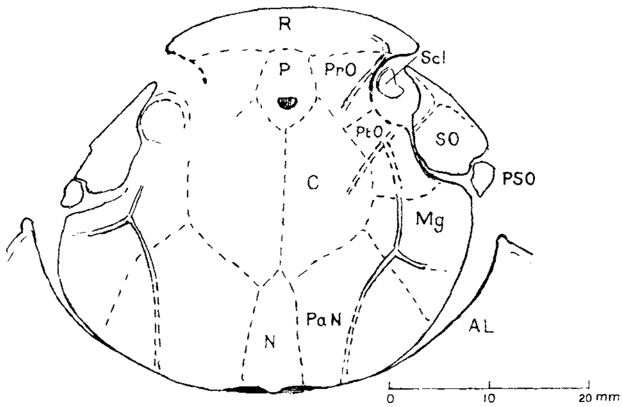

Fig. 4. *Arctolepis decipiens* (WD). (P.M.O. A 28639). Headshield and part of the dorsal body-carapace. Explanation to the letters see p. 40.

Thus it is obvious that the postnasal of *Arctolepis* from Spitsbergen does not constitute the preorbital processes. It would therefore here be of interest to discuss the development of the postnasal of Eoarthrodira in general and of Arctolepida in particular.

The postnasals are well known in the Brachythoraci and has been described in many specimens by several authors (GROSS, 1932; HEINTZ, 1931, 1932, 1938; JAEKEL, 1902, 1925; STENSIØ, 1925, 1934, 1945; TRAQUIER, 1890 b, and others). The postnasal of all known forms is a more or less minute plate, situated between the rostral, the preorbital and the suborbital. It limits the nostrils laterally, or post-laterally (STENSIØ, 1942), while the rostral and the ventral internasal process of the rostral limits them dorsally and medially. The supraorbital sensory canal from the preorbital usually runs across the postnasal and onto the suborbital.

The development of the postnasal of Arctolepida, however, is not by far so well known. The first to mention this plate in Arctolepida was WOODWARD (1891) in his description of *Phlyctaenaspis acadica* WHIT. However, he called it, the "premaxillare" – a name proposed by TRAQUAIR in 1890, for the postnasal of *Coccosteus decipiens* AG. STENSIØ (1925) redescribed the same specimen of *Phlyctaenaspis*, terming the mentioned plate "plate L" – the name he used for the postnasal. Upon re-examining the same specimen HEINTZ (1933) reached the conclusion that both WOODWARD and STENSIØ had misinterpreted the plate in question – actually it was one of the sclerotic plates and not the postnasal at all. On the other hand HEINTZ has not been able to prove the presence of the postnasal in *Phlyctaenaspis*, but in front of the suborbital he discovered fragments of a minute plate, which, however, was so badly preserved that it was impossible to reconstruct its form and size (HEINTZ, 1933, p. 129). In his reconstruction of *Phlyctaenaspis* the postnasal therefore is indicated by dotted lines only.

In all other hitherto described Arctolepida, with the exception of *Bryantolepis, Aethaspis, Anarthraspis* and *Kuidanowiaspis,* the presence of the postnasal is uncertain and only indicated in some reconstructions by dotted lines (comp. DENISON, 1958, Fig. 105).

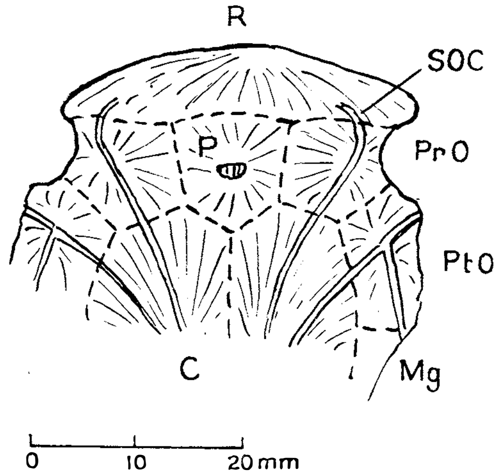

Fig. 5. Weathered head-shield of *Arctolepis decipiens* (WD) (P.M.O. A 28629) with well preserved sensory canals and boundaries between each of the plates. Explanation to the letters see p. 40.

In *Bryantolepis* (= *Euryaspis*) (BRYANT, 1932, 1934; CAMP, WELLS and GREEN, 1946; DENISON, 1958), the postnasal is depicted as a large plate, forming the greater portion of the latero-frontal part of the dermal skull-roof on both sides of the relatively minute rostral and pineal (Fig. 6 A). Although the fossils seem to be fairly well preserved, the reproduced photographs are not sufficiently distinct. That the boundary between each of the plates have been drawn in black or white, and the stone round the fossils also is coloured, results in obscuring the natural outline of the single plates and makes the whole shields indistinct.

In all reconstructions, however, given both by BRYANT (1932, 1934) and DENISON (1958) the postnasals are very definitely marked, in spite of BRYANT saying (1934, p. 134) that "the bones of the cranial roof in *Euryaspis* (= *Bryantolepis*) are so completely fused that only in a few specimens can their outlines be determined, and in distinguishing between them, one is forced to rely upon the general shape of the head-roof". DENISON (1958, p. 492) also points out that the pineal and postnasal "are fused to the preorbital". In two specimens of *Bryantolepis* in the Palaeontological Museum in Oslo (P. M. O. A 27118 and A 27116) the sutures between the plates in the frontal region of the head are not very clear, while the course of the sensory canals, among others the supraorbital, are more distinct. However, no traces of the ossification centres or ossification rays are preserved. Neither have BRYANT and DENISON mentioned the development of these structures which are so important for the determination of the boundaries and shapes of the plates in the skull-roof. Thus it is very difficult to ascertain, based only on the published photographs, reconstructions and the two specimens from our museum, whether the proposed boundaries between the plates in the rostral region in *Bryantolepis* are correct. Actually, it seems more likely that the arrangement of the plates was more or less similar to that in *Arctolepis* and that the postnasal did not form a part of the dorsal skull-roof. In Fig. 6 B I have attempted to indicate the possible position of the plates in the rostral region of

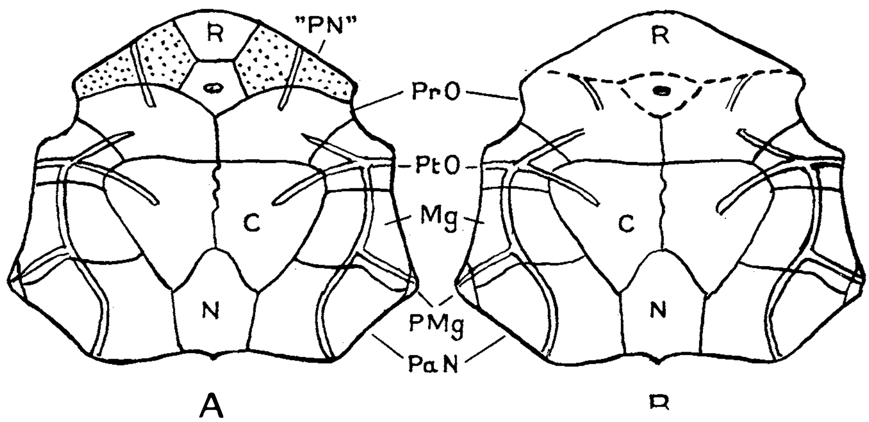

Fig. 6. *Bryantaspis brachycephalus* (BR), reconstruction of the head-shield: A – according to BRYANT 1934; B – new reconstruction. Explanation to the letters see p. 40.

Bryantolepis, an arrangement which corresponds to that known in *Arctolepis*. It is to be hoped that a more thorough investigation of *Bryantolepis* may solve this problem.

The two other American Arctolepida, the postnasals of which have been described, are *Aethaspis* and *Anarthraspis*.

In both forms the postnasals are depicted in the reconstructions only as minute plates on both sides of the rostral (DENISON, 1958, Fig. 105 A, B, E). Describing *Aethaspis* DENISON mentioned that "the postnasals were apparently extremely small" (p. 479). In one specimen he finds that the "anterior end of the preorbital is cut off in a concave fashion just lateral to the supraorbital sensory line; presumably the postnasals are absent here". In the other specimens "the preorbitals are continuous with an anterior lobe that continues the convex rostral contour; probably the anterior parts of the lobes represent the postnasals, completely fused to the preorbitals" (p. 479) (spaced-out letters by the author). As may be seen from the description and from the figures and photographs, the presence of the postnasal in *Aethaspis* is questionable. No clear sutures or distinct ossification centres can be identified and even DENISON expresses himself very cautiously when describing the position of the postnasal. Probably a more careful investigation of the known specimens will prove that the postnasals in *Aethaspis* are not developed in the manner shown in the reconstructions.

In *Anarthraspis* the matter is even more complicated. The reconstructions and photographs of this form published by BRYANT (1934) do not show the postnasal. On the contrary the *Anarthraspis* depicted in Fig. 6 by BRYANT on this point corresponds very well with the Spitsbergen forms: the rostral is very broad, though short, and no postnasals are seen. DENISON (1958, Fig. 105 E), however, gives a new reconstruction with a large, protruding "rostral region", composed of the rostral, the pineal and the two relatively large postnasals, but in the text he only states that in *Anarthraspis* the rostral and pineal are comparatively long and narrow and the postnasals "do not project so far laterally in front of the orbits"

(p. 511). DENISON mentions that his reconstruction is based on two specimens and he also refers to an isolated rostral, figured by BRYANT (1934, Pl. 24, 3). However, no photographs or more accurate descriptions of these specimens are given, so at the moment it is impossible to state with certainty which one of the two reconstructions – BRYANT's or DENISON's – is the more correct, and also whether the postnasals were developed in *Anarthraspis* at all. Personally I believe that a re-examination of the known specimens of *Anarthraspis* will show that the rostral region of this form was developed in the same way as in the forms from Spitsbergen, and that the postnasals do not constitute a part of the dorsal head-roof.

The last of the Arctolepida, where the postnasals are described, is *Kujdanowiaspis* from Podolia, which has been examined by STENSIØ. On STENSIØ's photographs and reconstructions (1942, 1945) the postnasals are situated in the anterio-lateral corner of the "rostral region" and form the preorbital processes (Fig. 7 A). They border on the rostral and pineal, but have only a short common boundary with the preorbital. The supraorbital canal runs to the anterio-lateral corner of the preorbital, but does not continue on to the postnasal.

STENSIØ, however, points out that "as in most Acanthaspida (=Arctolepida) the bones of the dermal skull-roof are so intimately fused that the course of the sutures between them cannot be made out with accuracy". Further on he also mentions that "the centres of radiation of the rostral and pineal plate are clearly distinguishable", but "the centre of radiation of the postnasal plate is not discernible, but .... was probably situated deep below the upper face of the bone" (STENSIØ, 1942, p. 4). Describing the postnasal in more detail, STENSIØ writes that "the centre of radiation of the postnasal is so obscure that its exact position cannot be ascertained. Judging from the shape of the postnasal, however, it must be assumed to be situated in the ventralmost part of the bone, approximately at the angle between the lateral and ventral portion of the subnasal lamina. The radiation in the upper part of the lateral vertical portion of the bone thus in all probability passed fairly straight upwards. It is only natural therefore that the radiating structure is very obscure on the dorsal face of the bone which enters in the formation of the dorsal face of the dermal skull-roof. This seems to explain why in Acanthaspids (= Arctolepids) in general the postnasal is very badly defineable from the rostral and pineal plates and why, except in *Euryaspis* (= *Bryantolepis*) and *Kujdanowiaspis*, it has so far been overlooked in this group of Arthrodires" (STENSIØ, 1942, p. 13) (spaced-out letters by the author).

In STENSIØ's photograph (1942, Fig. 1) it is impossible to see any traces of centres of radiation or radiation rays on the postnasals, but in the reconstruction (1942, Fig. 2) the ossification rays run more or less from the anterio-lateral corner of the preorbital process (Fig. 7 A).

As we have seen, STENSIØ's assumption that the postnasal "has so far been overlooked" in Arctolepida, is not correct – at least not with regard to the *Arctolepis* from Spitsbergen. In all hitherto investigated forms the course of the ossification rays and the development of the sutures between the plates in the rostral region proves that the postnasal *was not* developed in this region and thus did not

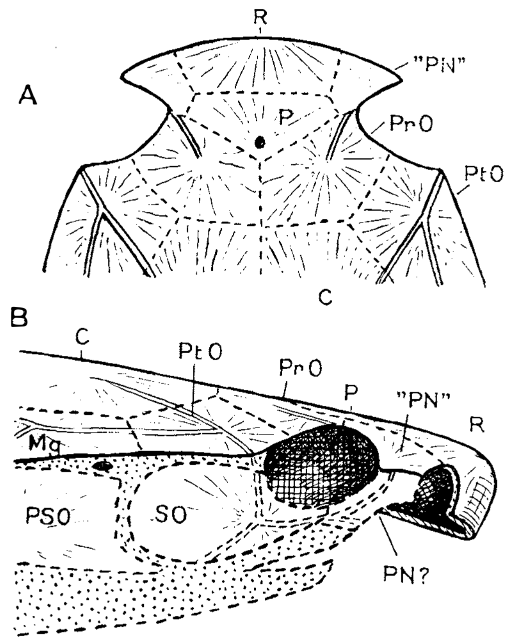

Fig. 7. *Kujdanowiaspis rectiformis* (BRTZ). Reconstruction of the front part of the head-shield seen from above (A) and from the side (B). Somewhat altered after STENSIØ, 1942. Explanation to the letters see p. 40.

constitute a part of the dermal skull-roof. On this point *Arctolepis* corresponds completely with most of the Brachythoraci – where the postnasal is not incorporated in the dermal skull-roof, but composes one of the more or less free dermal cheek-plates (GROSS, 1932; HEINTZ, 1931, 1932, 1938; JAECKEL, 1902, 1925; STENSIØ, 1925; TRAQUAIR, 1890 b, and others).

In my opinion, therefore, it is unprobable that the postnasal in *Kujdanowiaspis* composes the anterio-lateral corner of the rostral region, as mentioned by STENSIØ (1942). Most likely this region consists of the rostral and pineal plates only. Neither, to my mind, can the reconstructions of Arctolepida, proposed by DENISON (1958, Fig. 105) where the postnasals are indicated by dotted lines only, give a true picture.

However, only by a re-examination of *Kujdanowiaspis* as well as of *Aethaspis* and *Anarthaspis* can this problem be solved and evidence be found of whether Arctolepida have two different or only one common plate-pattern in the rostral region.

The suborbital and postorbital

Up to now the dermal cheek-plates in Arctolepida have not been very well known and only the suborbital has previously been described (BRYANT, 1932; DENISON, 1958, HEINTZ, 1933). The other cheek-plates referred to in literature are, firstly, a more or less questionable "internal", mentioned by HEINTZ (1933) in *Phlyctaenaspis acadica*, and, secondly, some well preserved but doubtful cheek-plates of an indeterminable Arctolepid from Utah, USA, described by DENISON (1958).

However, the suborbitals are also only known in a few forms. BRYANT (1932, Pl. 7, 1) has figured a badly preserved suborbital of *Euryaspis* (= *Bryantolepis*). A more complete suborbital of the same form was later depicted by DENISON (1958, Fig. 106 C). Another plate, determined by BRYANT (1932, Pl. 10, 1) as the "rostro-pineal" of *Anarthraspis montanus,* is, according to DENISON (1958, Fig. 106 E), actually a suborbital. A well preserved suborbital of *Phlyctaenaspis acadica* was described and depicted by HEINTZ (1933, Pl. 1, Fig. 1), and, lastly, DENISON (1958, Fig. 94 C and 106 F) mentions a suborbital of a new form *Aethaspis utahensis*.

The characteristic feature of all hitherto known suborbitals of Arctolepida is the anterior process ("handle" (HEINTZ, 1932)) being markedly, though to varying degrees, short. In most forms it is also comparatively broad (DENISON, 1958, Fig. 106). As known in the Brachythoraci the "handle" is generally long and narrow (GROSS, 1932, 1937; HEINTZ, 1931, 1932; STENSIØ, 1934, 1942, and others).

In the Arctolepida from Spitsbergen no suborbitals or fragments of such have hitherto been described. However, collections from the English–Norwegian–Swedish Spitsbergen-expedition in 1939, now in Stockholm, contain some specimens the suborbital of which is more or less well preserved. These will be treated in ØRVIG's forthcoming paper on Arthrodira from Spitsbergen.

The three best specimens, collected in 1960, have fairly distinct suborbitals. These lay in the natural position to the head-shield as well as to the body-carapace (Pl. I, 1, 2; Pl. II. Fig. 1, 2, 4).

The characteristic feature of the suborbital of *Arctolepis decipiens* (WD.) is the relatively deep orbital notch (Pl. I, 1; Pl. II, 1. Fig. 1, 2, 4, 8), this being more expressed than in any hitherto described suborbitals from Arctolepida. This results in the anterior process becoming rather slender and comparatively long, but of course nowhere nearly as long as in a typical Brachytoraci.

The posterior part ("the blade" (HEINTZ, 1932)) is more or less expressedly triangular, broadest at the middle and the lower margin being moderately convex. The anterio-dorsal margin first shows a moderate impression whereupon it runs rather steeply down to the base of the anterior process. The posterio-dorsal margin, on the other hand, is more slack and moderately convex. On the posterior corner of the blade a distinct, relatively deep angular indentation is developed, not reported from the suborbitals of any other Arthrodira. This indentation can clearly be seen in three well preserved suborbitals (Pl. I, 1; Pl. II. Fig. 2, 4), and therefore obviously has not been caused by some accidental damage.

The surface-sculpture of all our plates is badly preserved, being only partly visible. The sensory canals, too, are undistinct, a few more or less doubtful traces only having been observed here and there. Nevertheless it seems obvious that the infraorbital canal runs more or less parallel to the anterio-dorsal margin and cuts the ventral margin of the anterior process (Fig. 8).

The shape of the suborbital of *Arctolepis* and its position (Pl. I; Pl. II) clearly shows that the configuration of the posterio-dorsal margin of this plate corresponds well with the shape of the lateral margin of the head-roof. The postorbital process fits into the impression on the very top of the suborbital and its posterio-dorsal margin runs alongside the lateral margin of the postorbital and marginal (Pl. I, 1). Accordingly it will seem that the "internal" (= "ventral postorbital" STENSIØ) was not developed in *Arctolepis*.

The postorbital has never been described in any Arctolepida. In the reconstruction of *Kujdanowiaspis*, however, STENSIØ (1942, Fig. 7 B) indicates its probable size and position. As seen in two of our specimens (Pl. I; Pl. II. Fig. 2, 4) the postsuborbital is only a minute, more or less rhombic plate, the anterior corner of which fits perfectly into the indentation on the posterior corner of the suborbital (Fig. 8). The ventral and dorso-lateral margins of the postsuborbital thus are the immediate prolongations of the corresponding margins of the suborbital (Pl. I, 1, 2; Pl. II, 1. Fig. 2, 4). Accordingly, when placed in the correct position to the head-shield, the suborbital and the postsuborbital of *Arctolepis* seem to give the head-roof a remarkably round outline (Fig. 8). From the above (Fig. 8 A) the head-roof appears to compose a kind of "cover" over the anterior opening of the body-carapace. The rostral part seems to have run fairly far downwards and was situated only slightly higher up than the ventral surface of the body-carapace (Fig. 8 B).

As seen from the reconstruction and from the best preserved specimens (Pl. I, 1, 2; Pl. II, 1) the anterior process of the suborbital does not reach the rostral, and the orbital openings, accordingly, would not have been closed in front. This, however, is rather improbable and in my opinion a minute plate must have been developed here in the same way as in the Brachythoraci. In STENSIØ's side-view reconstruction of *Kujdanowiaspis* (1942), too, the presence of a kind of "tissue" connecting the suborbital with the front part of the head-roof is indicated (Fig. 7 B).

In the specimen A 28637 (Pl. I, 4) and, to a certain extent, also in the specimens A 28636–39 and A 28603 (Pl. I, 1, 2; Pl. II) fragments of a minute plate situated between the preorbital process and the anterior point of the suborbital can be seen. This minute plate is especially distinct in specimen A 28637 (Fig. 9), but here, too, it is too badly preserved to be identified as a definite independent plate. With regard to the position of this plate and its relation to the other plates, it corresponds to the postnasal of the Brachythoraci. I therefore presume that this plate actually is the real postnasal and that accordingly the postnasal of Arctolepida does not compose a part of the dermal head-roof, as assumed by BRYANT (1934), DENISON (1958), and STENSIØ (1942, 1945).

Between the other plates – only rarely seen in Arctolepids – is the postmarginal. This plate is depicted in several reconstructions (comp. BRYANT, 1934; DENISON, 1958; STENSIØ, 1942) but has never been described in detail. The postmarginal is always comparatively badly preserved and is more or less indistinct in the reproduced photographs.

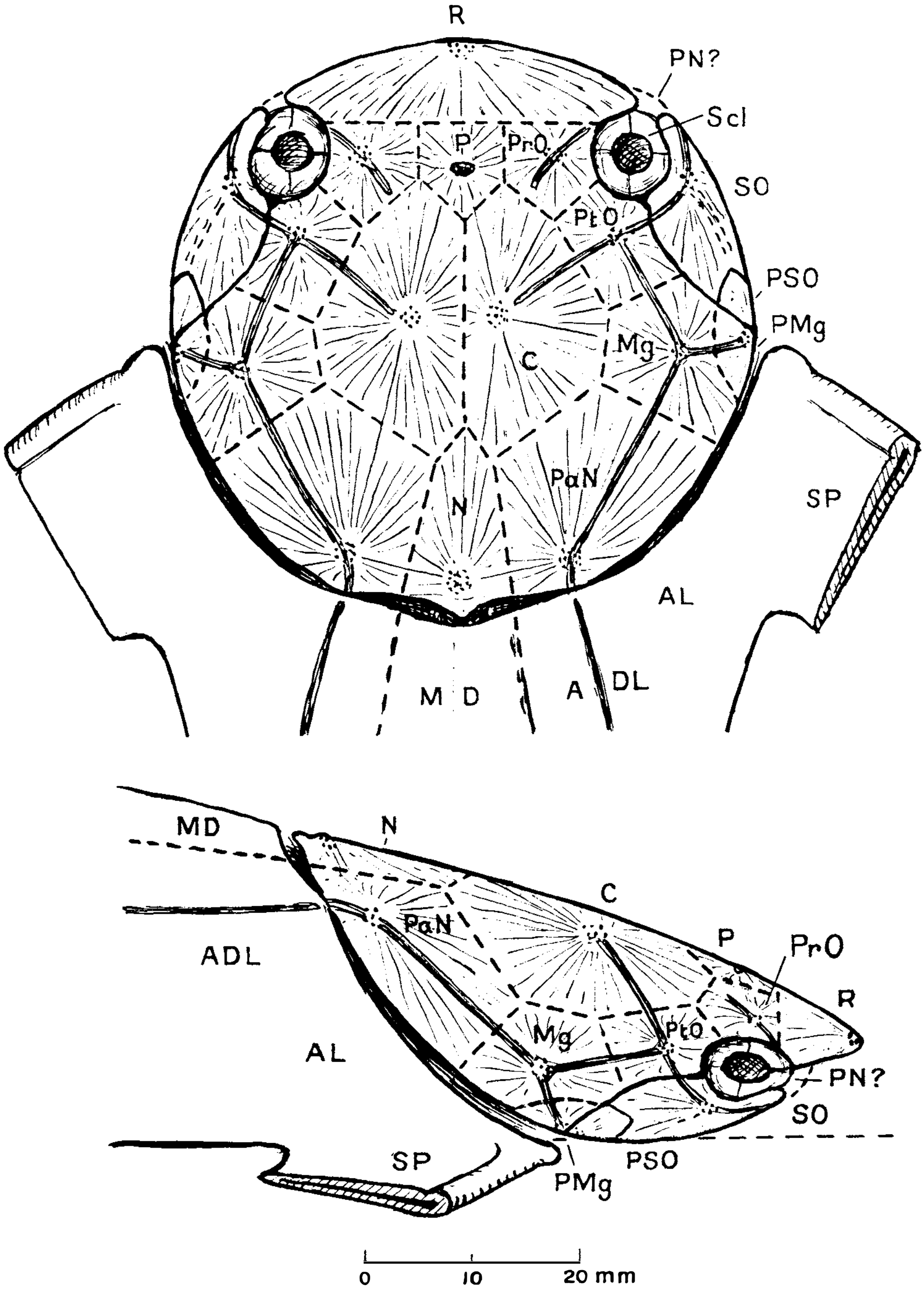

Fig. 8. *Arctolepis decipiens* (WD). A semidiagrammatical reconstruction of the head-shield: A – from above; B – from the side. Explanation to the letters see p. 40.

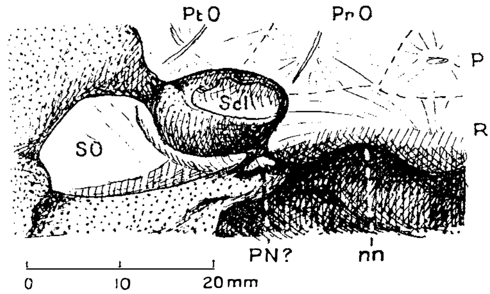

Fig. 9. *Arctolepis decipiens* (WD) (P.M.O. A 28637). Right anterior part seen from the front to show the position of the probable postnasal plate (PN ?). (Compare Fig. 1). Explanation to the letters see p. 40.

In the new specimens of *Arctolepis decipiens*, too, the postmarginal is very imperfectly preserved. However, some fragmentary plates observed in the new specimens can hardly be anything else than the postmarginal (PMg ? Pl. I, 4). I have therefore depicted the postmarginal on my reconstruction (PMg. Fig. 8), without being able to determine its size and boundaries with absolute certainty.

The sclerotic ossifications

The sclerotic ossifications are known in a number of Brachythoraci (GROSS, 1937; HEINTZ, 1931; JAEKEL, 1902; STENSIØ, 1942; TRAQUIAR, 1891b, and others), but are only very imperfectly known in Arctolepida.

BRYANT (1934, p. 136) mentioned sclerotic rings in *Euryaspis* (= *Bryantaspis*) *brachycephalus* and has a not very good illustration of these (Pl. IX, 2). HEINTZ (1933), however, gives a more thorough description of the sclerotic plates of *Phlyctaenaspis acadica* and also has photographs and a reconstruction of them. DENISON in his excellent survey of Arctolepida (1958) does not mention these structures at all. Neither does STENSIØ (1942) indicate the presence of sclerotic ossifications in his reconstruction of *Kujdanowiaspis* (Fig. 7 B).

In some specimens of *Arctolepis decipiens,* collected in 1960, the sclerotic ossifications are fairly well preserved (Pl. I; Pl. II. Fig. 1, 2, 4, 9, 10). As far as one can see the sclerotic ossifications in *Arctolepis* consist of four rather large plates and not only by portions of a narrow sclerotic ring as in Brachythoraci. In this manner they correspond completely to the sclerotic plates described in *Phlyctaenaspis acadica* (HEINTZ, 1933). They have a clear surface sculpture and they therefore obviously are of a dermal origin. In some respects they remind more of the sclerotic plates in *Bothriolepis canadensis* (STENSIØ, 1948, pp. 83–84) than of the sclerotic rings in Brachythoraci. In *Bothriolepis,* however, there are only three sclerotic plates, just two of which are large and broad ($Sclr_1$ and $Sclr_2$) while the third ($Sclr_3$) is narrow.

The sclerotic plates in *Arctolepis* are, as mentioned, large and more or less semispherical. Thus not only did they protect the front part of the eye-ball as in

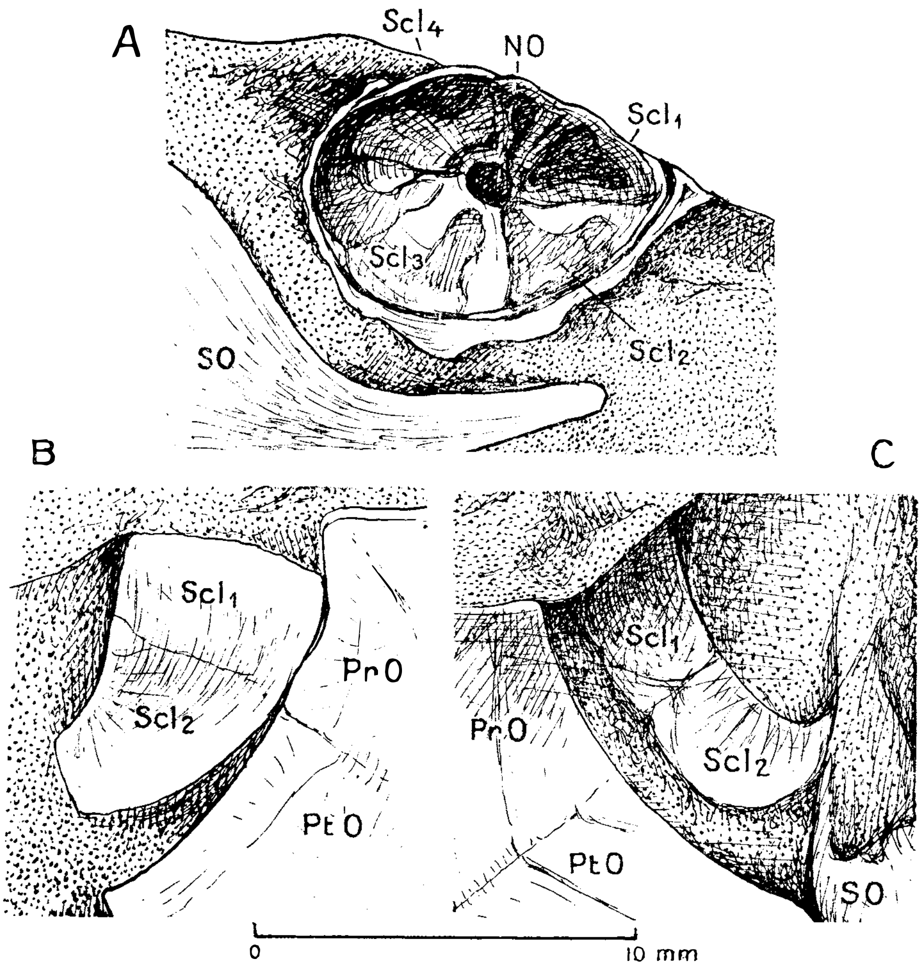

Fig. 10. *Arctolepis decipiens* (WD) (P.M.O. A 28603). Sclerotic ossifications: A – The bottom of the right "eye-ball" with four sclerotic plates and opening for the nervus opticus (?); B – left sclerotic plates; C – right sclerotic plates. Explanation to the letters see p. 40.

Brachythoraci, but also the sides, and, at any rate to some extent, the bottom part (Pl. II, 1. Fig. 10). They resemble thus to some extent the sclerotical ossification in *Jagorina* (STENSIØ, 1950). In two of our specimens (A 28637 and A 28603) the "eye-balls" are preserved as more or less spherical structures, protruding from the orbital openings over the surface of the head-shield (scl, Pl. I, 4; Pl. II, 1, 2. Fig. 1, 9). The opening in the front of the sclerotic "ball" is almost oval, another point which brings to mind *Bothriolepis* (STENSIØ, 1948, Fig. 21). It may, however, be possible that the oval shape has been caused by deformation during the fossilization.

In specimen A 28603 the right "sclerotic ball" comes loose and can therefore be studied from all angles. At the very bottom of the ball there is a distinct and comparatively large opening for the optical nerve (?) (Pl. II, 1. Fig. 10 A). The sclerotic plates slightly overlap, thus decreasing the natural size of the eye-ball. However, the boundaries of the four sclerotic plates can clearly be seen at the bottom of the eye cavity (scl, Pl. II, 1. Fig. 10, A).

It is difficult to imagine such heavily armoured eyes being movable to any great extent. STENSIØ points out that "the mobility of the eye-ball" in *Bothriolepis* "must naturally have been relatively small" (1948, p. 85). This also applies to the strongly protected eyes of *Aceraspis robustus* KIÆR – a Cephalaspid from the Downtonian of Norway (HEINTZ, 1939).

If the size of the eye-balls and eye-notches of *Arctolepis decipiens* are compared with the nasal notches and the probable size of the nasal sacs, it will be seen that these organs very probably were of about the same size. This also appears to have been the case in *Kujdanowiaspis* (STENSIØ, 1945) and at any rate in many other Arctolepida (DENISON, 1958). This seems to indicate that the sense of smell probably was of a greater importance to these animals than the sight.

The gnathal elements

I am in possession of five specimens of *Arctolepis*, collected in 1960, the head and the body-shields of which are in the natural position to one another. Unfortunately the rostral region of the head-roof is only preserved in two of them; in the other three the anterior part of the head is lost. All five specimens are only very slightly compressed, so the relative position of the body-carapace and the head-roof are practically undisturbed. In all these specimens the median-dorsal surface of the body-carapace and the head-roof slopes gently forwards (Fig. 8 B). The rostral division of the head therefore is found close to the bottom, indicating that the ventral side of the head was fairly flat.

In none of the new specimens were any fragments of the gnathal elements discovered. As will be remembered the knowledge of the gnathal elements in Arctolepida has up to now been very scant. Only a few questionable fragments of *Phlyctaenaspis acadica* (HEINTZ, 1933) and some well preserved supragnathals (?) of an unknown Arctolepid (DENISON, 1958) have been described. In the more or less complete specimens from Spitsbergen, described here, a number of minute and fragile plates can clearly be seen and have practically not been displaced (f. inst. sclerotic plates, suborbital, postsuborbital). This indicates that the animals have not been moved very far from where they died and have been "buried" very rapidly. It would then seem likely that if the gnathal elements were well ossified, they would have been preserved in the fossils, as they were in fact well protected by the head-roof and the body-carapace. But, as mentioned before, no traces of the gnathal plates have been discovered in any of the specimens, nor, as far as I know, in any specimens collected previously in Spitsbergen. To me, therefore, this seems to indicate that the gnathal elements in *Arctolepis* were cartilaginous or only very slightly ossified.

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Explanations to the abbreviations on all figures and plates

ADL – Anterodorsolateral plate.
AL – Anterolateral plate.
AMV – Anteromedianventral plate.
AVL – Anteroventrolateral plate.
C – Central plate.
MD – Mediandorsal plate.
Mg – Marginal plate.
MV – Medianventral plate.
N – Nuchal plate.
NO – Nervus opticus.
nn – Nostril notches.
OR – "Eye-ball".
P – Pineal plate.
PaN – Paranuchal plate.
PMg – Postmarginal plate.
PN ? – probably Postnasal plate.
"PN" – assumed Postnasal plate.
PrO – Preorbital plate.
PSO – Postsuborbital plate.
PtO – Postorbital plate.
PVL – Posteroventrolateral plate.
R – Rostral plate.
Scl – Sclerotic ossificacions (1 to 4).
SO – Suborbital plate.
SOC – Supraorbital canal.
Sp – Spinal plate.

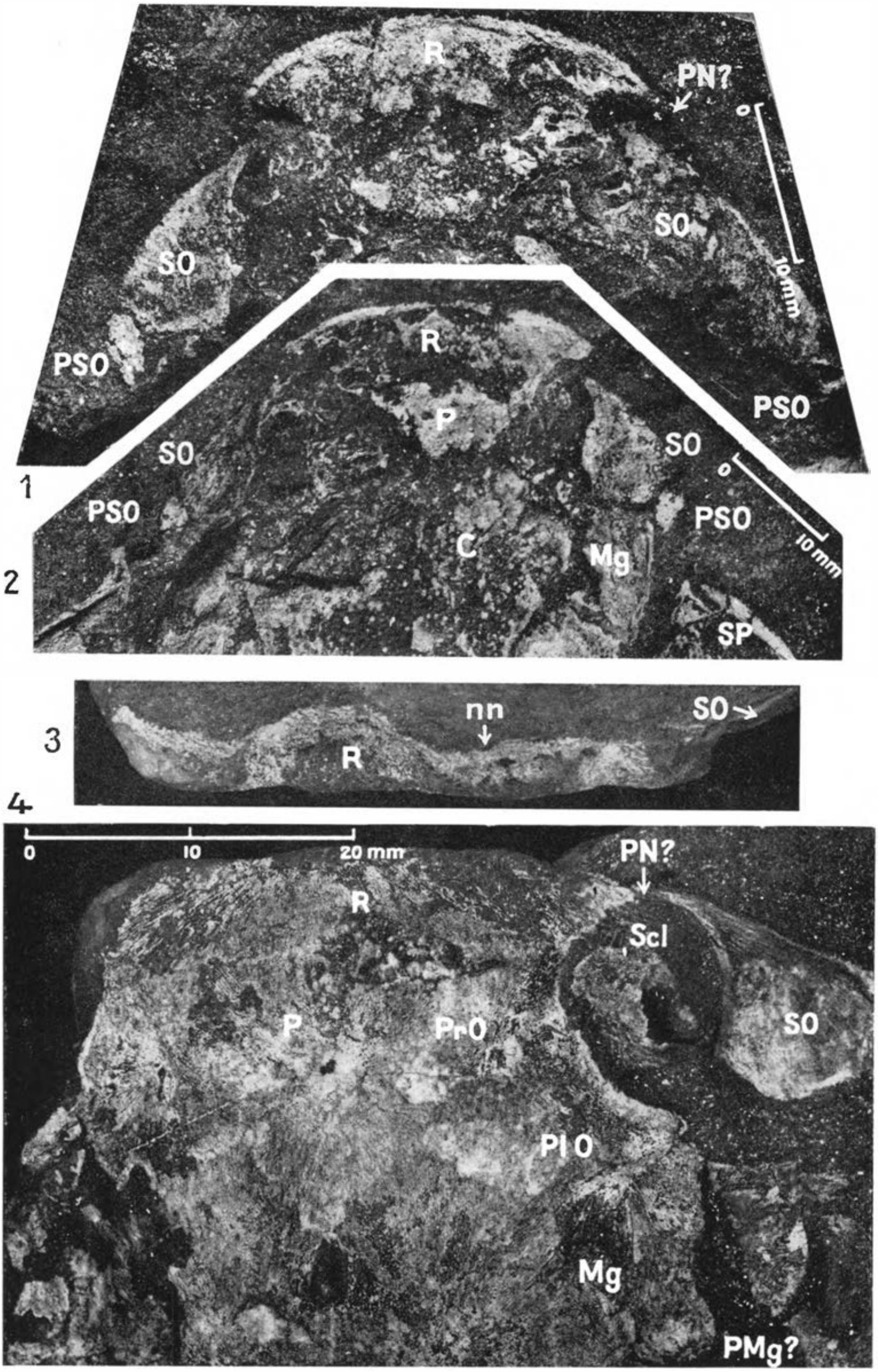

Plate I. *Arctolepis decipiens* (WD) Lyktan division, Wood Bay Series, Lower Devonian. Dicksonfjorden, Vestspitsbergen. Photo: B. MAURITZ

1 – Front part of the head-shield of specimen P.M.O. A 28636. Inside view.

2 – Counterpart of the same specimen (P.M.O. A 28639).

3 and 4 – Front part of the head-shield of specimen P.M.O. A 28637. 3 – frontview; 4 – seen from above. (Compare Fig. 1 in the text). Explanation to the letters see p. 40.

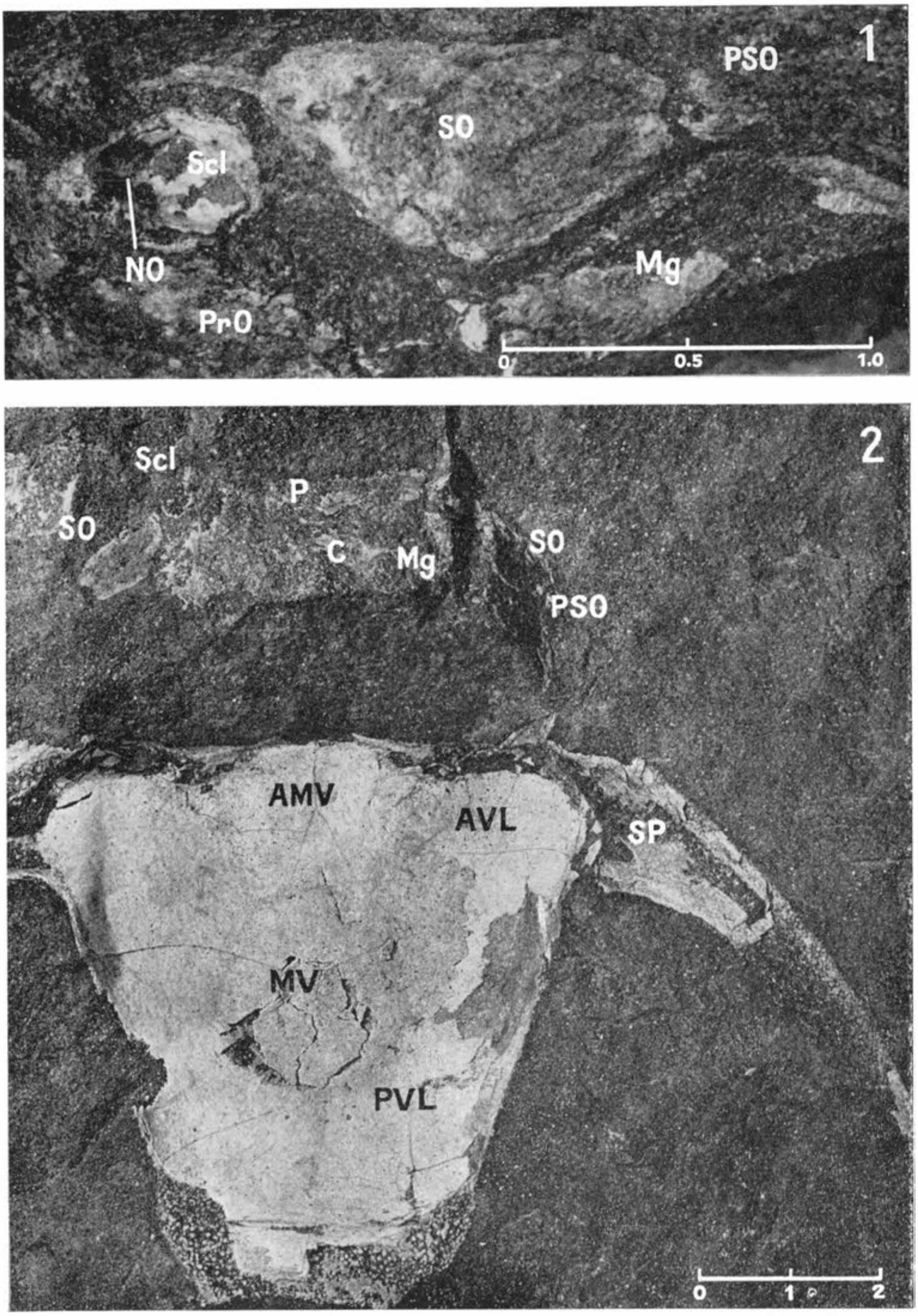

Plate II. *Arctolepis decipiens* (WD) (P.M.O. A 28603). Lyktan division, Wood Bay Series, Lower Devonian. Dicksonfjorden, Vestspitsbergen. Photo: B. MAURITZ.

1 – Sclerotic ossifications at the bottom of the "eye-ball" (compare Fig. 10A). Suborbital and postsuborbital plates and the margin of the head-shield are seen.

2 – Ventral body-carapace seen from the inside and a part of the head-shield with suborbital and postsuborbital plates and the sclerotic ossifications seen from the outside. Explanation to the letters see p. 40.

Lower Carboniferous Age of the so-called Wijde Bay Series in Hornsund, Vestspitsbergen

BY

KRZYSZTOF BIRKENMAJER AND ELZBIETA TURNAU[1]

Abstract

Spore investigations of dark shales in inner Hornsund, Vestspitsbergen, attributed hitherto tentatively to the Wijde Bay Series (Devonian) indicated a Lower Carboniferous (probably Visean) age of the rocks. Field investigations allowed to state that these rocks form a member separated by unconformities both from Devonian and from the possible Middle Carboniferous, and that in the lowermost part of the shaly sequence plant-bearing sandstones and conglomerates occur. The term Adriabukta Series is applied to these rocks.

Geological relations in Adriabukta, Hornsund, are demonstrated and explanations are offered as to the succession and character of geological events during the Lower Carboniferous in Hornsund. The relation of the Adriabukta Series to other Lower Carboniferous series within Svalbard is briefly discussed.

A. GEOLOGICAL PART

BY

KRZYSZTOF BIRKENMAJER

Introduction

It was A. K. ORVIN (1940, p. 16, Pl. II) who introduced a stratigraphical scheme of the Devonian of Hornsund, Vestspitsbergen, based on comparisons with the typical profiles in northern and central Vestspitsbergen. To the Wood Bay Series (?) he attributed a complex c. 150 m thick of limestones, red laminated sandstones, yellowish sandstones and conglomerates. The complex of sandstones and shales with bivalves, c. 200 m thick, was attributed to the Grey Hoek Series and, finally, a complex c. 650 m thick of dark shales (o. c., Pl. III) was included into the Wijde Bay Series (?).

The present author during the Polish 1958 Spitsbergen Expedition tried to trace in the field the above series basing only on differences of lithology of the beds as he had no personal knowledge of the type localities, and as the fossils were scarce and poorly preserved. He mapped near Marietoppen, inner Hornsund, three lithologically different complexes compared, tentatively, after ORVIN with the Wood Bay Series, Grey Hoek Series and Wijde Bay Series (BIRKENMAJER

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1959, 1960 a, b). The "Wood Bay Series" thus distinguished differed from the remaining series by the presence of coarse grained clastics (conglomerates and breccias) alternated with red and variegated shales and limestones. The "Grey Hoek Series" was characterized by the presence of variegated, red and green fine grained clastics (shales and sandstones), alternating with limestones. Finally, in the "Wijde Bay Series" were included dark grey or black fine grained clastics.

The above subdivision was preliminary and required further studies. Prof. Dr. A. HEINTZ kindly suggested to the present author[1] that the dark complex attributed tentatively by ORVIN (*o. c.*) and by the present author (*o. c.*) to the Wijde Bay Series might belong both to the Wood Bay Series and Grey Hoek Series or to the basal part of the Culm. The present author therefore examined again the area of Adriabukta during the Polish 1960 Spitsbergen Expedition and arrived at conclusions partly confirming the suggestions of Prof. HEINTZ. It seems also probable, that to the Grey Hoek Series belongs only the uppermost part of the deposits attributed there previously, the rest still representing the Wood Bay Series.

Geological relations in Adriabukta

Geological relations in Adriabukta are shown in Fig. 2 which is a modification of the profile published before (BIRKENMAJER 1960b, Fig. 3). From the west to the east we see at first an overturned sequence of beds represented by the Gåshamna Series and Blåstertoppen Dolomite (Hecla Hoek Succession) and the Devonian. The Devonian resting unconformably upon the Eocambrian Gåshamna Series is represented by a series of deposits which probably correspond to the Keltiefjellet and Stjørdalen Divisions (Wood Bay Series) and to the Grey Hoek Series (cf. WINSNES *et al.* 1960, FRIEND 1961). The next member hitherto known under the name of the "Wijde Bay Series" fills a complicated syncline, displays no transition both to its substratum and superstratum, and is generally characterized by predominant dark shales associated with sandstones, greywackes and conglomerates. In the light of new field and laboratory investigations (see below) it seems certain that this member does not belong to the Devonian. Therefore the term Adriabukta Series is introduced now for the member discussed.

A great part of the Adriabukta Series is strongly disturbed tectonically which makes it difficult to establish the sequence of the strata. Two tectonic units are distinguished: the lower, autochthonous, which occurs in the western part of the structure, and the upper, allochthonous, which was traced on the SW slopes of Hyrnefjellet down to the sea shore. In the autochthonous unit the Adriabukta Series contacts with the Devonian (possibly Grey Hoek Series) in the crest of the ridge between Marietoppen (481 m a. s. l.) and Hyrnefjellet (767 m a. s. l.), on the SE slope of Marietoppen and in the cliff profile south of Marietoppen (small promontory in Adriabukta). At the crest of the ridge mentioned grey quartz conglomerates 2–3 m thick occur in two places. It is thought that they belong to the same horizon displaced by a small oblique fault (cf. Fig. 2). The

[1] Letter of January 16th, 1960.

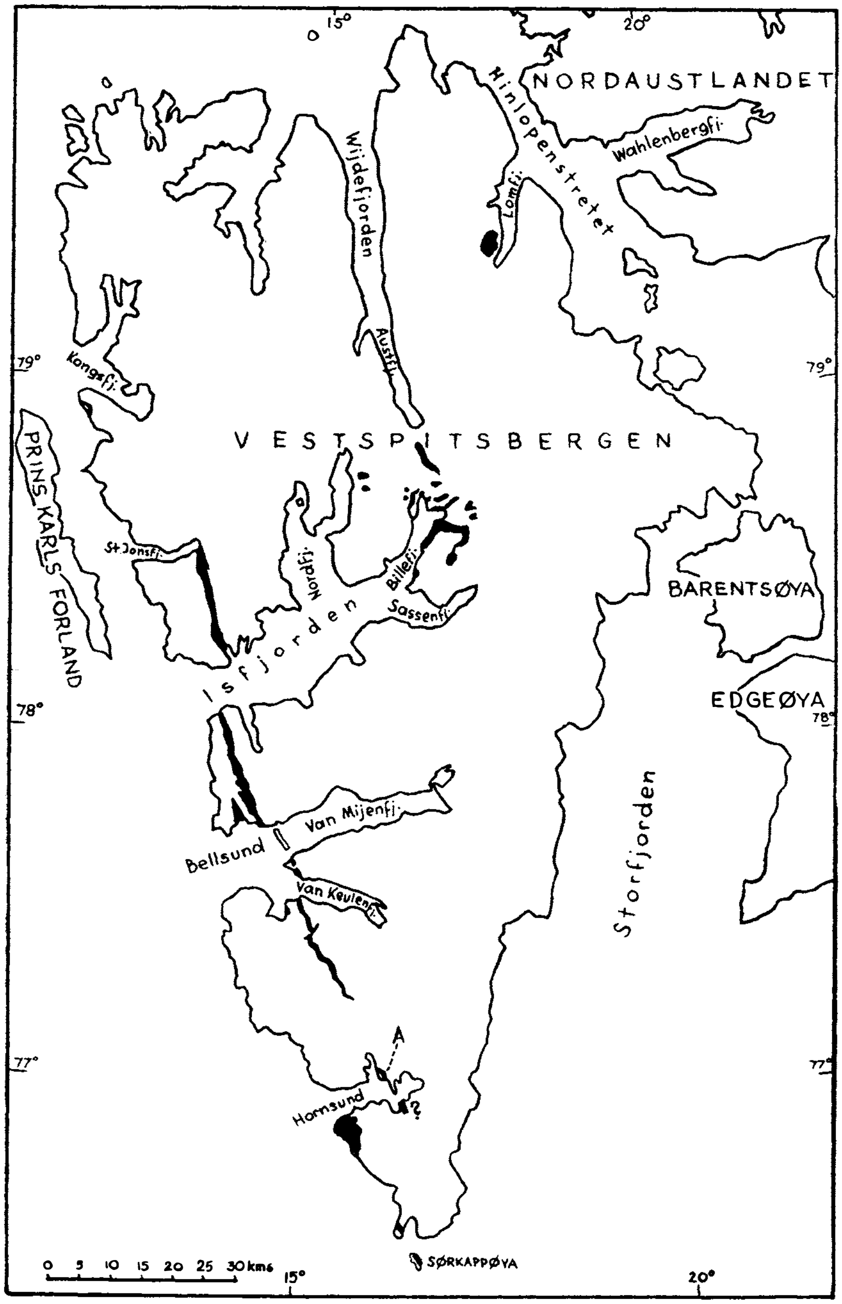

Fig. 1. Position of the Adriabukta Series (A) within Spitsbergen. Principal outcrops of the Lower Carboniferous deposits in black. Map compiled from ORVIN (1940), GEE *et al.* (1952), MAJOR and WINSNES (1955), FORBES *et al.* (1958), DINELEY (1958), RÓZYCKI (1959) and from unpublished maps by the present author.

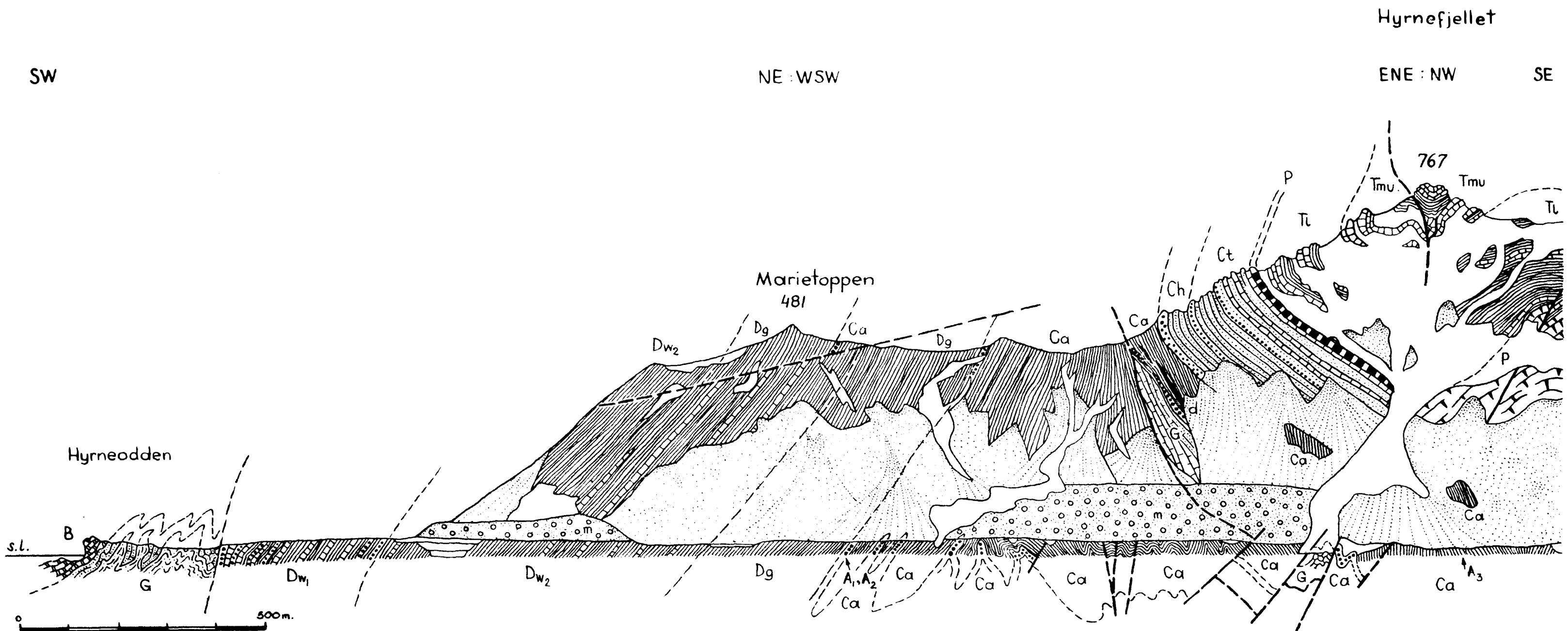

Fig. 2. Coast profile between Hyrneodden and Hyrnefjellet, Adriabukta, Hornsund. Re-drawn from BIRKENMAJER (1960 b) and modified.

G – Gåshamna Series (Eocambrian); B – Blåstertoppen Dolomite (Lower lower Cambrian ?); Dw_1 – Wood Bay Series (Keltiefjellet Division ?); Dw_2 – Wood Bay Series (Stjørdalen Division ?); Dg – Probably Grey Hoek Series; Ca – Adriabukta Series (Lower Carboniferous, probably Visean); Ch – Hyrnefjellet Beds (probably Middle Carboniferous); Ct – Treskelodden Beds (Upper Carboniferous-Lowermost Permian ?); Brachiopod Cherty Limestone (Upper Permian); Tl – Lower Trias; Tmu – Middle and Upper Trias; d – dolerites (sills); A_1, A_2, A_3 – Localization of samples for spore investigations; m – moraines; s. l. – sea level; scree and talus cones dotted.

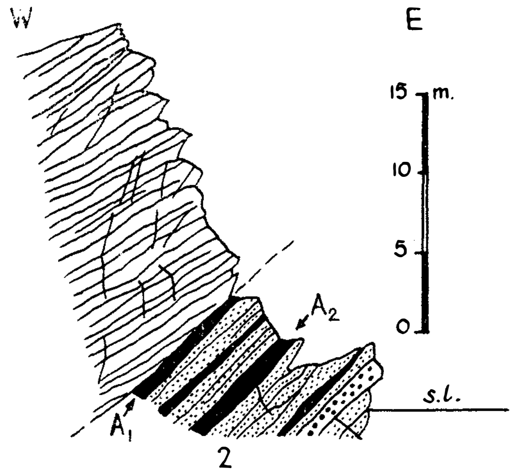

Fig. 3. Overturned contact of the Adriabukta Series and the Devonian. Adriabukta, cliff profile.
1 – Devonian shales (probably Grey Hoek Series); 2 – Adriabukta Series (Lower Carboniferous, probably Visean): shales – black; sandstones – fine dots; conglomerates – thick dots; s. l. – sea level; A_1, A_2 – localization of samples for spore investigations.

summit of Marietoppen and the mountain ridge between the conglomerates are built up of dark green or black shales containing further north a pelecypod fauna[1] which appears to be identical with that known to ORVIN (1940) and to FØYN and HEINTZ 1949 expedition[2] from a moraine of Lorchbreen to the NW of Marietoppen. According to ORVIN the latter fauna resembles that from the Grey Hoek Series of type localities. We may assume, therefore, that the shales in question belong to this series.

The contact of the conglomerates (considered to represent the basal member of the Adriabukta Series) with the Devonian shales dips westwards. The same is true of black and dark grey arenaceous shales (next member of the Adriabukta Series) occurring to the east of the eastern outcrop of the conglomerates.

The cliff profile is the most instructive. We see there (Fig. 3) from the west to the east an overturned sequence of the Devonian (probably Grey Hoek Series) and the Adriabukta Series. The Devonian consists of green or grey green strongly cleaved and slightly phyllitized shales which contact along a plane dipping west at an angle of c. 45° with black shales beginning the sequence of the Adriabukta Series. The shales are 0.5–0.7 m thick near the sea level and are wedging out upwards. They contain plant remains and numerous but poorly preserved pelecypods.

Sample A_1 was taken for spore investigations from the shales in question. As follows from the study of the second author (E. TURNAU) the spores found indicate with a great probability a lowermost Visean age of the rock (see part B of this paper).

There follows a sequence c. 25 m thick of grey, medium-, fine-, or coarse-grained sandstones in layers 2–50 cm thick, alternated with black arenaceous shales (sample A_2 with possibly Upper Visean spores was taken from these shales

[1] Collected by the present author and S. CZARNIECKI in 1960 in a small moraine of Lorchbreen just below the NE slopes of Marietoppen.

[2] Samples housed in the Paleontologisk Museum, Oslo.

– see part B) and with grey conglomerates. The ratio of the sandstones and conglomerates to the shales is 5 : 1 or 10 : 1. Within the shales and sandstones occur small lenses of sedimentary breccias consisting of green shale fragments resembling the shales of the Devonian substratum (probably Grey Hoek Series).

Current bedding may be found in the sandstones and conglomerates, which form lenses several meter to several dozen meter long. Well developed fine groove and prod casts are present at the bottom of some sandstone layers especially when medium or fine grained and rich in muscovite.

Within these beds, which are very similar to the bottom part of the Culm (Hornsundneset Beds) in Sigfredbogen, NW coast of Sørkapplandet, described by S. SIEDLECKI (1960), poorly preserved plant imprints – *Lepidophyta* – often occur, some of them 2–3 cm wide and up to 50 cm long.

The conglomerate layers 10–100 cm thick consist of angular and, subordinately, subangular or subrounded quartz pebbles, white, grey or yellowish, 0.5–5 cm in diameter, contained in sandy matrix.

Tracing the contact of the beds discussed with the Devonian towards Marietoppen we see that at a distance of about a score metres the conglomerates come into contact with green shales of the Devonian (the strata of the Adriabukta Series underlying the conglomerates are wedging out). This gives an impression of angular unconformity between the two discussed series (i. e. between the Adriabukta Series and the Devonian) amounting to 10–20°.

To the east of the promontory described the cliff is built up of strongly folded black, dark grey or dark green shales containing several intercalations of grey or whitish conglomerates up to 2 m thick. The conglomerates consist of angular or subangular (rarely subrounded) quartz pebbles 0.5–5 cm in diameter, contained in sandy matrix. Besides, frequent grey quartzite sandstone intercalations 5–50 cm thick occur in the shales. As the beds are strongly folded it is difficult to establish the number of these intercalations. Most of them might belong to the same layer tectonically repeated[1], as is indicated by the disappearance of conglomerates upslope and by the presence of anticlinal bents.

Farther east below an old moraine are visible in the cliff black or dark grey shales and paper shales, somewhat phyllitized and strongly folded and slickensided. In some parts of the cliff the shales form layers 50–100 cm thick alternating with black or dark green finely grained greywackes and sandstones, 2–15 cm thick, showing sometimes graded bedding. These beds represent the youngest member of the autochthonous unit of the Adriabukta Series (cf. Fig. 2). The thickness of this series amounts here to c. 300 m.

The strongest tectonic disturbances of the shaly complex are to be seen near an isolated cliff rock built up of grey or white quartz conglomerate bent in a

[1] Both the conglomerates at the base of the Adriabukta Series and the conglomerates discussed now were, at first (BIRKENMAJER, 1960 b), tentatively compared with the basal member of the Hyrnefjellet Beds (presumably Middle Carboniferous – cf. BIRKENMAJER, 1959 b, BIRKENMAJER and CZARNIECKI, 1960). The data obtained in 1960 allow, however, to believe that they belong to the Adriabukta Series. This, consequently, changes to some extent the previous tectonic interpretation of the area.

syncline (cf. BIRKENMAJER, 1960 b, Fig. 3)[1]. During the low tide small skerries emerge from the sea between the shore and this isolated cliff rock. The rocks forming these skerries are strongly recrystallized grey or bluish limestone (marble) veined with white or yellow calcite. The limestone is strongly brecciated and associated with whitish or greyish strongly brecciated quartzite forming two intercalations in the NE part of the outcrop.

Similar rocks are to be found on the mountain slope below a pass separating Marietoppen from Hyrnefjellet, where they form a scale c. 300 m long (cf. BIRKENMAJER, 1960 b, Fig. 3; BIRKENMAJER and MORAWSKI, 1960, Fig. 2)[2]. From the bottom to the top the scale is built up of grey or yellowish limestone followed by marmorized and phyllitized limestone and by quartz-sericite gneiss and, finally, by white and grey quartzite. The whole sequence is c. 50 m thick.

The metamorphic rocks in question included at first erroneously in the "Wijde Bay Series" (*o. c.*) resemble fairly well the rocks present in the upper part of the Gåshamna Series at Bogstranda and in Sofiebogen (cf. BIRKENMAJER, 1960 c). This refers especially to the limestone (marble) and to the quartzites. Quartz-sericite gneiss present in Adriabukta and absent in Bogstranda and Sofiebogen might have developed from quartzites of the Gåshamna Series under high stress.

The metamorphic rocks in question are thought to be the bottom part of the allochthonous tectonic unit in Adriabukta. This agrees well with the fact that the black shales of the Adriabukta Series are disturbed most strongly immediately below the metamorphic rocks.

The rocks attributed now to the Gåshamna Series are overlain on the SW slope of Hyrnefjellet by another sequence of beds belonging to the Adriabukta Series. The sequence begins with dark grey or black argillaceous or arenaceous shales, c. 60 m thick, intercalated with thin grey quartzites. Near the contact with the Gåshamna Series have been found in 1960 lenticular intercalations, c. 1 m thick, of tectonically disturbed grey conglomerate consisting of whitish quartz pebbles contained in dark sandy-conglomeratic matrix. Two dolerite sills[3] have been found in the shales.

The shales described above pass upwards into a complex c. 50 m thick of black and dark green highly cleaved shales intercalated with small, lenticular or boulder--like, black, or dark grey, fine grained greywackes 2–10 cm thick, exposed just below the contact of the Adriabukta Series with the Hyrnefjellet Beds. The contact is well exposed. This allows us to measure the angular unconformity between the two above mentioned stratigraphic members. The red conglomerate beginning the sequence of the Hyrnefjellet Beds dips 20° ESE 30° or 30° ESE 30°, while

[1] This conglomerate was thought before to represent the basal conglomerate of the Hyrnefjellet Beds (o. c.). After 1960 investigations it seems more likely that it begins the Adriabukta Series of the allochthonous tectonic unit.

[2] These rocks were known probably already to ORVIN (1940, Pl. II) who marked in the schematic profile a zone obliquely cross-shaded, unfortunately not explained.

[3] The first well outcropped sill, c. 5 m thick and over 25 m long was described by BIRKENMAJER and MORAWSKI (1960, p. 109, Fig. 2). The second sill, c. 0.5 m thick and several metres long has been found in 1960 in black shales c. 4 m to the west of the former.

the underlying shales of the Adriabukta Series are dipping 140° ENE 80° or 135° ENE 50°. This gives an angle of unconformity between 20° and 50°, which is undoubtedly primary, as the shales of the Adriabukta Series are strongly altered by weathering processes previous to deposition of the Hyrnefjellet Beds in a zone roughly parallel to the bottom surface of the latter, 0.3–5 m thick, and crossing the shales of the Adriabukta Series obliquely to their stratification. In this zone the shales of the Adriabukta Series are greenish, variegated or red.

The easternmost outcrops of the shales of the Adriabukta Series are to be found between the marble skerries mentioned above and the Eotriassic and Permian (Brachiopod Cherty Limestone) rocks exposed in the eastern part of Adriabukta, on the western limb of the Hyrnefjellet anticline. They are mostly black shales devoid of sandstone or conglomerate intercalations, possibly c. 300 m thick. Sample A_3 taken in the middle part of the cliff outcrop (higher part of the Adriabukta Series – see Fig. 2) contained a possibly lowermost Visean spore assemblages (cf. part B).

Conclusions and comparisons

The geological relations described indicate that the Adriabukta Series is independent both of the Devonian (probably Grey Hoek Series) and of the Hyrnefjellet Beds (probably Middle Carboniferous), separated from the former and from the latter by erosion which followed phases of tectonic deformations. As follows from the spore investigations by E. TURNAU the sedimentation of the Adriabukta Series commenced in the Visean. The samples investigated do not allow to determine the upper age limit of the Adriabukta Series, but as the sample A_3 taken from a higher part of the series still contains a possibly lowermost Visean assemblage of spores, it is only the uppermost part of the series which might represent eventually younger horizons, e. g. Namurian.

It is impossible to decide whether the Adriabukta Series is an exact age equivalent to the Culm series in northwest Sørkapplandet described recently by SIEDLECKI (1960), or only to a part of this series, as no palaeontologic criteria were established for the latter.

No coal seams have been found in the Adriabukta Series in contrast to the Sergeijevfjellet Beds of northwest Sørkapplandet (cf. SIEDLECKI, 1960).

The possible equivalents to the Adriabukta Series seem to occur on Meranfjellet (cf. BIRKENMAJER, 1960 b, Figs. 1, 2) where a contact with the Devonian may also be present. In the collection of rock samples taken by FØYN and HEINTZ 1949 expedition to Hornsund, housed in Paleontologisk Museum, Oslo, the present author saw pieces of black bluish finely micaceous shales (somewhat phyllitized) with casts of pelecypods (samples Nos. P. M. O. A 25811, 25812) which resemble those of the highest member of the Devonian of Marietoppen (see above). Prof. A. HEINTZ was so kind as to inform the present author that S. FØYN during this expedition found beds of the Culm type in the mountains near Samarinbreen. The results of his investigations have not been as yet published.

The angular unconformity at the base of the Adriabukta Series may be related to the Svalbardian phase which according to TH. VOGT (1928) took place between the deposition of the Middle Devonian Wijde Bay Series and of the Ursa Sandstone (Upper Devonian-Lower Carboniferous), the latter known from Bjørnøya. This phase caused the uplift of an area in Hornsund west of Burgerbukta built up of the Hecla Hoek Succession and possibly covered by the Devonian. During the erosion which followed the uplift most of the Devonian sediments have been washed out from the uplifted area; the only residues seem to occur in Sigfredbogen-Kviveodden (cf. SIEDLECKI, 1960). The Devonian sequence of the belt stretching from the head of Nornebreen across Hornsund to Olsokbreen persisted during the period of denudation probably downthrown in a graben, as suggested by ORVIN (1940).

It is highly probable that the whole area between Hornsundneset and inner Hornsund was at first covered by Lower Carboniferous deposits. This is implied by the eastward direction of transportation of the clastic material in the Culm of northwest Sørkapplandet as observed by SIEDLECKI, and by the change of facies towards the east which resulted in replacing the sandstones by shales. The shaly development of the major part of the Adriabukta Series and the presence of graded bedding in the greywacke intercalations may indicate, that the higher part of the Adriabukta Series was formed in a water filled basin much deeper than that of northwest Sørkapplandet, while the occurrence of coal, of cross bedding (fluvial type) and the abundance of plant remains (among others *Stigmaria*) in northwest Sørkapplandet may indicate deltaic conditions prevailing towards the west.

The graben filled with Devonian formed during the Svalbardian orogeny and covered by the deposits of the Adriabukta Series was a weak zone during the tectonic movements of post-Visean and pre-Middle Carboniferous phase [1]. This caused the intense folding of the Adriabukta Series in this area.

The tectonic structures formed during the orogenic phase mentioned may be reconstructed to some extent by turning the contact of the Hyrnefjellet Beds and the Adriabukta Series (cf. Fig. 2) to the horizontal position. Thus we see that the Devonian and the contact plane of the Devonian with the Adriabukta Series were dipping at steep angles (nearly vertically) towards the east and were traversed by small oblique fault dipping west (Fig. 4). The contact of the Devonian with the Hecla Hoek Succession followed the same direction of dip as that of the contact of the Devonian with the Adriabukta Series. The autochthonous unit of the Adriabukta Series formed a syncline where the tectonic complications grew towards the east. The core of this syncline was covered by the allochthonous tectonic unit built up of the Gåshamna Series and of the Adriabukta Series which dipped east at an angle of about 30°.

The allochthonous tectonic unit in question might have been formed by gravitational gliding from the west, i. e. from the eastern limb of the horst structure built up of the Hecla Hoek Succession and covered directly by the Adriabukta Series, or by overthrusting from the east, from another horst structure built up

[1] It is difficult to decide whether these movements were connected with the Sudetic phase or with the Asturic phase, as no palaeontologic data supported the Middle Carboniferous age of the Hyrnefjellet Beds.

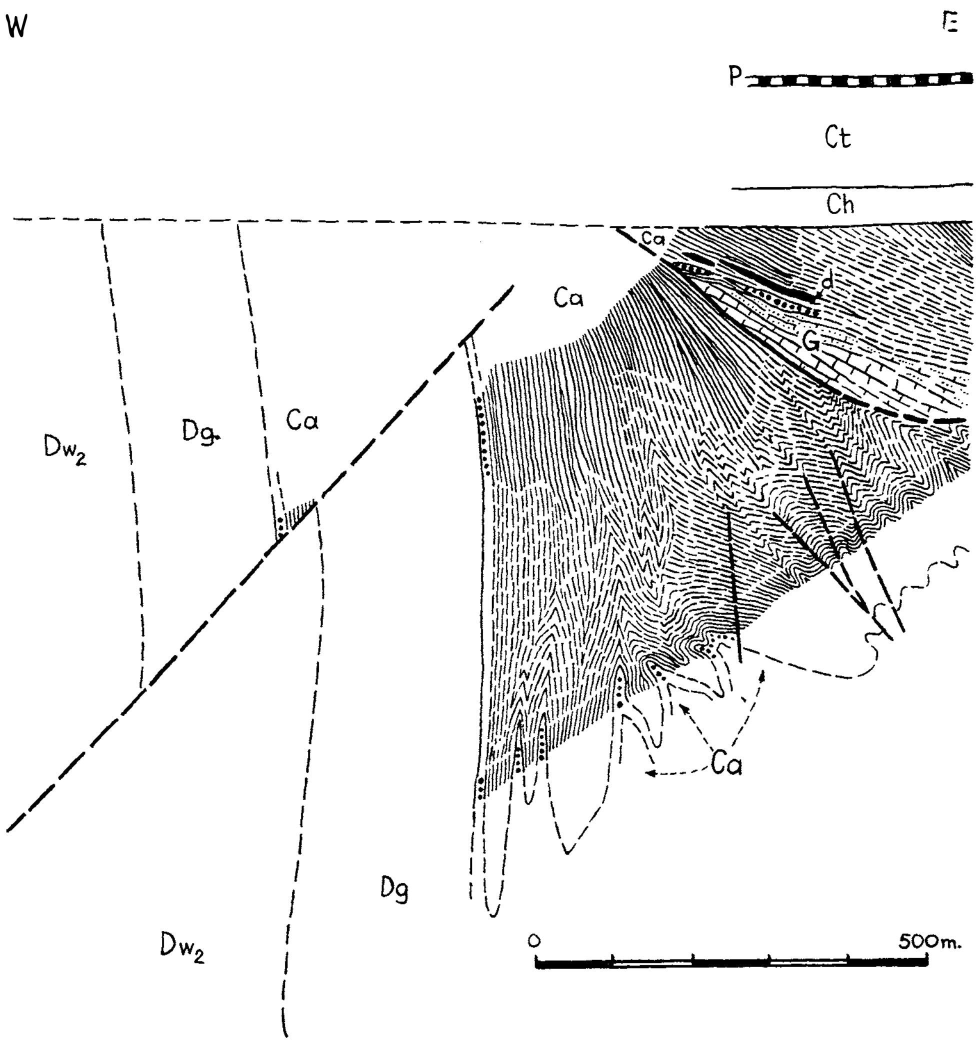

Fig. 4. Reconstruction of Variscian tectonic structure between Marietoppen and Hyrnefjellet by turning the contact of the Hyrnefjellet Beds (probably Middle Carboniferous) and the Adriabukta Series (Lower Carboniferous, probably Visean) to the horizontal position. For explanations see Fig. 2.

of similar members. There are some data which allow to choose between these explanations and to consider that the latter is more probable. For example in the above mentioned collection made by FØYN and HEINTZ 1949 Expedition in Sørkapplandet the present author saw a sample taken from Påsketoppen (P. M. O. A 25826) which consisted of micaceous-feldspar-quartz rock very similar to the gneiss at the southwest slope of Hyrnefjellet. As it was mentioned before such gneisses are absent in the Gåshamna Series to the west of Burgerbukta. Thus the Devonian rocks contacting with the Gåshamna Series along the eastern side of Samarinbreen (cf. MAJOR and WINSNES, 1955, Fig. 1; BIRKENMAJER, 1960 b, Fig. 1) might have been considered as forming the eastern limb of the graben filled with the Devonian and Lower Carboniferous deposits.

Other suggestions as to the direction of tectonic movements prior to the deposition of the Hyrnefjellet Beds may be obtained from the lithologic character of the Adriabukta Series. It may be seen that in the allochthonous tectonic unit in question shales are much more common than the conglomerates and greywackes, even at the base of the series, than in the Adriabukta Series of the autochthonous unit. This might agree with the supposition expressed above that towards the east the Lower Carboniferous in Hornsund became more shaly.

It seems probable that the tectonic movements of the discussed phase which led to the formation of strong tectonic disturbances of the Adriabukta Series and of the underlying beds were connected with horizontal movements of the borders of the graben formed already during the Svalbardian orogeny. The weak zone of this graben filled with Devonian and Lower Carboniferous (Visean) deposits was strongly compressed between these mobile borders, the eastern of which seemed to have been more active as a part of it was thrust over the folded deposits filling the graben. Hence the main difference between the Svalbardian tectonic movements, and those younger than Adriabukta Series and older than Hyrnefjellet Beds of the area in question, was that the first were of tensional character and the second of a compressional character.

The tectonic structures of the folded graben and its borders were subjected to erosion which levelled the area before the deposition of the Hyrnefjellet Beds commenced. The clastic material of the Hyrnefjellet Beds and of the Treskelodden Beds came from the east, from the Barents Sea Shelf (cf. BIRKENMAJER, 1959). Slightly folded Culm deposits of northwest Sørkapplandet crossed by a pre-Eotriassic peneplain (cf. BIRKENMAJER, 1960 b, Fig. 2) might have been preserved in a tectonic depression (syncline) formed during the same phase. It is possible that this peneplain was of the same age as that crossing the pre-Hyrnefjellet Beds tectonic structure on the southwest slopes of Hyrnefjellet.

In consequence of the events which took place during and after the post-Visean phase, before the deposition of the Hyrnefjellet Beds, the area situated on the west which influenced the sedimentation of the Lower Carboniferous ceased to furnish clastic material to the Carboniferous deposits.

It is beyond the scope of the present paper to give more detailed comparisons between the Adriabukta Series and other Lower Carboniferous series within Svalbard. However, a brief account on the position of the Adriabukta Series within the Lower Carboniferous of Svalbard may be attempted.

As follows from many reviews of the Permo-Carboniferous strata of Svalbard (e. g. NATHORST, 1910; FREBOLD, 1935, 1951; ORVIN, 1940; GEE *et al.*, 1952; DINELEY, 1958; FORBES *et al.*, 1958 and RÓZYCKI, 1959) the common features of the Lower Carboniferous (Culm) beds are the presence of unconformity at the base which is Devonian or Hecla Hoek Succession, and the occurrence of mostly light quartzose or quartzitic sandstones and conglomerates distinctly prevailing over dark shales, the latter being often carbonaceous. Plant remains may often be found both in sandstones and shales, and coal seams sometimes occur. A common feature of the sandstones seems to be the presence of cross (current) bedding, and some beds are current ripple-marked.

The Lower Carboniferous beds either pass upwards into the Middle Carboniferous mostly red beds or are overlain unconformably by the Middle Carboniferous. There are also areas where Upper Carboniferous-Permian deposits rest directly upon Culm.

The Adriabukta Series occupies a special position within the Lower Carboniferous deposits of Svalbard and has no equivalents either in Central Vestspitsbergen or in Bellsund or Bjørnøya. Such Lower Carboniferous thick dark shale sequence has been found nowhere at the surface outside inner Hornsund.

The lithological character of the Adriabukta Series in inner Hornsund may be, however, explained if we assume that this series has been deposited in a part of the Lower Carboniferous sedimentary basin more distant from the source area of clastics than the remaining series of that age in Svalbard. Consequently the latter series might be considered as belonging to the marginal parts of the main basin which was situated approximatively between the middle part of Isfjorden and the southern part of Storfjorden and was covered by a comparatively thick sequence of late Palaeozoic, Mesozoic and Cenozoic deposits (central depression of Vestspitsbergen).

The above suggestion should be verified by investigations of the direction of transportation. At present, little is known about the direction of transport but there is no evidence against the view that the Lower Carboniferous basins of Svalbard were filled from the west or, partly, from the north. Generally deltaic, fresh water or eventually brackish character of the Culm deposits in northwest Sørkapplandet, in Torell Land between Saussureberget and Ahlstrandodden, in Reinodden, Midterhuken, in Nordenskiöld Land between Bellsund and Kapp Starostin (Festningen section, Isfjorden), between Trygghamna and St. Jonsfjorden, in Brøggerhalvøya, in central Vestspitsbergen east of Dicksonfjorden (Dickson Land resp. Pyramiden area) and around Billefjorden and, finally, near Lomfjorden, may agree with the supposition set forth above.

Finally it may be pointed out that the major part of the Adriabukta Series has more in common with the Culm (Kulm) facies of central and western Europe, than with the "Culm" of the rest of Svalbard.

Acknowledgments

The preliminary results of the investigations presented here have been discussed by the first author (K. Birkenmajer) during the A. 16 Excursion of the XXI International Geological Congress, August 1960, to Hornsund, and during his visit to Cambridge, Newcastle upon Tyne and Oxford, April 1961. Messrs. P. F. Friend, W. B. Harland, N. F. Hughes, Professors A. Heintz and T. S. Westoll, Dr. K. S. Sandford and Doc. Dr. S. Siedlecki, leader of the Polish 1960 Spitsbergen Expedition offered much constructive criticism. Mr. N. F. Hughes and Dr. G. Playford kindly read the manuscript and offered valuable comments especially on the microspores described.

The courtesy of Prof. A. HEINTZ, Paleontologisk Museum, Oslo, where the author spent some time in June 1959 and examined collections of the Norwegian expeditions to Svalbard, is gratefully acknowledged.

Mr. S. CZARNIECKI, member of the Polish 1960 Spitsbergen Expedition assisted the author in the field and helped him with sampling. His generous aid and discussions are recorded here with gratitude.

B. MICROPALAEOBOTANIC PART

BY

ELZBIETA TURNAU

Introduction

The aim of the present spore investigations was to determine the age of the beds in inner Hornsund, hitherto attributed tentatively to the Wijde Bay Series (Devonian), as evidences have been found in the field by K. BIRKENMAJER which did not agree with the previous views and suggested a Lower Carboniferous age. The conclusions are based on investigations of three representative samples, two of them (A_1, A_3) collected by K. BIRKENMAJER and one (A_2) by S. CZARNIECKI, members of the Polish 1960 Spitsbergen Expedition. The localization of samples is shown in Figs. 2, 3.

The first palynological reconnaissance of the Lower Carboniferous (Billefjorden Sandstones) of Spitsbergen was made by N. F. HUGHES and G. PLAYFORD (1961).

Methods

Samples of rocks (black shales) were treated with hydrofluoric acid. The specimens of spores obtained were mounted in glycerine jelly.

Percentages of specimens belonging to particular genera and species have been established: for sample A_3 on 250 specimens, for sample A_2 on 100 specimens. Percentages for sample A_1 have not been established, as the quantity of specimens obtained was too small.

Age of microspore assemblages

The microflora of the Carboniferous of Spitsbergen is still inadequately known· It has been necessary to attempt to establish the age of assemblages dealt with in the present paper above all on comparisons with microfloras of Europe and of North America. The stratigraphical scheme of the Carboniferous accepted in the present paper is that used in Russia.

Samples A_1 and A_3 (Tables 1, 2). These assemblages will be considered together, as they seem to be very similar. Both assemblages appear to be Carboniferous, as

Densosporites are numerous and *Triquitrites* and *Tripartites* are present. The latter two genera are not known from the pre-Carboniferous deposits. Four of the species present are identical with, or very similar to, the species hitherto known exclusively from the Visean of the Donetz basin and of North America. It is therefore most probable that the present assemblages are of a Visean age.

The remaining species either had a wide vertical range, beginning in the Upper Devonian or in the Tournaisian and occurring till the Visean or Namurian, or were hitherto known exclusively from probably pre-Visean deposits. The latter are *Tholisporites foveolatus* HUGHES and PLAYFORD and *Velosporites echinatus* HUGHES and PLAYFORD, which were described from the probably Tournaisian lower part of the Billefjorden Sandstones of central Vestspitsbergen (HUGHES and PLAYFORD, 1961). The occurrence of these two species might imply that the present assemblages are of a lowermost Visean age.

Sample A_2 (Table 3). The few determined species do not allow to establish exactly the age. The presence of *Densosporites* cf. *granulosus* KOSANKE seems to indicate that the present assemblage is younger than those described above. It probably represents the upper part of the Visean.

Comparison with Visean floras of other regions

Quantitatively the most important in the microflora dealt with in the present paper are spores belonging to the genera *Densosporites* and *Tholisporites*. Similar forms (some species of *Hymenozonotriletes* and *Euryzonotriletes*) quantitatively predominate in the Visean of the Donetz basin (ISHCHENKO 1956). Microspores of *Lycopsida*, to which belong the genera mentioned below (cf. POTONIÉ and KREMP 1956 b), usually quantitatively predominate in the Visean assemblages, namely: *Densosporites* in the Upper Mississippian of Canada (HACQUEBARD and

Table 1. Microspore species present in sample A_1.

Spore	Occurrences previously described and comparable species	Vertical distribution
Punctatisporites sp.	—	—
Calamospora sp.	—	—
Granulatisporites sp.	—	—
Densosporites sp.	—	—
Tholisporites subfoveolatus sp. nov.	Comparable species: *Tholisporites foveolatus* HUGHES and PLAYFORD (1961) – prob. Tournaisian; *Densosporites capistratus* HOFFMEISTER, STAPLIN and MALLOY (1955) – Upper Mississippian.	Lower Carboniferous
Velosporites echinatus HUGHES and PLAYFORD	HUGHES and PLAYFORD (1961) – prob. Tournaisian	?Tournaisian

Table 2. Microspore species present in sample A_3.

Spore	%	Occurrences previously described and comparable species	Vertical distribution
Punctatisporites sp.	<1	—	—
Calamospora sp.	<1	—	—
Leiotriletes sp.	<1	—	—
Lophotriletes magnus NAUMOVA	<1	NAUMOVA (1953) – Middle Devonian; ISHCHENKO (1956) – Visean	Middle Devonian to Visean
Lophotriletes sp. cf. *Punctatisporites nahannensis* HACQUEBARD and BARSS	<1	HACQUEBARD and BARSS (1957) — Upper Mississippian	Visean
Lophotriletes ? sp. A	<1	—	—
Knoxisporites ? sp. A	<1	—	—
Convolutispora crassituberculata sp. nov.	<1	Comparable species: *Convolutispora clavata* (ISHCHENKO) HUGHES and PLAYFORD — Visean (ISHCHENKO 1956, HUGHES and PLAYFORD 1961)	Visean
Triquitrites sp.	<1	—	—
Tripartites sp.	<1	—	—
Lycospora sp.	1.2	—	—
Densosporites variabilis (WALTZ) POTONIÉ and KREMP	3.4	ISHCHENKO (1956) – Tournaisian to Namurian; BUTTERWORTH and WILLIAMS (1958) – Namurian; LOVE (1960) – Visean; HUGHES and PLAYFORD (1961) – Visean	Lower Carboniferous
Densosporites commutatus (WALTZ) comb. nov.	<1	ISHCHENKO (1958) – Visean	Visean
Densosporites sp.	32.8	—	—
Tholisporites subfoveolatus sp. nov.	43	Comparable species: *Tholisporites foveolatus* HUGHES and PLAYFORD (1961) – prob. Tournaisian; *Densosporites capistratus* HOFFMEISTER, STAPLIN and MALLOY (1955) – Upper Mississippian	Lower Carboniferous
Tholisporites foveolatus HUGHES and PLAYFORD	<1	HUGHES and PLAYFORD (1961) – prob. Tournaisian	? Tournaisian
Velosporites echinatus HUGHES and PLAYFORD	<1	HUGHES and PLAYFORD (1961) prob. Tournaisian	? Tournaisian
Endosporites endorugosus HOFFMEISTER, STAPLIN and MALLOY	<1	HOFFMEISTER, STAPLIN and MALLOY (1955) – Upper Mississippian	Visean or Namurian
Indeterminable specimens	c. 15	—	—

Table 3. Microspore species present in sample A_2.

Spore	%	Occurrences previously described and comparable species	Vertical distribution
Punctatisporites sp.	2	—	—
Granulatisporites sp.	7	—	—
Triquitrites sp.	1	—	—
Lycospora sp.	14	—	—
Densosporites variabilis (WALTZ) POTONIÉ and KREMP	1	ISHCHENKO (1956) - Tournaisian to Namurian; BUTTERWORTH and WILLIAMS (1958) - Namurian; LOVE (1960) - Visean; HUGHES and PLAYFORD (1961) - Visean	Lower Carboniferous
Densosporites cf. *granulosus* KOSANKE	10	KOSANKE (1950) - Westphalian; Comparable species: *Densosporites granulatus* DYBOVÁ and JACHOWICZ (1957, 1958) - Namurian to Westphalian	Namurian to Westphalian
Densosporites sp.	37	—	—
Indeterminable specimens	28	—	—

BARSS 1957), *Densosporites* and *Lycospora* in the Visean of central Vestspitsbergen (HUGHES and PLAYFORD 1961), *Densosporites* and *Cirratriradites* in the Upper Mississippian of Illinois and Kentucky (HOFFMEISTER, STAPLIN and MALLOY 1955), *Lycospora* in the Visean of Scotland (LOVE 1960) and of Canada (STAPLIN 1960).

The qualitative character of the present assemblages is related to that of the Visean assemblages from Billefjorden Sandstones (central Vestspitsbergen) described by HUGHES and PLAYFORD (1961). From the sixteen genera enumerated by these authors (*o. c.*) ten occur in the present assemblages.

Systematic descriptions

The scheme of classification of microspores accepted in the present paper is that proposed by POTONIÉ (1956) and POTONIÉ and KREMP (1955, 1956 a) and supplemented by BUTTERWORTH and WILLIAMS (1958).

Anteturma SPORITES POTONIÉ, 1893

Turma TRILETES (REINSCH) POTONIÉ and KREMP, 1954

Subturma Azonotriletes LUBER, 1935

Infraturma Apiculati (BENNIE and KIDSTON) POTONIÉ, 1956

Genus **Lophotriletes** (NAUMOVA) POTONIÉ and KREMP, 1954

Lophotriletes sp. cf. *Punctatisporites nahannensis* HACQUEBARD and BARSS
Pl. I, Fig. 3

Dimensions (one specimen only): 42.8 μ × 47.4 μ.

Occurrence: Sample A_3. Recorded by HACQUEBARD and BARSS (1957) from Upper Mississippian.

Lophotriletes magnus NAUMOVA
Pl. I, Fig. 4

Description of specimens: Spores yellow brown, radial, trilete, convexly subtriangular (with rounded apices) to suboval, probable original spherical shape indicated by lack of orientation preference, arcuate compression folds present. Laesurae straight, length ⅔ spore radius.

Dimensions (2 specimens): 102.5 μ in the longest diameter. This size exceeds NAUMOVA'S (1953) upper limit for the species by 12.5 μ.

Occurrence: Sample A_3. Recorded from Upper Devonian by NAUMOVA (1953) and from Visean by ISHCHENKO (1956).

Lophotriletes ? sp. A
Pl. I, Figs. 1, 2

Description of specimens: Spore yellow brown, radial, trilete, convexly triangular or circular in proximal view, compression folds present. Laesurae straight, with distinct lips, length ½ to ⅔ spore radius. Exine 3–4.5 μ thick, distinct, densely granulate, with grana hardly visible at the margin.

Dimensions (2 specimens): longest diameter 108 to 122 μ.

Holotype: Preparation Sp2/VIII.

Locus typicus: Sample A_3, Lower Carboniferous, Adriabukta Series, Adriabukta, Hornsund, Vestspitsbergen.

Discussion: Characteristic for this species are compact sculpture of exine and laesurae with distinct lips.

Infraturma Murornati POTONIÉ and KREMP 1954.
Genus **Convolutispora** HOFFMEISTER, STAPLIN and MALLOY, 1955.

Convolutispora crassituberculata sp. nov.
Pl. I, Figs. 5–7

Diagnosis: Spores brown, radial, trilete, originally spherical; amb circular or suboval. Laesurae straight, length ½ to ⅔ spore radius. Exine distinct, densely crypto-granulate, and densely sculptured, with low, flattened, irregular verrucae about 1.5 μ high and 4.5 to 9 μ wide.

Dimensions (7 specimens): 88.7 μ to 119.3 μ in the longest diameter, mean 102 μ.

Holotype: Preparation Sp2/E; longest diameter 113 μ, laesurae 30.6 μ.

Derivation of the name: crassituberculatus – with thick tubercules.

Locus typicus: Sample A_3, Lower Carboniferous, Adriabukta Series, Adriabukta, Hornsund, Vestspitsbergen.

Comparison: Convolutispora clavata (ISHCHENKO) HUGHES and PLAYFORD does not possess crypto-granulation of exine, and the verrucae are less wide. The verrucae of ISHCHENKO's (1956) species are 5 to 14 μ wide (this may be established on comparison of ISHCHENKO's (*o. c.*) descriptions and figures). In this respect, therefore, ISHCHENKO's species appears to be more related to *Convolutispora crassituberculata* sp. nov. than to the species of HUGHES and PLAYFORD (1961).

Genus **Knoxisporites** POTONIÉ and KREMP, 1954

Knoxisporites ? sp. A

Pl. II, Fig. 1

Description of specimens: Spores light amber brown, radial, trilete, amb subcircular. Laesurae straight, length ⅔ spore radius. Exine almost smooth, thinly punctate, translucent. On the distal surface dark ring of variable width, running near the equator. Proximal surface laevigate.

Dimensions (one specimen only): Overall equatorial diameter 146.8 μ, width of the ring 13 to 18 μ.

Holotype: Preparation Sp 2/F.

Locus typicus: Sample A_3, Lower Carboniferous, Adriabukta Series, Adriabukta, Hornsund, Vestspitsbergen.

Comparison: This species differs from other species of *Knoxisporites* in having less thickenings.

Turma ZONALIS (BENNIE and KIDSTON) POTONIÉ and KREMP 1954

Subturma Zonotriletes WALTZ 1935

Infraturma Cingulati POTONIÉ and KLAUS 1954

Genus **Densosporites** (BERRY) POTONIÉ and KREMP, 1954

Densosporites commutatus (WALTZ) comb. nov.

Pl. II, Figs. 4, 5

Hymenozonotriletes commutatus (WALTZ) ISHCHENKO. ISHCHENKO (1958), p. 69, Table VII, Fig. 94.

Description of specimens: Spore light yellow, radial, trilete, amb convexly subtriangular, granulate. Laesurae not observed. Equatorial portion consists of a thickened, grooved inner ring, adjacent to the central area, with a smooth margin, and a more translucent, membraneous outer part, granulated and sometimes with radial grooves.

Dimensions (2 specimens): Overall equatorial diameter 38.3 μ to 50.5 μ, diameter of central area 15.3 μ to 18.8 μ, width of inner ring 7 μ.

Occurrence: Sample A_3. ISHCHENKO (1952, 1956, 1958) records this species from Visean and Namurian of the Donetz Basin.

Discussion: In the Visean of some areas occur some species related to *Densosporites commutatus. Densosporites irregularis* HACQUEBARD and BARSS differs in having the inner ring of less regular width. *D. subserratus* HACQUEBARD and BARSS possess a much narrower membraneous outer margin. *Hymenozonotriletes bialatus* (WALTZ) ISHCHENKO var. *undulatus* WALTZ differs in having the diameter of central area two to three times greater than the width of the equatorial portion. *Hymenozonotriletes coronarius* ISHCHENKO differs in having a completely smooth surface of the inner ring.

Densosporites variabilis (WALTZ) POTONIÉ and KREMP.

Pl. II, Fig. 3.

Occurrence: Sample A_3 and A_2. ISHCHENKO (1956) records this species from Tournaisian to Namurian, BUTTERWORTH and WILLIAMS (1958) from Namurian, LOVE (1960) from Visean, HUGHES and PLAYFORD (1961) from Visean.

Densosporites cf. *granulosus* KOSANKE

Pl. II, Fig. 2

Occurrence: Sample A_2. KOSANKE (1950) – Westphalian.

Infraturma Patinati BUTTERWORTH and WILLIAMS, 1958

Genus **Tholisporites** BUTTERWORTH and WILLIAMS, 1958

Tholisporites subfoveolatus sp. nov.

Pl. II, Figs. 6, 7, 7 a.

Diagnosis: Spores yellow brown, radial, trilete, amb convexly subtriangular to irregular. Well defined proximal central area roundly triangular to subcircular, thin walled, granulate. Laesurae straight to sinuous, extending into equatorial zone. Thickened patina constituting wide equatorial zone and whole distal hemisphere. Equatorial zone (proximal view) thick in the inner region, thin and translucent near the margin. These two regions are of variable width and are not sharply defined. Whole equatorial zone possesses irregularly arranged oval or circular pits, small warts or grana. Whole distal surface with granulate, vermiculate or wart-like sculpture.

Dimensions (25 specimens): Overall equatorial diameter 52 μ to 70 μ (mean (57.5 μ), diameter of central area 23 μ to 38 μ (mean 25 μ).

Holotype: Preparation Sp2/E; dimensions: overall equatorial diameter 61.2 μ, diameter of central area 29 μ.

Locus typicus: Sample A_2, Lower Carboniferous, Adriabukta Series, Adriabukta, Hornsund, Vestspitsbergen.

Derivation of the name: subfoveolatus – similar to *foveolatus.*

Comparison: Differs from *Tholisporites foveolatus* HUGHES and PLAYFORD in not possessing a single thickened ring of closely compacted pits; the pits are always irregularly arranged. *Densosporites capistratus* HOFFMEISTER, STAPLIN and MALLOY is not patinate and has shorter laesurae.

Anteturma POLLENITES POTONIÉ, 1931
Turma SACCITES ERDTMAN, 1947
Subturma Monosaccites (CHITALEY) POTONIÉ and KREMP, 1954
Infraturma Extrornati BUTTERWORTH and WILLIAMS, 1958
Genus **Velosporites** HUGHES and PLAYFORD, 1961
Velosporites echinatus HUGHES and PLAYFORD
Pl. II, Figs. 9, 10.

Dimensions (4 specimens): Overall equatorial diameter 107 μ to 153 μ, diameter of central body 53 μ to 133 μ.

Occurrence: Sample A_1 and A_3. HUGHES and PLAYFORD (1961) record this species from the probable Tournaisian of central Vestspitsbergen (Billefjorden Sandstones).

Infraturma Intrornati BUTTERWORTH and WILLIAMS, 1958
Genus **Endosporites** WILSON and COE, 1940
Endosporites endorugosus HOFFMEISTER, STAPLIN and MALLOY
Pl. II, Fig. 8.

Dimensions (one specimen only): Overall equatorial diameter 91.8 μ, diameter of central body 52 μ.

Occurrence: Sample A_3. Recorded by HOFFMEISTER, STAPLIN and MALLOY (1955) from Visean or Namurian A.

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Plate I

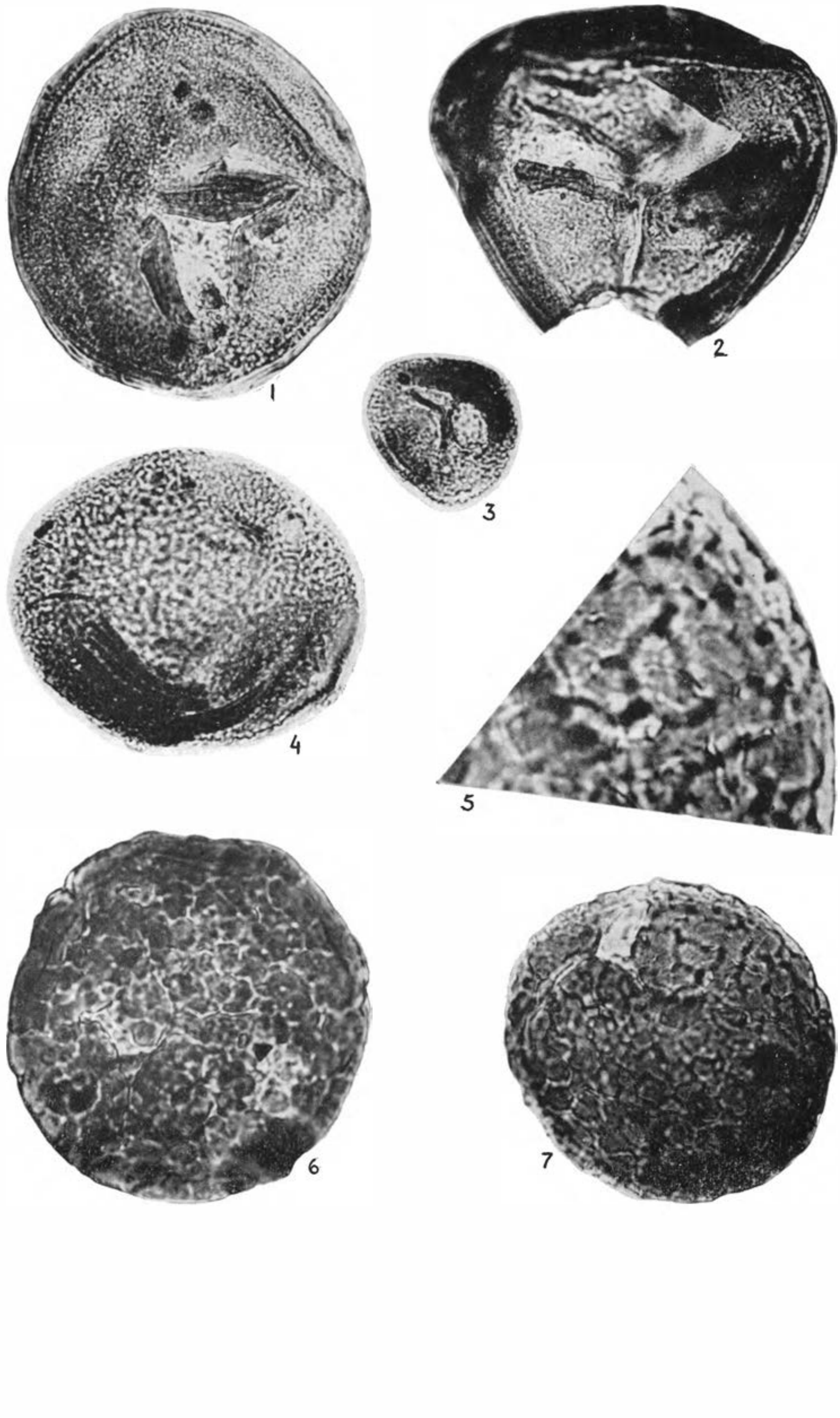
All figures × 500, except Fig. 5, which is × 1000, and from unretouched negatives.

Fig. 1. *Lophotriletes?* sp. A. Proximal view; preparation Sp2/A.
Fig. 2. *Lophotriletes?* sp. A. Holotype. Proximal view. Preparation Sp2/VIII.
Fig. 3. *Lophotriletes* sp. cf. *Punctatisporites nahannensis* HACQUEBARD and BARSS.
Proximal view. Preparation Sp2/XI.
Fig. 4. *Lophotriletes magnus* NAUMOVA.
Lateral view. Preparation Sp2/VII.
Fig. 5. *Convolutispora crassituberculata* sp. nov.
Part of surface; crypto-granulation of exina visible. Preparation Sp2/XI.
Fig. 6. *Convolutispora crassituberculata* sp.nov.
Holotype. Proximal view (laesurae not in focus). Preparation Sp2/E.
Fig. 7. *Convolutispora crassituberculata* sp. nov.
Lateral view. Preparation Sp2/XI.

Plate II

All figures × 500, and from unretouched negatives.

Fig. 1. *Knoxisporites* ? sp. A.
Holotype. Proximal view. Preparation Sp2/F.
Fig. 2. *Densosporites* cf. *granulosus* KOSANKE.
Preparation Sp13/I.
Fig. 3. *Densosporites variabilis* (WALTZ) POTONIÉ and KREMP.
Preparation Sp2/I.
Fig. 4. *Densosporites commutatus* (WALTZ) comb. nov.
Preparation Sp2/I.
Fig. 5. *Densosporites commutatus* (WALTZ) comb. nov.
Preparation Sp2/V.
Fig. 6. *Tholisporites subfoveolatus* sp. nov.
Proximal view of specimen lacking proximal central area. Preparation Sp2/II.
Fig. 7. *Tholisporites subfoveolatus* sp. nov.
Holotype. Proximal view. Preparation Sp2/E.
Fig. 7a. *Tholisporites subfoveolatus* sp. nov.
Holotype. Distal view. Preparation Sp2/E.
Fig. 8. *Endosporites endorugosus* HOFFMEISTER, STAPLIN and MALLOY.
Proximal view. Preparation Sp2/A.
Fig. 9. *Velosporites echinatus* HUGHES and PLAYFORD
Proximal view of fragment of a specimen. Preparation Sp2/VII.
Fig. 10. *Velosporites echinatus* HUGHES and PLAYFORD.
Preparation Sp2/I.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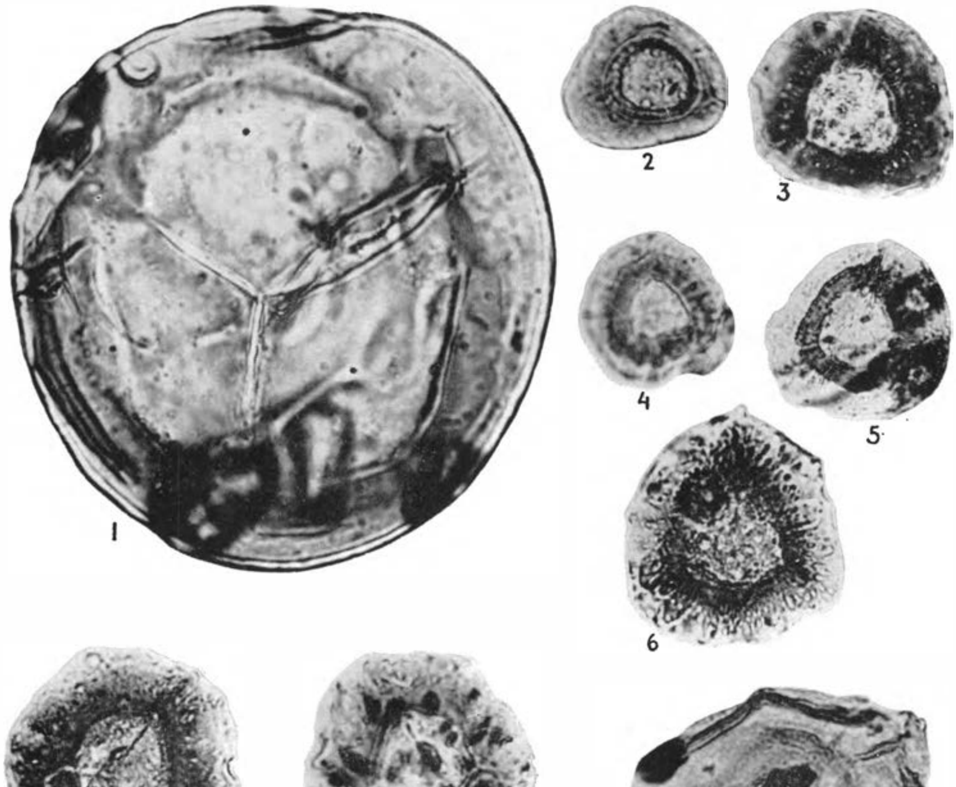
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Plesiosaurians from Spitsbergen

BY

PER OVE PERSSON[1]

Abstract

Two Plesiosaurian specimens from the Upper Jurassic (?Oxfordian and ?Portlandian, respectively) of Spitzbergen are described. One of them comprises the posterior parts of a skeleton, and is made the holotype of a new species, *Tricleidus svalbardensis*. The most prominent characters of this species are shown in the ischia, these being very broad and widely separated, and with an almost straight posterior border. The species is referred to the genus *Tricleidus* essentially because of the shape of the proximal bones in its hind limbs; these bones conform closely with the corresponding elements in *Tricleidus seeley* ANDREWS 1909.

The other specimen consists of a few more or less incomplete vertebrae, an incomplete ilium, the distal end of a ? femur, and a great number of fragments of various postcranial elements. The specimen is referred to Plesiosauridae, gen. et sp. indet.

Plesiosaurian remains from Spitsbergen were recorded as early as 1914, when WIMAN published a description of a vertebral centrum from Janusfjellet, south of Deltaneset. The age of this fossil is somewhat questionable, but according to WIMAN (1914, p. 201) it cannot be older than the lower part of the *Aucella* Shale (Upper Dogger – Malm; see WINSNES *et al.* 1960, p. 5), or younger than the *Ditrupa* layers (Neocomian). In 1916 WIMAN described another Plesiosaurian fossil, a ?pectoral vertebra from the ?Upper Triassic of the eastern side of De Geerdalen, near Sassenfjorden.

By courtesy of Professor A. HEINTZ and Dr. G. HENNINGSMOEN, both of the Paleontological Museum, the University of Oslo, the present author was enabled to study two interesting Plesiosaurian specimens from Sassenfjorden region which are in the possession of the museum mentioned. I am indebted to Professor HEINTZ for important information concerning the specimens in question, and to cand. real. T. S. WINSNES of Norsk Polarinstitutt, Oslo, for stratigraphical information. The specimens are described and discussed below.

One of the specimens (P.M.O. A 27745; here made the holotype of *Tricleidus svalbardensis* n. sp.) was figured by A. HEINTZ in the illustrated work "Svalbard – en del av Norge" (1950); it has also been mentioned and figured in various newspaper articles etc. Cand. real. NATASCHA HEINTZ mentioned the specimen and showed a photograph of it in a lecture entitled "Mesozoic Reptiles from Norway and Svalbard", given in Norsk Geologisk Forening on February 1, 1962.

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Genus **Tricleidus** ANDREWS 1909

Diagnosis: ANDREWS 1910, p. 149.
Genotype: Tricleidus seeleyi ANDREWS 1909.

Tricleidus svalbardensis n. sp.

Diagnosis: Posterior parts of the ischia broadly expanded and widely separated; posterior borders of these bones straight. Femur, tibia, fibula, tibiale and intermedium of almost exactly the same shape as the corresponding elements in the genotype.

The only known specimen is about twice as large as the holotype of *Tricleidus seeleyi.*

Holotype and material: The posterior part of a skeleton (Pl. I, Fig. 1), now in Paleontological Museum, the University of Oslo. (P.M.O. A27745). The specimen is exhibited approximately in the position in which it was found, its ventral side being exposed. The following parts are preserved:

1. A series of thirty-seven more or less complete vertebrae. The four foremost of these are in a reasonably good state of preservation. They obviously belong to the thoracic-lumbar region. The next six vertebrae, among which must be the ?four[1] sacrals, are very fragmentary and show no clear characters. The remaining twenty-seven vertebrae, most of which are in a fairly good state of preservation, are all caudals.
2. Some rib fragments.
3. Portions of the pelvic girdle, viz. the ?distal end of the right ilium; the major part of the right pubis; the posterior part of the left pubis; the major parts of both ischia.
4. The right hind limb (some distal phalanges lacking, otherwise probably complete); the left hind limb, incomplete (distal end of femur crushed; epi- and mesopodial bones crushed or missing, a few phalanges also missing).

Description: Measurements. The length of the preserved part of the skeleton is 2.25 m. If *Tricleidus* had approximately the same general proportions as the closely related *Cryptocleidus,* the length of the entire skeleton may have been about 6.20 m.

Measurements of some particular elements of the skeleton are given in the text below, and in Fig. 1.

Vertebrae. The proportions of the centra of two of the best preserved vertebrae are as follows: A posterior thoracic-lumbar centrum: Length 60 mm; height 87 mm; breadth 91 mm; H:L ind. 145; B:L ind. 152. ?10th caudal centrum: Length 46 mm; height 63 mm; breadth 74 mm; H:L ind. 137; B:L ind. 161.

In all the vertebrae preserved the neurapophyses (Pl. I, 2, np) are fused to the centra. The end faces are moderately concave, the concavity being a little deeper in the caudal centra than in the thoracic-lumbar centra. The caudal ribs are not

[1] The number of sacral vertebrae in *Tricleidus* is not known. However, the closely related genus *Cryptocleidus* had four sacrals (ANDREWS 1910, p. 172), and hence it is probable that *Tricleidus* had the same number.

fused to the centra; the facets for these ribs (cr) have the shape of a shallow, sub-circular crater facing straight laterally. In most of the centra the rib facets are situated a little more anteriorly than posteriorly. On the ventral face of the caudal centra there are two low longitudinal ridges, one on each side of the foramina for nutritive vessels. The presence of such ridges is mentioned by WELLES (1943, p. 136) as one of the distinctive characters of dolichodiran Plesiosaurians. The chevron facets (cf) have a more or less sub-triangular shape; they are situated one on each end of the ventral ridges just mentioned. Most of the chevrons are in a bad state of preservation. They seem to be fairly similar to those of *Muraenosaurus*, described by ANDREWS (1910, p. 104).

The preserved parts of the right ilium (Fig. 1, il) do not show any particular characters of interest. As in most Plesiosaurians the bone in question had the shape of a stocky, somewhat curved rod.

Of the pubes (p) the right one is best preserved. It has the shape of a broad, fairly thin plate with a thickening at the "head", the latter carrying the acetabular surface and the ischial facet. The thickening continues along the posterior border and reaches the symphysis. The acetabular surface makes an angle of about 140 degrees with the ischial facet. Most of the median, anterior and lateral borders are destroyed, and it is hence impossible to find out whether there was a prominent antero-lateral projection as is the case in the pubis of *Apractocleidus teretipes* (see SMELLIE 1917, Fig. 2).

The ischia (is) are also flat and fairly thin bones. They are somewhat thickened at their "heads", the thickening continuing transversely to the median symphysis. Judging from the symphysial parts preserved the bones must have been widely separated posteriorly. The posterior extension of each ischium is unusually broad; its postero-lateral border is slightly concave and forms an angle of about 115 degrees with the posterior border, the latter being almost straight.

The femur (f) is relatively slender. Its surface is badly weathered, a detailed study of the articular faces and the muscle insertions hence being impossible. The caput seems to have been continous with the trochanter. The posterior border of the bone is much more concave than the anterior one, and on the distal end there is a rounded posterior extension. The femur articulates distally with two elements only, tibia and fibula.

The tibia and the fibula (t and fi) are both considerably broader than long. There is a little foramen between them. The anterior (outer) border of the tibia is convex. Distally the bone mentioned bears a long facet for the articulation with the tibiale (tl) and a shorter one for the intermedium (in). The fibula articulates with the intermedium and the fibulare (fl) by two facets of about equal length, forming an angle of 120 degrees with each other.

There are six tarsals, the largest of which is the intermedium, a bone of roughly pentagonal shape. The tibiale articulates distally with the first distal tarsal (d_1), the intermedium with the second (d_2) and third (d_3), and the fibulare with the third, and with the fifth metatarsal (m_5).

The first of the metatarsals (m_{1-5}) articulates proximally with the first distal tarsal, the second with the first and second, the third with the second and third,

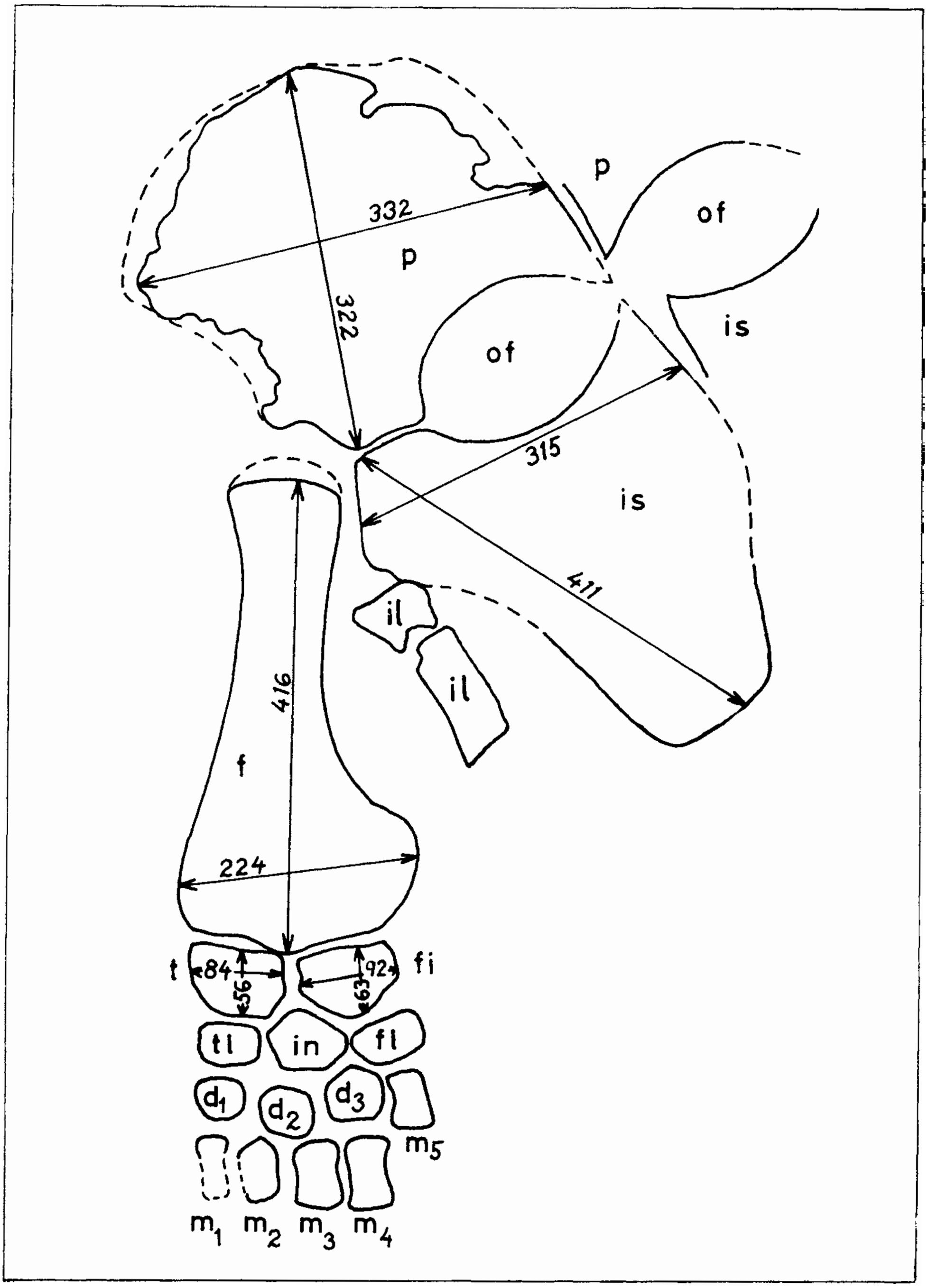

Fig. 1. *Tricleidus svalbardensis* n. sp. P.M.O. A 27745. Semi-diagrammatic sketch of parts of pelvis and right hind limb. Ventral aspect. Measurements (indicated by arrows) in mm. – About 1/6 nat. size.

d_{1-3} – distal tarsals; *f* – femur; *fi* – fibula; *fl* – fibulare; *il* – ilium; *in* – intermedium; *is* – ischium; m_{1-5} – metatarsals; *of* – obturator fenestra; *p* – pubis; *t* – tibia; *tl* – tibiale.

the fourth with the third only, while the fifth, as already mentioned, articulates directly with the fibulare.

The numbers of the preserved phalanges in the digits I–V are 3, 10, 12, 11 and 8, respectively.

Remarks: The general osteological characters of the specimen described show clearly that it represents the same type of Plesiosaurians as the probably closely related Oxfordian genera *Muraenosaurus, Picrocleidus, Tricleidus, Cryptocleidus* and *Apractocleidus* (see ANDREWS 1909 and 1910; SMELLIE 1915 and 1917). The characteristic shape of the ischia indicates that the specimen belongs to a genus or sub-genus of its own within the *Muraenosaurus–Apractocleidus* group, but with regard to the defectiveness of the material it seems more appropriate to refer it to one of the genera already established. The specimen shows close affinities particularly to two genera, viz. *Tricleidus* ANDREWS 1909 and *Apractocleidus* SMELLIE 1915. For reasons demonstrated below it is here referred to the former of these genera under the name of *Tricleidus svalbardensis* n. sp.

Where the characters of the ischia are concerned the present species agrees more with *Apractocleidus teretipes* SMELLIE 1915 than with any of the other forms which can come in question for a comparison.[1] In *A. teretipes* as well as in *T. svalbardensis* the ischia are widely separated and expanded posteriorly, although the expansion is not so broad in the former as in the latter species (cf. SMELLIE 1917, fig. 2). However, the two species differ from each other by the shape of the posterior ischial border, this being almost straight in *T. svalbardensis* but strongly curved in *A. teretipes.*

Where certain characters of the hind limb are concerned there is a conspicuous difference between *A. teretipes* and *T. svalbardensis.* In the former species the anterior border of the femur is much more concave than in the latter, the distal end of the bone hence being more expanded. Furthermore, according to SMELLIE (1917, p. 625) the femur in *A. teretipes* probably articulated distally with four elements, whereas in *T. svalbardensis* the distal articulation of the bone mentioned comprehends the tibia and the fibula only. Apparently the limbs in *A. teretipes* were much more specialized than in *T. svalbardensis.* As will be readily gathered from a comparison with the descriptions and figures given by ANDREWS (1910) the hind limb of the latter species differs in several details also from that of *Cryptocleidus and Muraenosaurus.*

Of the forms in which the hind limb is known, *Tricleidus seeleyi* is the only one that agrees well with the Spitsbergen species with regard to the proximal elements of that limb, the latter species hence being referred to the genus *Tricleidus.* Of the hind limb in *T. seeleyi* only the femur, tibia, fibula, tibiale and intermedium are known, but these bones show a very great conformity with the corresponding elements in *T. svalbardensis* (see ANDREWS 1910, pp. 161–162; Pl. 8, Fig. 4). The only differences worth mentioning are that the femur is comparatively a little

[1] Only three species of the genus *Tricleidus* are known, viz. the genotype (*T.seeleyi*), *T.? laramiensis* (KNIGHT 1900), and the form here dealt with. In *T. seeleyi* as well as in *T.? laramiensis* the pelvis is not known. In the latter species, which was provisionally referred to *Tricleidus* by MEHL (1912, p. 350), the hind limbs are also unknown.

stouter and the anterior border of that bone somewhat more concave in *T. seeleyi* than in *T. svalbardensis*. The latter species was probably about twice as large as the former (the original length of the femur in *T. svalbardensis* may have been as much as 420 mm, whereas the length of that bone in *T. seeleyi* is 216 mm only).

The vertebral centrum from Janusfjellet described by WIMAN (1914; see above, p. 62) represents a species which was perhaps contemporaneous with *T. svalbardensis* or with the form described below as Plesiosauridae, gen. et sp. indet. However, the Janusfjellet Plesiosaurian apparently had much shorter vertebrae than the two forms here described, and therefore it may not be conspecific, or even congeneric, with any of these. The other specimen described by WIMAN (1916; see above, p. 62) had two-headed ribs; it hence represents a more primitive type of Plesiosaurians than the present specimens. That this is so is of course to be expected because of the fact that it comes from a much older sediment (?U. Triassic).

Geological horizon and locality: The only information available concerning the age and find locality of the present specimen is a label with the text: "Jurassic? The mouth of Sassenfjorden, Vestspitsbergen". Since *Tricleidus* and allied genera are known essentially from the Oxfordian, and deposits of that age are present in the find region, *T. svalbardensis* may be recorded provisionally as an Oxfordian species.

Find history (according to information kindly given by Professor A. HEINTZ): The specimen was found accidentally in 1931 by three English physicians, Dr. FREEZE, Dr. MALLER and Dr. PAUL, who studied the influenza in Spitsbergen. The matrix was a dark grey shale which was partially weathered as to form a coarse gravel. Engineer G. AASGAARD, who was inspector of the Svalbard mines at that time, photographed the specimen *in situ*, and then he packed it up very carefully and sent it to Paleontological Museum in Oslo. In the museum it was skilfully mounted by Professor L. STØRMER. By guidance of the photographs and information from the collector the individual skeletal elements were placed as far as possible in the position they had when the specimen was found.

Plesiosauridae, gen. et sp. indet.

Material: Parts of a skeleton, including 1. A number of more or less fragmentary vertebrae: one anterior and two posterior cervicals, two ?sacrals, and 8 caudals. 2. A fragmentary right ilium. 3. The distal end of a propodial bone, probably a femur. 4. A great number of fragments, among which are pieces of vertebrae, ribs, girdle bones and limbs bones.

Description: The vertebral centra best preserved have the following dimensions:

Anterior cervical:	Length 37 mm;	height 30 mm;	breadth 38 mm.	H:L ind. 81	B:L ind. 103
Posterior » :	» 59 »	» 60 »	» 72 »	» » 102	» » 122
Anterior caudal :	» 42 »	» 58 »	» 65 »	» » 138	» » 155

The end faces of all the centra are moderately concave. In both the posterior cervical vertebrae preserved the neurapophysis is fused with the centrum, but this is not the case with the anterior one. The ribs were attached to the centra by sutures in all three cervicals preserved. In the anterior cervical centrum there is a very slight indication of a lateral longitudinal ridge (cf. WELLES 1943, pp. 135 and 137). The caudal vertebrae are very similar to those of *Tricleidus svalbardensis* described above (p. 63–64).

If the ilium is correctly reconstructed its length is about 195 mm.

The greatest breadth of the ?femur (Pl. I, 3) is 182 mm. The anterior border of the bone is almost as concave as the posterior one; the "shaft" seems to have been comparatively slender.

Remarks: The material described shows clearly that we are dealing with a dolichodiran Plesiosaurian. The proportions of the cervical centra and the slender shape of the propodial bone indicates a Plesiosaurid rather than an Elasmosaurid or a Cimoliasaurid (cf. WELLES 1943, p. 184; PERSSON 1959, pp. 6–7). The specimen is hence described here as Plesiosauridae, gen. et sp. indet. If the propodial fragment is a part of a femur the specimen may not be conspecific with *Tricleidus svalbardensis* n. sp. described above, the anterior border of the femur in this species being much less concave than the posterior one.

Geological horizon and locality: Cand. real T. S. WINSNES has kindly given me the following information, partly based upon diaries kept by Dr. A. K. ORVIN, who found the specimen in 1925, and by Dr. G. HORN, who took part in the excavation of it:

"The find locality was on a mountain (Janusfjellet?) south of Deltaneset, about 280 m above sea level, just above the *Aucella* Shale and below the Cretaceous border. The find stratum is probably identical with the Lower Wolga Shale, of Portlandian age (FREBOLD 1930, pp. 35–39)."

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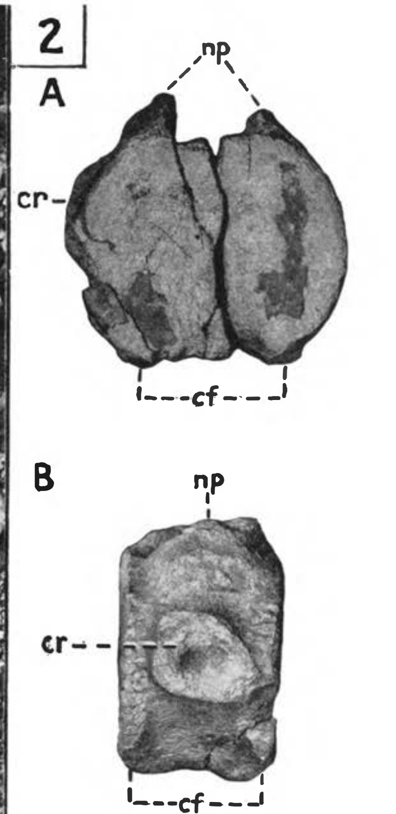

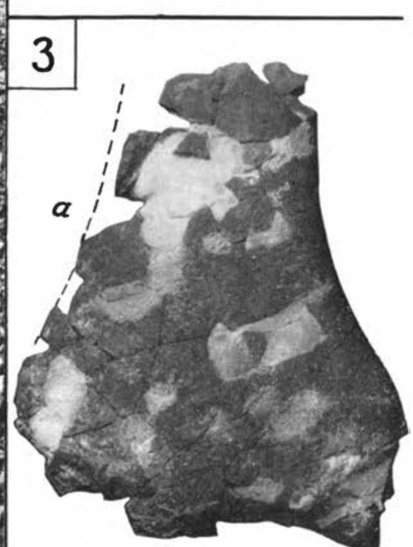

1. *Tricleidus svalbardensis* n.sp. Posterior part of a skeleton. Ventral aspect. P.M.O. A 27745. Sassenfjorden, Vestspitsbergen. About 1/12 nat.size.
2. *Tricleidus svalbardensis* n.sp. ?10th caudal vertebra in anterior aspect (A) and from the right side (B). About 1/2 nat.size. cf – chevron facet; cr – facet for caudal rib; np – basal part of neurapophysis.
3. Plesiosauridae, gen. et sp. indet. P.M.O. A 27746. Distal end of a ?femur. About 1/3 nat. size. a – anterior border.

Lavas of the southern part of Jan Mayen

BY

HARALD CARSTENS[1]

Abstract

The lavas of the southern part of Jan Mayen belong to three different volcanic groups:

Upper group	younger members (Kraterflya lavas) older members
Unconformity	
Middle group	lava domes lava flows
Lower group	

The lavas of the Upper group are mainly augite-olivine-plagioclase phyric basalts grading into ankaramites. In addition to these ankaramitic basalts of alkali olivine-basaltic parentage, ankaramites having mineral characteristics common with tholeiitic oceanites also occur on Jan Mayen.

The Middle group includes a series of alkaline andesitic lavas ranging from trachybasalt to trachyandesite. They are paralleled by the hawaiite – mugearite series of the islands of the Pacific and Indian Oceans. These lavas of the Middle group were later followed by dome-building latites and trachytes.

The lavas of the Lower group were not investigated.

The Jan Mayen lavas are characterized by high total alkalies and low soda to potash ratio.

Introduction

A topographical map of the island Jan Mayen in the North Atlantic Ocean was completed by Norsk Polarinstitutt in 1958. A geological survey of the island followed in 1959. A short communication of the trachytes was published in 1961. The present paper deals with the petrology of the basic and intermediate lavas of the southern part of Jan Mayen — the so-called Sør-Jan.

General geology

The rocks of Jan Mayen are entirely volcanic. Three different volcanic groups may be recognized:

[1] Norges Geologiske Undersøkelse, kjemisk avdeling. Trondheim.

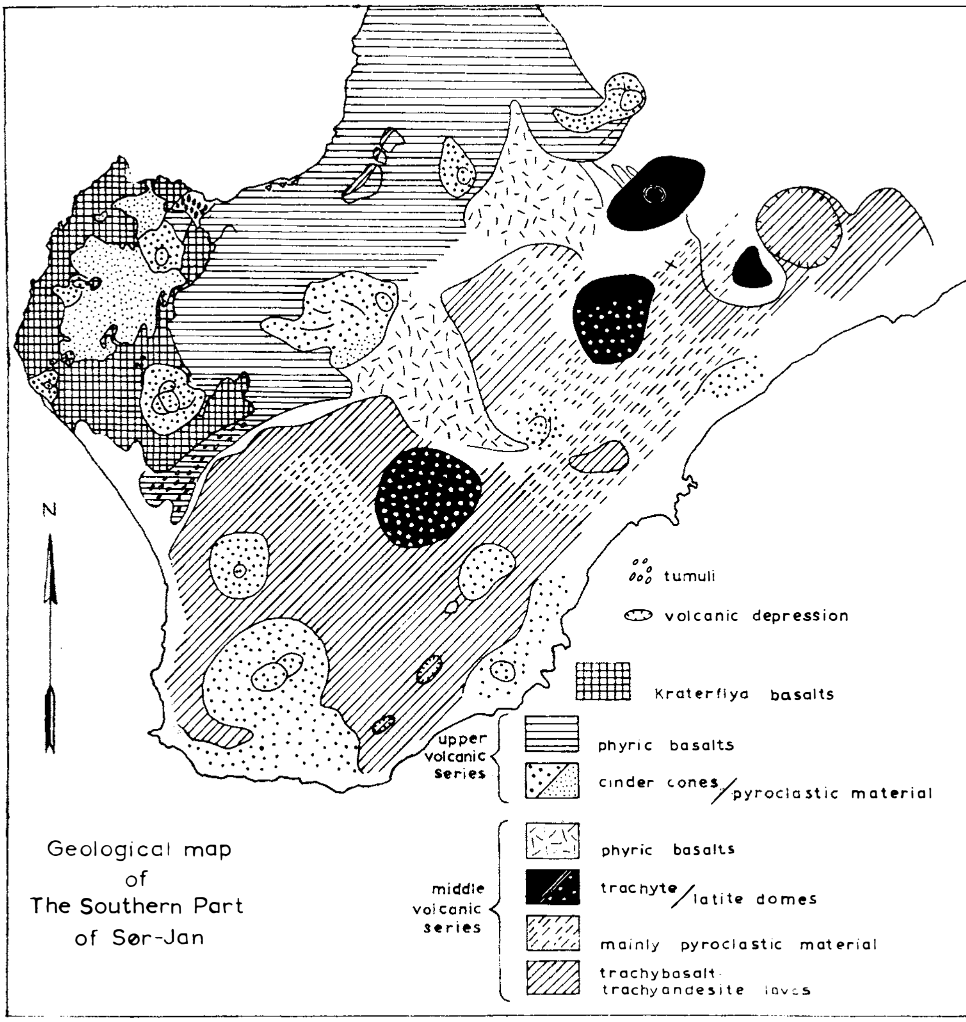

Fig. 1. *Geological map of the southern part of Jan Mayen.*

1. A Lower group consisting of basaltic lavas and pyroclastics forms the basement of the island above sea level. These rocks are exposed only on steep sea cliffs on the south and south-east sides. Pyroclastic material is very abundant. Intrusive sills and dykes cut through the extrusives. The thickness of this series may be over 300 meters, decreasing to the west.

2. A Middle group of trachybasalts, trachyandesites, latites, and trachytes, of which an older plateau-building stage may be separated from a younger dome-building stage. A short period with extrusion of augite-olivine-plagioclase phyric basalts probably preceded the formation of the trachyte and latite domes. The lavas of the Middle group build up a central high plateau on Sør-Jan. The lavas are cut by dykes of trachybasaltic and trachyandesitic composition which may have acted as lava feeders.

3. An Upper group separated from the Middle group by an erosional interval, consists of a large number of basaltic cinder cones and lavas emitted from their craters or from their base. These most recent products of the volcanic activity of Sør-Jan cover the western and the southern parts. The lavas associated with the cinder cones of Kraterflya probably represent the latest volcanic activity on Sør-Jan.

The geological sketch map, Fig. 1. shows the distribution of the various volcanic groups.

The Lower group was unfortunately not sampled due to the difficulty of access.

The phyric lavas of olivine-basaltic composition are both of the pahoehoe type with ropy surfaces and lava tunnels, and of the a–a type. The lavas are generally strongly vesiculated. On the flat terrain the pahoehoe lavas formed small domes or tumuli, slightly elongated in the direction of flow. They are 3–5 m in lenght and 1.5–2 m in height, and have a thin crust, 5–30 cm thick, of solidified lava. The domes are filled with small lumps of rugged lava. Related to these domes are lava tubes which occur where the ground is inclined. The tubes may be filled with similar lumps, but the smaller ones are usually empty (Figs. 2 and 3).

The intermediate lavas of the Middle group form thick series of thin lava flows which lack the usual pahoehoe structures. Vesiculation is also much less.

The large dome-shaped mountains which are so typical of Sør-Jan, were formed by the most acid and alkaline lavas — trachytes and latites.

The volcanic vents are conspicuously aligned.

Phyric basalts and ankaramites

The lavas which were emitted from the young scoria cones strewn over the island are all phyric basalts. The phenocrysts are mainly augite, olivine and plagioclase — usually in that order of abundance. The amount of olivine is always subordinate to augite, but the content of plagioclase may be higher than that of the augite, i. e. in the Kraterflya lavas. Occasionally titanomagnetite is also a phyric constituent. Glomerophyric structures are frequent. In a rare basalt found mostly as bombs or lapilli large phenocrysts of a titaniferous hornblende (probably kaersutite, $TiO_2 = 6.39$ %) were noted. Olivine was scarce or absent.

The essential constituents of the groundmass are labradorite, olivine, augite, and iron ore. Olivine is usually more abundant than augite. Alkali feldspar is present in minor amounts, often together with some analcite. Glass ($n = 1.507$) may occur interstitially or in patchy distribution. Sometimes nearly isotropic globules enriched in glass have been found.

The size of the augite phenocrysts is usually 0.5–1.0 cm or less. But large crystals, 7–8 cm across, occasionally occur (big-augite basalt). The augite-olivine-plagiclaseo phyric basalts grade into ankaramitic types (I, Table III) through an increase in the abundance of augite phenocrysts. The augite, in contrast to the corroded appearance of the olivine phenocrysts, is usually perfectly euhedral (Fig. 4), and is brown to violet in thin section but black in hand specimens. Inclusions of anhedral olivine are common, and zoning is distinct – a thin marginal zone (rarely

Fig. 2. *Dome of phyric basalt, Guineabukten. Boldvatoppen in the background.*

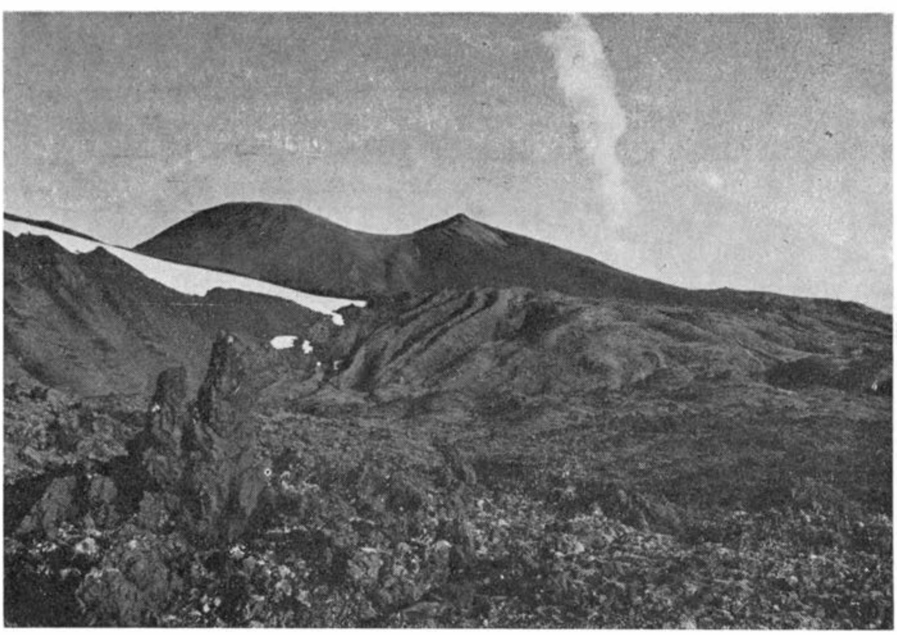

Fig. 3. *Lava tubes, Guineabukten. Boldvatoppen in the background.*

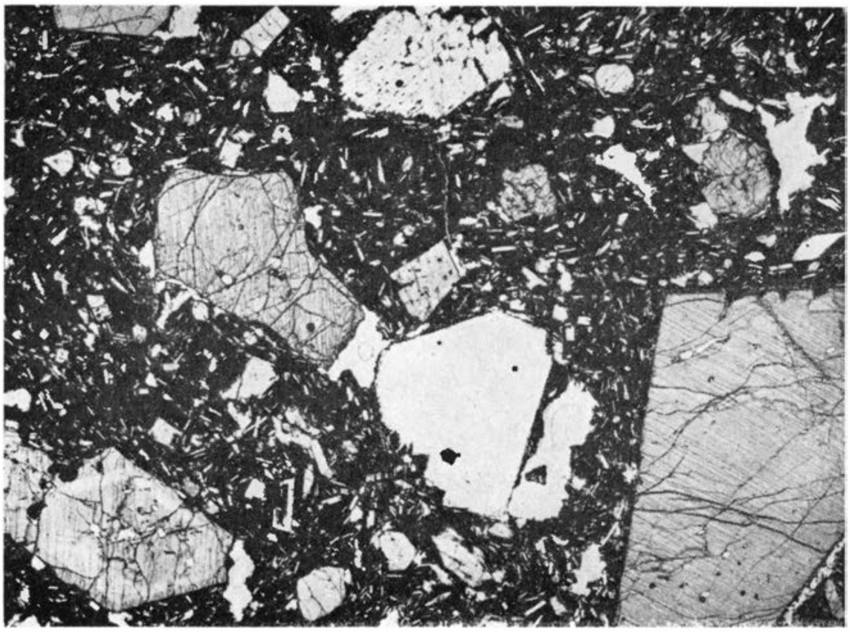

Fig. 4. *Phyric basalt, Båtvika. Phenocrysts of augite and plagioclase.* Photomicrograph, 11.5 ×.

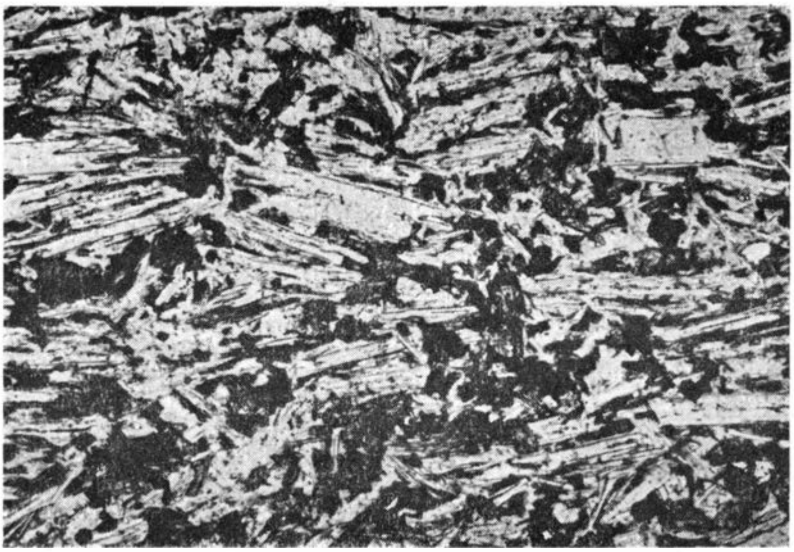

Fig. 5. *Trachyandesite, Kingstoppen. Trachytic texture.* Photomicrograph, 151 ×.

two) is sharply bounded against the core. The Becke line as a rule moves into the marginal zone when the tube of the microscope is raised, suggesting an increase in the amount of iron in this zone at the expense of magnesium, although exceptions have been noted. This augite has also been found in tuffaceous rocks on Jan Mayen. A chemical analysis of augite separated from big-augite basalt of Kapp Trail (outside the mapped area) is given in Table I, and it is found to be a titaniferous augite exceptionally high in Al_2O_3. According to I. KUSHIRO (1960) a high content of Al_2O_3 is to be expected in clinopyroxenes crystallizing in alkalibasalt magmas deficient in SiO_2 due to the ease of access of aluminium into tetrahedral positions. As Al is preferentially co-ordinated with $(OH)^{-1}$ ions (A. E. RINGWOOD, 1959), the Al-Si diadochy is also affected by the content of water in the magma. There is also the possibility of a temperature control of tetrahedral Al. The Mg/Fe ratio is as normal for clinopyroxenes from alkalibasaltic magmas (J. F. G. WILKINSON, 1956).

Table I. Analyses of augite phenocrysts in ankaramitic basalts.

	Weight %					Formulae of the augites on basis of 6 oxygen ions				
	1	2	3	4		1	2	3	4	
SiO_2	45.13	48.70	49.90	47.70	Si	1.67	1.80	1.83	1.77	Z=2.00
TiO_2	2.57	2.42	2.06	1.89	Al	0.33	0.20	0.17	0.23	
Al_2O_3	10.44	4.69	5.35	6.82	Al	0.12	–	0.06	0.07	X
Fe_2O_3	3.65	2.30	1.07	3.36	Ti	0.07	0.07	0.06	0.05	
FeO	3.88	5.00	4.88	4.43	$Fe^{\cdot\cdot\cdot}$	0.10	0.06	0.03	0.09	
MnO	n.d.	0.12	0.04	0.16	$Fe^{\cdot\cdot}$	0.12	0.15	0.15	0.13	
MgO	12.35	14.38	15.51	13.34	Mg	0.68	0.79	0.85	0.74	
CaO	21.53	21.89	20.20	21.35	Ca	0.85	0.87	0.79	0.85	Y
Na_2O	0.47	0.64	0.78	0.65	Na	0.01	0.04	0.03	0.04	
K_2O	0.07	0.06	0.28	0.03						
H_2O+	0.06	0.04	–	0.15	XY	1.95	1.98	1.97	1.97	
	100.15	100.24	100.08	100.79	Ca	49	46	44	47	
					Mg	39	42	46	41	
					Fe	12	12	10	12	

Refractive indices (1): $\gamma = 1.727 \pm 0.002$

$\alpha = 1.708 \pm 0.002$

Optic axial angle: $2V = +52°$

1. Big-augite basalt. Kapp Trail. Analyst: B. Th. ANDREASSEN.
2. Tristan da Cunha (J. C. DUNNE, 1946).
3. Azores (P. ESENWEIN, 1928).
4. Halekala, Hawaii (H. S. WASHINGTON and H. E. MERVIN, 1922).

Table II. Analyses of chromium diopsides of ankaramite and picrite-basalt.

	Weight % 1	Weight % 2	Weight % 3
SiO_2	52.17	51.72	51.85
TiO_2	0.64	0.92	n.d.
Al_2O_3	3.35	3.82	1.56
Fe_2O_3	0.70	0.90	2.44
FeO	3.21	5.77	3.46
MnO	n.d.	0.14	tr.
MgO	17.12	16.80	17.40
CaO	22.12	19.13	22.15
Na_2O	0.27	0.45	n.d.
K_2O	0.11	0.05	n.d.
Cr_2O_3	0.70	0.52	0.73
H_2O	0.10	n.d.	
	100.49	100.22	99.71

Formulae of the diopsides on basis of 6 oxygen ions.	1	2	
Si	1.89	1.89	Z = 2.00
Al	0.11	0.11	
Al	0.05	0.05	X
Cr	0.1	0.01	
Ti	0.02	0.02	
$Fe^{\cdot\cdot\cdot}$	0.02	0.03	
$Fe^{\cdot\cdot}$	0.10	0.18	
Mg	0.92	0.92	
Ca	0.85	0.75	Y
Na	0.02	0.03	
XY	1.99	1.99	
Ca	45	40	
Mg	49	49	
Fe	6	11	

Refractive index (1): $\gamma = 1.702 \pm 0.002$

Optic axial angle (1): $2V = +60°$

1. Phenocryst in ankaramite, type II, Båtvika, Jan Mayen. Analyst: B. Th. ANDREASSEN.
2. Phenocryst in picrite-basalt, flow of 1840, Kilauea. (I. D. MUIR and C. E. TILLEY ,1957.)
3. Ankaramite?, Jan Mayen. (R. SCHARIZER, 1884.)

On Nord-Jan associated with parasitic cinder cones on the flanks of the great Beerenberg volcano (2277 m), occurs a type of ankaramite (II, Table III) not recognized on the southern part of the island. Phenocrysts of green clinopyroxene characterize these ankaramites. Phyric plagioclase is absent. The clinopyroxene has been separated and analyzed and the result is shown in Table II. The contrasting composition of the two analyzed Jan Mayen clinopyroxenes is at once apparent. In order to demonstrate the close relationship of the green chromium diopside with clinopyroxenes from tholeiitic picrites an analysis of a diopside from a picrite basalt of Kilauea is also given in Table II. The composition is also similar to the diopsides of olivine nodules which may occur in basaltic lavas (C. S. ROSS, M. D. FOSTER, A. T. MEYER, 1954). The olivine phenocrysts in the Beerenberg ankaramites are often banded due to deformation lamellae parallel to (100) — also recalling a common feature of olivine nodules. When, as very seldom happens, chromium diopside and titaniferous augite appear together in the same thin section the diopside often forms a core surrounded by augite but never vice versa.

Table III summerizes the mineralogy of the phyric basalts and the ankaramites.

Table III. Mineral constituents of phyric basalts and ankaramites.

	Phenocrysts	Groundmass	Modes		
Phyric basalt ankaramite (I)	Titan-augite Ca_{49} Mg_{39} Fe_{12}	Labradorite-andesine	Augite	12	11
			Olivine	9	7
	Olivine Fa_{16-18}	Olivine	Plagioclase	5	14
			Magnetite	0.5	0.5
			Groundmass	73.5	67.5
	Plagioclase An_{80}	Titanmagnetite			
	Titanomagnetite (sometimes present)	Alkali feldspar			
		Accessories: augite, apatite			
Ankaramite (II)	Cr-diopside Ca_{45} Mg_{49} Fe_6	Augite	Diopside	33	
	Olivine Fa_{12-14}	Plagioclase	Olivine	10	
			Groundmass	57	
		Iron ore (skeletal)	Augite very abundant in the groundmass		

Trachybasalts — trachyandesites

The main part of the Middle volcanic group consists of grey to black, fine-grained holocrystalline lavas often with a well developed platy jointing due to a parallel arrangement of flattened plagioclase tablets. They are typically non-porphyritic, but phenocrysts of augite, olivine and plagioclase may occur. These rocks belong to the trachybasalt-trachyandesite series.

The plagioclase tablets responsible for the trachytic texture, Fig. 5, in the andesitic part of the series are in average $0.2 \times 0.2 \times 0.3$–4 mm in size and generally have forked ends. It is impossible to get exact determinations of the composition, but a number of optical measurements suggests andesine grading into labradorite in the mesocratic trachybasalts. The plagioclase is enveloped by alkali feldspar.

Olivine (Fa_{25-35}) and titanomagnetite are the most abundant ferromagnesian minerals. The habit of the olivine is long prismatic parallel to the a-axis and the crystals are commonly hollowed at both ends as described by H. Kuno (1944) and Y. K. Bentor (1954). The olivine prisms are well oriented parallel to the direction of flow. The titanomagnetite commonly shows idiomorphic outlines. The magnetite is homogeneous with no indication of exsolved ilmenite or ulvøspinel. The content of TiO_2 in magnetite from a trachyandesite was 10.6 %. Chromium shows a marked decrease with differentiation (200 ppm in the trachybasalts and 50 ppm in the trachyandesites). Martitization is far advanced in the trachyandesites. The amount of augite is always subordinate to olivine. The colour index varies from approximately 55–40 in the trachybasalts to 40–20 in the trachyandesites.

A small amount of biotite is common in the vesicles. The biotite flakes stand on edge or occur as 3–4 mm long "worms" in the vesicle. Sometimes also biotite occurs with feldspar in small oval-shaped ocelli. In a specimen of trachybasalt found on the shore near the dissected Høyberget vent, small white globulus of magnesite with a diameter of 1–2 mm occur together with biotite. Large nodules of pure magnesite were also present in the same specimen. Similar but still larger nodules occur in olivine basalts on the volcanic island Juan Fernandez in the Pacific Ocean. These have been named "Piedras de Campana" (P. D. QUENSEL, 1912). The olivine of the specimen from Jan Mayen was altered to a brown substance, and so the magnesia neccessary for the formation of the magnesite was probably set free by the alteration of the olivine.

There is a complete gradation from the trachybasalts to the trachyandesites and further to hornblende-trachyandesites in which the groundmass olivine has disappeared. The trachybasalt-trachyandesite series of Jan Mayen shows a great resemblance to the hawaiite-mugearite series of volcanic islands in the Pacific and Indian Oceans. They differ from the hawaiite-mugearite series by having a modal plagioclase in the labradorite-andesine range, by a higher olivine to augite ratio, and by the constant presence of interstitial alkali feldspar (soda to potash ratio lower than 2:1).

Some of the trachybasalts, however, conform closely to G. A. MACDONALD's (1960) definition of hawaiite. In fact, A. HOLMES (1917) has described a trachybasalt from Jan Mayen under this name. The intermediate rocks of this series are rather similar to the so-called "mugearites" of Tristan da Cunha (J. C. DUNNE, 1946). The term mugearite, however, implies modal oligoclase, and neither the Jan Mayen nor the Tristan da Cunha "andesites" are mugearites in this sense.

Chemical analyses of two members of the trachybasalt-trachyandesite series are shown in Table IV. The trachybasalt has a colour index slightly greater than 40 and a modal plagioclase near An_{50}. The trachyandesite is rather leucocratic. Both analyses show low soda to potash ratio compared to the hawaiite. Similar trachyandesites occur both on Tristan da Cunha and Gough. According to DUNNE (1946) the trachyandesites of Tristan da Cunha grade into the "mugearites". These oceanic trachyandesites may be very similar to some continental trachyandesites, e. g. in the Auvergne and on Etna.

The dome-forming trachyandesites or latites resemble the hornblende-trachyandesites, but have more phenocrysts. These are plagioclase (9–10 %), hornblende (4–5 %), clinopyroxene (2–3 %), olivine (0–1 %), iron ore, apatite, and black pseudomorphs after biotite and hornblende (1–4 %). The groundmass consists of laths of plagioclase embedded in alkali feldspar. An analysis of latite from Dollar-toppen is presented in the paper describing the Jan Mayen trachytes (H. CARSTENS 1961, Table I, Nr. 3).

Table IV. Chemical composition of the trachybasalt — trachyandesite series.

Chemical composition of the trachybasalt — trachyandesite series								
	1	2	3	4	5	6	7	8
SiO_2	46.25	54.83	48.76	49.30	55.51	54.85	54.34	54.69
TiO_2	3.75	1.96	3.29	3.18	2.12	1.03	1.90	2.31
Al_2O_3	16.07	17.58	15.82	16.36	18.20	16.92	17.94	18.16
Fe_2O_3	1.88	3.22	4.10	3.69	3.04	3.14	2.69	5.71
FeO	10.08	4.32	7.53	5.94	4.03	3.92	5.60	1.79
MnO	0.19	0.23	0.17	0.16	0.13	tr.	0.15	0.17
MgO	5.37	2.43	4.74	5.31	2.05	2.70	2.76	1.99
CaO	9.33	5.84	7.99	7.40	4.67	6.96	6.08	5.68
Na_2O	3.45	5.29	4.50	4.09	5.43	5.25	5.52	5.25
K_2O	1.97	3.21	1.58	1.71	3.15	2.55	2.80	3.28
H_2O+	0.18	0.25		1.67	0.56	1.08	0.10	0.19
H_2O-	0.02	0.02		–	0.25	0.80	0.02	
P_2O_5	1.17	0.69	0.72	0.49	0.56	0.78	0.47	0.71
	99.76	99.87	99.20	99.95	99.70	100.06	100.65	99.93
$\frac{\text{soda}}{\text{potash}}$	$\frac{1.7}{1}$	$\frac{1.6}{1}$	$\frac{2.8}{1}$	$\frac{2.4}{1}$	$\frac{1.7}{1}$	$\frac{2.0}{1}$	$\frac{1.9}{1}$	$\frac{1.6}{1}$

Molecular norms

	1	2
Or	12.0	19.0
Ab	24.3	46.7
An	22.7	15.0
Ne	4.3	0.5
Di	13.6	8.0
Ol	13.2	3.6
Mt	2.1	3.3
Il	5.4	2.6
Ap	2.4	1.3

1. Trachybasalt, Sørbukta, Jan Mayen. Analyst: R. Stokland.
2. Trachyandesite, near Skrukkefjell, Jan Mayen. Analyst: R. Stokland.
3. Average hawaiite, Hawaiian Islands (G. A. MacDonald, 1960).
4. "Mugearite", Tristan da Cunha (J. C. Dunne, 1946).
5. Trachyandesite, Tristan da Cunha (J. C. Dunne, 1946).
6. Trachyandesite, Gough Island (T. F. W. Barth, 1942).
7. Trachyandesite, Etna (H. S. Washington, M. Aurousseau, and M. G. Keyes, 1926).
8. Trachyandesite, Auvergne (Y. K. Bentor, 1954).

Trachytes

The trachytes of Sør-Jan have been described in detail in my previous paper (Carstens, 1961). The mode of a trachyte having globules of cristobalite and alkali feldspar is:

anorthoclase	pheno-crysts	18 %
clinopyroxene		0.5–1 »
black pseudomorphs (after biotite)		1–2 »
feldspar-cristobalite globules		30 »
matrix		50 »

A rhyolitic variety with modal quartz, Fig. 6, was found in the dome of Skrukkefjell (SiO_2= 74.50 %, Na_2O= 4.97 %, K_2O= 4.23 %). Acid lavas of soda-rhyolitic composition also occur on the Ascension Island and Bouvetøya of the Mid-Atlantic ridge.

Fig. 6. *Rhyolite, Skrukkefjell.* Photomicrograph, 22 ×.

Concluding remarks

Augite-olivine-plagioclase phyric basalts grade into ankaramitic basalts enriched in phenocrysts of titaniferous augite. Ankaramites of this type have also been recorded from other islands in the Atlantic Ocean: the Azores, the Tristan da Cunha, the Cape Verde, and the Canaries. It is noteworthy that picrite-basalts of the oceanite type, although of common occurrence in the Pacific and Indian Oceans, seem to be very scarce or totally absent in the Mid-Atlantic ridge province. The ankaramites of Nord-Jan, however, have mineral characteristics common with tholeiitic oceanites. Ankaramites are undoubtedly accumulative rocks formed by settling of early crystals of clinopyroxene and olivine (FR. WALKER and L. O. NICOLAYSEN, 1954; G. A. MACDONALD, 1949).

A gradual change in the mineral proportions also takes place between the phyric basalts and the trachyandesites. Although the relative proportions of the lava types are difficult to ascertain, one is immediately struck by the great abundance of intermediate lavas – trachyandesites – on Sør-Jan. The trachytes are, however, not connected with the trachyandesites through transitional types. Trachytes are a never-failing associate of the basaltic rocks of the oceanic islands. Silica minerals are frequent in the trachytes of the Atlantic islands, but undersaturated trachytes-phonolites – may occur as well (Tristan da Cunha, Gough, and Bouvetøya).

The trend of differentiation is towards a feldspathic rock – high in alkalies and with a soda to potash ratio near 1 : 1. As pointed out by T. F. W. BARTH (1952) the lavas of the Mid-Atlantic islands are all high in total alkalies. The alkali/silica

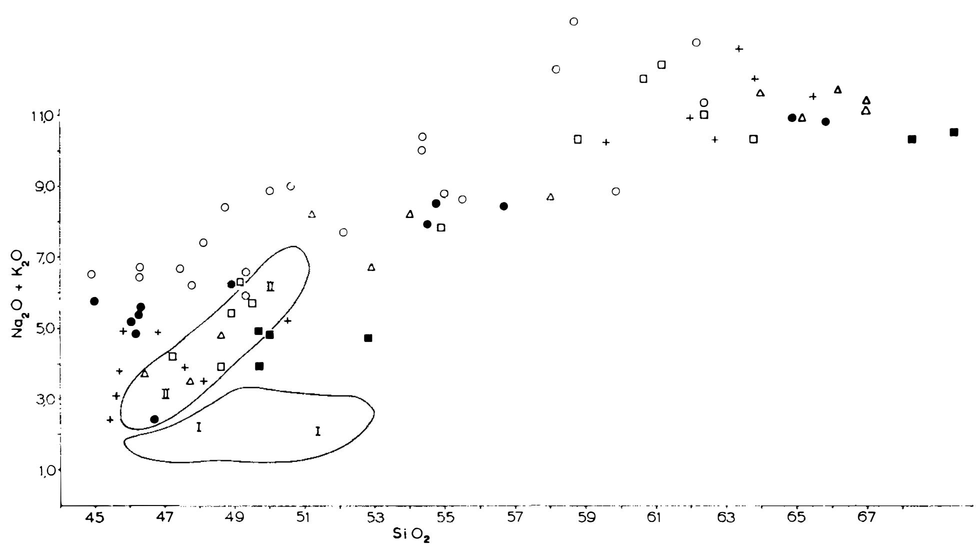

Fig. 7. *Alkali/silica diagram of lavas of the Mid-Atlantic ridge.*
Filled circles: *Jan Mayen* (G. W. TYRRELL, 1926). Crosses: *Azores* (P. ESENWEIN, 1928). Open triangles: *Ascension Island* (R. A. DALY, 1925). Open circles: *Tristan da Cunha* (J. C. DUNNE, 1946). Open squares: *Gough* (T. F. W. BARTH, 1942). Filled squares: *Bouvetøya* (O. A. BROCH, 1946).

I. *Field of tholeiitic lavas of Mauna Loa* (G. A. MACDONALD, 1949).

II. *Field of alkalibasalts, hawaiites, mugearites of Hualalai, Mauna Kea, and Haleakala* (G. A. MACDONALD, 1949).

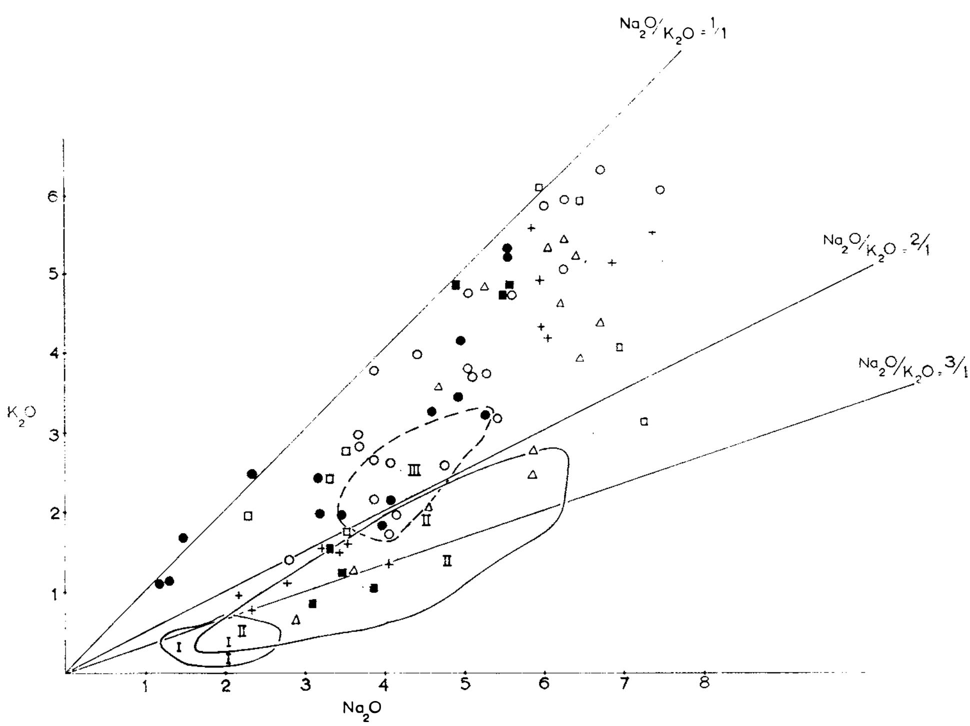

Fig. 8. *Alkali ratios of lavas of the Mid-Atlantic ridge.*
Legend as in Fig. 7.

III. *Field of trachybasalt – trachyandesite series of Jan Mayen and Tristan da Cunha.*

diagram, Fig. 7, shows that among the islands of the Mid-Atlantic swell, the Jan Mayen and the Tristan da Cunha basalts and andesites are especially rich in total alkalies. Trachyandesites occur in preference to oceanic andesites of the hawaiite-mugearite type, and trachybasalts are very common lavas. All lavas of the Mid-Atlantic ridge plot outside the field of Hawaiian tholeiitic basalts. – G. W. TYRRELL (1926) noted that the Jan Mayen lavas are very rich in potash. In accordance with this the Jan Mayen lavas show high contents of Ba and high Ba/Sr ratios (unpublished semi-quantitative trace element analyses). The diagram, Fig. 8, shows that most lavas of the Atlantic ridge have soda to potash ratio between 2:1 and 1:1.

Acknowledgment

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Contribution to the geology of the Hecla Hoek Formation in Nordenskiöld Land, Vestspitsbergen

BY

AUDUN HJELLE[1]

Contents

Abstract

A preliminary map of the area between Bellsund and outer Isfjorden is presented. The rocks are mainly of the Hecla Hoek Formation except for small areas of Carboniferous sandstone, which are preserved due to Tertiary faulting. Modal analyses of the main Hecla Hoek rocks are given. Owing to lack of fossils, the beds are presumed to be of Precambrian or Eocambrian age, and correlation with the middle and upper Hecla Hoek of Ny Friesland is suggested. The igneous amphibolite rocks present were probably intruded after the main folding. Ore mineralization occurs at several places, especially near the border to the Carboniferous beds in the east, and is supposed to be mainly of Tertiary age.

Preface

The field work reported in this paper was carried out for Norsk Polarinstitutt during the summers of 1958 and 1959, about five weeks in all.

The area includes the coastal plain and the western parts of the coastal mountains between Bellsund and outer Isfjorden (Figs. 1 and 2).

I wish to thank Dr. A. K. ORVIN, H. MAJOR and T. S. WINSNES for co-operation and valuable assistance. F. M. VOKES kindly corrected the English text of the paper.

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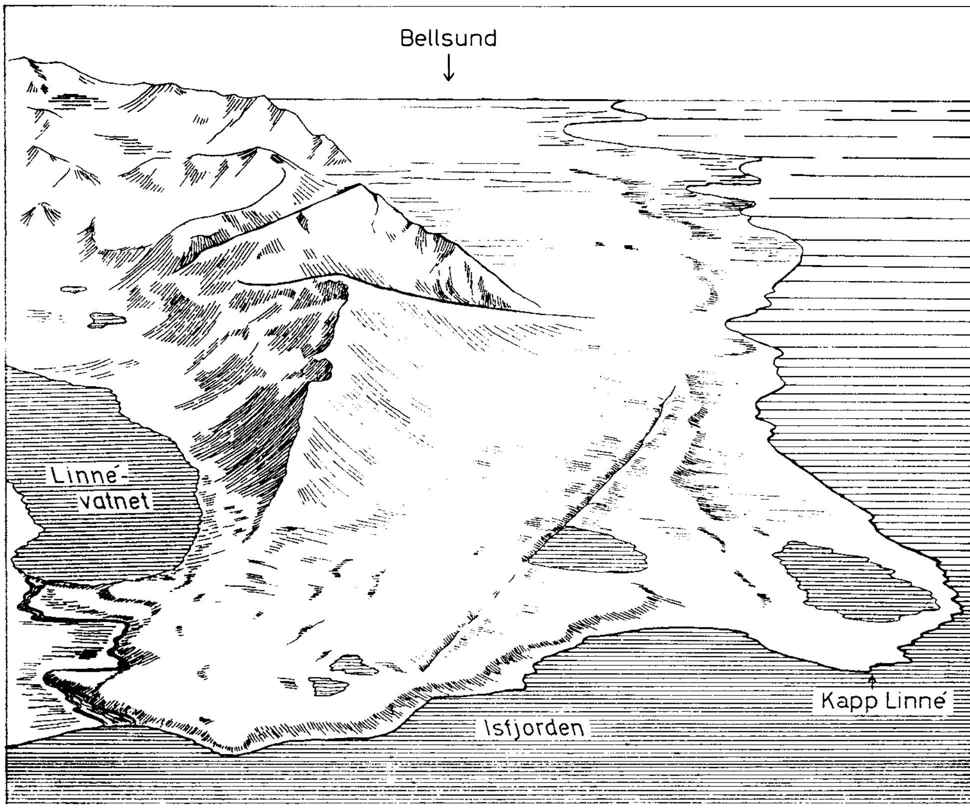


Fig. 1. *The coastal area between Isfjorden and Bellsund seen from north. Kapp Linné in the right foreground.* After photo by B. LUNCKE, Norsk Polarinstitutt.

Introduction

Of the previous geological investigations in this century, the expeditions of A. HOEL in 1913 and A. K. ORVIN in 1925 must be mentioned. The most comprehensive investigation was ORVIN's mapping in 1925. After a short period of field work, he outlined the main features of the Hecla Hoek Formation in the area. In 1956 H. MAJOR and T. S. WINSNES made a reconnaisance in the vicinity of Kapp Linné, and in the same year WINSNES worked for a short time in the area east of Kapp Martin.

For the present mapping, the author used the 1 : 100 000 topographical maps "Van Mijenfjorden" and "Isfjorden", published by Norsk Polarinstitutt in 1948 and 1955.

The greater part of the area is a typical strandflat. More than two thirds of the mapped area lies below 25 m a. s. l. The highest point is the peak of Ytterdalsgubben, 901 m a. s. l.

Large parts of the strandflat are covered by beach deposits of present and raised beaches, gravels and moraines. Especially north-northwest of Van Muydenbukta and north of Orustosen, the outcrops are few and small. Wind-blown sand can be seen as far as 3.5 km north-northeast of the mouth of Ytterdalselva.

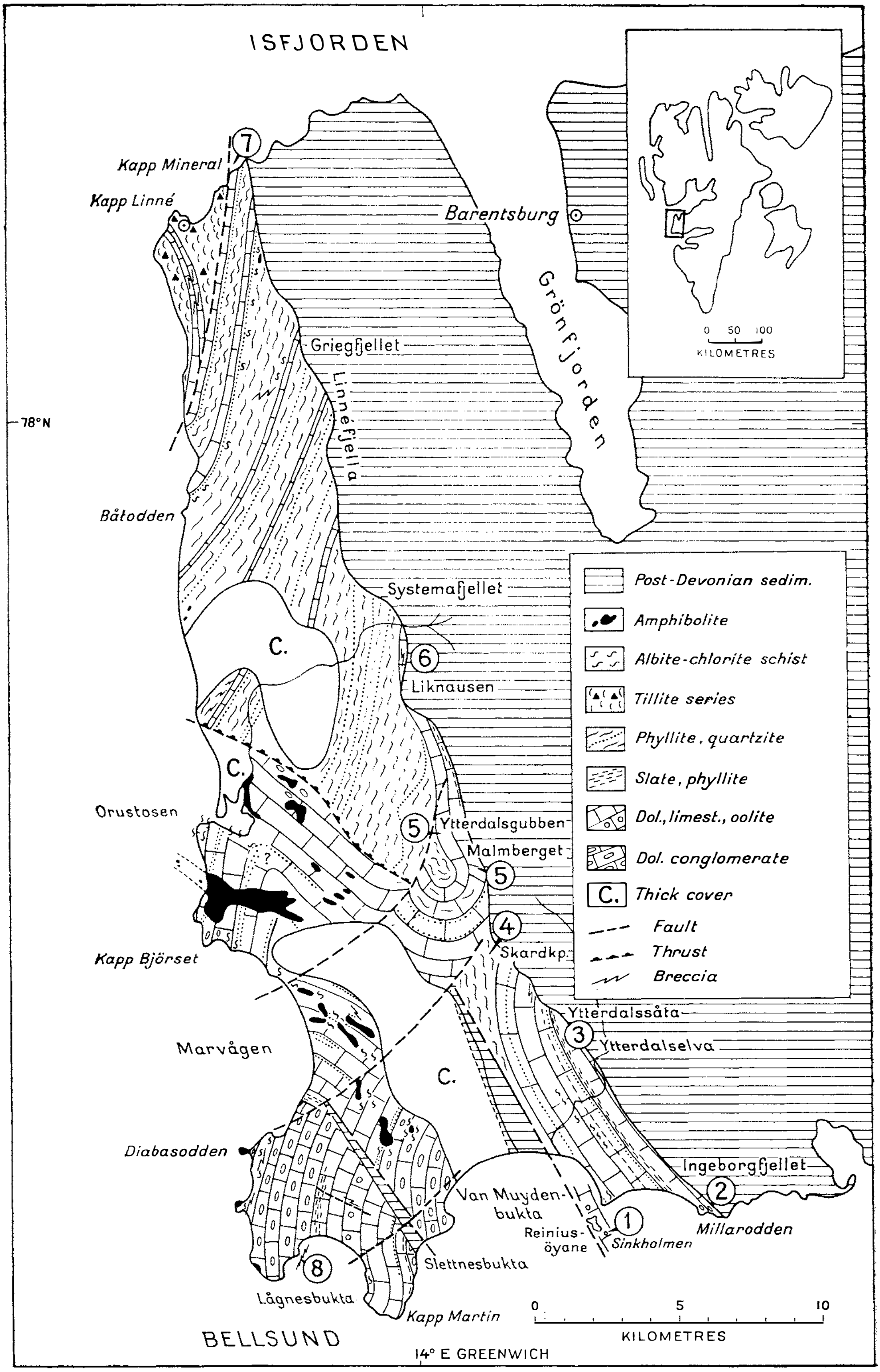


Fig. 2. *Geological map of the Bellsund–Isfjorden area.* Partly after A. K. ORVIN (unpublished map).

Besides my own material, I have used collections and notes from HOEL, ORVIN, MAJOR and WINSNES.

Values of strike and dip refer to a 400° circle.

Main petrographical and structural features

Except for small areas of Carboniferous sandstone near Bellsund, the mapping only covers rocks of the Hecla Hoek Formation. The main types of rocks are as follows:

1) Dolomite, limestone and dolomite conglomerate. Oolitic limestone occuring near Bellsund.
2) Quartzite, sandy and quartzitic phyllites and slates.
3) Amphibolites, mainly south of Orustosen.
4) Tillite and phyllite, Kapp Linné.

Green schist facies are dominant, except in the inner, massive parts of the amphibolite rocks, where the mineral combination amphibole, albite and epidote is common.

Schistosity and bedding strike mainly N–NNE, the dip varying due to the folding. In the southern part of the area Carboniferous sandstone is preserved, as a result of younger faults of probably Tertiary age (ORVIN, 1940). Generally the Carboniferous rocks can be seen resting unconformably on the Hecla Hoek rocks.

The distribution of joints in the Hecla Hoek rocks is shown in Fig. 3 a, b. The measurements are divided in two groups with different strike of foliation. It seems likely that the direction of supposed maximum stress varies and is perpendicular to the strike of the foliation. Thus a large number of joints probably can be classified as shear joints formed by the regional folding.

Fig. 3 c shows the main lineation, which generally is parallel to the horizontal projection of the regional fold axis. It is likely that the main lineation is due to

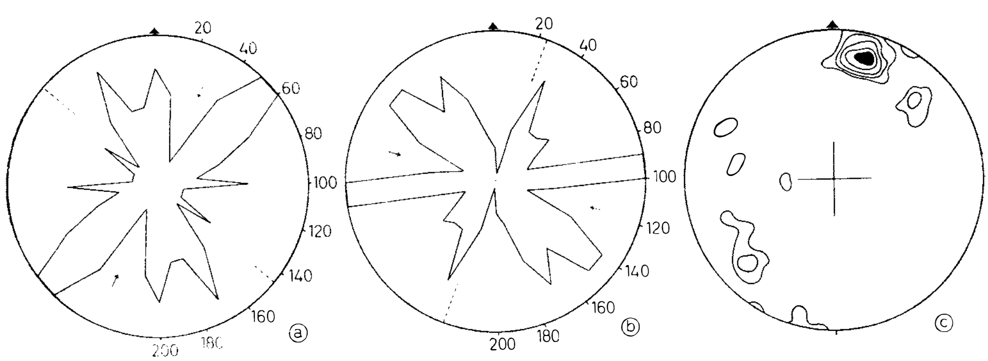


Fig. 3. a) *Joint directions, with foliation striking 120–175°. 56 measurements.*
b) *Joint directions with foliation striking 200–250°. 45 measurements.*
c) *Lineation. Contours: 3–5–7–10–15 %. Lower hemisphere. 150 measurements.*

the folding, and that the regional fold axis plunges shallowly towards north-northeast.

The measurements give no evidence as to the extent to which the Tertiary folding has affected the Hecla Hoek rocks in this area. However, considering the adjacent Tertiary zone of folding, it is likely that the Hecla Hoek rocks concerned have been deformed, partly at least, by the Tertiary movements. Analyses of detailed structural observations from a rather similar area south of St. Jonsfjorden, indicates that Hecla Hoek rocks in this area have been involved in at least two foldings, one Caledonian and one younger, probably lower Tertiary (WEISS, 1959).

The border to the Carboniferous sandstone in the east. Mineralization

At the contact between the Hecla Hoek Formation and the Carboniferous sandstone in the east, breccias occur at some places: at Millarodden, southeast of Ytterdalssåta, north-northwest of Ytterdalssåta, and in Orustdalen north-northeast of Liknausen. Both Hecla Hoek and Carboniferous rocks are brecciated. Investigations elsewhere along the border confirmed ORVIN's view as to primary contact. Breccias only seem to appear where younger sandstone rests on thick beds of competent Hecla Hoek rocks, i. e. where movements could easily have caused brecciation.

Near the younger sandstone minor ore mineralization may occur. This appears principally as secondary formations in cavities in brecciated rocks, less frequently as impregnations in undisturbed beds.

Ore mineralization is observed in the following localities (marked with numbers on the map, fig. 2):

1. *Sinkholmen, Bellsund.* The main rocks on this islet are dolomite and dolomite limestone. A supposed fault at the eastern border of the Carboniferous sandstone north of Van Muydenbukta, probably continues to the south-southwest, passing just west of Sinkholmen. Besides sphalerite, the most common ore-mineral on the islet, galena and chalcopyrite occur in lesser quantities. Coarse calcite is rarely absent and fluorspar is common. The sphalerite deposits were discovered by A. HOEL in 1913 and have been worked by the Northern Exploration Company.

2. *Millarodden, Bellsund.* Near the border zone between the Carboniferous sandstone and the Hecla Hoek dolomite conglomerate, pyrite, siderite, calcite and quartz occur in fissures in the sandstone. Pyrite and siderite also occur as impregnation in the sandstone, siderite acting as a secondary mineral.

3. *Southeast of Ytterdalssåta.* Black phyllitic shale of the Hecla Hoek here underlies the Carboniferous sandstone. This is partly cracked, and in the vicinity of the border the joint planes commonly are covered by hematite and iron hydroxides.

4. *In the west slope of Skardkampen* rocks with comparatively large amounts of hematite and iron hydroxides occur. The rocks are mostly quartzitic phyllites,

and dark brown colour indicates the presence of iron. The distribution of the ore minerals appears to be irregular, and cannot be traced for more than 50 m. Table 4, No. 1 shows a modal analysis of an iron-rich phyllite from this area.

5. *Malmberget and Ytterdalsgubben.* The main rock is limestone, which bears hematite near the Carboniferous sandstone. The name Malmberget (i. e. The Ore Mountain) indicates that this locality was known previously (ORVIN's mapping in 1925). The hematite occurs in lenses and layers from about 10 cm down to vanishing thickness. Analysis og a 6 cm hematite-bearing layer from Malmberget gave 58.6 % Fe_2O_3 and 1.3 % Fe.O (Analyst: R. SOLLI, Norges Geologiske Undersøkelse). On the south-eastern slope of Ytterdalsgubben the thickness of the limestone in which hematite-rich layers occur, is about 50 m.

6. *North-northeast of Liknausen, Orustdalen.* The rocks along the border between Hecla Hoek and the Carboniferous are rather brecciated, and fragments of Hecla Hoek dolomite and Carboniferous sandstone are embedded in a sandy dolomite-limestone mass. The slight ore mineralization includes sphalerite, pyrite and chalcopyrite. Minor amounts of fuchsite with 1.7 % Cr_2O_3 occur in dolomite fragments (Analyst: R. SOLLI).

7. *Kapp Mineral, east of Kapp Linné.* Galena and sphalerite are present in a dolomite breccia, which seems to accompany the fault line limiting the supposed tillite series to the southwest. The deposit was investigated by A. S. LEWIN and by the Northern Exploration Company.

8. *Islet near the west side of Lågnesbukta.* Pyrite, siderite, iron hydroxides and coarse dolomite occur in a quartz breccia, which could not be traced further on the mainland.

Description of the rocks. Suggestions concerning the sequence

The area south of Marvågen–Ytterdalen.

Hecla Hoek rocks. The original bedding is partly camouflaged by marked schistosity. The observations, however, suggest an overturned fold west of Lågneset, an anticlinal east of Kapp Martin and a synclinal west of Reiniusøyane (Fig. 4 a).

A sandy, homogeneous dolomite conglomerate probably forms the lowermost beds in this area. The thickness of these beds are doubtful, owing to deformation. With a folding as suggested, however, the thickness will exceed 1000 m. A possible repetition of the folds may reduce the thickness considerably. The size of the lens-shaped pebbles and boulders of the conglomerate vary from 1 to 50 cm across, a common size is 1–10 cm. The boulders, and most of the pebbles, consist of grey dolomite. Pink quartzite pebbles are, however, also present.

The dolomite conglomerate passes gradually into less uniform beds of dolomite and limestone. In these beds grey dolomite, containing cherty horizons, alternate with grey and black limestone including oolitic varieties. Total thickness of the series probably is about 400 m.

Three specimens of oolitic limestone from different parts of the southern area have been analysed for Ca and Mg, and Tab. 1 below shows that they correspond

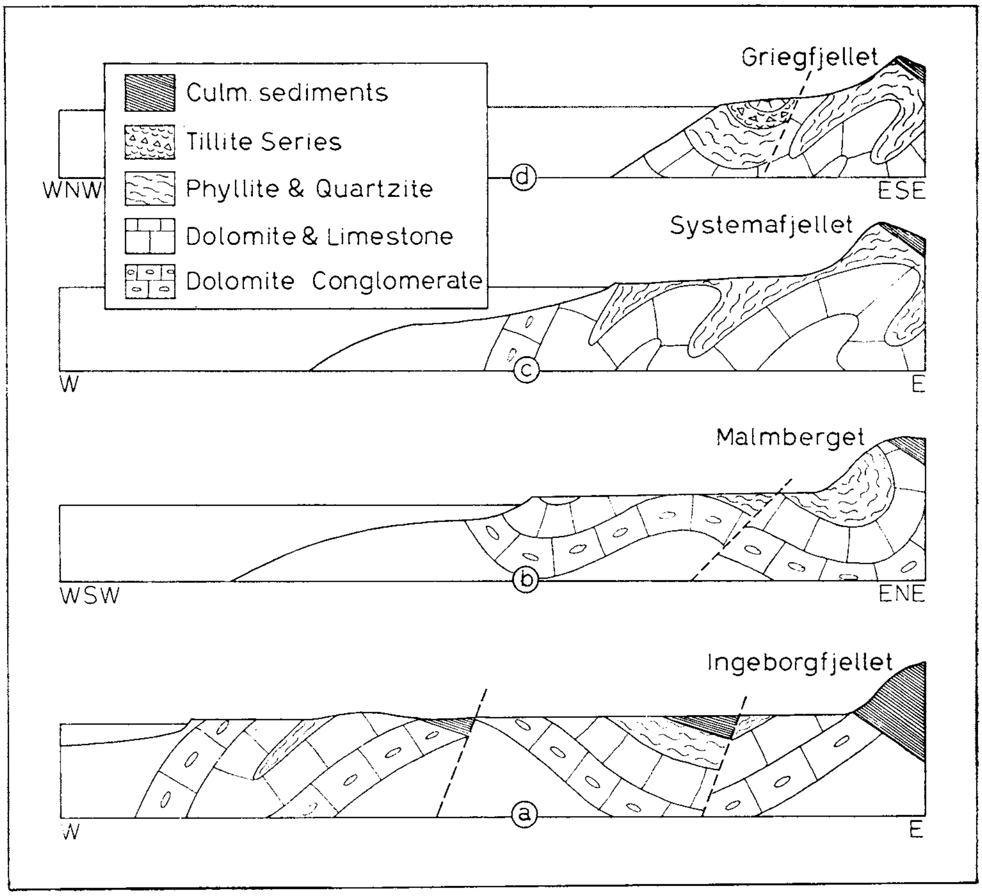


Fig. 4. *Simplified supposed sections. Igneous rocks not indicated.*

closely to each other. Modal analyses of common rocks are given in Table 4, No. 2, 3 and 4.

Table 1

$CaCO_3$: $MgCO_3$ ratio of the oolites near Bellsund.

4.5 km NNE of Kapp Martin	6.75
3.5 km NNE of Kapp Martin	4.95
Reiniusøyane	4.95

Igneous rocks. These are all basic as in the whole area between Bellsund and outer Isfjorden, and will be described in a later section.

Younger sediments. Fossil-bearing Carboniferous sandstone (Culm) rests with a basal conglomerate discordant on Hecla Hoek rocks north-northeast of Kapp Martin and north of Van Muydenbukta (ORVIN, 1940). The beds dip 30–40° towards east-northeast, with a suggested fault boundary to the east. From Slettnesbukta the western belt of sandstone runs about 5 km to the north with decreasing width, from probably about 600 m near the sea shore to less than 100 m in the northernmost part. With a 35° dip a 600 m belt of sandstone corresponds to a thickness of about 300 m, i. e. the fault throw exceeds 300 m near Slettnesbukta, diminishing northwards due to a rotary movement. In the other Culm area, north of Van Muydenbukta, only few outcrops can be seen in the easternmost part, near the supposed fault, and there is little evidence concerning the extension of of the Culm beds and the size of the fault throw.

The middle area.

The previously described dolomite and limestone beds seem to continue towards the north-northwest. Besides these, phyllite rocks are also common, both green chlorite-rich types, and sandy muscovite phyllite of light reddish brown colour. Quartzite, limestone and dolomite beds occur occasionally in the phyllite, with thicknesses usually from 1 to 10 m.

In the southern part of the middle area a line of structural discordance extends to the north-northeast from south of Marvågen. As Culm sandstone cannot be traced north of the line, this is possibly of fault origin, with the downthrow of the fault to the south.

The deformation due to folding, faulting and intrusions of basic igneous rocks, makes it difficult to make out a stratigraphy in the area around and south of Orustosen. Although quartzite occurs more frequently than near Bellsund, the rocks between Orustosen and south Marvågen are for the present suggested as belonging to the dolomite-limestone series exposed in Lågnesrabbane north of Kapp Martin.

On the islets west and northwest of Orustosen there are, besides basic igneous rocks, also dolomite and dolomite conglomerate with beds dipping about 50° southeast. The observations are few and conclusions cannot be drawn, it is however reasonable to correlate these beds with the dolomite and dolomite conglomerate farther south and east.

The mainly calcareous beds around Malmberget and Ytterdalsgubben seem to be overfolded and inverted as indicated in Fig. 4 b.

Oolite limestone is not found in the middle area, possibly owing to few outcrops of the oolite-bearing limestone beds.

Occasional occurences of tremolite and biotite in sedimentary rocks west of the mountains, between Ytterdalsgubben and Skardkampen, may indicate relatively high regional metamorphism in this area.

North of Orustosen a discordance occurs between the southern limestones, dolomites and quartzites, and the mainly phyllitic rocks to the north. This discordance is most pronounced in the northwest, and is suggested as being caused by a thrust in which the southern competent rocks were thrust above the phyllites (Fig. 4 b).

The northern area.

A relative uniform series of sandy phyllite rocks with minor quartzite, dolomite and limestone beds prevails. These rocks are well developed in Linnéfjella, and

Nos. 5, 6 and 7 in Table 4 shows modal analyses of common rocks from the northern area. The often strongly foliated phyllites vary in colour from green to reddish brown, due to the presence of chlorite and iron hydroxides. Although the foliation usually coincides with the bedding, the incompetent nature of most of the rocks occasionally causes a divergent foliation. Even if repeated foldings are possible, the phyllite series may extend to 1000 m and possibly more than 1500 m in thickness.

Slightly rounded loose blocks of sandstone, which both in texture and composition resemble the Culm sandstone, are found near north of Orustosen. Similar sandstone of dark grey colour forms the solid rock of two islets 2.7 km north of Båtodden. Though the Orustosen sandstone blocks show no signs of fossils, specimens from the islets contain dark spots with coatings of probably organic origin. Though there is little evidence, the possibility of small areas of younger rocks being preserved by faulting, as farther south, cannot be excluded.

To the northwest the phyllite series passes into dolomite, limestone and quartzites. These competent rocks are partly brecciated and fragments up to about 5 m across occur in the westernmost phyllites. As these often are dark Ti-rich types of possible igneous origin, the fragmentary zone may be regarded as an eruptive breccia.

To the west the dolomite, limestone and quartzite are separated from the suggested tillite beds by a line of discordance, probably due to faulting (Fig. 4 d). The main rocks of the tillite series consist of folded light green and grey uniform phyllite with a boulder horizon. Total thickness of these beds probably exceeds 300 m. The roughly rounded boulders consist of grey dolomite, grey quartzite and coarse to medium grained quartz diorite. Striated boulders are not seen. Modal analyses of the green phyllite and of two different quartz diorite boulders are given in Table 4, Nos. 8, 9 and 10. Chemical analyses of the first of these quartz diorite boulders is shown below. The plagioclase of this rock is partly decomposed, with inclusions of sericite and calcite, and large parts of the potassium and calcium content are due to these minerals. In the upper part the tillite beds pass into black and grey dolomite and limestone.

Table 2

Chemical analysis of tillite boulder from Kapp Linné.
(Modal analyses given in Table 4, No. 9.)

		Molecular norm	
SiO_2	73.39		
TiO_2	0.31		
Al_2O_3	12.72		
Fe_2O_3	0.79		
FeO	2.06	Q	34.6
MnO	0.02	Or	6.5
MgO	0.86	Ab	43.5
CaO	1.60	An	8.0
Na_2O	4.68	C	1.2
K_2O	1.08	Hy	5.0
H_2O-	0.06	Mt	0.9
H_2O+	1.10	Il	0.3
CO_2	1.01		
P_2O_5	0.02		100.0
	99.70		

Basic igneous rocks

These are mainly medium to fine grained amphibolitic types of dark green colour. The main mineralogical constituents of the massive rocks within this group are green hornblende, albite or oligoclase, epidote-clinozoisite and chlorite. Common accessories are garnet, titanite and olivine. Modal analyses of different types of amphibolites are given in Table 4, Nos. 11 and 12.

Fragments of surrounding rock in the amphibolite can be seen in the border zones. The intrusives are therefore younger than the surrounding rocks, and probably also younger than the main folding, as they cut through folded beds south of Orustosen.

In minor intrusions and in the outer part of the larger bodies foliation often appears, with transition of the amphibolite rock into chlorite-rich greenschist. Thus one may suggest that the rocks were intruded before the last movement ended.

Chemical analyses of two amphibolites are given in Table 3 below. For comparison, analyses of younger dolerites from Spitsbergen are also given. These latter are normal dolerites consisting essentially of pyroxene and basic plagioclase. The potassium content of the two older amphibolites is extremely low, and norm calculations show deficiency in quartz.

Near Ytterdalselva, some two km north-northeast of the mouth of the river, a 70 cm diabase dyke, dipping 35° west-northwest, cuts through Hecla Hoek dolomite. The fresh appearance and the mineralogical composition of this dyke, closely resemble the adjacent dolerite of Ingeborgfjellet, and it is reasonable to suggest that the dyke is of the same age. Similar rocks are not seen elsewhere in the investigated Hecla Hoek area.

Final remarks

No detailed stratigraphy can be deduced from my investigations as at the present stage, both the thicknesses and the positions of the Hecla Hoek beds in the area described are doubtful.

The supposed sequence presented below (Table 5, right) is therefore rather tentative.

Fossils are not seen in the Hecla Hoek rocks between Bellsund and outer Isfjorden, not even in the less metamorphic beds. Thus as a preliminary assumption the rocks were supposed to be of Precambrian or Eocambrian age. The beds near Bellsund, with dolomite conglomerate as the probably lowermost and then dolomite with cherty horizons and limestone with oolite, suggest a correlation with the beds of the Akademikerbreen series of the upper Middle Hecla Hoek of Ny Friesland (HARLAND and WILSON, 1956; HARLAND, 1960).

The sandy phyllite of Linnéfjella and the tillite series of Kapp Linné are further supposed to correspond to the Shale and Tillite Formations of the Polarisbreen series in the Upper Hecla Hoek of Ny Friesland. The correlations with other regions of Svalbard, in Table 5, in the main follow those of HARLAND and WILSON.

Table 3. Analyses of basic igneous rocks

	1	2*	3	4
SiO_2	46.72	50.50	48.29	49.2
TiO_2	3.28	1.87	3.94	2.9
Al_2O_3	11.98	14.16	13.63	14.4
Fe_2O_3	1.85	1.52	1.87	3.4
FeO	12.46	10.88	12.80	10.1
MnO	0.24	0.13	0.20	0.4
MgO	7.67	6.79	5.35	5.4
CaO	9.41	6.93	8.67	9.4
Na_2O	2.74	4.35	2.78	2.0
K_2O	0.05	0.02	0.88	1.0
H_2O-	0.04	0.17	0.17	1.6
H_2O+	3.41	2.72	1.23	
P_2O_5	0.22	0.10	0.37	0.2
	100.07	100.14	100.18	100.0

* Modal analysis given in Table 4, No. 11.

Molecular norm

	1	2	3	4
Q	—	—	0.0	5.2
Or	0.5	—	5.5	6.0
Ab	26.0	40.0	26.0	18.5
An	21.3	19.8	23.0	28.8
Ol	7.2	9.6	—	—
Di	21.2	11.6	15.2	14.8
Hy	16.4	14.4	21.8	18.2
Ap	0.5	0.3	0.8	0.5
Mt	2.1	1.7	2.1	3.8
Il	4.8	2.6	5.6	4.2
	100.0	100.0	100.0	100.0

1. Amphibolite, Diabasodden, N. Bellsund.
2. Amphibolite, 4 km SE of Orustosen.
3. Dolerite, Kleivdalen, Ingeborgfjellet, Bellsund.
4. Average of 4 analyses of younger dolerites from Spitsbergen (TYRELL and SANDFORD, 1933).

New analyses, analyst: R. SOLLI, Norges Geologiske Undersøkelse

The boulder beds west of Recherchefjorden on the south side of Bellsund are, however, considered to be equivalent to the dolomite conglomerate north of Bellsund, rather than being of glacial origin.

The amphibolites in the investigated area are probably the equivalents of those of Chamberlindalen south of Recherchefjorden, which they closely resemble both in mineralogical composition and mode of occurrence.

Concerning the ore mineralization, the most striking feature is the distribution of most of the deposits close to the younger sandstone in the east, and in areas

Table 4

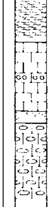
	1	2	3	4	5	6	7	8	9	10	11	12
Quartz	25	14	3	33	44	43	42	36	32	24	–	–
Ortocl., microcl.	–	–	–	–	–	x ?	–	–	x ?	–	–	–
Plagioclase	–	–	–	xa	10a	6a	14a	xa	41a	64a	25a	25o
Muscovite	6	5	x	14	25	25	5	46	16	5	–	–
Biotite	–	–	–	–	–	x	–	–	x	–	–	–
Amphibole	–	–	–	–	–	–	–	–	–	–	44	48
Chlorite	22	–	–	10	13	6	–	5	5	x	15	9
Epid., zoisite	x	–	–	–	–	x	–	x	x	–	7	12
Carbonate	–	80d	95c	37c	4c	14cs	38c	10c	3c	5c	x	–
Pyrite	–	x	x	–	x	–	–	x	x	–	–	x
Magnetite	–	–	x	–	–	x	–	–	x		–	–
Ilmenite	–	–	–	–	–	–	–	–	x	x ?	–	–
Hematite	45	–	–	–	–	–	–	–	–	–	–	–
Sphene	x	x	–	–	3	x	x	–	x	–	7	4
Apatite	–	–	–	–	–	–	–	–	x	–	–	x
Zircon	x ?	–	–	–	–	–	–	x ?	x	x	–	–
Garnet	–	–	–	–	–	–	–	–	x ?	–	x	x
Galena	–	x	–	–	–	–	–	–	–	–	–	–
Iron hydroxides	x	x	–	–	–	3	–	–	–	–	–	–
Tourmaline	–	–	–	x	x	x	x	x	3	–	–	–
Rutile	–	–	–	x	–	–	–	–	x	–	–	–
Olivine	–	–	–	–	–	–	–	–	–	–	x	x

x = accessories a = albite o = oligoclase d = dolomite c = calcite s = siderite

1. Hematite-bearing quartz phyllite. 500 m a. s. l., the W slope of Skardkampen.
2. Dolomite, NW of Millarodden. Collected by A. K. Orvin, 1925.
3. Brecciated limestone, 3.5 km N of Kapp Martin.
4. Quartz-calcite phyllite, 4.5 km NW of Millarodden.
5. Quartz phyllite, 2 km S of Båtodden.
6. Quartz phyllite, 3.5 km E of Båtodden.
7. Quartz-calcite phyllite, 1 km S of Griegfjellet.
8. Phyllite, 3 km S of Kapp Linné.
9. Tillite boulder, 1.5 km SSW of Kapp Linné.
10. Tillite boulder, Kapp Linné. Collected by T. S. Winsnes, 1956.
11. Amphibolite, 4 km SE of Orustosen.
12. Amphibolite, Diabasodden.

Table 5

Correlation of Middle and Upper Hecla Hoek rocks in Svalbard.
Partly after Harland and Wilson (1956) and Harland (1960).

W. NORDENSKIÖLD LAND This paper	S. NY FRIESLAND Harland & Wilson 1956		N.W. NORDAUST-LANDET Kulling 1932 & 1934		SÖRKAPPLAND Major & Winsnes 1955		BJÖRNÖYA Holtedahl 1920	WEDEL JARLSBERG LAND Birkenmajer 1958	Supposed sequence in Hecla Hoek W. Nordenskiöld Land
Kapp Linné Tillite	Polarisbreen Tillite Form.	Polarisbreen ser.	Sveanor Form.		Phyllite with Quartzite	Gåshamna ser.	Slate & Quartzite	Sofiebogen Formation	 Kapp Linné Tillite series 2-300m
Linnéfjella Sandy Phyllite, Quartzite	Lower Polarisbreen Shale form.		Shaly beds	Ryssö series					Linnéfjella Sandy Phyllite, Quartzite ~1500m?
Lågenesflya Dol., Limest with Oolite	Backlundtp. Dol Backlundtp. Oolite	Akademikerbreen ser.	Ryssö Dol.		Quartzite Limest with oolite Dolomite	Hoferpynten ser.	Older Dolomite Series		Lågenesflya Dolomite with chert, Limestone with oolite Total thickness 6-800m? ~50m slate, phyllite
Bellsund Dol. Congl	Draken Congl.								Bellsund Sandy Dolomite Congl. >1000m?

with signs of relatively great Tertiary tectonic activity. The zone of mineralization seems to continue towards the south, as similar ore mineralization can be seen in the dolomite of Midterhuken and east of Recherchefjorden, both localities in the vicinity of younger formations and Tertiary faults.

On the basis of the relations mentioned above and of the mineral parageneses of most of the ore mineralizations, they seem to be low temperature deposits of probably Tertiary age.

The fact that the mineralizations occur preferentially near the younger formations can indicate that these have acted as a roof which has partially dammed up the circulating hydrothermal solutions from the underlying Hecla Hoek rocks.

Similar mineralization occurs near the sub-Cambrian peneplane in Scandinavia. The age of this mineralization is considered as Caledonian (GRIP, 1960), and the solutions seem to have followed tectonic structures formed during folding, faulting and overthrust movements. SKJESETH and VOKES (1957) considered a similar deposit at Krækkjeheia, Hardangervidda, to be Permian.

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Notes on the geology and petrology of the mountains in Fimbulheimen, Dronning Maud Land, Antarctica

BY
TORE GJELSVIK

Abstract

On the coastal slope of the great inland ice of Dronning Maud Land, Antarctica, a number of mountain peaks rises above the ice cap. The central part of the nunatak area consists of very coarse-grained hornblende-biotite granite, poor in quartz and rich in porphyroblastic microcline crystals. It is cut by foliated or banded gneisses consisting essentially of the same minerals. The granite clearly intersects the gneiss, and both are cut by more fine-grained granite veins as well as by pegmatite. In some places the gneiss contains red garnet crystals, but with one possible exception it is not proper charnockite.

Introduction

During the Norwegian-British-Swedish Antarctic Expedition, 1949–52, the geologists E. F. ROOTS and A. REECE investigated the outcrops in the areas between 12° W and 2° E of Greenwich, and Lat. 71°–74° S (ROOTS, 1953). The Norwegian Antarctic Expedition, 1956–60, working eastwards to about 12° E, did not include geologists. Glaciologist TORBJØRN LUNDE, however, when exploring the mountains along the 72° S parallel between 2° 30′ and 7° E, collected more than sixty large rock samples and made various geological observations. In the austral summer season 1958–59 geologist THORE S. WINSNES, in the course of a tellurometer survey, was able to do geological fieldwork on some small nunataks from 7° to 12° E, located north of the main mountain range. The map shows the distribution of the rock samples. It is seen that no samples were collected inside the main range east of 5° E, which makes it impossible to compile a detailed geological map of the area. The author has made a petrological study of the samples collected by LUNDE and WINSNES, and together with WINSNES studied the air photos of the area. The data thus collected, have enabled us to give at least a general picture of the geology and petrology of the region (Fig. 1).

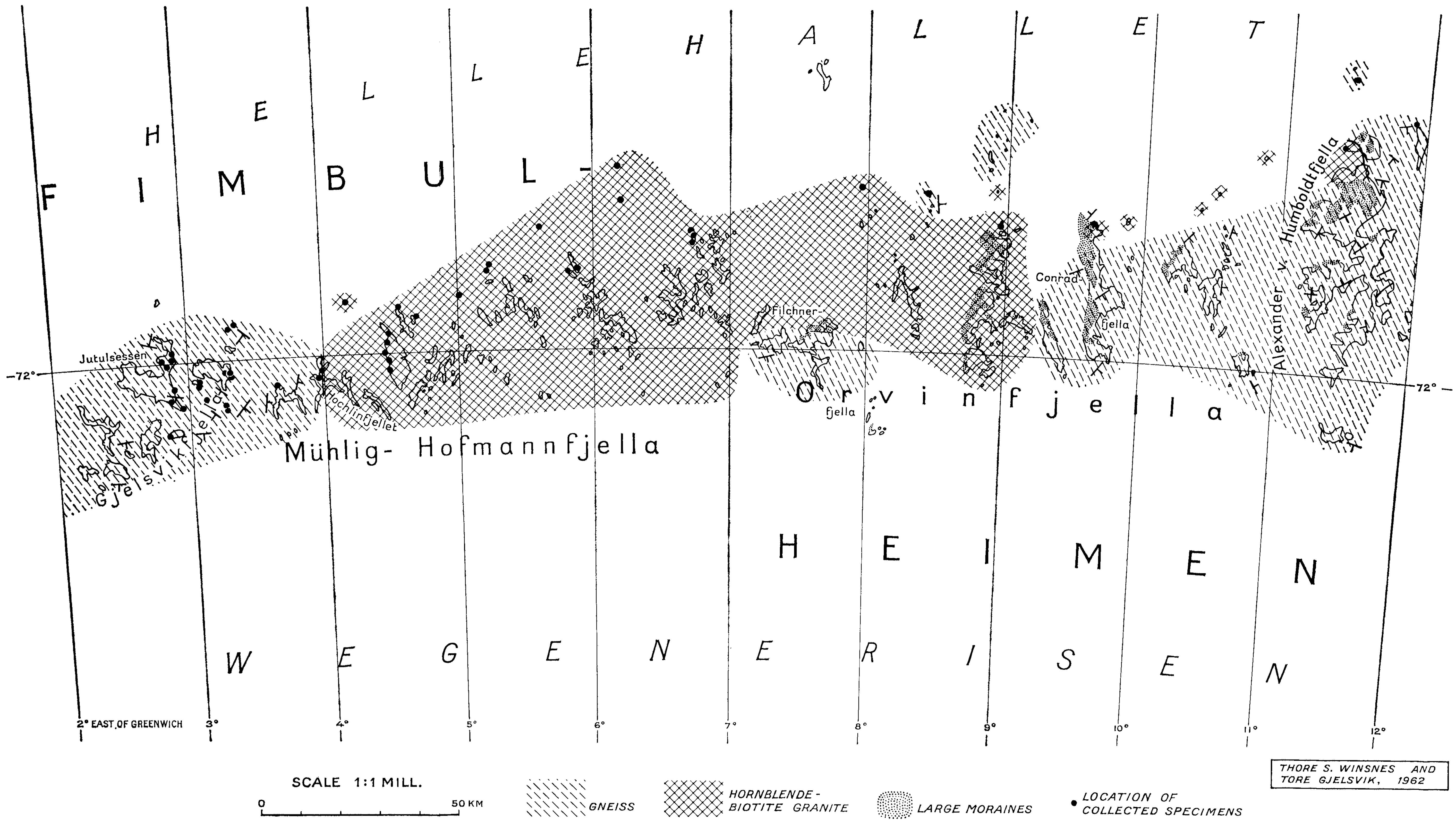

Fig. 1. *Geological map of Fimbulheimen, Dronning Maud Land, Antarctica.*

Fig. 2. *Banded gneiss with subconcordant layer of agmatite, cut by 1 m wide fine-grained granite dike. Risemedet (72° S, 3° 15′ E).* Photo: T. LUNDE.

Description of the rocks

The area west of 4° E consists of banded and veined gneisses (Fig. 2), partly augengneisses, all mainly consisting of quartz, microcline, oligoclase, biotite and amphibole. Garnet seems to be rare. The plagioclase feldspar is commonly sericitized and to a large extent replaced by perthitic microcline and myrmekite. Accessory minerals are apatite, zirkon, sphene and iron ores. Biotite is sometimes slightly chloritized. Most of the gneiss layers apparently are formed from argillaceous sedimentary rocks, but some layers of amphibolite, partly broken up and replaced by granite, forming agmatite (Fig. 2), may represent igneous rocks of basaltic composition. LUNDE reports mafic dikes of at least two generations, one altered porphyritic type (the samples, unfortunately, were lost), another young and unmetamorphic type, usually of ordinary doleritic composition. One specimen, however, consists of limburgite (GJELSVIK, 1962). White, fine-grained dikes of granitic composition, usually less than 1 m wide, intersect the gneisses (Fig. 2). Cross-cutting pegmatites also occur, some of which contain conspicuous magnetite crystals. Also fine-grained granite veins may contain this mineral.

The gneisses are commonly much folded, in a small as well as in a large scale (Fig. 3). Strike and dip varies considerably, though generally the strike trend is E–W, and the dip southerly. In the southeast part of Gjelsvikfjella, including the southern part of Jutulsessen, the gneiss bands dip about 20°–40° S. In the northern part of Jutulsessen, however, the dip is slightly north, thus it appears to be an anticline with E–W axis in the central part of this mountain. In the eastern part

Fig. 3. *Folded gneiss in the Jutulsessen mountains (72° S, 2° 30′ E).* Photo: T. LUNDE.

of Gjelsvikfjella the gneiss dips 5°–25° SW. A marked structural change takes place further east, since the gneisses in the westernmost part of Mühlig-Hofmannfjella strike N–S with steep, or even vertical, easterly dips. Near the contact of the coarse granite in Hochlinfjellet the dip is steeply east. Most of the fine-grained granite dikes apparently trend E–W.

The rest of the area covered by LUNDE consists of massive, coarse-grained granite or syenite (Figs. 4 and 5). The western contact follows the 4° E Long. across Hochlinfjellet. It is sharp, but apparently conformable to the strike and dip of the gneiss, which is vertically N–S in this place. In other places the massive rocks contain sharp-edged inclusions of the gneiss. In the contact zone of Hochlinfjellet a remarkable rock type is found, consisting of very calcic plagioclase, biotite, amphibole, scapolite as well as an unidentified isotropic mineral. It is perhaps a skarn rock.

The dominant mineral of the massive rock is microclineperthite in large, idiomorfic crystals, 0.5–5 cm long, mostly 1–2 cm. It contains inclusions of altered plagioclase (present composition oligoclase), rounded quartz and myrmekite. In the interstices oligoclase, quartz, biotite and amphibole are found, the internal proportion of which varies considerably. In some samples, quartz is so scarce that the rock would be called a (quartz) syenite. Although the content of the black minerals may vary considerably, there is in general enough of them to give the rock a mesocratic appearance. Accessory minerals are apatite, sphene, zirkon, allanite and muscovite. The plagioclase is frequently sericitized. Biotite may be chloritized, or altered to a mixture of muscovite and hematite.

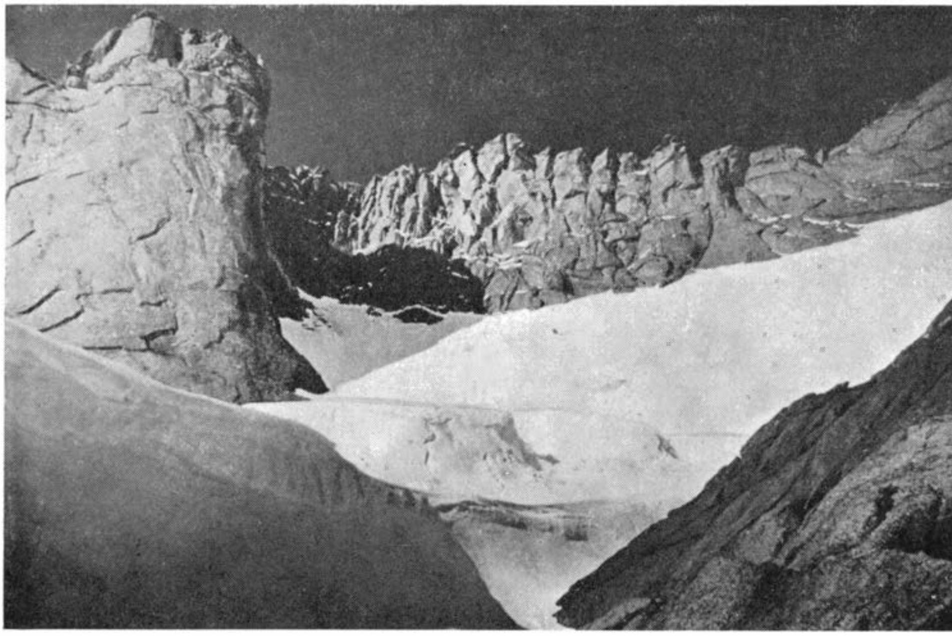

Fig. 4. *Granite-sculptured mountains at 72° S, 4° 30′ E.* Photo: T. LUNDE.

The massive rock contains less quartz than the gneiss, and garnet is absent. Otherwise it seems to be no great difference in mineralogy. It is apparent from the map that our samples of the massive complex represent only its western and northern fringe. If it is a differentiated complex, more basic rocks may be found in the central mountain area.

The massive rock is intersected by some fine-grained, mesocratic dikes, which consist of intimately intergrown crystals of quartz, microcline, biotite and altered plagioclase. Amphibole is not present in this rock. Also more medium-grained granitic dikes were observed. These dikes usually are narrow, not more than a few metres wide. In one case, however, a 50–60 m wide dike was noted, which was of granitic or granodioritic composition, with a central core of foliated diorite, containing zoned and porphyric plagioclase, biotite and amphibole.

The area investigated by WINSNES exhibits a more complex geology. In the western part the big intrusive masses of granite continue east and terminates at about 9° E. Further to the east the area consists of foliated and banded gneisses, but a few smaller granite bodies were also found in the northern part of Conradfjella and Alexander v. Humboldtfjella.

An area with gneiss is situated in the central and southern part of Filchnerfjella between 7° and 8° E at about 72° S. The strike is E–W with the dip mostly towards south. The area east of 9° E mostly consists of foliated and banded gneisses, mineralogically the same as the gneisses to the west, but with a higher proportion of red garnet. The strike is changing from N–S to E–W with dips to the south and east. To the east dips towards north have also been observed. In the gneisses

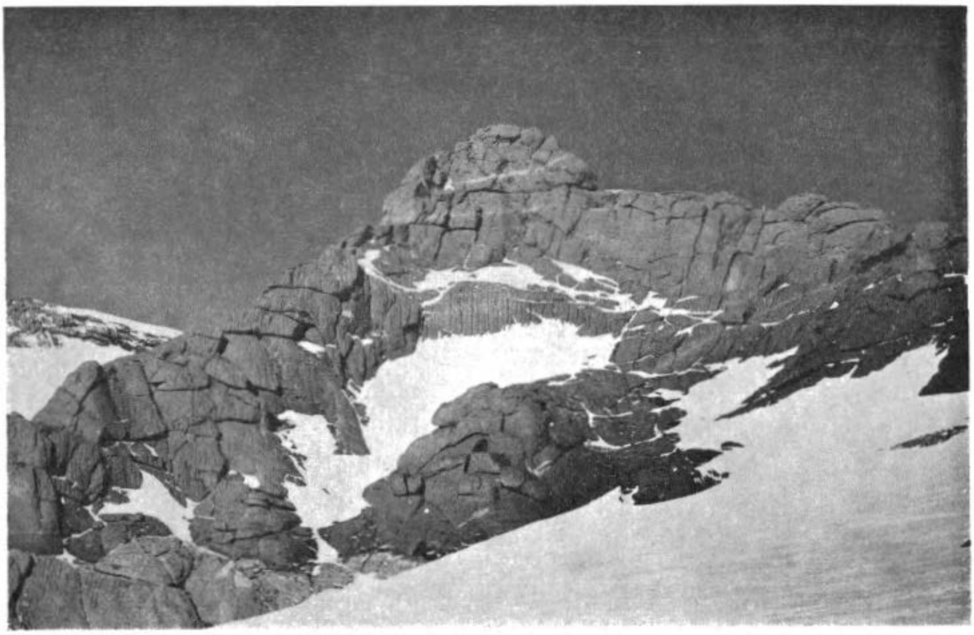

Fig. 5. *Fractured granite in nunatak at 71° 45′ S, 6° E.* Photo: T. LUNDE.

bands and lenses of amphibolite are common. Monomineralic rocks, consisting of black or green hornblende were observed. One of WINSNES' gneiss specimens contains mesoperthitic feldspar, oligoclase, biotite, garnet and quartz, thus demonstrating charnockitic affinities. Another specimen, taken from a dike, consists approximately of 60 % calcic plagioclase and 40 % diopsidic pyroxene, and accessory amounts of iron ore and biotite. Part of the specimen, perhaps representing the contact zone, contains more biotite, and the diopside is altered to amphibole, biotite and serpentine. The dike is possibly some kind of lamprophyre. The gneiss is commonly cut by small granitic dikes, which mineralogically and structurally are identical to the massive rocks to the west and southwest, but perhaps less coarse-grained. Even some more leucocratic fine-grained dikes occur.

Conclusions

The mountains of Fimbulheimen mostly consist of migmatic gneisses in amphibolite facies, intruded and intersected by quartz-poor hornblende-biotite granite, apparently forming a large massive in the central part of the mountain area. The supposition of an igneous character of the granite is supported by the observations made by ROOTS of crosscutting "hornblende-biotite syenite" found in the gneisses to the west (ROOTS, 1953, p. 25). The similarity in mineralogy of gneiss and granite points to a common syn-orogenic formation. The granite in many respects seems to be similar to the Dais granite in Victoria Land (MCKELVAY and WEBB, 1962) but for the lack of alignment of the porphyric feldspar crystals.

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Talus terraces in Arctic regions

BY

OLAV LIESTØL

Abstract

Talus formations at the foot of steep slopes, common in arctic regions, are described. They are built of ice and rock débris from the slope above, and brought down by avalanches. The formations often have a typical flow structure and are somewhat like rock-glaciers.

Terrace-like talus formations at the foot of large rock slopes are a characteristic feature of several arctic regions.

At Spitsbergen, where the writer has made most of his observations, these formations are found first and foremost near the coast, at the foot of the mountains along the inner edge of the strandflat. Elsewhere in Spitsbergen, such features are

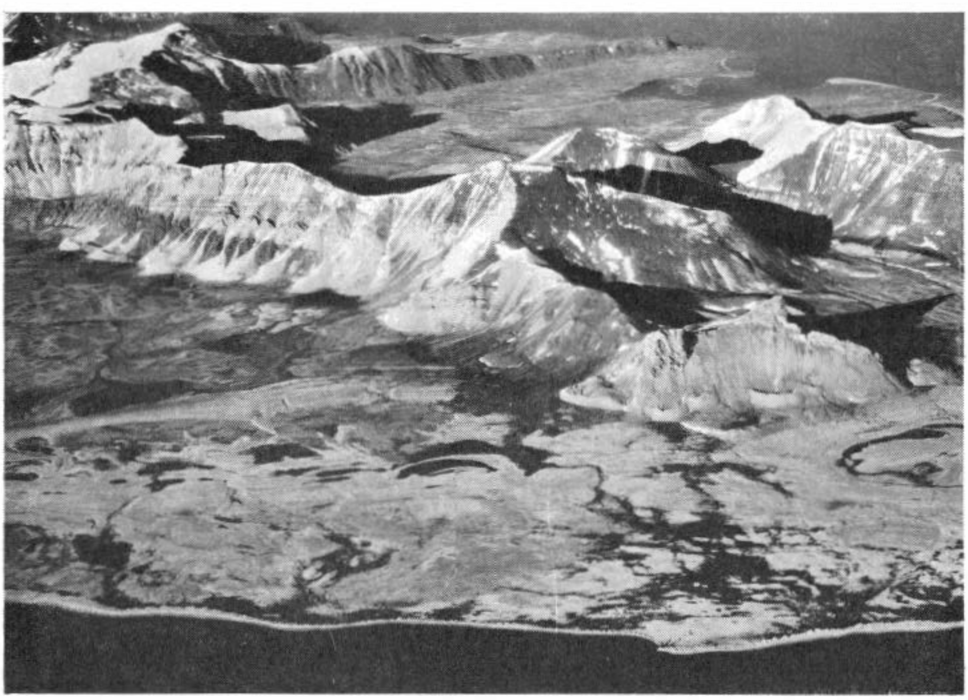

Fig. 1. *Talus formations north of Kapp Mitra at the west coast of Vestspitsbergen. Krossfjorden in the background.*

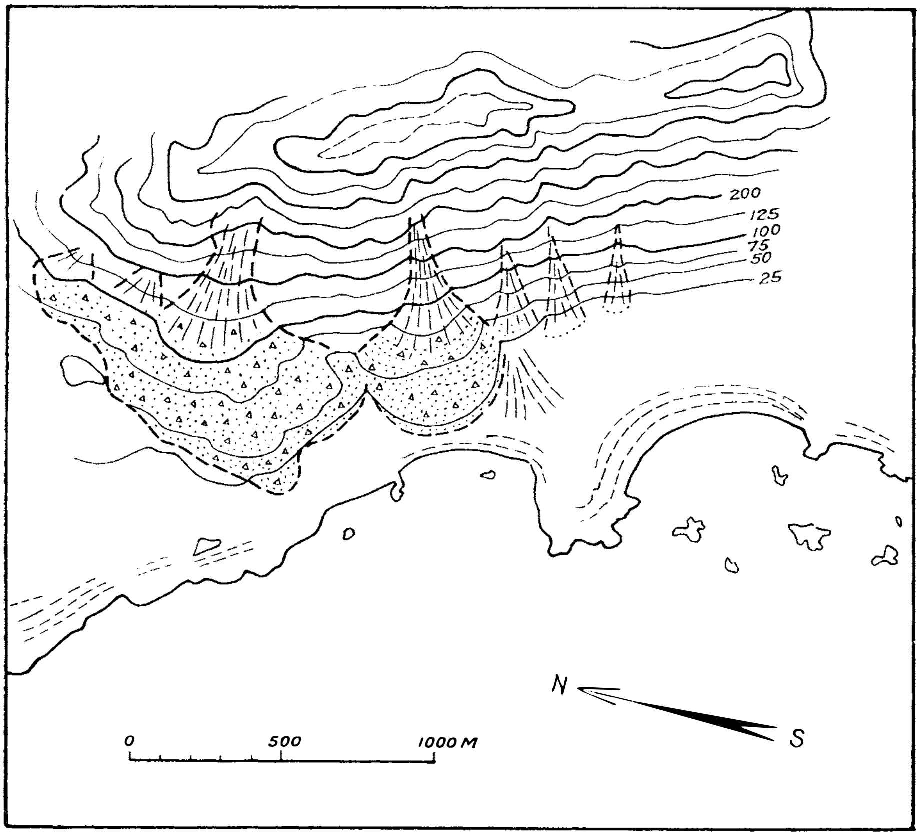

Fig. 2. *Map of the talus formations at the foot of Gullichsenfjellet, north of Hornsund.*

to be found inland, though more cut up and of much smaller dimensions. The shape can vary, though the method of formation clearly is the same. At some places isolated, semicircular, high tongues lie in front of rock slide cones (Fig. 1 and Fig. 2). At other places, especially along the strandflat, these often coalesce to give long, relatively irregular forms, which at a distance may appear to be terraces or a kind of flat lateral moraine (Fig. 3). Some have a higher rampart towards the border, whilst others form fine arched tongues. A transition to what could be termed a "rock-glacier" is to be found at a number of places, for instance near Kapp Mitra, on the south side of Scoresbyfjellet (Fig. 1). At this last place the feature starts as a "talus-slope" and changes progressively into a mass with clear large corrugations and stream structures. At the mountain foot the mass spreads out and becomes very similar to the forms described above.

Some workers have believed that the features must be a type of lateral moraine, and they are marked as moraines on the topographic map of Vestspitsbergen. Several characteristics of the "terraces", however, suggest that this is not the case. Firstly, there is their position. It is difficult to imagine a glacier which could deposit a lateral moraine at most of the places at which these "terraces" are to be found. Possibly one could imagine some kind of piedmont glacier or shelf-ice.

Fig. 3. *Talus terraces at the west coast of Vestspitsbergen below Fløyfjellet and Dørdalsnuten south of Dunderbukta. In the right part of the picture light limestone and dolomite form light terraces below the mountain slope, indicating a local origin of the material in the terraces.*

However, moraines and other traces of the glacier ought then to be found at other places where they might be expected. Also, the terraces ought to possess a gradient corresponding to the gradient of the imagined glacier. No such features are to be found; on the contrary, there are examples of a surface sloping against the probable direction of movement. Naturally, in a moraine a mixture of all the rocks over-ridden by the glacier is to be found, i. e. a heterogeneous material. Along the west coast of Spitsbergen the Hecla Hoek formation is found, with very varied rock types. In these areas the terraces investigated by the writer, with a couple of exceptions, contain material only from the rocks which are to be found in the mountain side directly above (Fig. 3). For this reason, it does not seem likely that the features are moraines. Most probably, the terraces are a form of talus deposit.

Avalanches, often containing large masses of stones and weathered material, descend the steep mountain sides. Ordinary rockslides are also common. The snow drifts which are formed at the mountain foot in winter cause the stone-rich slides associated with spring and summer disintegration to go a long way out. Thus there is the possibility of the formation of protalus forms, such as mentioned above, with a rampart at the outermost part of the terrace. Where the slide material covering the snow has some thickness, it will cause a considerable decrease in the melting of the underlying snow. As the thawing in the course of the summer attains a depth of the order of one metre, snow or ice at a depth greater than about one metre will never thaw. Snow which is covered, and by this means preserved, throughout the summer will be transformed gradually into ice, and finally will form a kind of ground ice. That this sort of terrace does indeed contain great amounts of ice could be seen in 1954, in Longyeardalen, where a slip had occurred in one such feature. Irregular layers of sharp-edged stone and gravel alternated with layers of dirty ice. The ice content also can account for the typical flow structure which is very characteristic at many of the localities, for instance at Hyttevika, north of Hornsund (Fig. 2).

The writer also has studied features of this type in the Antarctica. An opportunity to investigate particularly fine and marked talus terraces of this kind was presented during a visit to Cape Adare in January 1961. Here they extend along the mountain foot, about 20–30 m above the low strandflat. This place has one of the largest penguin colonies in the Antarctica; the penguins have their nesting places on the talus terraces. Dead penguins and skeletons of penguins are to be found everywhere. Decomposition proceeds slowly in the Antarctic climate, so that layers of guano and penguin carcases are formed in the terraces. A small slip which had occurred at the edge of one terrace had caused an exposure 4–5 m deep. Here it was seen that the terraces were composed of layers of ice and gravel, and in part of sharp-edged stones. Bones – and in places complete skeletons with feathers – of penguins were visible through the entire series of layers. It is clear that here the terrace is built up gradually by snow and stone slides from the mountain above. At a couple of places, remnants of the previous winter's avalanches could be seen; these had gone right to the outer edge of the terrace, and were covered partly by gravel and stone.

The Axel Heiberg Glacier

Following R. Amundsen's trail 50 years later.

BY

WALLY W. HERBERT[1] F. R. G. S.[2]

The Amundsen versus Scott race to the pole in 1911–1912 was the starting point of a controversy that has raged for the last 50 years among armchair explorers, over whether Amundsen was lucky to get there first. It is not the purpose of this paper to enter into a controversy with such formidable opponents as the armchair explorers, but to record my impressions of Amundsen's route on the Axel Heiberg Glacier as a fellow sledging man.

Between the Beardmore and the Robert Scott Glaciers there are only three major glaciers draining the polar plateau – the Mill, Shackleton and Amundsen. In these three glacier systems there is a very definite and extensive flow of ice from the polar plateau, usually into a basin at the head of each glacier. From these basins, the ice flows towards the gaps in the mountain chain, and is disturbed by the constriction into chaotic icefalls. The Liv Glacier follows precisely the same pattern but on a smaller scale. The distance from the rim of the basin to the icefalls is not much more than 15 miles – but the turbulent effect on the ice as it passes through the gap at the head of the glacier is both remarkable and spectacular (1).

We discovered that, in most cases, the plateau surface at the rim of the basins was heavily crevassed, but by sledging across this basin or neve just above the icefalls we could generally find a safe route. At first we were puzzled by the scatter of the crevasses on the polar plateau – but once we had determined the approximate ice divide between the neves and the direction of the ice flow, most of the crevassed areas fell into a neat pattern.

Between the head of the Keltie Glacier and the Shackleton Glacier, the plateau ends abruptly in a gigantic escarpment, which in most cases can be approached right to the edge with reasonable safety. There is one small tributary glacier which flows into the Shackleton Glacier, and one which flows into the Liv Glacier, both from the Prince Olav Mountains, and there are four glaciers between the Liv and

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the Amundsen Glaciers which flow from the polar plateau. But these four glaciers, of which the Axel Heiberg is one, do not drain the polar plateau. Their névés extend only about ten miles onto the polar plateau, and the volume of ice carried by these glaciers comes almost entirely from a heavy local precipitation.

The most distinctive feature of these four glaciers is the height they loose in a relatively short distance compared with the other glaciers in the Queen Maud Range. The Axel Heiberg falls almost 8,000 feet in only 20 miles, and 12 miles of that distance is almost flat terrace. Another distinctive feature of this area is the heavy precipitation and lack of wind.

There is probably a greater precipitation in the Axel Heiberg region than anywhere else in the Queen Maud Range. By comparison, the Amundsen Glacier to the east and the Shackleton Glacier to the west are cold deserts, receiving probably no more than four inches of snowfall a year. Most of this is blown off the glaciers and the steeper rock faces leaving the area exposed to almost continual wind and drift erosion. The prevailing wind in this part of the Antarctic appears to be an east-south-easterly, occasionally swinging round to a north-easterly. Windless days are extremely uncommon. During the 84 days that we spent on the polar plateau, there were only 11 days when the wind dropped to less than 10 knots. Undoubtedly the high mountains surrounding the Axel Heiberg and its neighbouring glaciers are a perfect shield from the wind, for there were many occasions when travelling on the Axel Heiberg, when through binoculars, we could see a blizzard blowing on the polar plateau and around the summits. The drifting snow would appear to blow over the glacier at plateau altitude – hang suspended above the glacier, and then settle into this windless area. I would guess that most of the precipitation on the Axel Heiberg is of this origin, but there were a few occasions when large snowflakes fell, that could not possibly have been wind-blown. Consequently this region lies under a mantle of deep snow for most if not all of the year, and is only occasionally surface-hardened in the lower reaches of the glacier, by a north-easterly wind (2).

The physiography of the Axel Heiberg is particularly interesting and in some respects unique in the Queen Maud Range. It is a valley glacier which tumbles from the polar plateau in spectacular icefalls over a dolerite sill onto basement granite, and again over a further "step" (possibly granite) into the main glacier valley. Only in one other locality in the Queen Maud Range have I seen physiography of this nature. This region is to the west of the Shackleton Glacier, where the polar plateau descends in icefalls over dolerite sills into the only tributary glacier feeding it from that side. But here the icefalls are not as high as those of the Axel Heiberg, and the ice flows slowly over a great area of low flat terraces.

The frequency of avalanches in the Axel Heiberg region is also worthy of mention, and indicates clearly a very heavy precipitation on the mountains and a fast rate of ice movement. Amundsen mentioned the avalanches in his account – "The huge avalanches were more frequent than on the outward journey. One mass of snow after another plunged down"(3). During a total of nine days that we spent on the Axel Heiberg, most of the avalanches came off Mt Fridtjof Nansen, falling onto the middle terrace of Axel Heiberg icefalls – there were also a good

Fig. 1. *"Southern Party". From left to right: V. M. McGregor, P. M. Otway, K. P. Pain, W. W. Herbert.* Photo: P. M. Otway.

many that fell from the top terrace onto the middle terrace, but to the best of my memory, I cannot remember any avalanches falling from the slopes of Mt Don Pedro Christophersen. However, this is of little significance.

The only comparison that can be made with Amundsen's observations of any definite value are in a comparison of photographs. Two of the photographs in Amundsen's book were taken from the same campsite, although he did not say so (4), — one of Mt Fridtjof Nansen and the other of Mt Don Pedro Christophersen. When we had negotiated the bottom icefall we looked around for the first possible campsite. There was not much choice, in fact there was really only one spot within a mile where there was enough room between the crevasses, and flat enough to set up two tents and span out two teams of dogs. This very spot, we discovered, was almost the exact location of Amundsen's campsite of November 18th and January 5th. On which date he took the photographs we cannot be sure, but by using them to get a photographic re-section of Amundsen's position, we found that we could not move more than a hundred feet in any direction without upsetting the comparison with what we saw with our eyes and what we saw on Amundsen's photographs. A very careful study would have to be made of Amundsen's original negatives before any conclusions could be drawn on the present state of the glacier, as I suspect that the prints in his book "South Pole" have been photographically touched up.

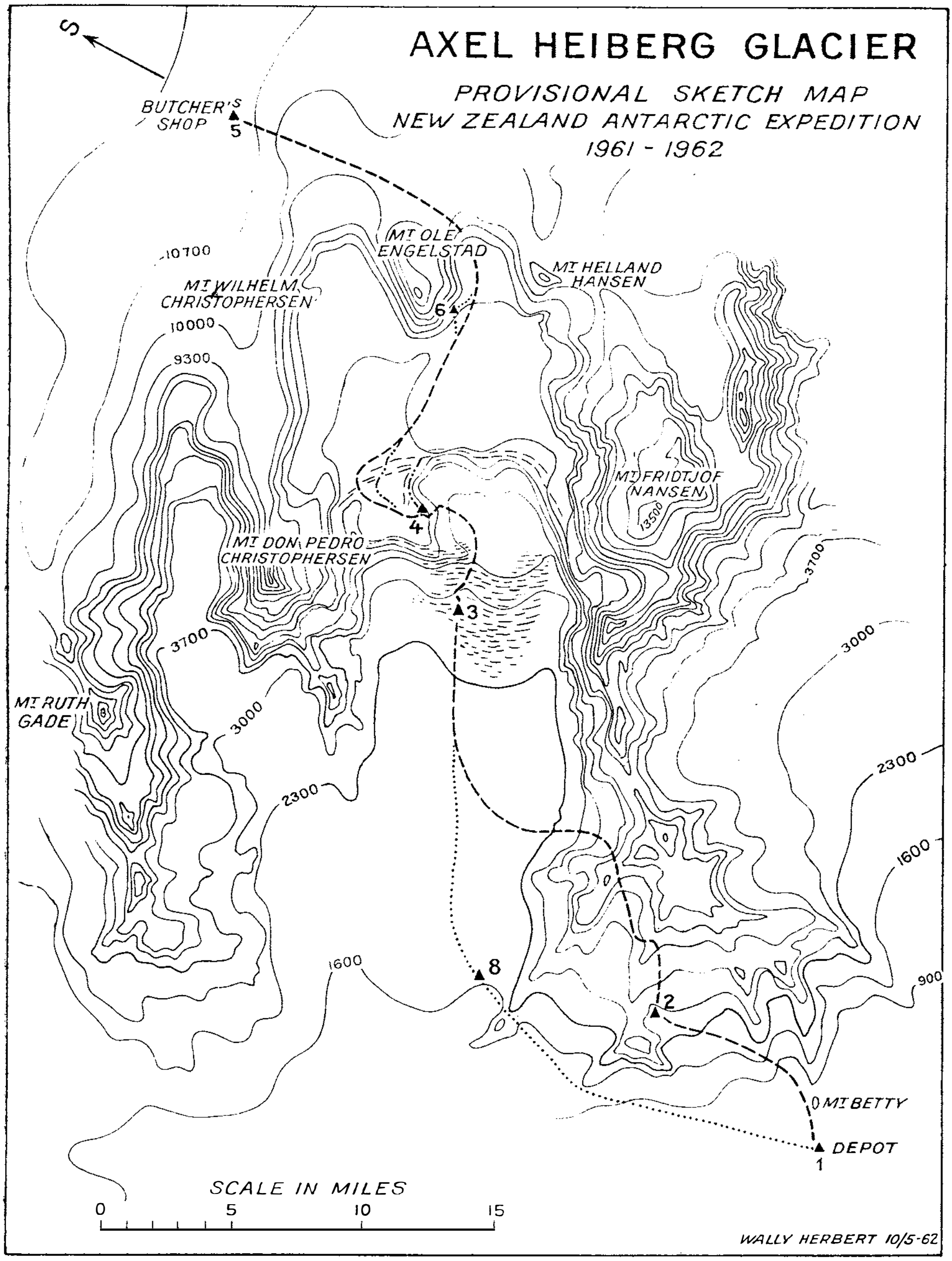


Fig. 2. *Map of Axel Heiberg Glacier. This is a provisional map only – compiled from Gould's map 1929, recent aerial obliques flown by the U. S. Navy, and field observations by the New Zealand Geological and Survey Expedition 1961/62. Amundsen's uphill route shown by pecked line, and the downhill route, where it differed from his uphill route by a dotted line. Campsites are marked by a triangle and numbered 1–8. Camp number 7 was on the same site as camp number 3. Amundsen's sledging distances should not be scaled off this provisional map.*

The foreground crevasses are of course quite different since the ice is moving all the time, but the general level of the glacier is much the same as it was 50 years ago — if anything, slightly higher. By the time we had got to the bottom of the icefalls and taken those pictures, we only had an academic interest in the possible change in the glacier over the last 50 years — very different to the worry we had at the top of the glacier over whether it had changed so much that we would not be able to get down. There could not be much erosion of the dolerite sill over a period of 50 years, and of course there are no moraines visible by which to judge the amount of erosion because of the frequent falls of snow. It seems reasonable to believe that the basic rock foundation over which the ice flows is relatively unchanged in 50 years. The only variable then, is the amount of ice moving down the glacier. If there is about the same amount of ice in the glacier now as there was 50 years ago — and I believe this may be the case — the pattern and nature of the crevasses will be similar. By selecting what I considered the best route down the glacier icefalls, I would guess that it would be no more than 50 yards from Amundsen's route at any point, although I can only say this with certainty at the spot from where Amundsen took his photographs. Our adventures on the way down this glacier therefore make an interesting comparison with Amundsen's.

There is only one way to unravel any mysteries of a previous explorer's route — and that is to travel the same route at the same time of the year by the same method of transport. There were many mysteries about Amundsen's route up the Axel Heiberg, chiefly because he neither took photographs of the icefalls nor made a map of the glacier. The outstanding physical features of the area he was able to describe well enough to be recognized by later travellers, but many of the minor features, and his route up the icefalls, were extremely difficult to locate. The fault lies partly in the fact that the narrative of his journey in "South Pole" was not designed to be used as a route guide for later travellers, and partly because his description only makes sense when you arrive at exactly the same spot.

The first men to see the Axel Heiberg Glacier after Amundsen's successful pole party descended it in January 1912 were Admiral Byrd and his crew on the depot laying flight to the foot of the Liv Glacier. This was on November 18th 1929. As he flew towards the mountains his confusion over Amundsen's text increased – "It seems almost absurd, as I look back upon it, to have been standing thus, staring one moment at the far flung shield of snow-draped rock, and the next at a few words and photographs, striving to put them together. If ever I saw the inadequacies of words I did then. Cones, summits, peaks, flanks, ridges, turrets – scramble them together, add a dash or two of adjectives, and one has, at best, an approximation" (5).

Byrd and his crew — Balchen, June and McKinley — on their flight to the South Pole on November 29th, 1929, flew up the Liv Glacier in preference to the Axel Heiberg because the plateau altitude at the head of the Liv was a little lower. After a most successful and courageous flight up the Liv Glacier and on to the pole, they decided to make their return run down the Axel Heiberg. Their flight down the Axel Heiberg took only 10 minutes — hardly enough time to study the glacier as a dog sledging route, and it was obvious from Byrd's errors in positioning

Amundsen's place-names, that he had found Amundsen's text difficult to follow. A close comparison of the photograph in Byrd's book "Little America" (facing page 349) with the U. S. aerial oblique photos of the Axel Heiberg, will clearly show that Byrd thought Mt Don Pedro Christophersen was Mt Ruth Gade. But then what did he think was Mt Don Pedro Christophersen? He called the small dome between Mt Don Pedro Christophersen and Mt Fridtjof Nansen — Mt Wilhelm Christophersen while this is really Mt Ole Engelstad. Later he says — "While moving towards it (a depression to the east of Mt Don Pedro Christophersen) we noticed still another pass to the left of Mt Ruth Gade (Mt Don Pedro Christophersen) apparently the most accessible of all, and decided to make for that. The maneuver brought Mt Don Pedro Christophersen into full view. He was a good sized fellow — but how very beautiful was Mt Ruth Gade!" (Mt Don Pedro Christophersen) — (6). Here he must have been referring to Mt Ole Engelstad — but earlier he had called Mt Ole Engelstad, Mt Wilhelm Christophersen. Without wishing to confuse the reader with further examples of Byrd's errors in Amundsen's place-names, it can be summarized thus: Byrd thought that Mt Don Pedro Christophersen was Mt Ruth Gade — that Mt Ole Engelstad was Mt Don Pedro Christophersen — Mt Wilhelm Christophersen he was not sure about. The real Mt Ruth Gade he did not mention, and Mt Fridtjof Nansen he had placed perfectly. I have elaborated on these errors for two reasons — firstly, to enable Byrd's flight down the Axel Heiberg to be plotted accurately on the map, and secondly to illustrate how difficult it is, unless you are on the ground, of identifying geographic features seen from that angle.

The Southern Geological Party of that expedition, under the leadership of Laurence McKinley Gould, made a long and very worthwhile journey from Little America to the Queen Maud Range, and travelled along the foot of the range from the Liv Glacier to the Everett Glacier. They penetrated as far inland as the north-east spur of Mt Fridtjof Nansen by sledging up the Strom Glacier, and made valuable geological collections in that locality.

From a running survey along the Ice Shelf and by using the very fine aerial photographs taken by captain McKinley, a reliable map was made for the first time of this region. With the exception of the icefalls of the Axel Heiberg, which they could really see from the mouth of the glacier, the topography was well shown. But they had still not solved the mystery of Amundsen's route.

With the advent of flying activities from McMurdo Sound in 1956, the Beardmore Glacier was flown over and photographed on pole flights, and in the last two years a tremendous area has been covered by American trimetrigon photography of a very high standard. With these excellent photographs of both the Beardmore and the Axel Heiberg Glaciers, the armchair explorers were again tempted to make a comparison of routes. But to their surprise, in the case of Amundsen, it was impossible to plot his route up the icefalls. His narrative was so modest and un-dramatic, that it had, in the days before the aerial photographs, created the general impression that he had found an easy route to the Polar Plateau — an impression that was strengthened by the fact that he had climbed from the Shelf Ice to the Polar Plateau in only five days.

The routes of Shackleton and Scott could be plotted more accurately on the photos, and both British explorers had produced a map of the glacier which served as an extra guide. However, all three explorers had limited their map-making, since their principal objective was the Geographic South Pole, and a vast majority of the area between the Beardmore and the Axel Heiberg remained un-mapped until this year. With our descent of the Axel Heiberg in February 1962, Amundsen's route may now be re-written and illustrated with many more photographs than were taken by the pole party 50 years ago. But Amundsen's achievements on this glacier are none the less because it has been travelled a second time — on the contrary, it is very easy to look at a photograph on which a route has been drawn and say "well of course that is obvious" — and it is even easy to descend a route that looks appalling if you know that it has been done before. But to attempt to climb the icefalls of the Axel Heiberg just because it was the shortest route showed great determination and courage.

Amundsen made two errors on the glacier part of his polar journey and one on the Polar Plateau. All three errors were quite understandable in the circumstances and do not reflect on his judgment. It was a race he was having to get to the South Pole — he had been forestalled at the North Pole by Peary, he could not afford to be beaten at the South Pole by Scott, since he had no secondary motive for going "South" as had the Englishman. To follow the longitude of Framheim to the South Pole would be the shortest route, and this was precisely what he intended to do. As he was approaching the Queen Maud Range he was looking for a glacier that would flow in a south to north direction, and automatically ruled out the Liv and Axel Heiberg Glaciers because they were slightly off his set course, and flowed in the wrong direction. He chose to go inland from Mt Betty, hoping to find a direct route up to the Polar Plateau. This, I think, was his first mistake, and I still cannot understand his reason — but then I am biased because I know the country. In any case Amundsen probably regretted his decision in retrospect.

His party of five men and forty-two dogs left their depot just north of Mt Betty on November 17th, travelled 11½ miles and climbed 2,000 feet. It was an uncomfortable day's sledging, hard work and hot. After camp had been pitched, two parties sett off to investigate the route ahead; Wisting and Hanssen as one pair, and Bjaaland skiing off alone in another direction. It was perhaps just as well that Amundsen insisted on the prerogative of making the final decision, for a healthy argument developed over which route was the better. On November 18th they sledged just over 2,000 feet up to a saddle from where they had their first view of the Axel Heiberg icefalls. Amundsen writes: "It was a magnificent panorama that opened up before us" — "We now saw the southern side of the immense Mt Fridtjof Nansen; Mt Don Pedro Christophersen we could see in his full length. Between these two mountains we could follow the course of the glacier that rose in terraces along their sides. It looked fearfully broken and disturbed, but we could follow a little connected line among the many crevasses; we saw that we could go a long way, but we also saw that the glacier forbade us to use it in its full extent. Between the first and second terraces the ice was evidently impass-

Fig. 3. *U. S. aerial oblique. "Official U. S. Navy photograph". Campsites marked are Amundsen's. Dotted line indicates Amundsen's reconnaisance routes.*

able. But we could see that there was an unbroken ledge up on the side of the mountain; Mt Don Pedro Christophersen would help us out. On the north side of the mountain there was nothing but chaos, perfectly impossible to get through" (7). I believe that from Amundsen's altitude and distance, he was only able to form a general impression of which way to go; he could not possibly be sure that there was a route. The Axel Heiberg was in his way, and although it looked appalling as a route, he decided to try it out. This to me is the most impressive example of Amundsen's determination in the face of an obstacle that would have turned away any lesser man.

The next part of his narrative is easy to follow on the map, but after he has reached the Axel Heiberg his description becomes most unclear, and his ambiguity over this part of the route caused us great problems in trying to plot his route on the photographs before we made the descent. Knowing as we now do, exactly where he camped on the evening of November 18th, and approximately where he got down onto the Axel Heiberg, it all fits in very nicely. It is obvious to me that he went right out into the middle of the glacier, along one of the ice-streams and up to a point just before the chaos of the bottom icefall. He camped a little nearer Mt Don Pedro Christophersen than Mt Fridtjof Nansen — it was confusing of him to say "Directly under Mt Don Pedro Christophersen" (8).

They had difficulty just as we did 50 years later of pitching their tent in the soft snow, and in the evening Bjaaland and Hanssen went off to reconnoitre a route up to the middle terrace. Going up this terrace the next day Amundsen says:

"The arm of the glacier that led up was not very long, but extremely steep and full of big crevasses; it had to be taken in relays two teams at a time. The state of the going was fortunately, better than on the previously day, and the surface of the glacier was fine and hard, so that the dogs got a splendid hold" (9). This part of the route was the very crux — had we had a "fine and hard" surface it would have been an extremely unpleasant experience negotiating those icefalls. Amundsen sledged across the middle terrace, took a rest below the middle icefall, and started off with double teams to ascend it. He soon found himself "under the ridge among the many open chasms", and decided that it would be prudent to first make a reconnaissance.

They set up their tent at 5,650 feet above sea level, and then set off. As usual Amundsen tried the shortest way first, and here he made his second mistake on the glacier. He says himself: "But it is not always the shortest way that is the best; here in any case, it was to be hoped that another and longer one would offer better conditions. The shortest way was awful — possibly not altogether impracticable, if no better was to be found. First we had to work our way across a hard smooth slope, which formed an angle of 45 degrees, and ended in a huge, bottomless chasm. It was no great pleasure to cross here on ski, but with heavily-ladened sledges the enjoyment would be still less. The prospect of seeing sledge, driver, and dogs slide down sideways and disappear into the abyss was a great one. The mountainside along which we were advancing gradually narrowed between vast fissures above and vaster fissures below, and finally passed by a very narrow bridge, hardly broader than the sledges, into the glacier. On each side of the bridge, one looked down into a deep blue chasm. To cross here did not look very inviting; no doubt we could take the dogs out and haul the sledges over, and thus manage it, presuming the bridge held, but our further progress which would have to be made on the glacier, would apparently offer many surprises of an unpleasant kind. It was quite possible that, with time and patience, one would be able to tack through the apparently endless succession of deep crevasses; but we should first have to see whether something better than this could be found" (10).

They returned to the tent where everything had been put in order and the dogs fed, then three of them set off to see if another route could be found. This time they took a slightly longer route and went up right under Mt Don Pedro Christophersen, where they found a good safe passage between the huge crevasses. They pressed onward until they could see before them the last slope to the plateau. They in fact went right across the top terrace of the glacier until they could see round the corner of Mt Ole Engelstad towards the icefalls between it and Mt Helland Hansen, and from that point they returned to their campsite 2,500 feet below.

Amundsen's description of the scenery that met their eyes on the return deserves to be quoted: "It was a grand and imposing sight we had when we came out on the ridge under which — far below — our tent stood. Surrounded on all sides by huge crevasses and gaping chasms, it could not be said that the site of our camp looked very inviting. The wildness of the landscape seen from this point is not to be described; chasm after chasm, crevass after crevass, with great blocks of ice scattered promiscuously about, gave one the impression that here nature was too powerful for us. Here no progress was to be thought of. It was not without a certain satisfaction that we stood there and contemplated the scene. The little dark speck down there – our tent – in the midst of all this chaos, gave us the feeling of strength and power. We knew in our hearts that the ground would have to be ugly indeed if we were not to manoeuvre our way across it and find a place for that little home of ours. Crash upon crash, roar upon roar, met our ears. Now it was a shot from Mt Fridtjof Nansen, now one from the others; we could see the clouds of snow rise high in the air. It was evident that these mountains were throwing off their winter mantle and putting on a more spring-like garb" (11).

On November 20th, they set off on what proved to be the biggest climb of the journey to the Pole. They did not take exactly the course they had reconnoitred the day before, and Amundsen does not say clearly which way they went. I would guess, however, that they sledged closer under Mt Don Pedro Christophersen. The surface was not good up on the top terrace, and it was very hard work getting up the last slope. Amundsen says: "The dogs seemed positively to understand that this was the last big effort that was asked of them; they lay flat down and hauled, dug their claws in and dragged themselves forward." They continued their march after they had ascended the last icefall determined not to stop until they had reached the flat plain of the Polar Plateau, and they finally camped on the summit of the ridge running onto the plateau from Mt Don Pedro Christophersen. They had travelled 19¼ statute miles with an ascent of 5,750 feet, a remarkable achievement for men and dogs. Twenty-four dogs were slaughtered that night, and the site became known as the "Butcher's Shop".

On November 25th, Amundsen's party set off into the teeth of a blizzard, heading due south, and after a while they started to descend. This worried them, for they knew from Shackleton's account that he had kept climbing for a long time after reaching the Plateau. Amundsen, in travelling due south from the head of the Axel Heiberg had descended into the basin-like névé of the Isaih Bowman Glacier — but since visibility was practically zero and remained very poor for the next few days they did not realize this. In fact the third mistake that Amundsen made on the way to the Pole, was that he ran into some of the worst crevass systems on this part of the Polar Plateau by travelling due south from the head of the Axel Heiberg. All three mistakes were quite understandable — I mention them only to show that in each case there was an easier route, and had Amundsen only known of it at the time, he would have saved himself and his companions a lot of anxiety and hard work.

It is quite clear from Amundsen's account of his journey across the Polar Plateau that he dropped 2,570 feet from the Axel Heiberg to the foot of the glacier that he called the "Devil's Glacier", and yet on most maps of the south polar region, the Devil's Glacier is plotted as an extention of the Axel Heiberg. This is obviously a cartographer's error. Certainly Amundsen referred to the feature as a glacier, but he never at any time said that this glacier flowed uphill to the head of the Axel Heiberg (12). There is a very definite flow of ice from Amundsen's "Devil's Ballroom", which is really just below the rim of the plateau basin or névé of the Amundsen Glacier, and not of the Axel Heiberg.

Amundsen's trip down the Axel Heiberg was so uneventful and straightforward

Fig. 4. *Setting off on the reconnaissance from the top of the Axel Heiberg Glacier. Home-made Norwegian flag flying from the cowcatcher in honour of Amundsen and his companions.*[1]
Photo: P. M. Otway

that it barely gets a mention in his book, and yet by reading between the lines of this master of understatement, I can see how breath-taking this trip down must have been. He covers the crux of the descent with no more words than this: "On the ridge where the descent to the glacier began we halted to make our preparations. Brakes were put under the sledges, and our two ski-sticks were fastened together to make one strong one; we should have to be able to stop instantly if surprised by a crevass as we were going. We ski-runners went in front. The going was ideal here on the steep slope, just enough loose snow to give one good steering on ski. We went wizzing down, and it was not many minutes before we were on the Axel Heiberg Glacier. For the drivers it was not such plain sailing: They followed our tracks, but had to be extremely careful on the steep fall" (13).

Our own adventures in descending this same glacier 50 years later were so different to those experienced by Amundsen, that, had he been alive today, he would have laughed at our problems and the way we surmounted them. The New Zealand Geological and Survey Expedition 1961/62 had two field parties working on the Polar Plateau, both parties with four men and two teams of dogs. One party operated between the Beardmore Glacier and the Nimrod Glacier, and my party between the Beardmore and the Axel Heiberg Glaciers. Basically the object of my party was to be landed at the head of the Mill Glacier on the Polar Plateau at an altitude of 9,000 to 10,000 feet with 55 days food. We were to receive one re-supply air-drop of 30 days food later in the season, and be picked up either from the spot where we were landed or at any other more suitable location on the Polar Plateau.

[1] The flag has later been presented to Norsk Polarinstitutt.

I had proposed a plan of geological reconnaissance and topographical mapping for the season as follows: To sledge down the east arm of the Mill Glacier, and across the main stream of the Mill Glacier to the Dominion Range. Return across the Mill Glacier and set up survey stations between the Mill and the Keltie Glaciers before heading for the Shackleton Glacier region. Survey stations would be set up on the plateau edge wherever possible to survey down onto the coastal ranges, and further survey stations would be occupied down either side of the Shackleton Glacier — where there would be a re-supply airdrop of 30 days food and fuel. Further stations would be occupied at the head of the Liv Glacier and the Axel Heiberg before turning due south and heading "all out" for the Pole. This plan if carried out successfully, would complete the control for a map covering about 17,000 to 18,000 square miles, and the dash to the Pole would have the following advantages: Firstly, it would be far easier and safer to be picked up by Hercules aircraft of the U.S. Navy from Pole Station and be flown directly back to McMurdo, than to be relayed off the plateau by Dakota down to the Ice Shelf and from the Ice Shelf back to McMurdo Sound. And secondly, a dash to the Pole would be safer travelling than attempting to get off the Polar Plateau by sledging down one of the glaciers. It was one of my greatest disappointments that I was not given permission to sledge the 300 miles to the Pole, on the grounds that, should any misfortune occur to my party on the way to the Pole, search and rescue operations would involve too many aircraft and crew at a time in the season when every aircraft is fully occupied bringing in the other field parties.

Nevertheless, the season was a great success, and the programme of mapping and geological reconnaissance was completed. We spent a total of 84 days on the Polar Plateau at a mean altitude of just over 9,000 feet. The highest air temperature we recorded during this period was —13.3° C and the wind blew almost continually. It will perhaps be of interest to mention at this point that at one stage during the season, the dogs pulled our sledges up to 12,000 feet above sea level, with apparently less ill effects to them than to us. In fact the dogs did not seem to suffer from breathlessness or altitude lassitude in any degree.

On the day that we celebrated the 50th anniversary of Amundsen's arrival at the Pole, it suddenly occurred to me that there was, after all, a prospect of ending a fine sledging season with a climax. Why should not we have a go at getting down Amundsen's route on the Axel Heiberg. It would save the Americans, on whom we depended for aircraft support, many anxious flying hours and the risk of landing on the plateau, and it would give us a better opportunity of mapping and geologising the Axel Heiberg region. I asked for permission by radio on December 19th to descend the Axel Heiberg, and after many conferences at McMurdo and Christchurch, after we had climbed Mt Fridtjof Nansen (13,500 feet), studied the glacier with binoculars from the summit, and made a reconnaissance of the glacier to the bottom of the icefall, flagging a route with 40 marker flags — I was finally given permission to descend the glacier on February 1st.

On January 16th I wrote in my diary: "Climbed Mt Fridtjof Nansen — 13,500 feet, a very easy climb from the technical point of view, but one of the longest and most exhausting, cold and miserable climbs I have ever done. We were on the

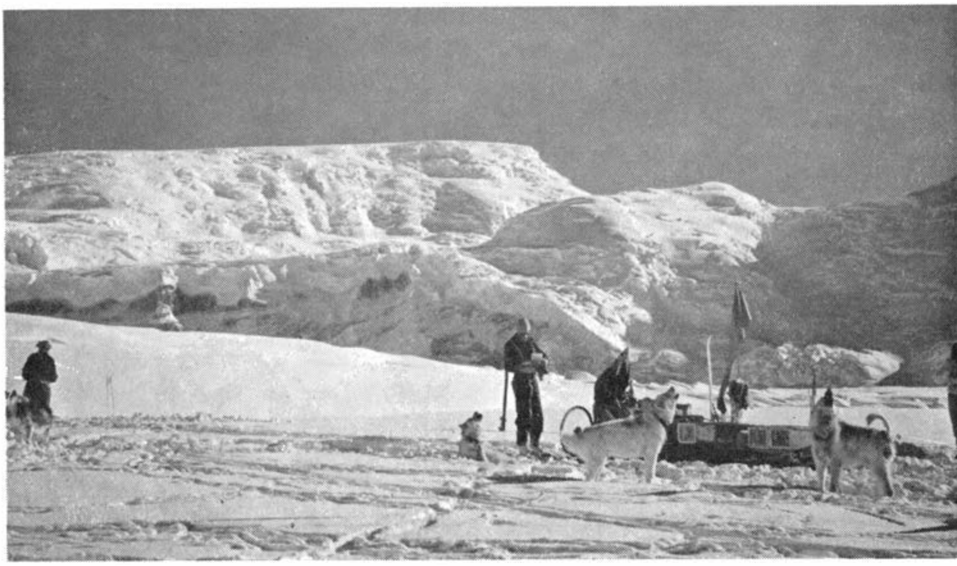


Fig. 5. *Mt Fridtjof Nansen, 13,500 feet, taken from Amundsen's campsite of November 18th 1911 and January 5th 1912. Compare this photograph with the one facing p. 50 in Amundsen's book "South Pole"*. Photo: W. W. HERBERT.

mountain for 17 hours, and the temperature was —29° C and the last six hours were pure hell with a 15 knot wind blowing and a long, long way to walk back to camp. Got back to camp at 4.30 a. m. However, there were consolations; I got some very good photos of the Axel Heiberg and had a good look at the route, but part of it only, and the easiest part at that. What I could see of it looked fine, and we all got a great thrill in seeing it for the first time in three dimensions. One of the nastiest bits of the route as seen on the aerial oblique photos was a traverse above the middle icefall — this appears to be hardly a traverse at all I am very relieved to say, but the crux of the route we still could not see, so now all we have got to do, is go down and have a look at the rest of it. We probably walked 20 miles altogether, and only just made it back to camp. Had to rope up twice on the way up, but nothing serious."

Mt Fridtjof Nansen was the most miserable survey station we had during the whole season, we spent about eight hours on the summit trying to complete the survey in appalling conditions and acute discomfort. Four days later we were at the head of the Axel Heiberg and all ready to go down for a reconnaissance. This was a very anxious period — it was quite impossible to follow Amundsen's description of the route through the icefalls, and plot it on the aerial photographs. We looked in vain for a "little connected line among the many crevasses". There was one very obvious one on the photographs, but it went over the steepest and most disturbed part of the icefall, — surely it couldn't be that. Maybe the glacier had changed over the last 50 years so much that we would not find Amundsen's route — maybe the route lay under the shadow of Mt Fridtjof Nansen in the photographs, the run off at the bottom looked smooth enough — but this did not fit Amundsen's description at all. There was only one way to be sure, and that was to get onto the glacier and have a look at the icefalls.

While my three companions were breaking camp and checking a depot, that we intended to leave on the plateau, I went off alone, on ski, to have a look at what Amundsen had called "the severe, steep slope" (14). The sky was almost completely overcast by thick alto-cumulus, with just a few tracers of weak sunlight piercing the mists in the valley. I skied between two fair sized crevasses at the top of the fall, then the ground dropped away from me into a misty basin. It was quite impossible to judge the fall without going down it, so I skied down the drop as slowly as I could, and in what seemed like no time at all I was at the bottom, about 1,200 feet below the camp.

It took me an hour and a quarter to get back up to the top, skiing on skins as fast as I could go. I told my companions how I had found the slopes and with great excitement we set off to see how it would go. To make quite sure that we did not get out of control, we travelled the drop using rope brakes under the runners, and not riding the foot break at all — this was only to be used in an emergency. As the slope became too rapid I would stop the sledge with the foot break, change the number of ropes under the runners, and leave a message written in the snow to tell the following team what brakes I was using. This system worked very well indeed, and if anything we over braked the sledges — perhaps not as exciting as getting out of control, but far less damage to the dogs and sledges.

Sledging away from below that top icefall was an unforgetable experience — by that time the weather had changed for the better, the alto-cumulus had broken up and the sun was streaming onto the glacier in a patchwork of light and shade. It was a beautiful sight. Huge icefalls towered above us on either side, and ahead, a ground mist lay thick and grey, with only the glorious sun-capped summit of Mt Don Pedro Christophersen piercing it. We made slow progress across the top terrace in deep loose snow, and camped on a ledge under Mt Don Pedro Christophersen in white-out conditions. There appeared to be a tremendous drop only a few feet from the tents. For the next 36 hours the cloud lay like a thick blanket over us and we were unable to move, six inches of snow fell on our outward tracks, and we began to get a little anxious about our food supply.

Two of my companions, Otway and Pain, volunteered to sledge back to the top of the plateau, leaving McGregor and myself with all their remaining food. This struck me as the greatest sacrifice of the whole season; we had done nothing but talk about the prospects of getting down the icefalls for a month or so, and by sacrificing their privilege to share the reconnaissance and leaving us their food, we would be in a position to stay another couple of days if necessary to wait for the weather to clear. At 1 a. m. on January 23rd McGregor and I set off in perfect weather with two climbing ropes, ice-axes, a long pole for probing crevasses, 40 marker flags and plenty of chocolate. We free skied as far as the top of the middle icefall and right into the corner overlooking the bottom icefall and the middle terrace. From this point the view was quite indescribable, and one of the finest sights I have ever seen. For almost an hour we studied the icefalls through binoculars and wondered how on earth we could get down. At first I could not believe

Fig. 6. "*At first I could not believe that Amundsen had made his way through the confusion of gigantic crevasses and icefalls below us*" *(P. 119). McGregor looking down over part of the bottom icefall – this photograph was taken from nearly 2,000 feet above the icefall.*
Photo: P. M. OTWAY, February 4th, 1962.

that Amundsen had made his way through the confusion of gigantic crevasses and icefalls below us, but must have climbed to the middle terrace right under Mt Fridtjof Nansen. On that side of the icefalls there appeared to be a fairly smooth run-off from the middle terrace to the glacier; but I did not like the look of the avalanche debris along the route. Then my suspicions were confirmed as a roaring avalanche hit the very spot I was looking at through the binoculars. Maybe he didn't come that way after all — or perhaps he timed the avalanches and made his bid for the middle terrace in between two falls. However, the avalanches were

Fig. 7. *"Maybe he didn't come that way after all" (P. 120). View down to the middle terrace – on the extreme right the top of the bottom icefall. Avalanche falling from the slopes of Mt Fridtjof Nansen.* Photo: W. W. HERBERT.

not at all regular, and it would have been foolhardy to attempt a dash down that side of the glacier — in any case I felt sure that Amundsen would have mentioned the experience had he gone that way. No, he must have come up the center, and the only way we could be sure was to try it ourselves.

From that bird's eye view I selected a route, and admit quite frankly that it looked awful. We skied down to the middle terrace at a fair pace, and many were the tumbles I had before coming to a positive halt at the bottom. I was grateful that only McGregor had witnessed my loss of dignity, and shaking myself clean of snow, we roped ourselves together. In this fashion, and with infinite care, we proceeded across the middle terrace and onto the bottom icefall. What we had seen of the route from above did not fit at all with what we were looking at from below, and there was nothing for it but to tackle each obstacle as we came to it, and forget the pre-conceived plan. At the top of the icefall, and one of the first obstacles we encountered, was a great hump-backed bridge over a most impressive crevass on one side and a chasm on the other. This ran off onto a fairly steep traverse about a quarter of a mile long which ended at the bottom in most unhealthy looking country. We snow-ploughed and slipped our way across this traverse roped together, I dreaded to think how the dogs would fare across this part of the route, for below us were huge open chasms just waiting to swallow a run-away sledge. At the bottom of the traverse our meandering course began. Up and down we went and round the lips of monstrous pits and chasms, until we came onto a comparatively undisturbed tract of the glacier; across this and into another region of beautiful pits. Sometimes we had to go down into the belly of these depressions and steeply up the other side, but more often we were able to find a route that took us around the lip of these unpleasant looking places. Eventually at 6.30 a.m. we were through the worst of the icefalls, and we turned back from a spot that I thought would make a reasonable campsite.

On our way back up the glacier we stuck in marker flags at every distinct change of direction, so that on the return, should the weather be against us, we would be able to feel our way between the crevasses by taking a straight line between any two successive marker flags. There were a few spots that I was not too happy about, the glacier was under a thick fall of snow — just how safe were some of these bridges? To set my mind at rest I probed everything time and time again, and even jumped up and down on some of the more critical bridges — but they all held well — we would get down safely I felt sure. McGregor and I arrived back at our campsite exhausted, -and on the last steep climb up to the tent, we had to lie down and rest many times.

The next day we sledged back to the top of the plateau with the good news for our companions that we would do it. They had been far from idle while we were making our reconnaissance of the icefalls – they had climbed Mt Ole Engelstad and completed the survey of the Axel Heiberg, and had, over one period, been on the move for 34 hours without a rest. We were all in high spirits that night at the prospect of making the descent, but first we had to get the official permission. Surely, we thought, this permission will be given without question, once we said that we had already been down the glacier to the bottom of the bottom icefall. But this was not the case. How Amundsen would have laughed if he could have seen us, huddled over a radio, tapping a morse key, sometimes for half an hour at a time, trying to convince the authorities that we really had been down and had flagged a route to the bottom, and that we really could get down safely.

How very different was the heroic age of polar exploration, when a party many hundreds of miles from base and without radio, would take their calculated risks with almost a gay abandon. No longer are explorers permitted to face their dangers alone. Nor are they permitted to go off the air and take their calculated risks in peace and quiet. The humane society we live in insists upon a multitude of men, most of them strangers, standing by a radio and waiting for the signal to scramble and risk their lives in flying to the rescue of an explorer in trouble. What a relief of responsibility it would be for the modern explorer if he only had the safety of his companions and himself to worry about.

All four of us were getting very tired, we had been on the Polar Plateau for a long time, the weather had been bad for weeks, and every day it was a little colder. We had spun out the rations over a long period of time, so that we would have a surplus of about two weeks food — we were now on that surplus, and still no decision had been reached about the descent of the Axel Heiberg. Meanwhile we sledged on to the head of the Liv Glacier and down the east side of the Shackleton Glacier, completing the survey of that area, making an effort to contact base twice a day for a verdict one way or the other.

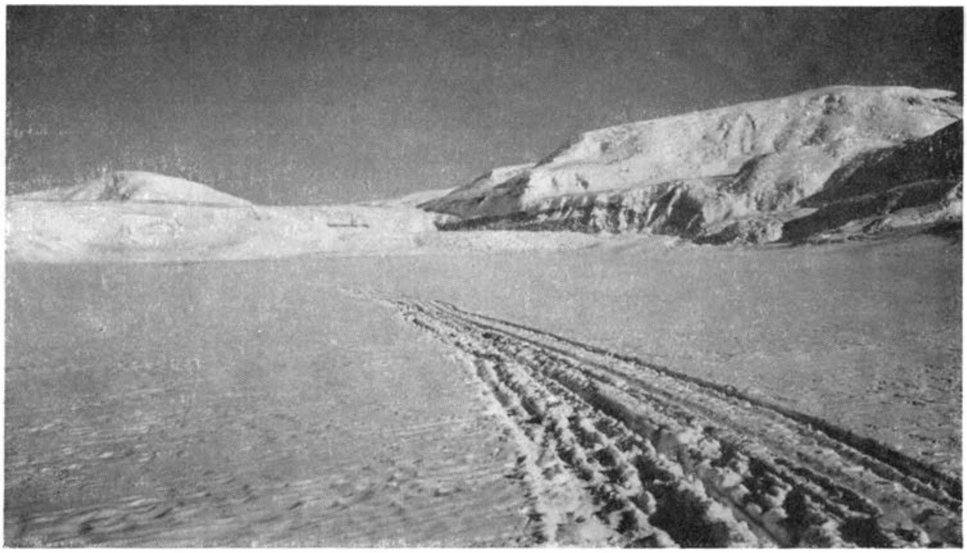


Fig. 8. *The Axel Heiberg icefalls from a distance of about 12 miles. Mt Fridtjof Nansen on the right, Mt Ole Engelstad on the left.* Photo: P. M. OTWAY.

On January 29th I was given a tentative approval, and told to be in a position to start the descent as soon as possible, but to wait there for final permission. We were many miles from the Axel Heiberg at that time, and pinned down by a blizzard and bitterly cold winds. We packed up and set off, the travelling conditions were appalling, and after travelling into a head wind for about 18 miles we could go no more. We camped at 7 a. m. after travelling all night, and were out again at four in the afternoon, but only made another five miles before the dogs and men became exhausted and camp had to be pitched. On February 1st I was given final permission to descend, but we were still some miles from the depot at the head of the glacier. After a painfully slow and throughly exhausting days travel we got to the depot, loaded up the sledges with 850 lbs of gear and our precious geological specimens, and descended the first fall. At last we were off the plateau, and on our way down.

The next morning the radio packed up and one of my companions felt very ill, so we postponed the start until after midday. At first things went well, and I even had visions of getting right to the bottom in one day; but the snow conditions became worse and worse, until, with the heavy loads on the sledges, we were sometimes floating in the deep snow. Dogs and men were completely exhausted by 6.30 p. m. and we had to camp. The snow at the campsite that evening was over a foot deep, and it took us a long time to clear an area for the tents.

On February 3rd we had the hardest day of the whole season, we only made 4.3 miles even though we had descended 1,000 feet. That night we camped above the big drop down to the middle terrace, but there was one consolation, the weather had been perfect all day, not a cloud in the sky. With the prospect of descending the icefalls the next day, that night should have been the most exciting one of the whole trip for me, but it wasn't. We could not get through to base to tell them that we were safe, every minute I expected to hear the search planes roaring overhead, disturbing the perfect stillness and beauty of the scene. Would the crevass bridges hold the weight of the heavy sledges? If anything went wrong, aviators would be man-hauling over a treacherous glacier for the first time in their lives in a humane effort to rescue us. It was a most oppressive burden to bear — how I envied Amundsen's freedom to shout with pure joy and exhilaration as they went "wizzing down" the icefalls 50 years before us.

At 10 a. m. the next morning, wishing each other a safe ride, we moved off. But what a struggle it was — the snow lay so deep on the glacier that I thought at one stage we might have to relay, but we gathered a little speed as we went across the middle terrace, and shot over the hump-backed bridge onto the traverse. Here we had to employ a most unusual technique of sledging to get down safely. The heavily loaded sledges tended to "lean" down the slope towards the chasms below us, and to keep the sledges on an even keel we had to fasten ropes to the downhill sledge pillars, bring them over the load and pull on them with all our weight — riding the sledge as one would race a yacht — hanging way out on the uphill side.

From the bottom of the traverse to the campsite, where we had turned back from the foot reconnaissance, we experienced a mixture of all that is exciting and frustrating in sledging. One moment we were careering down and around the lips of gigantic chasms, and the next moment we were pushing and struggling to get the sledges up a stiff rise from the sunken bridge of a crevass to the safety of the lip again. How thrilled we would have been if we could have got through to base that night by radio to say that we were safely down the icefalls, but this satisfaction

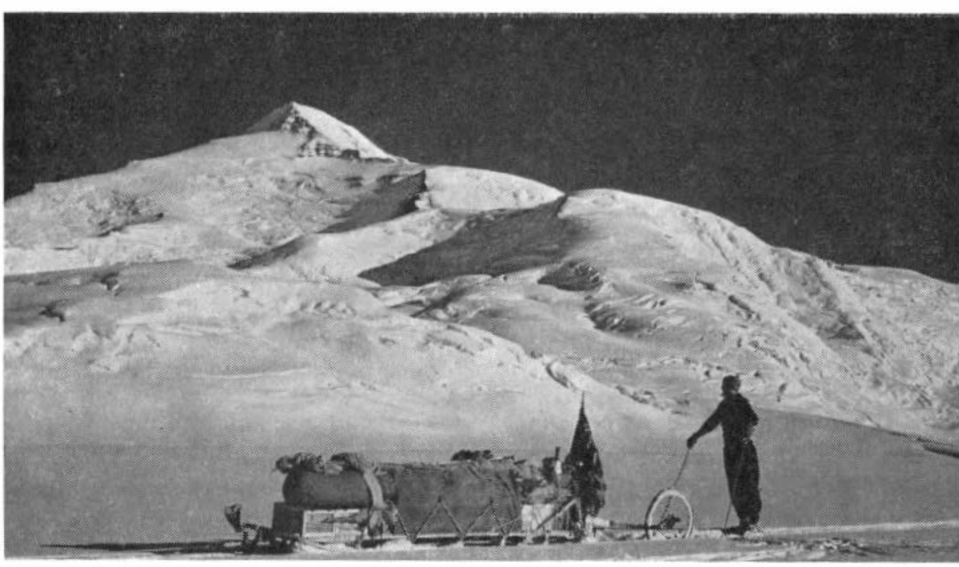


Fig. 9. *Mt Don Pedro Christophersen from about two miles below the bottom icefall.*
Photo: W. W. HERBERT.

was denied us. We had one final days sledging on the glacier and the following day we reached a suitable site for aircraft to land, a few miles short of Mt Betty. This last day's sledging was I think the most relaxing experience of the whole season — we had been at a high altitude for 84 days, and now we had got down to the Ice Shelf safely and it was all over.

Had the surface conditions on the icefalls been firmer than we experienced, as evidently they were when Amundsen descended them in January 1912, this remarkable route would have been hazardous if not almost impossible. There are no bounds to our admiration of the men who made the first descent of those icefalls, and this is a feeling that I know I share with many hundreds of sledging men. Byrd said: "So often we make the mistake of believing that because a mission is executed with sureness and without mishap it must have been easy. The history of polar exploration is full of contrasts. Witness the southern journeys of Scott and Amundsen. For years it was the practice of certain critics to minimize the risk and difficulties in Amundsen's dash to the pole. Even Scott on being confronted by the Norwegians tracks a few miles to the pole, decided hastily they must have found an easier way" (15).

Generally one sledging man will hold the highest regard for another, whether he is a competitor or not, as long as his achievements are worthy of respect. Had Scott survived the appalling hardships of his return from the Pole, he most certainly would have honoured Amundsen's splendid journey, and would not have permitted the patriotic bias to develop among the armchair explorers. On the subject of armchair explorers, Amundsen has this to say: "Just as in times of war it may be observed that the soldiers of opposing sides retain a high respect for their foes in arms, while the non-combatants at home seem to feel obligated to indulge in hymns of hate against their enemies, just so in exploration it often happens that the men in the field retain a high regard for their competitors, while their effortless compatriots at home seem to feel obligated to detract from the success of an explorer just because he is not of their nation" (16).

I find myself in the unique position of having mapped both the Beardmore and the Axel Heiberg Glaciers, of having flown up the Beardmore many times and descended the Axel Heiberg twice. What a glorious opportunity this would be to re-kindle the flame of patriotic bias, which developed over the Amundsen versus Scott race, by suggesting that one route was easier than the other. This, neither I, nor any other sledging man would ever do, and only the armchair explorers would have the temerity to attempt it. How can we judge great courage and indomitable will by statistics — and what a mouse of a man is he who tries to depreciate an explorers remarkable achievements by whispering the word "luck".

References

(1) Byrd – "Little America" p. 333.
(2) Amundsen – "South Pole" Vol. 2. p. 48. p. 155.
(3) Amundsen – "South Pole" Vol. 2. p. 58. p. 157.
(4) Amundsen – "South Pole" Vol. 2. p. 50. p. 156.
(5) Byrd – "Little America" p. 315.
(6) Byrd – "Little America" p. 343.
(7) Amundsen – "South Pole" Vol. 2. p. 44.
(8) Amundsen – "South Pole" Vol. 2. p. 48.
(9) Amundsen – "South Pole" Vol. 2. p. 48.
(10) Amundsen – "South Pole" Vol. 2. p. 51/52.
(11) Amundsen – "South Pole" Vol. 2. p. 56/57.
(12) Amundsen – "South Pole" Vol. 2. p. 84.
(13) Amundsen – "South Pole" Vol. 2. p. 157.
(14) Amundsen – "South Pole" Vol. 2. p. 155.
(15) Byrd – "Little America" p. 240.
Scott's Last Expedition. Vol. 1. p. 544. (January 16th. 1912).
(16) Amundsen – "My Life as an Explorer". p. 71.

The weather in Svalbard in 1961

BY

VIDAR HISDAL

The following tabular description of some salient features of the large scale atmospheric circulation pattern over the Svalbard area is based on a study of the weather maps for 1961. The pressure systems most closely connected with these circulation patterns and the character of the resulting air flow are briefly indicated.

General characteristics of the circulation pattern

	—	Extensive high pressure area over the Polar Basin with Northeasterly winds over Svalbard. Temperatures about the normal for the season.
	10th—	Intensive cyclones approache from the southwest. Southeasterly winds.
January	—	A cyclonic centre passes Svalbard. Mild Southerly winds in advance of it and colder winds between West and North in the rear.
	20th—	Several depressions pass to the south of the Svalbard area. Winds between East and North. Cold.
	—	
	—	Very cold Easterly and Northeasterly winds between an anticyclone that has formed over Greenland, and depressions in the south.
	10th—	
February	—	In the rear of a depression to the east cold air from the North continues to stream over the Svalbard area.
	20th—	Passages of cyclones from the southwest. Milder.
	—	A high pressure ridge with winds between East and North. Again colder.

	Passages of cyclonic centres. Southerly winds and milder.
10th *March* *20th*	The cyclones now pass just south of the Svalbard area. Winds between East and North. Mostly cool.
10th	Advection of cold air from the Northeast between an anticyclone over the Polar Basin and cyclones over Scandinavia and adjacent areas.
April *20th*	The cyclonic centres pass farther north again, just south of Svalbard. Easterly winds and milder. Somewhat colder, more Northerly winds in the middle of the period, as the above mentioned anticyclone moves towards Greenland.
10th *May*	The pressure field is very weak, with varying winds from East (cool), South and West (milder).
20th	Cyclonic systems to the south and winds between East and North over Svalbard. Colder.
	The cyclones take a more northerly course. Weak to moderate winds between East and South. Milder.
10th *June*	A high pressure area spreads gradually towards Svalbard. Weak and variable winds.
20th	Cyclones pass over or just south of the Svalbard area. Periods with strong Easterly winds. Well developed high pressure ridges with more favourable weather between the cyclones.

10th	
July	
20th	The situation is characterized by an anticyclonic development.
	The circulation pattern is again closely connected with cyclones passing south of Svalbard, and we get largely the same weather systems as before the development of the anticyclone.
10th	
August	A high pressure centre to the east. Calms or moderate Southerly winds. After about a week the situation starts to be more unstable, but remains, on the whole, to be dominated by high pressure areas over or in the vicinity of Svalbard. Light, variable winds and mostly fair weather.
20th	
10th	
September	During the whole period low and high pressure situations alternate in comparatively rapid succession, and the weather conditions are very variable.
20th	
10th	
October	
20th	

	An anticyclone forms over Greenland and the islands north of Canada. A strong Northeasterly air stream between this anticyclone and depressions in the ocean between Norway and Svalbard.
November 10th–20th	The weather is again dominated by cyclonic systems moving over the Svalbard area.
10th	A new anticyclone forms with centre over Ellesmere Island. Frequently strong winds between Northeast and North. Cold.
December 20th	Most of the period advection of cold air from the North between a high pressure area over Greenland and depressions south of Svalbard. Strong winds.

The above description is couched in general terms. It goes without saying that the weather conditions may vary quite considerably from place to place within the area considered. However, our knowledge of this variation is still insufficient. The only permanent meteorological stations on the main islands are those situated closely together on the coast of Isfjorden in Vestspitsbergen (Isfjord Radio, Barentsburg and Longyearbyen). In the table below are given preliminary monthly mean temperatures for Isfjord Radio for 1961 and their deviation from the means of the period 1947–59. (The final data for 1961 are not yet available. They will be published later in "Norsk meteorologisk årbok 1962".)

Mean temperatures (degrees centigrade). Isfjord Radio

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1961 means	−10.4	−14.8	−10.5	−9.9	−3.4	2.2	5.4	4.8	1.2	−0.7	−5.1	−13.1
Deviation of 1961 means from 1947–59 means	−0.1	−5.1	1.3	−1.4	−0.2	0.3	0.8	0.5	0.1	1.7	0.5	−4.8

The Cambridge Spitsbergen Expedition, 1961

BY

WALTER B. HARLAND[1]

The expedition, leader P. F. FRIEND, consisted of nineteen members, working in five parties. Details of the organization, membership and narrative, as well as the geological work, were published in the *Polar Record* Vol. 11, No. 70, 1962, p. 44–46.

The motorboat "Salterella" was built by WILHELM FORLAND & SONS, Håkonsund, and first used in 1961 (leader A. H. NEILSON and two engineers) for the support of northern parties, A, B and C. The main base in the north was at Biskayerhuken, where the enlarged Party A built a hut (approximately 6.1 m × 5 m × 2.4 m) financed by private donations in England (Fig. 1). A bronze plaque is mounted inside the hut with the following inscription:

COLIN BLAIR WILSON MEMORIAL HUT

THIS HUT WAS BUILT BY THE
CAMBRIDGE SPITSBERGEN EXPEDITION 1961
AND PARTICULARLY BY MEN FROM
GUILDFORD COUNTY TECHNICAL COLLEGE
AND PRESENTED TO THE NORSK POLARINSTITUTT
IN MEMORY OF C. B. WILSON 1928—1958
WHO BEFORE HIS DEATH IN CAMBRIDGE
SPENT SIX SUMMERS WORKING ON THE
GEOLOGY OF HECLA HOEK ROCKS

The expedition was greatly indebted to Norsk Polarinstitutt for transport of the hut materials and other help by the vessel "M/S Brandal", leader K. Z. LUNDQUIST.

The following geological work was carried out in the field.

Party A (leader D. G. GEE and generally four others) began the detailed study of Hecla Hoek rocks of the peninsula between Biskayerhuken and Liefdefjorden

[1] Department of Geology, Sedgwick Museum, Cambridge, England.

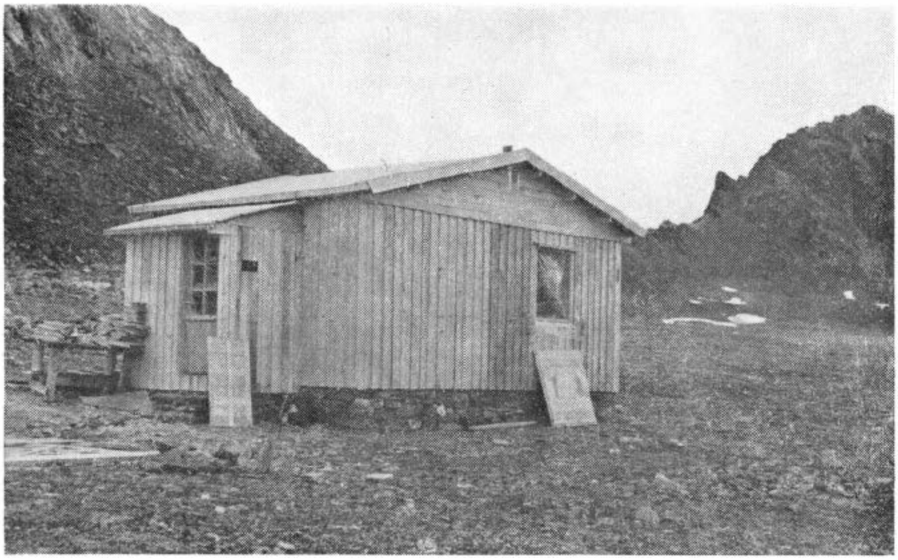


Fig. 1. *C. B. Wilson Memorial Hut at Biskayerhuken, Vestspitsbergen. Built in 1961 by the Cambridge Spitsbergen Expedition.*

working from centres at Biskayerhuken, Richardvatnet, Breibogen and Liefdefjorden. P. E. WOODCOCK collected some oriented Devonian rocks for palaeomagnetic work.

Party B (leader P. F. FRIEND and three others) continued to investigate the Devonian rocks of central and northern Spitsbergen from fjord-side camps at Breibogen, Kapp Auguste Viktoria, Svartdalsneset, Andredalen, Forkdalen, Sjettedalen, Krosspynten and Overgangshytta. During this time geological mapping on a scale of 1 : 50,000 was continued, including reconnaissance of central Andrée Land and revision of other areas, with systematic palaeontological collecting for stratigraphical purposes. Sedimentological observations were made. K. C. ALLEN extended his collection of palynological samples across to central Dickson Land, remaining there at the end of the expedition for further work.

Party C (leader R. A. GAYER and two or three others) continued the study of the stratigraphy and structure of the Hecla Hoek rocks of Ny Friesland and Olav V Land, recently investigated by M. B. BAYLY, W. B. HARLAND, and C. B. WILSON. Mapping on a scale of 1 : 50,000 was extended from camps in northwest Ny Friesland at Eolusneset, Mosselbukta, Femmilsjøen and Sørbreen.

Parties D and E worked independently of the northern parties. Party D (A. CHALLINOR and one other) compared the structure of the area described by A. K. ORVIN south of Kongsfjorden with that investigated in 1960 by P. J. COOK and A. CHALLINOR in the Tre Kroner and Garwoodtoppen areas, and CHALLINOR later visited the classic stratigraphical section west of Festningen.

Party E (J. L. CUTBILL) first worked alone on Mesozoic rocks of Deltaneset and then, with American Overseas Petroleum Company Ltd., measured stratigraphical sections in post Devonian rocks over a wide area.

Norsk Polarinstitutts virksomhet i 1961

Av

TORE GJELSVIK

Organisasjon og administrasjon

Personale

Norsk Polarinstitutt hadde pr. 31. desember 1961 22 regulære stillinger, hvorav 2 ubesatte. 12 personer var midlertidig engasjerte, vesentlig for oppgaver vedrørende Antarktis.

Den faste staben:

Direktør:	TORE GJELSVIK, dr. philos.
Geolog I:	HARALD MAJOR, cand. real.
Geolog II:	THOR SIGGERUD, cand. real.
Geolog II:	THORE S. WINSNES, cand. real.
Glasiolog:	OLAV LIESTØL, cand. real.
Meteorolog:	VIDAR HISDAL, cand. real.
Hydrograf I:	KAARE Z. LUNDQUIST, o/kapt.
Hydrograf II:	HELGE HORNBÆK
Topograf i særklasse:	BERNHARD LUNCKE, ingeniør.
Topograf I:	HÅKON HILL, jordskiftekandidat.
Topograf II:	Ubesatt stilling.
Geodet II:	SIGURD G. HELLE, cand. mag.
Karttegner I:	BJØRN ARNESEN
Karttegner III:	BJARNE EVENSEN
Konsulent I:	NATASCHA HEINTZ, cand. real.
Sekretær I (bibliotekar):	SØREN RICHTER, mag. art.
Kontorsjef:	JOHN GIÆVER, kaptein, fortsatt invalidepensjonert. Cand. jur. EINAR SAXEBØL ble ansatt midlertidig 1. mars. Han fratrådte 31. oktober for å gå over i ny stilling.
Fullmektig I:	SIGNY BANG fratrådte som kassererske 30. november ved oppnådd aldersgrense etter 26 års tjeneste. EVA ANDERSEN ansatt i samme stilling fra 1. desember.
Fullmektig II:	MARTHA LUNCKE
Fullmektig II:	GUDRUN EDWARDSEN

Fullmektig II: SIGNE ØVERLAND, ansatt fra 1. mars.
Vaktmester og bud: KIRSTEN DANIELSEN

Midlerrtidig engasjerte:

Cand real. TORBJØRN LUNDE
Cand. real. TORGNY E. VINJE
Sivilingeniør EINAR JONSJORD
Jordskiftekandidat SVERRE ØYGARD til 23. november.
Ingeniør THOR ASKHEIM
Ingeniør WILHELM SOLHEIM
Konsulent, jordskiftekandidat NIELS ROER til 14. oktober.
Radiotekniker JOHN SNUGGERUD til 28. februar.
Radiotelegrafist KNUT ØDEGAARD til 15. juni.
Karttegner MAGNE GALÅEN fra 17. april.
Korrespondent ALINE TORSTENSON, i deltidsstilling til 24. mars.
Fullmektig ELI HOLMSEN, i deltidsstilling fra 18. september.
Forøvrig har endel midlertidige beregnere vært ansatt på timelønnsbasis.

Tjenestefrihet

VIDAR HISDAL har hatt tjenestefrihet til 1. juli for fortsatte studier ved universiteter i Paris og London.

THOR SIGGERUD har hatt tjenestefrihet fra 1. januar til 1. mai for å virke som teknisk ekspert for FN i Den forente arabiske republikk.

TORBJØRN LUNDE har hatt tjenestefrihet fra 24. juli for å delta i en internasjonal ekspedisjon til Karakorum i Himalaya.

Oppnevnelser

Hydrograf KAARE Z. LUNDQUIST har blitt oppnevnt til medlem av «Utvalget for elektroniske navigasjonshjelpemidler for fiskeriene m. v.»

REGNSKAP FOR 1961

Kap. 565

Poster:		Bevilget		Medgått
1. Lønninger	kr.	493.000	kr.	500.551
2. Til disposisjon etter Departementets bestemmelse	»	60.000	»	60.374
3. Kontorutgifter	»	50.000	»	51.230
4. Trykning og bearbeidelse	»	60.000	»	66.120
5. Svalbardekspedisjonen	»	285.000	»	289.500
6. Antarktisekspedisjonen 1949–52. Bearbeidelse og trykning	»	50.000	»	49.008
7. Breundersøkelser i Norge	»	9.000	»	8.695
	kr.	1.007.000	kr.	1.025.478

Kap. 559.

Undersøkelse av statens kullfelter på Svalbard	kr.	150.000	kr.	150.059

Kap. 31.

Fyr og radiofyr på Svalbard	kr.	25.000	kr.	21.349

	Budsjettert	Innkommet	Medgått
Kap. 2506.			
Inntekter (salg m. m.)	kr. 5.400	kr. 11.712	
Kap. 2251.			
Svalbardbudsjettet	kr. 200.000	kr. 200.000	
Kap. 224 C.			
Antarktisekspedisjonen 1956–60.			
Overført beholdning pr. 1. januar		kr. 514.587	
Medgått			kr. 342.219
Tilbakeført til statskassen			» 172.368
		kr. 514.587	kt. 514.587

Ad Kap. 565, post 1. – Endel innsparing på lønninger for ubesatte stillinger har i det vesentlige vært brukt til midlertidig engasjert personell. Forøvrig har lønnstillegg forårsaket en mindre overskridelse.

Post 4. – Overskridelsen skyldes en raskere fullføring enn ventet av trykkeriarbeider mot slutten av året.

Post 5. – Ved endel innsparing på fartøyleie m. v., samt ved samarbeiding av planene for undersøkelse av statens kullfelter, ble det med departementets tillatelse benyttet et leiet helikopter under ekspedisjonen. Totalt bevirket dette en mindre overskridelse.

Ad. Kap. 224 C. Bevilgningen på denne post var overførbar til og med 1961.

Diverse

De trange kontorplassforholdene ble noe bedret på slutten av året, da det lyktes å få leie et nytt kontor i observatorboligen ved Observatoriet og ved visse omflytninger i selve hovedbygget etter at en hybelleilighet ble ledig.

Instituttet hadde allerede i juni 1960 levert tegninger til sin del av lokalene i det nye bygget som Vassdragsvesenet skal oppføre, men disse planene måtte omarbeides i juni 1961 p. g. a. endringer i Vassdragsvesenets disposisjoner. THOR SIGGERUD har fungert som instituttets kontaktmann i byggesakene, og har sørget for at oppgavene fra instituttet i tide er blitt gitt til Vassdragsvesenet, arkitektene og konsulentene. Bygget blir åpenbart noe forsinket, da anbudsinnbydelsen ikke ble ferdig før årets slutt.

Innredning av rommet for Svalbardsamlingen på Universitetets Paleontologiske Museum på Tøyen har kommet godt i gang, og instituttet har også i 1961 bevilget kr. 7.500 til dette arbeidet, som forutsettes fullført i nærmeste fremtid.

Ekspedisjonsvirksomheten

Svalbard

Hva isforholdene angår var sommeren 1961 en av de vanskeligste på mange år. Foruten de vanskeligheter som dette medførte for Kongens eskadre og for kullskipene på vestkysten, la de hindringer i veien for de forskjellige partiene, og førte til at mange måtte legge om sine planer. Hinlopenstretet og østkysten var stengt praktisk talt hele sommeren.

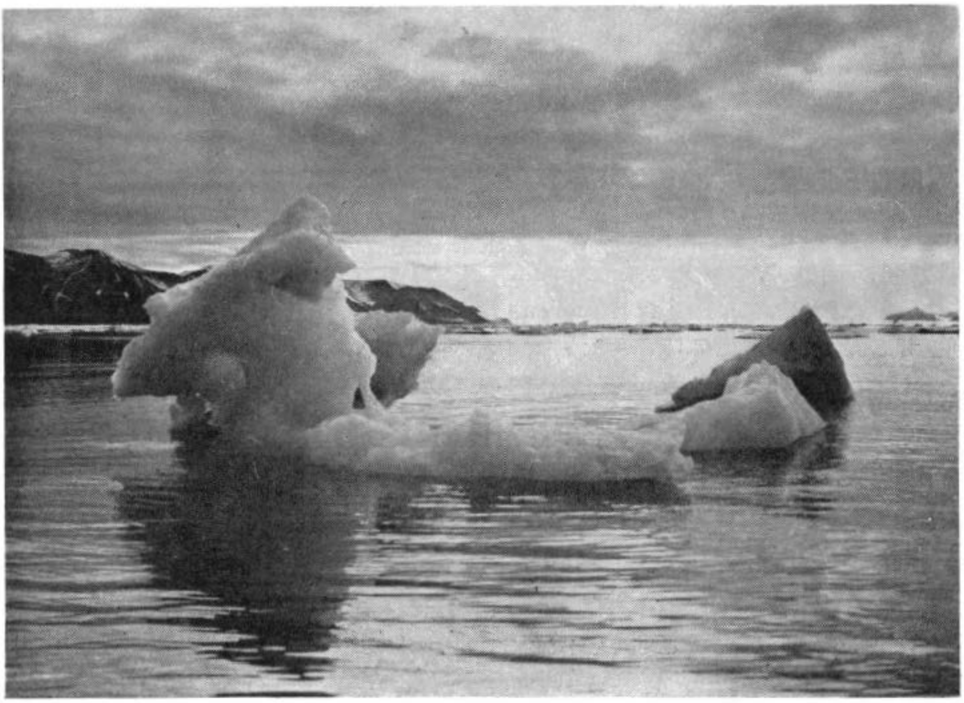


Fig. 1. *Isforholdene på Svalbard sommeren 1961 var vanskeligere enn på mange år. Bildet er tatt fra Sveagruva med utsikt utover Braganzavågen.* Foto: T. LARSEN.

Årets Svalbardekspedisjon bestod i alt av 30 personer, fordelt på 11 partier.

Ekspedisjonsfartøyet og hydrografparti 1. – Leder orlogskaptein KAARE Z. LUNDQUIST. Ekspedisjonsfartøyet M/S «Brandal» med JOHS. BRANDAL som fører ble overtatt av LUNDQUIST i Ålesund 20. juni. Båten ankom til Longyearbyen 28. juni. Den første halvdel av juli måtte vesentlig anvendes til utsetting av partier på vest- og nordkysten, og til frakting av helikopterpartiet til Sveagruva. Etterpå ble fyrtilsynet utført, og båten kom til Tromsø i slutten av juli, da LUNDQUIST skulle ombord i kongeskipet for å være islos under kongebesøket på Svalbard ved månedskiftet.

I forbindelse med den ovennevnte virksomheten ble det foretatt prøver med LORAN-C – et elektronisk system for posisjonsbestemmelse – av tre mann fra Forsvarets Fellessamband, som var med båten. Prøvene viste at systemet vil egne seg godt for lodding i havet vest og sørvest for Svalbard.

I Tromsø ble LORAN-folkene og deres utstyr satt av, og fartøyet gikk til verksted for reparasjon av hjelpemotoren. Deretter gikk fartøyet igjen nordover til Sveagruva, flyttet et par partier og assisterte D/S «Ingerfire», som var kommet i vanskeligheter i isen.

På grunn av issituasjonen måtte LUNDQUIST stå ombord i kongeskipet helt til Harstad, og han kunne først overta ekspedisjonsfartøyet igjen 14. august. Fartøyet hadde umiddelbart forut flyttet helikopterpartiet fra Sveagruva og plassert forskjellige partier på nye steder.

Under forflytting og utsetting av partier på nordkysten kom skipet opp i store isvansker, som bl. a. førte til at skipet et par dager sto på grunn i Murchisonfjorden.

Opploddingsarbeidet kunne først begynne 20. august i området Gråhuken–Moffen, men tåke hindret stadig arbeidet.

I slutten av måneden begynte innsamlingen av partiene. Fartøyet forlot Longyearbyen 1. september og kom til Åndalsnes 7. september.

Hydrografparti 2. – Leder HELGE HORNBÆK, med assistenter SVERRE LIE, HÅKON NØSTVOLL og SIVERT UTHEIM. På nordkysten var værforholdene stort sett gode, og HORNBÆKS parti med hydrograferingsbåten «Svalis» hadde en god sesong. Men fjordisen hindret en tidlig start, og de første fjorten dagene ble derfor anvendt til lodding i området ved Forlandsrevet og til gjenoppbygging av varder som isen hadde tatt i dette området. Senere ble arbeidet forlagt til Liefdefjorden hvor loddingen ble fullført.

Helikoptervirksomheten. – Basen i Sveagruva. Årets Svalbardekspedisjon ble i teknisk henseende et eksperiment, i det en fikk anledning til å bruke helikopter i en måneds tid. Mesteparten av aktiviteten ble derfor konsentrert til området mellom indre Van Mijenfjorden og Storfjorden. En hovedbase ble opprettet i et av husene i Sveagruva etter elskverdig imøtekommenhet fra Store Norske Spitsbergen Kullkompani A/S (S.N.S.K.).

Partiet i Sveagruva omfattet i alt seksten mann.

Været viste seg fra den mest uheldige side. Bortsett fra de første og de siste dagene av operasjonstiden, som varte fra midten av juli til midten av august, lå det nærmest kontinuerlig skodde over operasjonsfeltet. De enkelte oppklarninger varte sjelden mer enn noen få timer, dog i noen tilfeller opp til 10–12 timer.

Helikopteret var leiet av det svenske firmaet Ostermans Aero AB, Stockholm. Det var et Bell 47 G-helikopter med en engelsk fører som ikke tidligere hadde erfaring i flyvning i arktiske områder. Helikopteret viste seg også å ha for liten lasteevne, og førerens manglende felterfaring gjorde sitt til at mulighetene ikke kunne utnyttes helt tilfredsstillende. Vi fikk således prøve helikoptertjenesten under nokså vanskelige forhold, men det ble likevel en vellykket operasjon, og vi gjorde mange viktige erfaringer med henblikk på fortsatt helikoptervirksomhet.

Helikopteroperasjonene foregikk uten uhell, ikke minst takket være den ansvarsbevisste og forsiktige helikopterføreren. Det var hele tiden radiokontakt mellom helikopteret og basen i Sveagruva, og det ble dessuten lagt opp et sikringssystem sydover fra Sveagruva i tilfelle helikopteret skulle komme i vanskeligheter, styrte ned eller nødlande. Operasjonene ble fra starten ca. 10. juli og til utgangen av måneden ledet av TORE GJELSVIK, senere overtok SIGURD HELLE og THORE WINSNES. Assistenter i basen var THOR LARSEN, REIDAR NEGAARD og PEER OTTO SVENKERUD.

Kartleggingen. Ledere var SIGURD G. HELLE og WILHELM SOLHEIM, med assistenter henholdsvis SVEIN BURVALD og ERIK RAVDAL. Takket være helikopteret lyktes det å få gjennomført det planlagte programmet, og dermed er det topo-

Fig. 2. *Helikopteret i aksjon over Strongbreen i en av de få stundene med godt vær.*
Foto: T. SIGGERUD.

grafiske markarbeidet for kartbladene Braganzavågen og Kvalvågen på det nærmeste fullført. Det området som ble dekket var de vanskelig tilgjengelige bre- og nunatakområdene langs vannskillet – steder som man forgjeves hadde søkt å dekke med konvensjonelle metoder i mange år.

I tillegg til sitt eget arbeide satte topografene opp endel utmålsvarder for S.N.S.K. innenfor konsesjonsområdet, og målte disse inn.

Geologiske undersøkelser. Det var opprinnelig meningen at helikopteret også skulle betjene to av de tre geologiske partiene, nemlig et kartleggingsparti ledet av THORE S. WINSNES og et kullundersøkelsesparti ledet av HARALD MAJOR. Umiddelbart før ekspedisjonens avreise fra Oslo ble imidlertid MAJOR syk, og måtte sykepermitteres for hele sommeren. Det ble derfor nødvendig å sette inn THOR SIGGERUD som leder for kullundersøkelsespartiet, som forøvrig besto av assistentene JENÖ NAGY og EIGILL NYSÆTHER, og å legge om kullundersøkelsene fra detaljerte kvalitetsundersøkelser til rekognoserende undersøkelser med henblikk på kull-lagenes utbredelse sydover fra Sveagruva.

Kullpartiet oppholdt seg i baser ute i terrenget, hvorav mesteparten av tiden i en leir på Paulabreen ved vannskillet til Strongbreen, hvor de ble sterkt hemmet av skodde. Kull-lagene ble fulgt sydøstover fra utkanten av Sveagruvas konsesjonsområde og til sør for Kvalhovden. Kull-lagene var ikke sammenhengende og varierte meget i tykkelse, fra vel 1,5 m og nedover. Også kvaliteten var åpenbart sterkt varierende, men detaljundersøkelser ble ikke gjort. I tillegg til den direkte oppsøking av kull-leiene foretok partiet stratigrafiske undersøkelser.

Fig. 3. *Av hensyn til helikopteret ble det opprettet en base på Strongbreen som stod i stadig radiokontakt med hovedbasen i Sveagruva.* Foto: T. SIGGERUD.

Helt tilfredsstillende var likevel ikke resultatet for geologene, da de måtte gi prioritet til topografene for bruk av helikopteret i de gode gløttene som var.

For å utnytte forholdene best mulig ble geologene i flere tilfeller sendt med topografene som assistenter. Dette førte til at de fikk for liten tid til de geologiske undersøkelser i de forskjellige profiler. Det lyktes dog å få tilstrekkelige data til en geologisk kartopptrekking i målestokk 1 : 100.000 for kartbladet Braganzavågen, men materialet ble for knapt til de nødvendige sedimentologiske og paleontologiske tilleggsundersøkelsene.

Kartlegging forøvrig. – Etter oppløsningen av basen i Sveagruva i midten av august foretok topografene trianguleringsarbeid og satte opp varder i Bockfjorden, spesielt med henblikk på senere sjømålinger der. De foretok også en tellurometermåling. Det var opprinnelig meningen å utføre en del målinger i Storfjorden, men ekspedisjonsbåten klarte ikke å forsere isen, og dette arbeidet måtte utsettes.

Andre geologiske undersøkelser. – THOR SIGGERUD, med assistenter STIG OTTAR BANG og KNUT A. EDIN, hadde før han ble beordret til Sveagruva foretatt undersøkelser av marmorforekomstene i Kongsfjorden, men han måtte avbryte disse før undersøkelsene var ferdige. Likeledes ble SIGGERUDs opprinnelige program med undersøkelser av malmmineraliseringen i forbindelse med Hecla Hoekformasjonen sterkt nedskåret.

Etter oppholdet i Sveagruva foretok han en undersøkelse av diverse malm- og mineralforekomster i Recherchefjorden. Jernforekomsten som engelskmennene i sin tid nedla et stort arbeide på, består av små utgnidde malmslirer i dolomittisk sandstein, og er uten verdi. En rapportert kopperforekomst kunne ikke finnes. Asbestforekomsten er av dårlig kvalitet og mengdemessig av liten interesse. På slutten av sommeren foretok SIGGERUD en undersøkelse av blymineraliseringen ved Kapp Mineral, som synes å være helt ubetydelig. Synken var isfylt og ikke tilgjengelig. Det ble gjort forsøk med geokjemisk prospektering, men det viste seg at kjemikaliene ikke var anvendbare ved de lave temperaturer.

Etterat basen i Sveagruva var avviklet, fortsatte NAGY og NYSÆTHER undersøkelsene etter kull innerst i Van Keulenfjorden. På sydsiden av fjorden ble det undersøkt fire profiler uten at kull ble observert. På nordsiden av fjorden ble det observert et meget tynt kull-lag, som var uten økonomisk interesse.

Kvartærgeologparti. – Leder den sveitsiske geolog dr. JEAN P. PORTMANN, med assistenter DAG HUSEBY og TORE VRÅLSTAD. PORTMANN var engasjert til spesialundersøkelser av kvartæravsetninger på kartbladet Adventdalen. Han undersøkte områder i Adventdalen, Reindalen, Colesdalen, nordre del av Sassendalen og munningene av smådalene mellom Sassendalen og Adventdalen (det siste området ved hjelp av S.N.S.K.'s båt «Einar Sverdrup»). PORTMANN fikk hjelp av helikopteret til undersøkelsene i siste delen av sesongen, og rakk en god del mer enn det ellers hadde vært mulig.

Biologparti. – Leder cand. mag. CARLOS CHRISTOPHERSEN, med assistent KJELL HAUG. Det ble foretatt innsamling og observasjoner av hvirvelløse dyr som lever i fjæren i forbindelse med en geografisk-økologisk undersøkelse av Spitsbergens fjærefauna. Det planlagte arbeidet på Kong Karls Land måtte sløyfes p.g.a. isforholdene, og arbeidet i Murchisonfjorden kunne først ta til etter 15. juli. Før denne tiden ble det foretatt undersøkelser ved Gråhuken.

Paleontologparti. – Leder NATASCHA HEINTZ, med assistenter ARNE W. MARTINSEN, LILY MONSEN og ERIC STÅHL. Partiet ble organisert i samarbeid med Universitetets Paleontologiske Museum. Oppgaven var å foreta avstøpninger av spor etter en landøgle av slekten Iguanodon fra kritt-tiden, som ble funnet på Festningsodden i Isfjorden sommeren 1960 av en fransk professor. I tillegg ble det foretatt detaljundersøkelser av det kjente Festningsprofilet, og dessuten et profil gjennom karbonavleiringene i Vardefjellet innenfor Kapp Linné.

Filmfotograf BJØRN REESE fra Owesen-Film var med i samme parti som C. CHRISTOPHERSEN, og tok opp bilder av arktisk dyreliv i forbindelse med en film om Norges dyreliv som nå blir laget.

Utenlandske ekspedisjoner til Svalbard

American Overseas Petroleum Ltd., Norsk Caltex Oil A/S: Fortsatte sine oljeundersøkelser. Leder A.S. WESTERHOLM – 15 deltakere. Leiet ekspedisjonsbåt M/S «Polarøy» og 3 helikoptere.

University of Cambridge, Sedgwick Museum: Geologiske undersøkelser i nordlige del av Vestspitsbergen. Leder P. F. FRIEND – 19 deltakere. Egen motorbåt «Salterella» på 26 fot og 2 doryer. Ekspedisjonen førte opp en ny hytte på Biskayerhuken etter den som brant ned året før, og kalte den Wilson Memorial Hut.

Spitsbergen, Ny-Friesland Expedition: Flora- og parasittundersøkelser ved Billefjorden. Leder D. HAFFNER – 6 deltakere.

Tysk vitenskapelig ekspedisjon: Geologiske og zoologiske studier rundt Billefjorden og Nordfjorden. Leder cand. geol. G. TIDTEN – 4 deltakere.

Medical Research Council, London: Dr. M. C. LOBBAN overvintret i Longyearbyen 1961/62 for medisinske studier.

Russisk ekspedisjon, Arktikugol: Kull- og oljeundersøkelser. 15 deltakere med 2 helikoptere overvintret i Barentsburg.

Forøvrig endel mindre, turistbetonte ekspedisjoner.

Jan Mayen

Utenlandske ekspedisjoner

Birkbeck College, London: Geologiske og glasiologiske undersøkelser i Beerenbergområdet. Leder F. J. FITCH – 10 deltakere. Ved en tragisk båtulykke 26. juni 1961 omkom fem mann. Ekspedisjonen ble senere supplert med to deltakere.

Dronning Maud Land, Antarktis

Utenlandske overvintringsekspedisjoner

I 1961 ble antall overvintringsstasjoner i Dronning Maud Land redusert til tre. Alle var bemannet av utenlandske ekspedisjoner.

1. Norway Station, 70° 30′ S, 2° 32′ V, sørafrikansk ekspedisjon. 11 overvintrere.
2. Novolazarevskaja, 70° 46′ S, 11° 49′ E, russisk ekspedisjon. 11 overvintrere.
3. Syowa, 69° 22′ S, 39° 35′ E, japansk ekspedisjon. 16 overvintrere.

Breundersøkelser i Norge

I mai 1961 foretok OLAV LIESTØL rutinemessige målinger av snøakkumulasjonen på Storbreen i Jotunheimen. Samme sted ble ablasjonsmålinger utført i to perioder i august måned. I slutten av august ble det også foretatt målinger på noen av Jostedalsbreens utløpere, innbefattet opptak av fotogrammer for hastighetsmålinger i noen profiler på Nigardsbreen og for konstruksjon av kart over bretungen. Brevariasjonen ble målt ved Folgefonni, Jostedalsbreen, Svartisen, Jotunheimen og på Møre, i alt ved 26 breer.

Tre studenter, R. PYTTE, O. DYBVADSKOG og R. KLEMSDAL, har med støtte fra instituttet gjort hastighetsmålinger og regimeundersøkelser av tre breer i forbindelse med hovedfagsoppgaver.

Instituttet har vært behjelpelig med utlån av utstyr til en mindre engelsk ekspedisjon til Svartisen, hvor instituttet har gående en undersøkelse av bresjøen ved Østerdalsisen.

Bearbeidelse av materiale fra Svalbard

Topografisk-geodetisk avdeling

Da avdelingen fortsatt har måttet gi prioritet til konstruksjon av Antarktiskarter, har bare mindre arbeider vedrørende Svalbard blitt utført, således korrekturlesning av kartbladet A 7, Kongsfjorden, og en del konstruksjonsarbeid og tegnearbeid på den nye serien oversiktskarter over Svalbard i målestokk 1 : 500.000. Dr. A. K. ORVIN har fullført navnearbeidet for denne kartserien. Avdelingen har videre gjort noen mindre konstruksjoner i forbindelse med oppmålinger på nordkysten foretatt av den hydrografiske avdelingen, samt rutinemessig bearbeidelse av sommerens observasjonsmateriale. Servicearbeidet med å skaffe flyfotografier, karter og andre opplysninger for de forskjellige utenlandske og innenlandske ekspedisjoner på Svalbard har fortsatt lagt stort beslag på avdelingens tid.

Hydrografisk avdeling

Sjøkart nr. 514, Barentshavet, ble utgitt i februar, og kartredaksjon og korrektur i forbindelse med et nytt sjøkart nr. 515, Grønlandshavet, ble utført. Likeledes ble det forberedende arbeidet i forbindelse med et nytt sjøkart fra nord-vestre Vestspitsbergen påbegynt. Et foreløbig kart over det sistnevnte området ble utført for D/S «Lyngen» i forbindelse med dets utvidete rute til Bockfjorden. Tidevannsberegninger for Murchisonfjorden er utført, likesom forberedende arbeider for opplodding i Liefdefjorden og for bruk av LORAN C-systemet. Resultatet av sommerens opplodding er blitt bearbeidet.

Tegnekontoret

Tegnekontoret har, i tillegg til deltakelse i ovennevnte arbeider, tegnet karter i forbindelse med dosent A. HOELS brearbeider og publikasjon om Svalbards historie. En revisjon av tittelsiden for SKRIFTER og MEDDELELSER ble foretatt.

Dessuten har avdelingen arbeidet med illustrasjoner til publikasjoner for meteorologene og geologene, samt plantegninger for instituttets nye kontorer i Vassdragsvesenets bygg. Dybdekart over Nordishavet og Sørishavet ble tegnet for professor HJ. BROCH til en av hans avhandlinger.

Geologisk avdeling

Avdelingens arbeid i vinterhalvåret har vært endel redusert på grunn av sykdom, permisjon og arbeid i forbindelse med polarjubiléet.

Kullundersøkelsene

HARALD MAJOR har utarbeidet manuskriptkart for kartbladet Adventdalen, hvor de viktigste kull-leier ligger, samt utført fotogeologiske detaljstudier av overgangen mellom kritt- og tertiærformasjonene. Han har videre utarbeidet grunnlaget for utmålskrav for åtte funnpunkter i Reindalen, samt utarbeidet redegjørelse for Departementet vedrørende områder der statens utmål dekker områder som er av interesse for oljespørsmålet.

Andre arbeider

THORE S. WINSNES har ordnet et stort materiale fra Reinodden, Bellsund, og fra forskjellige områder på Vestspitsbergen. Han har utarbeidet et oversiktskart over prekambrium på Spitsbergen, og skrevet en artikkel om dette til et geologisk verk som skal utgis av «Interscience Publishers Ltd.», London. I høstsemesteret holdt han hovedfagsforelesninger om Svalbards geologi ved Universitetet i Oslo. Han var Polarinstituttets representant i arbeidskomitéen for Sydpolsutstillingen.

THOR SIGGERUD var, som nevnt annetsteds, permittert i første halvår. Han har senere bearbeidet sitt materiale fra sommerens feltarbeid, og publisert et arbeid om jernforekomsten i Farmhamna på Vestspitsbergen. Han har tatt opp en undersøkelse av radioaktive sporelementer i Svalbardmaterialet i tilknytning til undersøkelser som tidligere er gjort i Norge. Videre har han forestått planleggingen av de nye kontorlokalene i samarbeid med Vassdragsvesenet og bygningskonsulentene, og påtatt seg meget arbeid for å gjøre våre nåværende lokaler mer brukbare, samt forestått innkjøp av diverse utstyr.

NATASCHA HEINTZ har bearbeidet materiale av devonfisk fra Svalbard og utgitt en beskrivelse av en ny slekt av disse. Sammen med T. SIGGERUD har hun utgitt en oversikt over aldersbestemmelser av bergarter i Dronning Maud Land.

Geofysisk avdeling

OLAV LIESTØL har fortsatt bearbeidelsen av innsamlet materiale og målinger fra breundersøkelsene. Han har videre holdt en forelesningsserie for studenter ved Universitetet i Oslo.

VIDAR HISDAL hadde permisjon inntil 1. juli. I løpet av høsten inspiserte han de meteorologiske stasjonene ombord på de norske hvalkokeriene og stasjonenes utstyr for fangstsesongen 1961/62 ble komplettert.

Vedrørende HISDALS arbeid forøvrig se «Bearbeidelse av materialet fra Antarktis».

Bearbeidelse av materiale fra Antarktis

Glasiologi

TORBJØRN LUNDE har foretatt en del beregningsarbeider over brebevegelsen samt over temperaturvariasjonene i dypet av Fimbulisen.

Kartarbeider

I arbeidet med kartserien i målestokk 1 : 250.000 over Dronning Maud Land har SIGURD G. HELLE, HÅKON HILL, EINAR JONSJORD, NILS ROER og SVERRE ØYGARD deltatt. Arbeidet har pågått for fullt hele året og trianguleringsog passpunktberegningene ble avsluttet. Kartkonstruksjonen hos Widerøes Flyveselskap A/S ble også ferdig i årets løp. I alt ble seks kartblad utgitt (se listen over publikasjoner).

Et flyrutekart i fire blad i målestokk 1 : 100.000 som viser de norske fotograferingene for kartleggingsformål i Dronning Maud Land ble påbegynt.

Meteorologi

På grunnlag av det meteorologiske materialet fra Norway Station har TORGNY E. VINJE gjort nesten ferdig et arbeid om avkjølingsmålingene, og to andre arbeider om strålingsmålinger og snøens varmehusholdning ble delvis fullført.

En del meteorologiske data er utregnet og sendt til IGY Meteorological Data Centre i Genéve.

VIDAR HISDAL har stått for bearbeidelsen av observasjonene av synsvidde, skydekke, fuktighet og nedbør fra Den Norsk–Britisk–Svenske Antarktis ekspedisjon, 1949–52 og dette arbeidet nærmer seg fullførelsen og skal danne avslutningen av Maudheim-seriens vol. I, part 2.

Oson

Bearbeidelsen av osonobservasjonene ble påbegynt.

Bidrag til innsamlinger og bearbeidelse utført av andre forskere

Følgende har mottatt bidrag til forskningsoppgaver fra Norsk Polarinstitutt:

Lektor THOM ASKILDSEN til å foreta en reise til Canada for å samle inn materiale til sin undersøkelse av endringene i samfunnsforholdene hos en indianerstamme i Nordvest-Canada.

Cand. mag. CARLOS CHRISTOPHERSEN til en undersøkelse av hvirvelløse dyr i fjæren på Svalbard. Materialet til denne undersøkelse har dels vært samlet av Tromsø Museums ekspedisjoner til Svalbard, dels av CHRISTOPHERSEN på Nordaustlandet sommeren 1961.

Statsgeolog AUDUN HJELLE til fullførelse av bearbeidelsen av sitt innsamlete geologiske materiale fra Bellsundområdet.

Stud. real. JENÖ NAGY til bearbeidelse av mikrofossiler fra Svalbard.

Dr. JEAN P. PORTMANN, Sveits, til bearbeidelse av kvartærgeologisk materiale innsamlet på Svalbard sommeren 1961.

Cand. mag. PER SUNDING til bearbeidelse av plantemateriale som han samlet på Svalbard sommeren 1960. Arbeidet er blitt trykt i Norsk Polarinstitutt Årbok 1960.

Biblioteket

I løpet av 1961 har biblioteket fra sine faste bytteforbindelser mottatt i alt ca. 2500 nummer. Dessuten er det blitt innkjøpt 33 bøker, mens ca. 500 bøker og småskrifter er mottatt i gaver i samme tidsrommet. Når det gjelder forsendelsen av instituttets publikasjoner til våre faste bytteforbindelser, blir dette nå gjort av Universitetsforlaget under tilsyn av instituttets bibliotekar. Derimot blir mer tilfeldige forsendelser ordnet direkte fra instituttet, og dette har etterhvert fått et ganske stort omfang og er en uforholdsmessig stor belastning på bibliotekaren.

Konsulent- og informasjonsvirksomhet

NATASCHA HEINTZ har i årets løp gjennomgått den innkomne russiske faglitteraturen vedrørende Arktis og Antarktis. Hun har oversatt en del artikler om de geologiske undersøkelsene som russiske geologer har foretatt i Dronning Maud Land. Videre har hun besvart en del spørsmål i forbindelse med fredningsarbeidet på Svalbard, og begynt innsamling av materiale til belysning av den sterke tilbakegangen i antall av individer av en del fuglearter på Svalbard. En del spørsmål vedrørende fredning av dyre- og plantelivet i Antarktis har også vært behandlet.

Den utadvendte konsulent- og informasjonsvirksomheten har stort sett vært av samme karakter som i de siste årene. Det har kommet en rekke forespørsler både fra norske og utenlandske enkeltpersoner, ekspedisjoner og selskaper om opplysninger, flyfotografier, karter osv. Dette arbeidet har vært belastet både den geologiske og den topografiske avdelingen. Dessuten har det kommet mange forespørsler vedrørende polare skrifter etc., og denne del av informasjonsvirksomheten har i alt overveiende grad falt på SØREN RICHTER. Ikke minst i forbindelse med 50-års jubiléet for AMUNDSEN's erobring av Sydpolen fikk instituttet mange forespørsler om billedmateriale og andre opplysninger. Instituttet har i det forløpne året i mange tilfeller tjent som konsulent for forskjellige departementer.

Reiser, kongress- og møtevirksomhet

OLAV LIESTØL oppholdt seg ved årsskiftet 1961 i Antarktis på en amerikansk ekspedisjon i området ved Beardmore-breen i Ross-sektoren. Han reiste tilbake til Norge via New Zealand, Australia og det fjerne Østen, og kom til Oslo i begynnelsen av februar.

TORGNY VINJE avla i februar et besøk ved det meteorologiske observatorium i Hamburg i forbindelse med kalibrering og reparasjon av strålingsbalansemåleren som ble brukt på Norway Station.

TORE GJELSVIK og O. LIESTØL deltok i april i et «Fridtjof Nansen Symposium» ved universitetet i Würzburg, hvor glasiale og preglasiale problemer på Svalbard ble drøftet. Etterpå var deltakerne med på en ekskursjon i de klassiske områder for istidsforskning i Alpeforlandet i Syd-Tyskland. GJELSVIK la veien tilbake om England, og besøkte universitetene i Cambridge, Oxford og London, hvor han drøftet sikkerhetsproblemer vedrørende ekspedisjoner fra disse universiteter i norske arktiske farvann.

O. LIESTØL representerte Norsk Polarinstitutt ved OLAV BJAALANDS begravelse 12. mai 1961. BJAALAND var den siste gjenlevende av ROALD AMUNDSENS sydpolsparti.

Instituttets tidligere direktør, dr. ANDERS K. ORVIN, deltok i juli som rådgiver for den norske delegasjonen i Canberra, Australia, ved det 1. konsultative møtet under Antarktistraktaten av 1959.

KAARE Z. LUNDQUIST representerte Norsk Polarinstitutt ved innvielsen av Tromsø Museums nybygg 29. juli, og i oktober representerte han instituttet ved forskjellige arrangementer i forbindelse med feiringen av 100-årsdagen for FRIDTJOF NANSENS fødsel.

T. GJELSVIK representerte Norge på det 5. møtet i SCAR (Scientific Committee on Antarctic Research) som ble holdt i Wellington, New Zealand, i tiden 9.–14. oktober. Det vitenskapelige samarbeidet i Antarktis er kommet i god gjenge gjennom denne organisasjonen. En del av suksessen for dette kan sikkert tilskrives at SCAR ikke har svulmet opp til et slikt omfang som internasjonale organer har lett for å gjøre. Da SCAR-møtet imidlertid viste tendenser til dette p. g. a. de samtidige møtene i de mange underkomitéer, traff møtet foranstaltninger til å regulere de sistnevnte møtene på en slik måte at bare et fåtall av underkomitéene vil holde møter samtidig med årskonferansene.

På sin reise til New Zealand besøkte GJELSVIK Washington D. C., hvor han hadde konferanser med de amerikanske Antarktismyndigheter i anledning av 50-årsjubiléet for Sydpolens erobring. Etter initiativ fra Norsk Polarinstitutt var det blitt enighet om en felles feiring av AMUNDSENS og SCOTTS ekspedisjoner på selve Sydpolen. Det nærmere arrangement for dette ble avtalt under møtet i Wellington mellom de amerikanske, britiske og norske representantene. Etter møtet reiste derfor T. GJELSVIK sammen med GORDON Q. DE ROBIN, direktør f Scott Polar Research Institute i England, til den amerikanske hovedbasen i

Fig. 4. *Direktør* T. GJELSVIK *(helt til venstre) og direktør* G. Q. DE ROBIN *(ikke med på bildet) har nettopp overrakt minneplaten over* AMUNDSENS *og* SCOTTS *ekspedisjoner til den amerikanske vitenskapelige stasjonen på Sydpolpunktet. Nærmest* GJELSVIK *står* B. HARLAN, *vitenskapelig leder for stasjonen, deretter* PH. K. SWARTZ, *representant for* U. S. Navy, *og bakerst admiral* D. M. TYREE. Foto: "Official U. S. Navy Photograph".

McMurdo Sound på Rossøya. Herfra fløy de 30. oktober til Sydpolen for å overrekke ledelsen for den amerikanske Amundsen-Scott-basen en felles minneplakett i anledning av 50-årsjubiléet. Høytideligheten ble innledet i polstasjonens messerom med taler av admiral D. M. TYREE, commander of the U.S.N. Antarctic Support Force, og PH. M. SMITH, lederen for den amerikanske vitenskapelige feltvirksomheten i Antarktis, samt G. Q. DE ROBIN og T. GJELSVIK. Lederen for den ny zealandske Scottbasen, A. R. ROBERTS, bragte hilsener fra sitt land. Overrekkelsen av minnetavlen fant sted ute på selve Sydpolpunktet. Begivenheten ble gitt atskillig publisitet gjennom radio, televisjon og filmopptak. Etter seremonien reiste deltakerne tilbake til McMurco Station, og herfra ble det foretatt besøk til den ny zealandske Scottbasen og den amerikanske Byrdstasjonen, samt en rekke andre interessante lokaliteter i nærheten av Rosshavet.

GJELSVIK reiste tilbake til Norge via New Zealand og Australia og besøkte i denne forbindelse en del av de institusjonene som beskjeftiger seg med antarktisk forskning i disse landene.

Ved innvielsen av nybygget til Norges Geologiske Undersøkelse i Trondheim 13. november var instituttet representert ved HARALD MAJOR.

Avslutningen av året var viet feiringen av 50-årsjubiléet for ROALD AMUNDSENS erobring av Sydpolen. I anledning av jubiléet mottok instituttet en rekke telegrafiske hilsener fra polarinstitusjoner i utlandet.

Sammen med Aftenposten arrangerte instituttet en Sydpolsutstilling i Kunstindustrimuséet i Oslo i tidsrommet 8.–17. desember. Utstillingen sto i det internasjonale samarbeids tegn, i det Scott Polar Research Institute og det belgiske sjøfartsmuséum hadde sendt verdifulle samlinger som hadde tilknytning til ROALD AMUNDSENS virksomhet i Antarktis. H. M. KONGEN, statsrådene KJELL HOLLER og HELGE SIVERTSEN, samt representanter for en rekke ambassader var tilstede ved åpningen av utstillingen.

14. desember arrangerte Det Norske Geografiske Selskap et festmøte i anledning av 50-årsdagen for Sydpolens erobring. Hovedtalen ble holdt av general HJALMAR RIISER-LARSEN, og GJELSVIK fortalte om feiringen av jubiléet på Sydpolen og viste frem lysbilder.

Besøk

M. A. LEAL fra Argentina besøkte instituttet 6. februar. Han har vært deltager i argentinske antarktisekspedisjoner i perioden 1954–1957.

A. J. HEINE fra New Zealand Geological Survey besøkte instituttet 6. februar. Han har vært deltager i ny zealandske antarktisekspedisjoner fra 1956–1960.

R. B. BLACK, rear-admiral of Naval Research, Washington, U.S.A., besøkte instituttet 24. februar på hjemvei fra Expedition Antarctique Belge, 1960–61.

T. VAN AUTENBOER, geolog fra Centre National de Récherches Polaires de Belgique, oppholdt seg ved instituttet i september–oktober for studier av geologiske samlinger fra Dronning Maud Land, og for å diskutere spørsmålet om et samarbeid mellom Belgia og Norge om nykonstruksjon av topografiske kart over Sør-Rondane.

A. STEPHENSON, professor ved Imperial College, London, og L. M. FORBES, konservator ved Scott Polar Research Institute, Cambridge, avla besøk på instituttet i desember i forbindelse med utstillingen «Sydpolen 1911–1961» hvor de representerte henholdsvis Royal Geographical Society og Scott Polar Research Institute.

Publikasjoner

Skrifter:

Nr. 120 – ANDERS K. ORVIN – The place-names of Jan Mayen.
» 121 – HARALD CARSTENS – Cristobalite-trachytes of Jan Mayen.
» 122 – MICHAEL F. W. HOLLAND – The geology of certain parts of Eastern Spitsbergen.
» 123 – TORBJØRN LUNDE – On the snow accumulation in Dronning Maud Land. Den norske Antarktisekspedisjonen, 1956–60. Scientific Results No. **1**.
» 124 – OLAF I. RØNNING – Some new contributions to the flora of Svalbard.

List of publications ble sendt ut som supplement til Skrifter Nr. 123.

Meddelelser:

Nr. 86 – ROLF W. FEYLING-HANSSEN and INGRID OLSSON – Five radiocarbon datings of Post Glacial shorelines in Central Spitsbergen.
» 87 – THORE S. WINSNES, ANATOL HEINTZ and NATASCHA HEINTZ – Aspects of the geology of Svalbard.
» 88 – GUNNAR ØSTREM – Breer og morener i Jotunheimen.

Norwegian–British–Swedish Antarctic Expedition, 1949–52.
Scientific Results:

Vol. IV – Glaciology II; E: VALTER SCHYTT – Blue ice-fields, moraine features and glacier fluctuations.

Kart:

Kirwanveggen	F 7	1: 250.000
Ahlmannryggen	G 5	1: 250.000
Jutulstraumen	G 6	1: 250.000
Neumayerskarvet	G 7	1: 250.000
Jutulgryta	H 5	1: 250.000
H. U. Sverdrupfjella	H 6	1: 250.000

Sjøkart:

514 – Barentshavet

Instituttets medarbeidere har dessuten i andre serier publisert:

NATASCHA HEINTZ – Avstøpninger av øglespor på Svalbard. – Museumsnytt, nr. 3. 1961.

OLAV LIESTØL – Breer i Norge. Bremålinger og brevariasjoner. – Begge artikler i Den Norske Turistforening, Årbok 1961, pp. 20–24 og 24–35.

SØREN RICHTER – Fridtjof Nansen. Liv og gjerning. – Dreyers forlag, pp. 86–103.
— Fridtjof Nansen som polarforsker. – Naturen, nr. 7–8, 1961, pp. 422–447.
— Diverse artikler om polare emner.
— Medredaktør av Polarboken.

THOR SIGGERUD – Radioaktivitetsundersøkelser av bergartsprøver i magasinene på Mineralogisk-Geologisk Museum, Universitetet i Oslo. – Norges Geologiske Undersøkelse, Nr. 213. Årbok.
— On radioactive raw materials, United Arab Republic. – International Atomic Energy Agency 1961. Ta. No. 14.

The activities of Norsk Polarinstitutt in 1961

Summary of the annual report

BY

TORE GJELSVIK

Staff

At the end of the year Norsk Polarinstitutt had twenty-two permanent positions, two of which were vacant. Twelve persons were temporarily engaged, mostly for preparing data collected by The Norwegian Antarctic Expedition, 1956–60.

Expeditions to Svalbard

The ice conditions in the Svalbard waters during the summer of 1961 were worse than for many years, and several of the field parties had to alter their plans and take up work at other places than originally selected. All in all, eleven field parties were organized, totalling thirty persons. The greater part of them went to Svalbard by the chartered sealer M/S "Brandal", leaving Norway around June 20 and returning in the beginning of September.

Hydrography

K. Z. LUNDQUIST, using M/S "Brandal", was only able to start surveying in the Gråhuken-Moffen area, to the north of Vestspitsbergen, in the second half of August, and then the work was very much hampered by fog. During most of the summer the boat had to be used for logistic support of the field parties, this taking more time than usually, because of bad weather and heavy ice in particular. The coastal navigation aids were controlled and maintained.

H. HORNBÆK, using the hydrographic survey-boat "Svalis", started work in the area near Forlandsrevet, later he continued to the north coast of Vestspitsbergen, where he completed the soundings of Liefdefjorden.

Airborne operations

In several respects the Svalbard expedition 1961 could be regarded as an experiment, as a helicopter was used for logistic support of the topographers and some of the geologists during most of July and the first half of August. A main base, accommodating sixteen men, was established in an abandoned mine, Sveagruva, at the head of Van Mijenfjorden. Unfortunately, the weather was rather foggy most of the time, which to a great extent reduced the possibilities of using the helicopter. This was a Bell 47 G-helicopter, the capacity of which, unfortunately, proved to be too small. In the few good spells, priority had to be given to the topographers, and the geologists did not get much of the planned support. However, valuable experience was gained in future use of helicopters for logistic support in Svalbard. T. GJELSVIK headed the helicopter party from July 10 to the turn of the month, when he was succeeded by S. G. HELLE and T. S. WINSNES.

Topographic mapping

S. G. HELLE and W. SOLHEIM carried out the trigonometric survey and covered the area of the map sheets Braganzavågen and Kvalvågen as planned.

Geology

As H. MAJOR fell ill immediately before the expedition was to leave Oslo, T. SIGGERUD had to take over the exploration for coal, which took place in the area south and east of Sveagruva. The coal beds in this area were found to be discontinuous and to vary greatly in thickness. The geologists also joined the topographers on some of their helicopter trips and made general stratigraphical investigations, hereby obtaining enough field information for the production of a geological map of the Braganzavågen sheet.

Topographic mapping elsewhere

In the middle of August, after the close of the base in Sveagruva the topographers moved to Bockfjorden, where they carried out trigonometric survey and a tellurometer measurement.

Geological survey in other areas

In the beginning of the summer T. SIGGERUD examined the marbles in Kongsfjorden. After conducting the coal exploration in the Svea area he spent some time in Recherchefjorden investigating severall smal ore- and mineral deposits, closing up the summer by studying the lead mineralization near Kapp Mineral.

Quaternary geology

A Swiss geologist Dr. J. P. PORTMANN had been engaged by the institute to carry out investigations of the Quaternary deposits in the areas of Adventdalen, Reindalen, Colesdalen and the northern part of Sassendalen. Thanks to logistic support both from boat and helicopter PORTMANN managed to cover a larger area than originally expected.

Biology

Cand. mag. C. CHRISTOPHERSEN collected invertebrate littoral animals and made observations on their distribution and ecology around Gråhuken and in Murchisonfjorden on Nordaustlandet.

Palaeontology

N. HEINTZ with three assistants made plaster casts of seven Dinosaur footprints from Cretaceous, found in 1960 by prof. A. F. DE LAPPARENT at Festningsodden. This work was carried out in co-operation with the Palaeontological Museum in Oslo.

B. REESE, photographer, joined the biological group and took pictures of arctic animal life.

Foreign expeditions

Five foreign expeditions worked in Svalbard and two of them also wintered. In addition American Overseas Petroleum Ltd. continued their geological investigations for oil, started the previous year.

One British expedition visited Jan Mayen.

Expeditions in Dronning Maud Land

South Africa, Russia and Japan each maintained one wintering scientific station in Dronning Maud Land.

Glaciology (in Norway)

In May O. LIESTØL continued his glaciological investigations of Storbreen in Jotunheimen, and in August he examined Jostedalsbreen, Folgefonni, Svartisen, and several glaciers in Jotunheimen and in the county of Møre. In July and August three students supported by Norsk Polarinstitutt worked on regime studies of three glaciers in Jotunheimen.

Preparation of data from Svalbard

Topography-geodesy

As the topographic-geodetic section still had to concentrate on the preparation of maps from Dronning Maud Land, Antarctica, only little time was devoted to the Svalbard maps. However, the proof-reading of the standard map sheet A 7 (1 : 100,000) Kongsfjorden was finished and some drafting on the new series of general maps at a scale of 1 : 500,000 was accomplished. Dr. A. K. ORVIN prepared the list of place-names for this map series.

Hydrography

Chart No. 514, Barentshavet was published in February. The proof-reading of chart No. 515, Grønlandshavet, was completed and preparatory work on a new chart covering the north-west coast of Vestspitsbergen was initiated. Tidal observations from Murchisonfjorden were computed and preparations were made for soundings in Liefdefjorden. Further studies of the possibilities of using electronic locating systems in charting Svalbard waters were undertaken.

Geology

H. MAJOR prepared for publication a geological map of Adventdalen (1 : 100,000) map sheet, where the most important coal deposits in Svalbard occur. Furthermore, he undertook detailed photogeological studies of the transitional beds between the Cretaceous and Tertiary formations. A large collection of samples, mostly from Reinodden, Bellsund, was put in order. T. S. WINSNES prepared a general map on the Precambrian of Svalbard and wrote an article on this subject. In addition to routine preparation of field data, a study of the radioactive trace elements in the Svalbard material was initiated.

Geophysics

Glaciological data both from Norway and Svalbard were collected and analyzed.

Preparation of data from Antarctica

Map construction

The work on the map series at a scale of 1 : 250,000 has been continued and six maps in this series were published in 1961. Calculations of angular measurements and barometric height measurements were finished. Four sheets of flight index maps at a scale of 1 : 100,000 giving the route of Norwegian airplanes taking part in air photography of Dronning Maud Land, were prepared for publication.

Meteorology

Some meteorological data were prepared and sent to IGY Meteorological Data Centre in Geneva. A paper on the cooling power measurements was completed and two other papers, one on the radiation measurements and the other on the heat balance in the snow fields are under way.

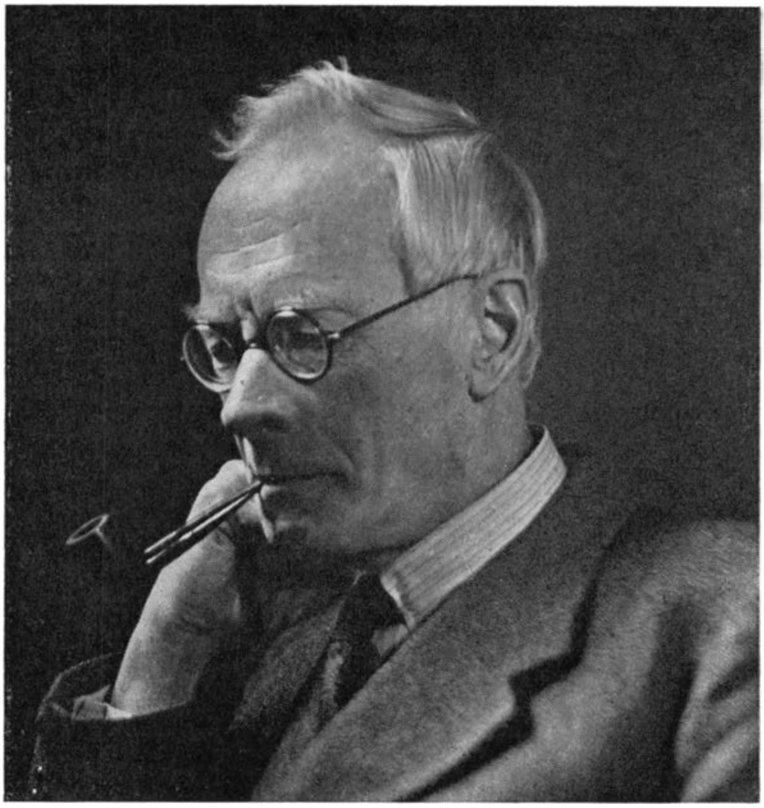
Meteorological data collected by the Norwegian-British-Swedish Antarctic Expedition, 1949–52, were prepared for publication.

Glaciology

Calculations of the movement of Fimbulisen and of the variation of the temperature in the depth of the glacier were done.

Ozone

The preparation of the ozone data was undertaken.



Professor dr. Werner Werenskiold

A veteran of arctic science and exploration, professor dr. WERNER WERENSKIOLD died on 2nd August 1961 at the age of 78. After graduating he joined Geological Survey of Norway and made important contributions to the knowledge of Pre-Cambrian, Eocambrian and early Paleozoic rocks in southern Norway. In 1914 he wound up his service in the Survey by producing a new geological map of southern Norway at the scale of 1 : 1 million.

In 1915 WERENSKIOLD took up teaching geography at the University in Oslo. He was very well fitted for this work as he was a master of mathematics and other natural sciences besides geology. Being a man of good humour and plain ways, he became a most popular university teacher. His field-work and excursions brought him all over Norway, and he took a great interest in explaining his science to farmers and workers. In addition to textbooks and scientific papers he wrote many articles in newspapers, journals, and in popular scientific books. He actually became the perhaps most well-known natural scientist in his country among common people.

Every summer in the years 1917 to 1924 WERENSKIOLD took part in The Norwegian State-supported Spitsbergen Expeditions. At this time the southern part of Vestspitsbergen was very little known, and no topographic base maps existed.

WERENSKIOLD therefore had to erect cairns, make topographic measurements and take photo-stereograms in addition to geological observations, which included mapping as well as exploration of deposits of coal, iron, phosfate, and asbestos. Using a row-boat, he and his assistants covered much of the coast of Vestspitsbergen from Sørkapp to Bellsund, including Hornsund, Recherchefjorden, Van Keulenfjorden, Van Mijenfjorden, and moreover parts of Isfjorden. In 1922–23 he took part in coal exploration of Bjørnøya, co-operating a. o. with O. SVERDRUP. WERENSKIOLD's contributions to the cartography and geology of Svalbard have been of great importance.

WERENSKIOLD was particularly interested in glaciology, and took up field-work as well as theoretical studies. In the beginning he was especially interested in the study of the mechanics of glacier flow, and was among the first to make wax-models in order to imitate the glacier movements. Further he took up the study of the relation between glacial activity and variations of climate, and resumed measurements of glacier fronts in Jotunheimen originally started by P. A. ØYEN. Together with A. HOEL he undertook detailed studies of selected glaciers, and the aim of this work was to gain more knowledge of the variations in extension and volume of the glaciers. The results of these investigations are now being published by Norsk Polarinstitutt. In later years WERENSKIOLD turned to glacial geology, particularly the melting sequence at the end of the great Pleistocene ice.

With his great knowledge of earth sciences and his wide range of interests, WERENSKIOLD has inspired many students and scientists to take up work in this field, and he has no doubt also in this way been of great importance to Norwegian arctic research in general.

Norsk Geografisk Tidsskrift vol. 18, 1–2, contains a complete bibliography of WERENSKIOLD's publications. The following list gives only the papers dealing with glaciology and the results of his work in Svalbard:

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En tilnærmet metode for beregning av en isbræs tykkelse. (Foredr. tittel og disk.) *Norsk geol. tidsskr.* **3** (1914/1916), (10). 18–19. 1916.

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Frozen Earth in Spitsbergen. *Geofysiske Publ.* **2,** (10). 10 p. 1922.

A burning Coal Seam at Mt. Pyramide, Spitsbergen. (By W. Werenskiold and Ivar Oftedal.) Det norske videnskaps-akademi i Oslo. *Resultater av de norske statsunderstøttede Spitsbergenekspeditioner.* **1,** (3). 14 p. pl. 1922.

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Glaciers in Jotunheim. *Norsk geol. tidsskr.* **7** (1938/1939). 638-647. 1939.
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Vind og breer. *Svensk Geogr. Årsbok.* Årg. 25. 128-129. 1949.
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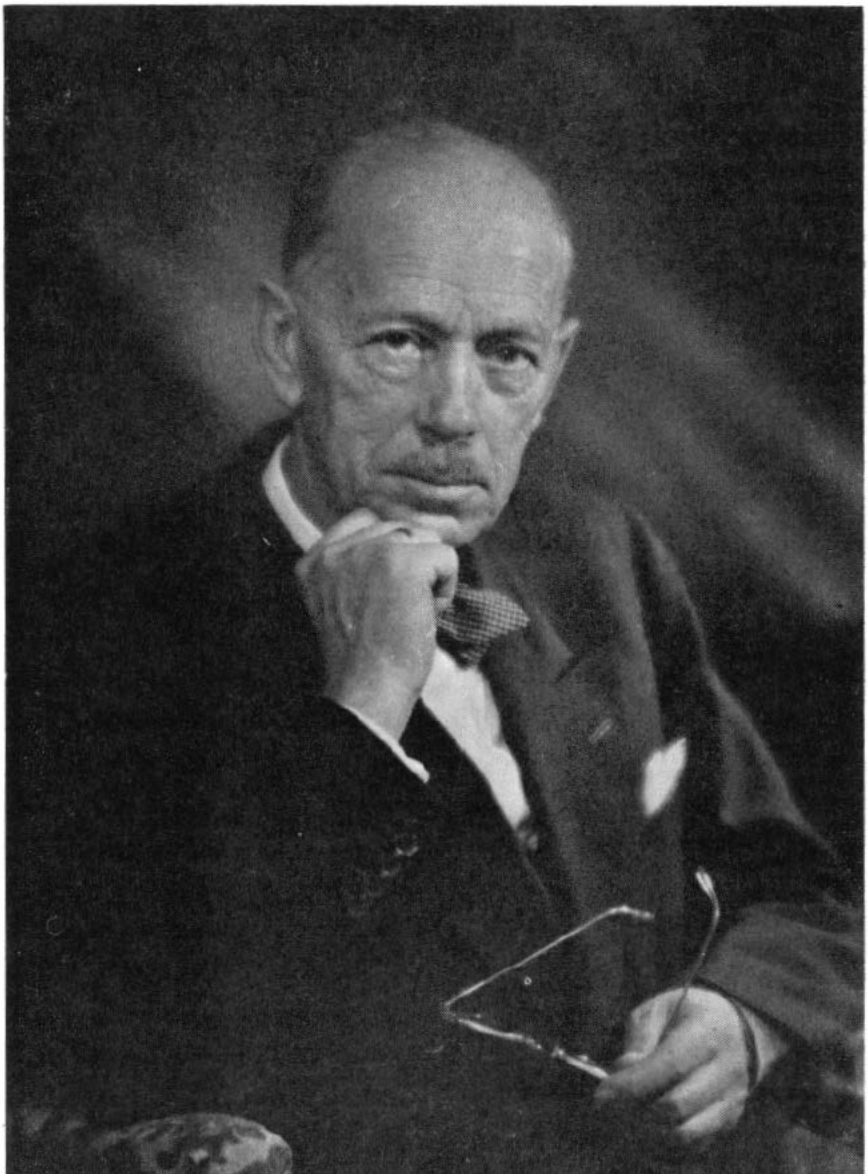
Fra istiden til idag. *Årbok 1960. Den norske turistfor.* 39–53. 1960.
Breen lever. *Årbok 1961. Den norske turistfor.* 17–19. 1961.
Glaciers and snowfields in Norway. (By Adolf Hoel and W. Werenskiold.) *Norsk Polarinstitutt. Skrifter nr. 114.* Oslo. 1963.



Professor Harald Ulrik Sverdrup
1888–1957.

Professor H. U. Sverdrup[1]

BY

HÅKON MOSBY[2]

The importance of a scientist is primarily judged by the results he has achieved within his particular field of activity. In the case of H. U. SVERDRUP much of his most important work is hardly a suitable subject matter for a short broadcasting talk. However, the scope of his researches, as carried out at his desk as well as in the Polar regions, should make it possible, I hope, to draw a picture of this exceptionally active and productive geophysicist, who until his death in 1957 ranked among the most prominent, specially within the fields of oceanography and polar meteorology.

A glimpse at the list of his publication says a great deal: The same year as he graduated, in 1914, he wrote, on his own or in co-operation with others, 4 papers; he continued at the same rate all through his life, producing an annual average of 5 to 6, totalling 220 publications. Only during the 6 years he spent on board the "Maud" in the Polar Sea, nothing was printed. This is no doubt a productivity far beyond the ordinary, and bears witness not only of a continual flow of ideas, but also of his ability of efficient work and of an exceptional working capacity.

HARALD ULRIK SVERDRUP was born in Sogndal in West-Norway on 15th November 1888, and received his first education from governesses. Later on he became a pupil of the Grammar School in Stavanger, where, 17½ year old, he took his student examination with Latin as his main subject. He then sat for the preliminary University exams, spent a year at the Military Academy, and started his science studies in 1908. It is interesting to note that besides mathematics, physics, and chemistry he also studied botany. But at the time when he should take up astronomy as his major subject, he became assistant to VILHELM BJERKNES, and in his new position his interest in meteorology and oceanography was aroused. He accompanied BJERKNES to Leipzig, graduated in 1914, and took his doctor's degree in 1917, the same year as BJERKNES moved to Bergen. His thesis, on the North Atlantic trade wind, was his twelfth work. Six of his previous works had been carried out in co-operation with another of BJERKNES' assistants, Dr. HESSELBERG, who later became Director of the Meteorological Institute. This

[1] University Profiles. Norwegian Broadcasting Corporation, 9th January 1962.

[2] Geofysisk Institutt, Universitetet i Bergen, Bergen.

was a quick and fruitful development under the leadership of the man who was to become the father of the later so well known Bergen School in meteorology.

As early as in 1913 SVERDRUP had been asked by ROALD AMUNDSEN if he would join in a Polar expedition, but he said no; he wanted first to learn more. Now the opportunity was offered him once more, and now he felt the need of studying in nature herself some of the problems he had so far only treated at his writing-desk. In the summer of 1918 SVERDRUP travelled to the North as scientific leader of the AMUNDSEN "Maud" Expedition. The plan was to repeat NANSEN's drift with the "Fram" in order to penetrate deeper into the mysteries of the Polar Sea, by means of new and better equipment. But, as we know, the "Maud" was not carried across the Polar Sea, she stayed drifting with the ice in the shallow sea north of Siberia. The first winter when the "Maud" was icebound near Cape Chelyuskin, SVERDRUP spent 8 months among the Chukchi natives, a primitive Siberian tribe whose mentality and culture he studied and later described. But on board the "Maud" all imaginable measurements continued systematically for three years; at the end of that time they were again near the Bering Strait, and sailed southwards for repairs. SVERDRUP then spent a year at the Carnegie Institution of Washington, where he worked up the material on terrestrial magnetism from the expedition. The following summer the "Maud" was ready for a new voyage, and this time ROALD AMUNDSEN did not join the expedition. SVERDRUP was the leader, and on his staff were FINN MALMGREN, a young Swedish meteorologist, and a young Norwegian pilot and designer, the now so well-known Dr. ODD DAHL.

Again they failed to enter the current that could carry them across the Polar Sea, and perhaps even across the Pole. However, of greater importance than reaching the Pole itself was the fact that the ice wastes of the Polar Sea afford a unique laboratory for him who understand to use it. The 10 million square kilometres of flat and homogeneous ice cover represents for many natural phenomena a state of purity equalled only on the Antarctic Continent. In the "Maud" they not only possessed the best instruments of their time, but they developed themselves important new types of apparatus, which were used with great success. A gigantic material of data was gathered and studied during this three years' stage. There were photographs of northern lights and radiation measurements, measurements in the ice and in the ocean – and in addition what could be found of animals and plants, geological specimens etc.

For all members of the expedition this meant a full workday under difficult conditions, mostly busy with continual measurements, and handling apparatus that did not always like the severe cold. But, when necessary, everybody took their turn of the daily routine on board, of repairs and cooking. SVERDRUP joined in everything, but for him, as scientific leader, there were other things as well – he has described it himself as follows: "Although there were periods when I was so completely absorbed in my work that weeks and months passed quickly, there were other periods when I had an uneasy feeling that I might have made some elementary mistakes, or that the new investigations were perhaps afflicted with a systematical error, or that our new instruments did not work as they should, or that my theories might not be fruitful. There was nobody with whom I could confer, no literature for references. Looking back now, I find myself wandering up and down the deck, turning the questions over and over again in order to find, if possible, a flaw in my reasoning."

This again was a hard, but good school. A training in trusting his own thought and his own judgment without having anybody to ask. Perhaps the best school for a young scientist with a good education. This is what is so fascinating and difficult as well, with every new problem: To find the correct solution oneself.

When the expedition had ended, SVERDRUP started to study seriously all available data. He was appointed professor at the Geophysical Institute in Bergen, succeeding VILHELM BJERKNES who had now moved to Oslo. This professorship as well as the other chairs at the Bergen Museum were at the time ideal positions, in fact the professors were scientists with no other duties than to do research work. During these years I was assistant to SVERDRUP, and also collaborator in the "Maud" publication, and I had the opportunity to follow at close quarters his systematic and effective working methods. Faced with this gigantic material he displayed an exceptional ability to separate and state a well-defined and solvable problem, and then to concentrate on the completion of this concrete piece of work, "get it off his hands", as he used to say.

The scientific results from the "Maud" Expedition are published in five big volumes of more than 2000 large pages, nearly three fourths of which were written by SVERDRUP himself. One of the most important results concerned the tidal currents. The measurements revealed that the current was always of practically the same strength, but that the direction changed clockwise. At the very bottom and just below the ice the current was weaker. SVERDRUP managed to explain this result as a combined effect of the rotation of the earth and the turbulent friction in the water. Another important result concerned the drift of the ice, which according to observations did not follow EKMAN's classical theory. SVERDRUP demonstrated that this was due to tension in the ice when packed. These works and the investigation of the water masses in the Siberian shelf strongly increased his interest in oceanography, and altogether it may perhaps be said that his greatest achievements are within this field. But also the meteorological data supplied interesting results, and by combining the results of temperature and heat flux in the ice with those of in- and outgoing radiation, he could for instance reveal that the air temperature could not get below about —45° C, in good agreement with what has been measured.

In 1931 SVERDRUP was appointed a Fellow of the Chr. Michelsen Institute in Bergen, a still freer scientific position, and in addition to his theoretical studies he analyzed British and American measurements from the Pacific and the Antarctic Oceans. But nature, and in particular the Polar regions attracted him, and in 1931 he sailed northward with HUBERT WILKINS in the submarine "Nautilus". The enterprise was hazardous, a submarine of those days was not what it is today; and they did not do very much diving underneath the polar ice. However, in the bottom of the "Nautilus" a hatch could be opened and instruments could be lowered from a pressure chamber. A series of first class measurements was made in the deep sea, and the results were published the same year.

In the summer of 1934 SVERDRUP again sailed northward, this time together with Professor AHLMANN in order to study conditions in and over a large glacier in Spitsbergen. They made exceedingly fine measurements, the study of which lead SVERDRUP into a field where later on he made important contributions to the understanding of the evaporation from the sea.

The following year SVERDRUP was offered the leadership of the Scripps Institution of Oceanography at La Jolla, California. He started with a 3 years' leave, which was prolonged to 5 years; then the war broke out and his stay in America lasted for no less than 12 years. Being an excellent administrator, SVERDRUP found this work just what he liked, and he had at his disposal all the resources he could wish for. Moreover, this institute was founded for the study of the most different branches of oceanography; not only physics and chemistry, but also biology and geology. During his earlier studies of botany he had developed a keen eye for biological research, and could therefore find possibilities of direct co-operation between different types of specialists. This way of looking at the problems has become the leading motive for his successor at Scripps, where today between 100 and 150 scientists are working.

The war brought in a series of problems, which were often taken up as separate projects. Together with his young pupils SVERDRUP developed a system for the forecasting of swell, which came in useful in connection with the landing operations on the Continent during the war. They further drew up current charts to be used in rafts. But in addition to this, the demand for young oceanographers and meteorologists suddenly increased, and SVERDRUP started educational courses. For a long time he had been working on a handbook or textbook in oceanography; now there was a need for it. Together with two others he wrote "The Oceans" counting over 1000 pages, where he himself wrote all on physical oceanography. It was the first work of its kind since before the first World War, and the first that treated all the advances made since that time; it is "the Bible" for all oceanographers today. Particularly the chapter on the water masses in the ocean is important; it gives a comprehensive conception and review which previously did not exist. It reflects not only SVERDRUP's great knowledge and understanding, but also what Dr. DEVIK in his commemoration speech to the Norwegian Academy of Sciences called his "rational fantasy" and his "supremacy in applying his knowledge to the interpretation and combination of observational data". And, as is almost always the case with SVERDRUP, it is characterized by clear and concise presentation.

His studies of the drift of the ice with the wind, of the heat exchange between sea and air, of the evaporation and on the whole of the interaction between sea and air, were followed in 1947 by an important work on wind driven currents in the ocean. This pioneer work was carried on by his American pupils, and is the basis of a number of the newest theories in this field. On the whole it may be said that the enormous expansion within American oceanography during the later years, is hardly imaginable without the inspiration of SVERDRUP. To many of these scientists, he stands out, therefore, as a genius whom they can never thank enough.

After the war SVERDRUP was asked to take over the leadership of the new Norwegian Polar Institute in Oslo. For various reasons he could not take over until 1948, and at the same time he became attached to the University of Oslo as a professor. One of his first tasks was to take part in the preparations for the Norwegian–British–Swedish expedition to the Antarctic 1949–52; this expedition established the Maudheim base on the ice shelf, and wintered there for two years.

The main objectives of the expedition were meteorological, glaciological, and seismological measurements as well as topographical and geological mapping. Norway's particular responsibility was the meteorological observations and the topographical mapping. In the course of two summer seasons vast mountain areas in the western part of Dronning Maud Land and long stretches of coastal regions were photographed.

In the antarctic summer of 1950/51 SVERDRUP himself went to Maudheim with the purpose of better acquainting himself with the conditions in the Antarctic, and inspecting the station.

His next great task was the preparation and equipment of the Norwegian Antarctic expedition to Dronning Maud Land, as part of the Norwegian activity in connection with the International Geophysical Year.

The expedition was planned as a two-year wintering expedition, but was later prolonged by one year. The fourteen members of the expedition, who went out in the autumn of 1956, established the base of Norway Station. Also this time extensive photographing of mountain areas and coastal regions was carried out.

Both these expeditions were planned and carried out in an exemplary manner, which is evident from the results published so far.

SVERDRUP's energy also found other outlets; he was head of the American Summer School at Oslo for three years, was dean of the faculty, and was elected pro-rector to the University of Oslo. He proposed radical alterations of the curriculum of studies; this was the first step towards the new curriculum that has now been introduced both in Oslo and Bergen.

His professional problems were universal, and his work was of nature international. Perhaps he also felt the desire for a certain change. When he was asked to direct the India Fund, he at once saw an exciting, if complicated, experiment in the Travancore project. His experience from the little community on board the "Maud", from the Chukchi natives, and from many different social classes in America and in Europe, no doubt proved helpful also here.

It goes without saying that a man of so great achievements was honoured in many ways. He was a member or honorary member of more than 20 societies, and he was decorated with the orders of St. Olav, Dannebrog, the Nordstjernen, and with nearly all the medals that could come into question, such as Agazzis, Royal Geographical Society, Bruce Memorial, Vega, Bowie, Meteor, Ritter etc. In this connection it may be of interest to mention the Sverdrup Gold Medal, which is being instituted in memory of his great achievements, and will be awarded for important contributions to the understanding of the interaction between sea and air.

For years SVERDRUP held important international offices of trust; he was President of the International Association for Physical Oceanography, Vice President of the American Geophysical Union, President of the International Commission for Polar Meteorology, President of the International Council for the Exploration of the Sea, and chairman or active member of a great number of other committees. All this undoubtedly meant a lot of work, but it did not seem so. We were together in many of these groups, and time and again I saw how quickly he grasped the problems and how swiftly he formed his opinion. It was apparently the same power of adaptability and adjustment that he had shown during his early years in Bergen, where his door was always open for those who sought his advice, and where he had always time to spare. As a rule he took up a matter immediately and "got it off his hands". He found a rest in doing "something else", and thought that sitting behind the wheel was the best way to relax. And never did he find a game of bridge more entertaining than when occasionally he had the opportunity of matching himself against real experts. In a similar way he liked freshing up his activities from the old days, whether it was the matter of testing the strength of his muscles, or spending late hours in the kitchen busy with the frying-pan. All this got him friends everywhere. But until the last moment he was engrossed in his work; the same summer as he died he gave lectures on new scientific results, and wrote a newspaper article that had the significant headline: "The World is full of possibilities". For, in spite of his tireless energy within his own professional field he often directed his attention beyond that, in articles and lectures. This side of his character is perhaps best illustrated by the following quotation from his address at the annual celebration of the University of Oslo in 1956:

"Finally I am tempted to make a reference to the importance of the exact sciences to our outlook on life. It seems clear to me, then, that because the exact sciences are concerned only with a limited part of our experience, namely, that which is related to the lifeless nature around us, they *alone* cannot form the foundation of a complete outlook on life. Our attitude to life must be built also on our evaluation of what is good or evil, right or wrong.

But the importance of science is illustrated in a different way when, looking back through history, we see how innumerable generations have tried to make themselves masters of their surroundings. Then it becomes clear that where the control of nature is concerned, we have in the results of natural science obtained far more effective tools than any earlier generation has ever dreamed of. Then, natural science does not stand out as a philosophical system, then, it is not the objective of natural science to find the eternal truths, then natural science is not placed in an exclusive position compared to the other sciences. And then all research stands out like a mighty intellectual achievement that has contributed and will continue to contribute to making life more harmonious for all mankind."

SVERDRUP did not reach the age of 69, but in return he had the good fortune to live in full activity until the end. And his work is one of basic importance to the cultural status of our country.

Notiser

Nyere iakttagelser over fuglelivet på Bouvetøya

I «Informasjons-bulletin for den sovjetiske Antarktisekspedisjon», nr. 13, (1959) har G. A. SOLJANIK publisert en liten artikkel om fuglelivet på Bouvetøya. Da forfatteren har vært i land nær Kapp Circumcision hvor det tidligere, så vidt jeg kan bringe i erfaring, ikke har vært foretatt noen landing, kan det kanskje være av interesse å referere noen av de opplysningene han kommer med, ikke minst da det på en interessant måte utvider vårt kjennskap til fuglefaunaen på denne ugjestmilde øya.

Det var den 27. november 1958 at zoologen SOLJANIK sammen med en del andre vitenskapsmenn og sjøfolk ble satt på land på en liten strandflate på sydvestsiden av Kapp Circumcision. Strandflaten var ca. 2 km lang og 100–500 m bred. Den syd-sydvestlige delen av denne flaten er oppstått forholdsvis nylig ved at noe av fjellet bak er rast ut, mens resten av den må ha eksistert forholdsvis lenge, da den var dekket av små, vel rundete steiner. På grunn av dårlig vær ble det ilandsatte partiet nødt til å oppholde seg på Bouvetøya i tre døgn.

På den vestre delen av strandflaten fant de en større pingvinkoloni bestående av ringpingvin (*Pygoscelis antarctica*), gulltopp-pingvin (*Eudyptes chrysolophus*) og Adeliepingvin (*Pygoscelis adeliae*). Alle tre pingvinartene ruget her og av de undersøkte eggene fremgikk det at eggene til ringpingvinene og gulltopp-pingvinene må ha vært lagt ganske nylig, da man makroskopisk ikke kunne konstatere at fosterutviklingen var begynt. Derimot i eggene til Adeliepingvinene var fostrene allerede ganske store.

Det var flest ringpingviner, forfatteren talte mellom 680 og 800 individer. At antallet svingte så pass meget skyldtes at det stadig var en del fugl ute i sjøen, selv om været var meget dårlig og store bølger slo mot land. De ca. 150 gulltopp-pingvinene og 56 Adeliepingvinene dannet ikke egne grupper, men hekket inne mellom ringpingvinene.

I de bratte fjellskråningene som omgav den lille sletten ble det iakttatt hekkende en hel del kappduer (*Daption capensis*) og sølvgrå petreller (*Fulmarus glacialoides*). Alle de eggene til disse fuglene som ble undersøkt, var ennå ikke ruget nevneverdig.

Snøpetrellen (*Pagodroma nivea*) ble til stadighet sett flyvende rundt Bouvetøya og det lykkes også for russerne å finne noen primitive reder mellom klippene som tilhørte snøpetrellene, og her var eggene allerede langt ruget.

Det ble sett en hel del med storjo (*Stercorarius skua macckormicki*), men noe rede lyktes ikke å finne. De hunnene som ble undersøkt hadde alle velutviklete eggstokker med mange egg, hvorav de største var ca. 15 mm i diameter.

På et område nordvest for sletten ble det funnet to kolonier med terner (*Sterna vittata*). Koloniene lå like ved hverandre og fuglene satt på redene. Dette er så vidt jeg vet første gang man har iakttatt denne ternearten hekkende på Bouvetøya.

Av interesse er det også å nevne at under stormen så det ut til at de fleste fuglene fant det meste av maten i fjæren og i magesekken til kappduer, sølvgrå petreller og terner ble det funnet polychaeter, bundformer av krepsdyr og fisk, som var blitt slengt opp med de kraftige bølgene. I godt vær derimot trekker fuglene vanligvis langt ut i havet og lever da hovedsakelig av de pelagiske krepsdyr, først og fremst Euphausiidae og Thysanoessa.

Natascha Heintz

Reinflokk på svømmetur

Under opplodningsarbeidet mellom Lernerøyene i Liefdefjorden sommeren 1961 fikk jeg sammen med mine assistenter 28. juli se en liten flokk med reinsdyr (*Rangifer tarandus spitsbergensis*) som svømte i vannet. Flokken var på i alt 10 dyr, derav 6 voksne og 4 kalver. De kom tydeligvis fra Lernerøyene, antagelig med kurs for fastlandet og på kartet har jeg siden kunnet måle ut at den distansen de måtte svømme var minst 2700 m. Det var pent vær, lett vekslende bris og + 10° C ved middagstiden, temperaturen i vannet var antagelig et par grader. Ved andre anledninger iakttok vi reinsdyr også på andre øyer i samme området, mens det senere ikke fantes dyr på de samme øyene. Det er således ganske tydelig at det kalde vannet ikke er noe hinder for at reinsdyrene svømmer fra fastlandet til øyene og tilbake.

Helge Hornbæk

The volume of ice in Antarctica

At present c. 15 mill. km^2 of the earth's surface is covered with ice. Of this area about 85 % falls to the account of Antarctica, 11 % to Greenland and c. 4 % to other areas. From this it is evident that a good knowledge of the ice mass of Antarctica is a deciding factor for the calculation of the total ice volume on earth and its effect on eustatic changes.

Concerning area and surface shape, the greater part of Antarctica is roughly known, though there are vast areas especially in the inner part of Dronning Maud Land that are totally unknown. In the latest years a series of works containing maps and profiles of the ice thickness has been published. The most detailed maps of the bedrock have been accomplished by the Americans in the area between the Ross- and Weddel Seas. The rest of the continent is more poorly covered. Only a few long profiles cross the ice-cap leaving vast unknown areas inbetween. The isohypses of the subglacial bedrock have therefore to be calculated or roughly estimated for long distances. The reliability of the hypsographic curves of the subsurface in Fig. 1 are therefore limited. Calculations of areas and hights determining the curve of the ice surface are mainly based on: Map of Antarctica, Department of National Development, Canberra, 1961. The area between the two curves represents the volume of ice resting on land.

The results of the calculations are presented in the table below:

Total area of Antarctica	$13.82 \cdot 10^6$ km^2
Ice-shelves	$1.31 \cdot 10^6$ »
Areas uncovered by ice	$0.20 \cdot 10^6$ »
Total volume of ice in Antarctica	$20.2 \cdot 10^6$ km^3
Mean height of the continent (ice-shelves included)	2040 m
Mean thickness of ice	1455 m

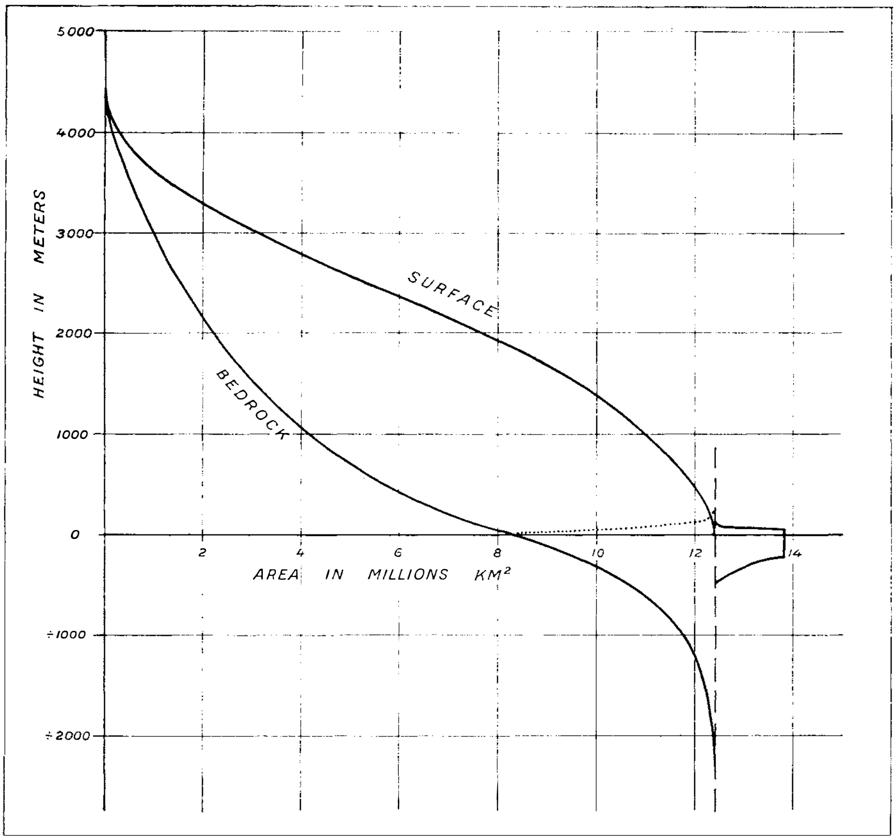


Fig. 1. *Diagram showing area-distributions' curves for the Antarctic inland ice surface and the underlying bedrock. The ice-shelves are represented by the curves to the right of the vertical dotted line.*

The rise of sea level if all the ice in Antarctica was to melt is also calculated. This has been done in a series of works with figures varying from c. 20 m to c. 80 m. The latest figure published is that of A. BAUER (1960). He calculates the volume of ice to $29.5 \cdot 10^6$ km³ and the corresponding rise of sea level to 73 m.

In the figures below the difficult calculations of isostatic movements following melting of ice-caps are not taken into account. The ice-shelves are left out of consideration because their melting have no effect on the sea level. To be subtracted is also that part of the ice-cap that lies below the sea level, or more accurate, below the new and higher level that forms after the melting of the ice. In addition this last mentioned volume of ice by melting decreases c. 10 % and have to be replaced (by meltwater from the rest of the ice-cap). The remaining volume of melt-water to be spred out over the $361 \cdot 10^6$ km² of sea (and a few million km² of flooded land) is $15.3 \cdot 10^6$ km³. Its effect is a rise of the sea level of c. 42 m. Adding the rest of the earth's ice the figure amounts to c. 50 m.

Olav Liestøl

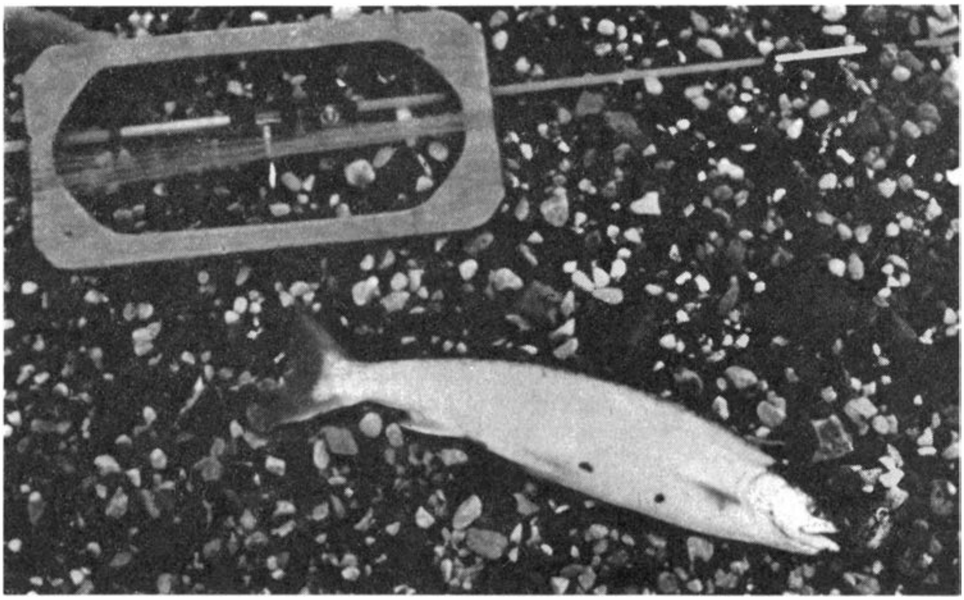


Fig. 1. *«Spitsbergenlaks»* (*Salvelinus alpinus* L) *tatt på stang i Linnévatnet i august 1961. Fiskens lengde 37 cm.* Foto: A. W. MARTINSEN.

Spitsbergenlaks tatt på stang i Linnévatnet

Linnévatnet ligger på sørsiden av Isfjordens munning vel 3 km øst for Kapp Linné, Vestspitsbergen. Vannet er ca. 5 km langt og 1 km bredt, og elven er 2 km lang med et fall på ca. 4 m.

Det er alminnelig kjent at en i elveosen kan ta store garnfangster av en form av sjørøye (*Salvelinus alpinus L*) som populært kalles «Spitsbergenlaks». Det er derimot delte meninger om hvorvidt den kan tas på stang i elven eller vannet. I august 1961 fikk jeg anledning til å forsøke stangfiske med sluk i Linnévatnet.

Sammen med preparant Lily Monsen fisket jeg oppover østsida av elven og langs vannet til omtrent midt på dette. Bredden som heller svakt, er dekket med grus og rullestein uten vegetasjon. Det er grunt utover til 10–12 m fra bredden. Vannet var noe grumset. Det var ved middagstid, sløret sol og nesten vindstille. Det ble ikke observert dyr eller planter i vannet. Her fikk jeg fast fisk ca. 10–12 m fra land og landet en sølvblank og trinn spitsbergenlaks (Fig. 1). Den ble tatt på en 12 grs. kobberfarget skjesluk og 0,30 mm nylon fortom.

Fisken var 37 cm lang og veide noe over ½ kg. Kjøttet var fett, sterkt rødfarget og velsmakende. Innvollene var innleiret i rikelig fett. Gonadene var uutviklete og kjønnet kunne ikke bestemmes makroskopisk. Magesekken var praktisk talt tom. For denne fiskens vedkommende kan turen til Linnévatnet neppe ha vært hverken gyte- eller næringsvandring.

Huggreaksjonen var imidlertid til stede, og en burde her ha mulighet til å nyte et uvanlig sportsfiske.

Arne Werner Martinsen

Ærfugl på landtur

Av og til kan det forekomme at typiske sjøfugler drar lange stykker over land. 25. juli 1961 fløy en flokk på 13 ærfuglhanner (*Somateria mollissima*) over fra øst- til vestkysten på Svalbard. De ble observert i det de passerte over en geolog-leir på overgangen mellom Strongbreen og Paulabreen. Fuglene må ha kommet fra den smale landråken i Storfjorden, nærmere bestemt Kvalvågen, en avstand på ca. 25 km, og de fortsatte ned Paulabreen mot Van Mijenfjorden, en tilsvarende avstand på ca. 25 km. I alt var altså avstanden fra sjøen på den ene siden til den andre omkring 50 km og passhøyden der fuglene passerte lå på ca. 420 m o. h. Toppene i det området hvor de krysset er fra 700 til 1200 m høye. Fuglene fløy i lav høyde over breen, men dette kan kanskje skyldes at skydekket lå bare ca. 50 m over brepassets høyeste punkt. Det var helt stille vær og temperaturen i passet var $+1°$ C.

En gang senere på sommeren ble en enslig ærfuglhann iakttatt i det den passerte over breen i motsatt retning.

Så vidt jeg har kunnet bringe i erfaring har det ikke tidligere vært kjent at ærfugl foretar lange flyveturer over land på Svalbard.

Dessuten kan det nevnes at i nunatakkene i området mellom Strongbreen og Paulabreen hekket det en del havhest (*Fulmarus glacialis*). Det ble også iakttatt en del ismåker (*Pagophila eburnea*) som temmelig sikkert hekket ikke langt unna.

Thor Siggerud

Minneutstilling ved 50-årsjubiléet for Roald Amundsens Sydpols-ekspedisjon 1910–12, 8.–17. desember 1961

Utstillingen kom i stand etter initiativ fra Aftenposten. Journalist Reidar Lunde fikk gjennom The United States Information Service tilbud om å få til Oslo en vandreutstilling om amerikansk virksomhet i Antarktis i dag. Denne vandre-utstillingen inneholdt også utsnitt av Antarktisforskningens historie med bl. a. gjenstander fra Scott's og Shackleton's ekspedisjoner.

En naturlig tanke i jubileumsåret for Roald Amundsens Sydpolsferd var å arrangere en utstilling som viste historien om Sydpolsferden illustrert med bilder og gjenstander, samtidig som relasjonen mellom pionerenes og de moderne forsk-ernes utstyr ble illustrert.

Aftenposten tok kontakt med Norsk Polarinstitutt og det ble besluttet i felles-skap å arrangere en slik utstilling. Aftenposten stillet de nødvendige økonomiske midler til disposisjon. Som æreskomité for utstillingen fungerte:

Belgias ambassadør, Chevalier Jean de Fontaine,
Storbritannias ambassadør, Sir John Walker, K.C.M.G., O.B.E.,
De forente staters charge d'affaires ad interim, Fisher Hove,
Kirke- og undervisningsminister Helge Sivertsen,
Rektor ved Universitetet i Oslo, professor dr. Johan T. Ruud,
Direktør ved Norsk Polarinstitutt, dr. Tore Gjelsvik,
Sjefsredaktør i Aftenposten, Henrik J. S. Huitfeldt.

Som arbeidskomité ble nedsatt:

Journalist Bjørn Bøstrup, Aftenposten,
Arkitekt Guttorm Kavli, M.N.A.L.,
P.R.-sjef Nic. Stabenfeldt, Aftenposten,
Geolog Thore S. Winsnes, Norsk Polarinstitutt.

Ved inngangen til utstillingen ble de besøkende møtt av et kjempekart over Antarktika med reiserutene til de ekspedisjoner som har nådd Sydpolen over land med start ved kysten.
I silhuett sees Roald Amundsens karakteristiske profil.

FOTO: AFTENPOSTEN.

Takket være velvilje og imøtekommenhet fra en lang rekke institusjoner og enkeltpersoner, ble det mulig å skaffe til veie et betydelig materiale, som, for den største del, ikke tidligere har vært vist for det norske publikum. Av institusjoner som stillet verdifullt materiale til rådighet må nevnes:

Scott Polar Research Institute, Cambridge
Nationaal Schepvaart Museum i Antwerpen
The Falkland Island Dependencies Survey.

Det viste seg at et meget rikt materiale av gjenstander og papirer fra Roald Amundsens Sydpolferd var spredt på mange institusjoner og privatpersoner. Det bød på problemer å finne fram til materialet, men også på gledelige overraskelser, og ukjente ting dukket opp.

For bl. a. å få registrert materialet ble det utarbeidet en katalog over utstillingens gjenstander.

Utstillingen ble holdt i Kunstindustrimuséets lokaler. Til tross for tidspunktet like før jul, ble utstillingen besøkt av ca. 12 000. Det ble arrangert omvisninger av skoleklasser og ca. 40 % av de besøkende var skoleelever.

I tilknytning til utstillingen ble vist utdrag av filmen «Roald Amundsen» og tre kortfilmer fra Antarktis.

Thore S. Winsnes

SKRIFTER

Skrifter nr. 1—99, see numbers of Skrifter previous to Nr. 100.

Nr.

100. PADGET, PETER: *Notes on some Corals from Late Paleozoic Rocks of Inner Isfjorden, Spitsbergen.* 1954. Kr. 1.00.
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MAPS

General, geographical, topographical, and technical maps:

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Geographical Society-øya		1:100,000	1937	....	Published by NSIU 1937. Limited stock, not for sale.
Jordan Hill		1:100,000	1937	....	Published by NSIU 1937. Limited stock, not for sale.
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Jan Mayen		1:100,000	1955	2.20	Preliminary map.
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Wall map:				
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