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1974

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OSLO 1976

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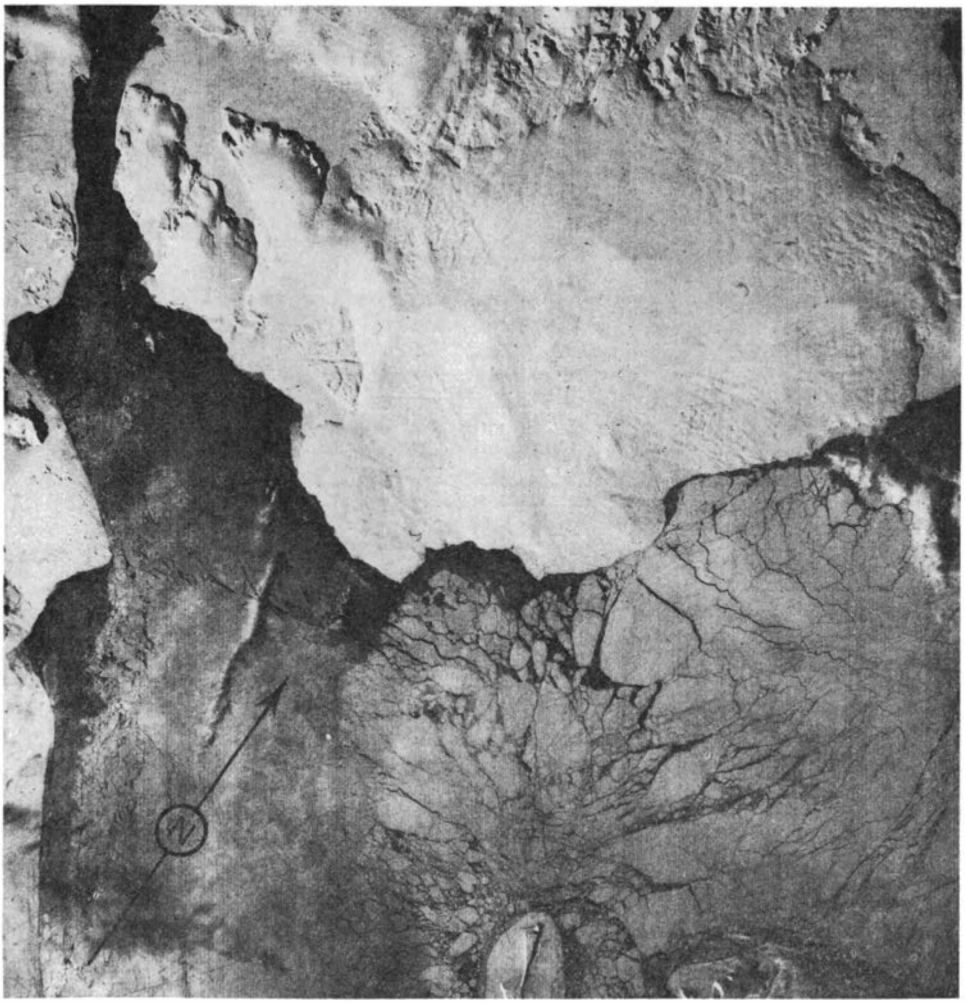

Satellittbilde fra Landsat-1 med senter sør for Nordaustlandet, tatt den 25. mars 1973. Til venstre sees det delvis isfrie Hinlopenstretet og nederst deler av Kong Karls Land. Landsat-1 går i ca. 900 kilometers høyde, og bildet er tatt i den nær infrarøde del av spektret. Billedbredden tilsvarer 185 kilometer og man kan skjelne isflorer på ned til 50 meters tverrsnitt på originalbildet.

Satellite picture from Landsat-1 centered over southern Nordaustlandet, taken on 25 March 1973. To the left is Hinlopenstretet, partly ice free, and at the bottom, part of Kong Karls Land. Landsat-1 orbits at a height of 900 kilometres and this picture was taken in the near infrared part of the spectrum. The width of the picture is 185 kilometres and in the original picture ice floes as small as 50 metres across can be distinguished.

Photo: NASA

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Interlocking antiperthite from the Smeerenburgfjorden area

By Yoshihide Ohta

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Abstract

Peculiar interlocking antiperthites from the Caledonian metamorphic rocks of N.W. Spitsbergen were studied by both optical and chemical means. Some potash feldspar inclusions occur in sets along the internal discontinuities of the host plagioclase, but many of them have no systematic orientation. Mutual lattice orientation of the host and the guest feldspars varies from grain to grain. This evidence does not confirm the exsolution and simultaneous crystallization of these antiperthites. Eleven analyses of feldspars were made and the bulk composition of antiperthitic grains was calculated from the modal analyses. Obtained Na partition coefficients between two feldspar phases are in keeping with the metamorphic conditions of the district. The bulk compositions are in the field of meso-perthites from igneous and metamorphic rocks and the present antiperthites are explained as a meso-perthite mantled by oligoclase.

In the course of study of Caledonian metamorphic rocks from the northwestern part of Spitsbergen, a particular type of antiperthite with interlocking pattern was found in a felsic gneiss from the Smeerenburgfjorden area. The occurrence is restricted to narrow layers of migmatized calcareous rock and the antiperthite seems to be formed in an intermediate stage of feldspathization during metamorphism. The antiperthitic feldspars were studied by optical and chemical means and are considered in connection with the grade of metamorphism in the neighbouring rocks.

The rocks

The antiperthite bearing rock occurs along the northeastern side of Kennedybreen, northeastern entrance of Smeerenburgfjorden (Fig. 1), where garnet biotite gneiss with a thin layer of marble occurs closely mixed with granitic migmatite. The granitic migmatite occupies about 70% of the exposure and includes many angular agmatitic blocks of the gneiss. The gneissosity of the granitic rock is represented by thin layers rich in dark grey quartz, which might have been derived from impure quartzite layers of the original sediments. Aplite veins cut with a network pattern.

The gneiss is medium grained granoblastic texture and has large poikiloblastic garnet, sepia-colored biotite flakes, partially dusty and rarely myrmekitic plagioclase, faintly twinned and slightly perthitic potash feldspar and quartz. Skarn associated with the gneiss is composed of wollastonite felts, diopside, intensely dusty plagioclase and a large amount of quartz.

The host rock of the antiperthite is a leucocratic medium grained gneiss with occasional small white aggregates of wollastonite and dark green diopside. Quartz embayes to all other mineral grains with a smooth contact. Some plagioclase grains are almost invisible due to a dusty cover of tiny sericite flakes, but the dust free grains are often antiperthitic. Myrmekite quartz drops are rarely observed in the dust free plagioclase. Potash feldspar occurs in small quantities as interstitial irregular grains with very weak twinning and without perthitic texture.

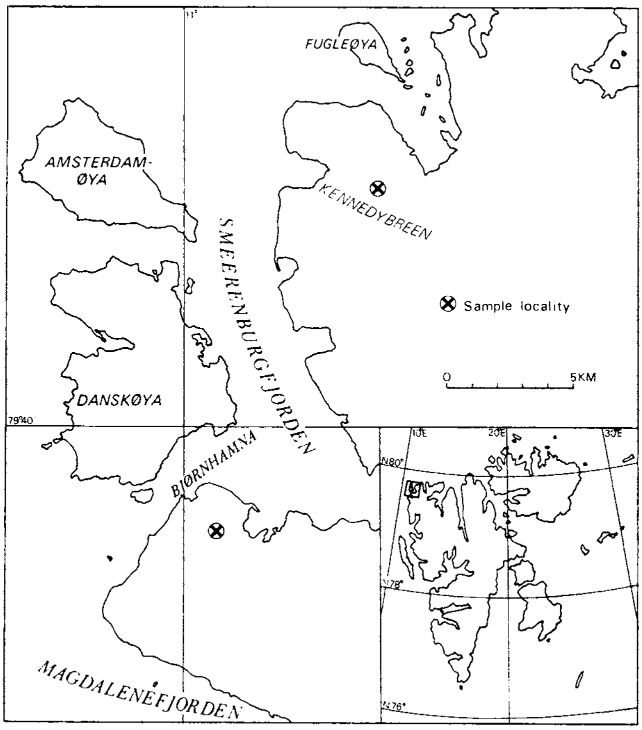

Fig. 1. *Localities of the samples.*

The metamorphic rocks around this area were studied by the present author (OHTA 1960 and 1974a) and are considered to have formed under the upper amphibolite facies; the highest metamorphic conditions are estimated to be $675° \pm 25°C$ and 5.5 Kb.

The antiperthite

There are three types of plagioclase in the specimen: (1) intensely dusty grains associated with wollastonite and diopside; (2) partly dusty, mainly antiperthitic grains; and (3) small, dust-free mosaic grains. Most plagioclase grains show thin albite twin lamellae, while the potash feldspar inclusions show no internal texture, and have 2Vx from 46° to 72°.

The potash feldspar inclusions develop typically in the partially dusty grains (Pls. II–1, 2, and 3), but also occur in small quantities in some intensely dusty grains (Pl. I–1). The inclusions are always more dusty than the host and the dust is not believed to be a later alteration product, but to be inherited from the dusty plagioclase grains of the skarn, in which the inclusions were originated (Pls. I–2 and II–2). The inclusions are densest in the inner part of a grain and are absent from a narrow irregular zone around the margins (Pl. I–3). This inclusion free margin is very similar to the small mosaic grains without antiperthitic texture.

The observations mentioned above suggest that the decalcification of older basic plagioclase of the skarn and assimilation of the sericite-rich dusts were closely related to the development of the potash feldspar inclusions. K and Al of the sericite could be used to form potash feldspar. Some decalcified plagioclase components could be mobilized and precipitate around the margins of the antiperthitic grains to form small mosaic oligoclase grains without inclusions. This process can reasonably be assumed under the conditions estimated from the study of the surrounding metamorphic rocks.

Myrmekitic drops of quartz are seen in some antiperthitic grains. The quartz drops occur with a smooth sharp contact with the feldspars and have no influence on the distribution and shape of the potash feldspar inclusions.

Two shapes of antiperthitic inclusions are distinct, rectangular- to irregular-shaped beads and slender rods, each arranged in parallel sets (Pls. II–1, 2, and 3).

The beads are cross sections of three dimensional rods (hereafter the rod) and are mostly of irregular shape of less than 0.04 mm across. They are distributed homogeneously but irregularly in the host. Some rods tend to have a rectangular shaped cross section and are arranged roughly parallel to the albite twin lamellae of the host (Pl. II–3). Most rod-sets occur in a plane about 8° from the (010) of the host and many of them make small angles with the c-axis of the host (Fig. 2). Other sets are aligned at high angles to the c-axis in the plane, or high angles to the (010) of the host. Some rods occur along irregular borders of blocks showing slightly different extinction position in a grain and grain boundaries (Pls. III–1 and 2).

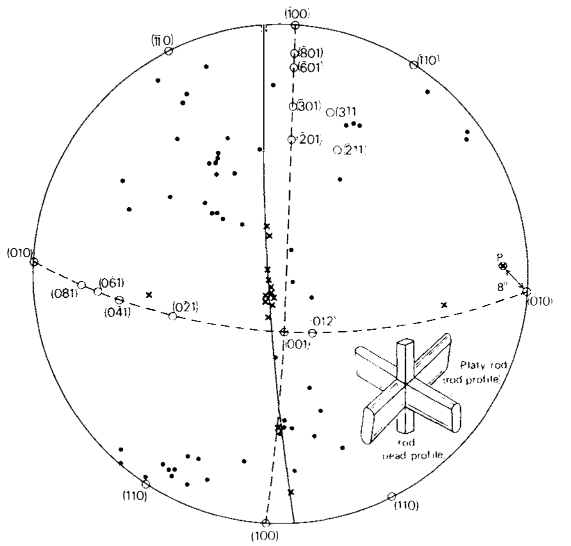

Fig. 2. *Orientation of the antiperthitic inclusions in the host plagioclase. Dots: poles of the planar face of the platy rod inclusion sets; cross: elongation direction of the rod inclusion sets; P: pole of the plane including most of the rod inclusion sets.*

The slender rods are platy in the third dimension (hereafter the platy rods), with a pair of planer faces on both sides. Their elongations are impossible to measure as they lie nearly parallel to the plane of thin section when they are able to be observed. The orientations of the planar faces (Fig. 2) vary in a range of 20° within a set while the orientations of the sets show no systematic relation to the host plagioclase. It is common to have two sets of the platy rods, intersecting at angles of 30°–80°, with or without a set of the rods, in one antiperthitic grain, sometimes with a third set of the platy rods occurring between them. The elongations of these platy rods may make high angles with the (010) of the host.

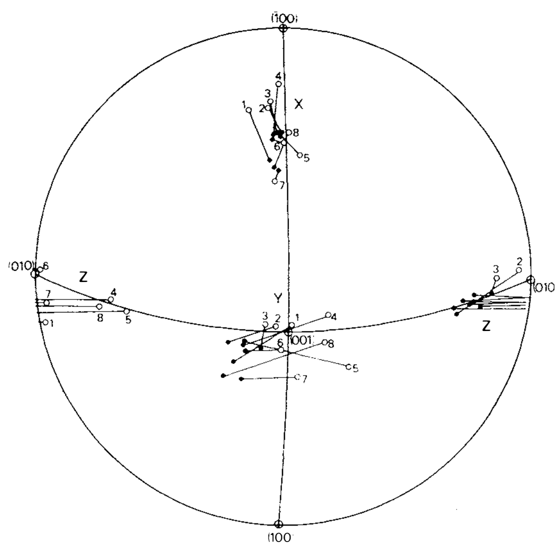

Fig. 3. *Mutual lattice orientation of the host and inclusion feldspars. Dots: optic vibration axes of the host plagioclase; open circles: optic vibration axes of potash feldspar inclusions. Tie lines connect antiperthitic pairs and numbers indicate corresponding sets.*

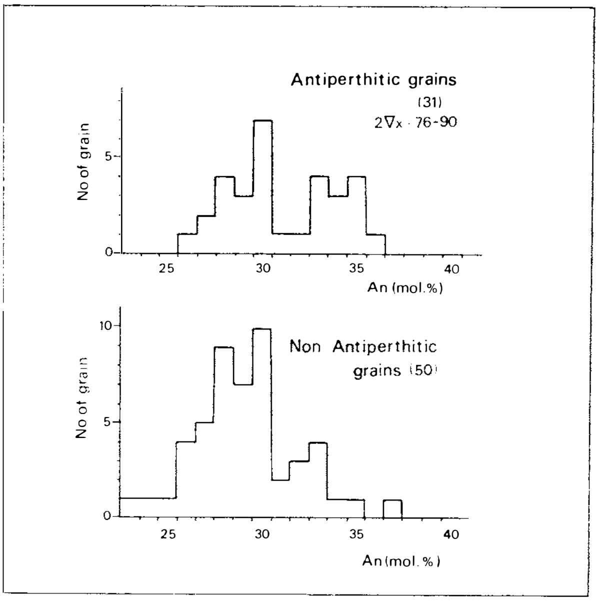

Fig. 4. *An content of plagioclase by means of optic methods.*

Although most platy rods are randomly orientated, the relatively regular orientations of the rod sets near the (010) of the host suggest that they precipitated along internal discontinuities such as twin borders, cleavages, and irregular crack sets of the host. Some platy rods are weakly bent (Pl. I–3) and this supports the idea that they were formed along a set of curved cracks. Similar evidence was reported by NAIDU (1954) from a charnockite of India. Dust free host plagioclase grains were recrystallized from the dusty old ones and the original relation between the host and guest might be disturbed in some grains.

Mutual lattice orientation of the host and inclusion feldspars was examined by comparing their optical orientations (Fig. 3). Although they look homoaxial under common microscope, the U-stage measurements show that the scattering of the optical vibration axes of the inclusion potash feldspar from those of the host plagioclase is evidently larger than that estimated from the small variations in their chemical composition (Table 1 and Fig. 4). This evidence argues against an exsolution and simultaneous crystallization origin of the potash feldspar inclusions.

Chemical composition of the feldspars

Preliminary measurements of the An content of plagioclase were made by optic means, such as the a-normal method, Kano's diagram (KANO 1955) and Uruno's diagram (URUNO 1963). A small variation in An content, about 15%, can be expected from grain to grain (Fig. 4). Measurement of strongly dusty grains was difficult, but they may have a much higher An content than that measured, according to the comparison of refractive indeces. No zonal structure was seen. The frequency histogram of the An content for both the anti-

Table 1

Chemical composition of the feldspars in felsic gneiss from Kennedybreen

	Mosaic grain K-feld.	Mosaic grain Plag.	Antiperthite I K-feld.	Antiperthite I Plag.	Antiperthite II K-feld.	Antiperthite II Plag.
SiO_2	65.78	57.42	64.04	60.11	63.59	59.64
Al_2O_3	18.36	25.93	17.31	25.66	18.95	25.54
CaO	0.22	7.42	0.14	7.30	0.17	6.97
Na_2O	0.84	7.69	1.03	7.16	1.11	7.45
K_2O	15.28	0.17	15.03	0.20	15.24	0.22
Total	100.48	98.63	97.55	100.43	99.06	99.82
Molecular % of feldspar						
Or	91.20	0.95	89.96	1.13	89.26	1.31
Ab	7.67	64.60	9.34	63.24	9.95	65.02
An	1.13	34.45	0.70	35.63	0.79	33.67
Weight % of feldspar						
Or	92.13	1.20	90.76	1.44	90.16	1.65
Ab	7.30	77.01	8.88	75.88	9.48	77.15
An	0.57	21.79	0.36	22.68	0.36	21.20

(Analyses by M. KOMATSU)

perthitic and non-antiperthitic grains are very similar and some An rich grains are believed to be derived from calcareous original rocks.

The composition of the potash feldspar inclusions were estimated from the lowest refractive index, $\alpha = 1.520$, indicating an Or content of 90%.

Chemical analyses of the feldspars were carried out by electron microprobe analyser for two pairs of antiperthitic host and inclusion and mosaic grains of plagioclase and potash feldspar (Table 1). Each analysis is the mean of five measurements. The standards used were albite (OHMI, Japan) for Si and Na, synthetic anorthite glass for Ca and Al, and muscovite (HIDA, Japan) for K. The results confirm the optical estimates. These feldspar phases are nearly pure alkaline feldspar and plagioclase series, and their partition coefficients of Na are 0.119 for the non-perthitic grains and 0.148 and 0.153 for the antiperthitic pairs. If the antiperthites were formed under the highest metamorphic conditions of this area, at $675° \pm 25°C$ and 5.5 Kb., the partition coefficient could be 0.2 ± 0.05 according to PIWINSKII (PIWINSKII 1968) and 0.425 ± 0.025 after BARTH (BARTH 1956). Thus, the results confirm PIWINSKII's experiments (PIWINSKII & WYLLIE 1970). The tie lines of the present feldspars on the Or-Ab-An diagram (Fig. 5) are close to the granite No. 705 sample of PIWINSKII and WYLLIE (1970), which had an experimentally determined formation temperature of 690°C. This data is consistent with the present case.

Another antiperthitic feldspar of a hornblende-biotite gneiss from Bjørnhamna, about 15 km south of the Kennedybreen area (OHTA 1974b), was analysed for comparison (Pl. III–3). The gneiss is a granitized part of calcareous rock having a small amount of diopside. Myrmekite and irregular-patch type

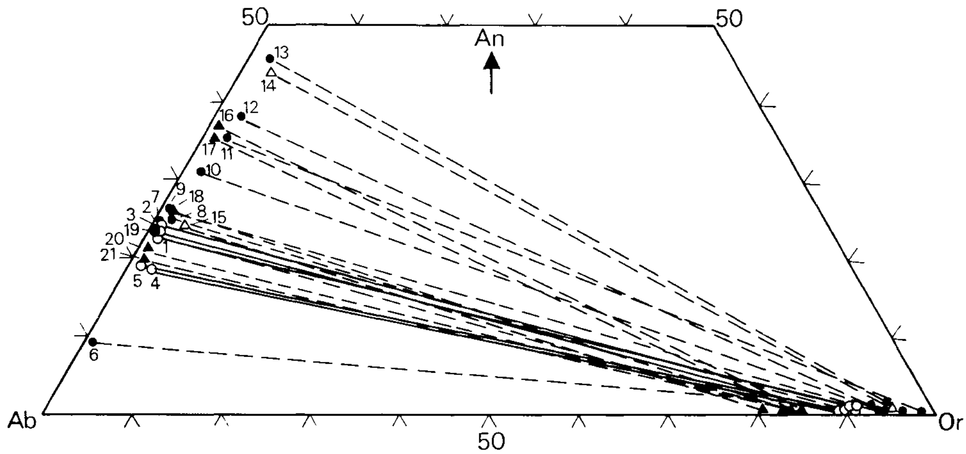

Fig. 5. *Composition of the co-existing feldspars. 1: co-existing, non-perthitic feldspars, Kennedybreen; 2 and 3: antiperthictic pairs, Kennedybreen; 4: co-existing, non-perthitic feldspars, Bjørnhamna; 5: meso-perthitic pairs, Bjørnhamna; 6–9: meso-perthitic pairs from charnockite and mangerite, Rogaland, S-Norway* (DAHLBERG *1969); 10–13: meso-perthites from norite and anorthosite, Rogaland* (DAHLBERG *1969); 14, 15: experimental pairs at 770° and 720°C* (YODER *et al. 1957); 16, 17: feldspar pairs of quartz monzonite at 700° and 690°C* (PIWINSKII *and* WYLLIE *1970); 18, 19: feldspar pairs from granite No. 705 at 700° and 690°C* (PIWINSKII *and* WYLLIE *1970); 20, 21: feldspar pairs from granite No. 104 at 700° and 690°–680°C* (PIWINSKII *1968).*

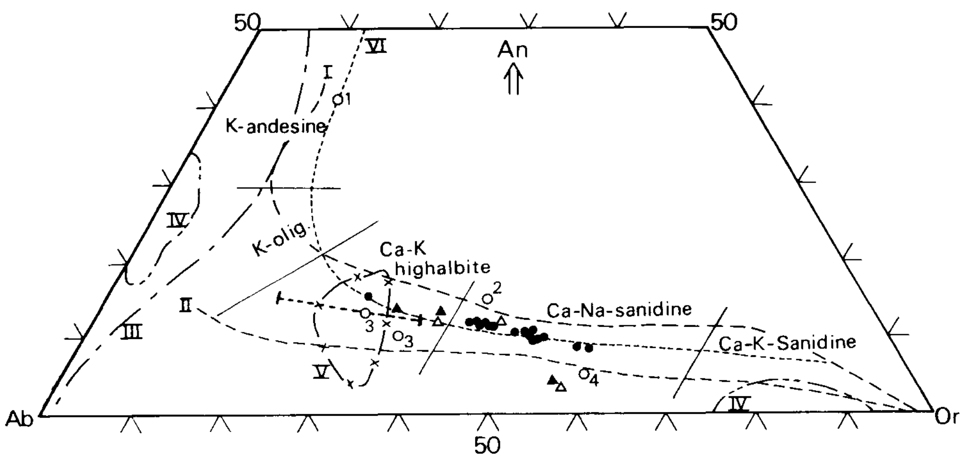

Fig. 6. *Bulk composition of the antiperthitic feldspars. Dots: antiperthites from the Kennedybreen sample; thick broken line: composition range of meso-perthites from the Bjørnhamna samples; Triangles: meso-perthites, Rogaland, S-Norway, solid = bulk chemical analyses, open = EPMA analyses* (DAHLBERG *1969); 1: antiperthite, Nigeria* (HUBBARD *1965); 2: interlocking perthite, Søndeled, S-Norway* (ANDERSEN *1928); 3: mesoperthite, Uruguay* (SÀENZ *1965); 4: meso-perthite, Nigeria* (HUBBARD *1966); I, II: phenocrysts and groundmass feldspars from Rhombporphyry of Oslo region* (HARNIK *1969); III: plagioclases from various metamorphic rocks* (SEN *1959); IV: co-existing feldspars from Rogaland granulites, S-Norway* (DAHLBERG *1969); V: ternary feldspars from Larvikite, Oslo region* (HARNIK *1969); VI: mixing limit of natural ternary feldspars* (TUTTLE *and* BOWEN *1958).*

macroperthite occur replacing plagioclase. A large amount of potash feldspar with weakly developed stringlet perthite is one of the main constitutent minerals. The antiperthitic plagioclase is a well twinned mosaic, mostly after the albite law; the pericline twins are few, of oligoclase-andesine composition. The potash feldspar inclusions have flame shape and are more than 0.2 mm wide. These antiperthitic grains are believed to represent an intermediate stage of metasomatic replacement of plagioclase by potash feldspar (Pl. III–3). The chemical composition of feldspars from this sample are listed in Table 2. The tie lines of co-existing feldspars and antiperthitic pairs project close those of the Kennedybreen sample on the Or-Ab-An diagram, and have a similar trend to the granite No. 104 sample of PIWINSKII (1968), which was formed at 680° and 690°C.

Two meso-perthites from a mangerite and a charnockite, both from the granulite terrain of Rogaland, south Norway, have a similarly trending tie line on the diagram (DAHLBERG 1969).

Modal analyses of host and inclusion feldspars were carried out on the enlarged photographs. In antiperthitic grains the amount of inclusions is larger in the inner part, up to 58%, than the margins, down to 7% (Table 3). Most grains can be called meso-antiperthite, because the two components tend to occur equally.

HUBBARD (1965) discussed on the exsolution origin of the antiperthites from Wasimi enderbite, Nigeria, based on the small variation range of the modal ratios of the host and guest feldspars. The range of his samples is 7% among 12 samples. The modal variation range of the present samples is about 18% for

Table 2

Chemical composition of the feldspars in hornblende-biotite gneiss of Bjørnhamna.

	Mosaic grain K-feld.	Mosaic grain Plag.	Myrmekitic plag.	Antiperthite K-feld.	Antiperthite Plag.
SiO_2	64.14	62.06	60.96	63.96	60.13
Al_2O_3	18.69	25.04	25.04	18.55	25.17
CaO	0.18	6.23	6.47	0.15	6.35
Na_2O	0.95	7.90	8.16	0.87	7.88
K_2O	15.10	0.41	0.21	15.15	0.19
Total	99.05	101.64	100.84	98.68	99.72
Molecular % of feldspar					
Or	90.41	2.34	1.18	91.20	1.10
Ab	8.68	68.01	68.73	7.99	68.48
An	0.91	29.65	30.09	0.81	30.42
Weight % of feldspar					
Or	91.28	2.88	1.45	91.99	1.36
Ab	8.26	78.88	79.62	7.60	79.82
An	0.46	18.24	18.93	0.41	18.82

(Analyses by M. KOMATSU)

Table 3
Modal analyses and calculated bulk composition of the antiperthitic feldspars

No	Modal proportion						Calculated bulk composition, (Wt.%)		
	Inner part		Margins		Bulk grain				
	Plag.	K-feld.	Plag.	K-feld.	Plag.	K-feld.	Or	Ab	An
1					43.15	56.85	51.35	38.69	9.96
2					50.00	50.00	45.14	43.74	11.12
3					53.04	46.96	42.45	45.53	12.02
4	43.98	56.02	70.00	30.00	45.00	55.00	49.60	40.12	10.28
5	54.86	45.14			66.70	33.30	29.53	55.32	15.15
6					51.32	48.68	43.98	44.38	11.64
7	34.21	65.79	93.33	6.67	50.94	49.06	44.36	44.10	11.54
8					37.76	62.24	56.06	35.23	8.71
9					36.34	63.66	57.35	34.25	8.40
10	43.60	56.40			51.35	48.65	43.94	44.41	11.65
11	48.11	51.89	56.30	43.70	50.23	49.77	44.90	43.68	11.42
12	42.80	57.20	61.40	38.60	44.60	55.40	49.95	39.86	10.19
13					43.16	56.84	51.26	38.88	9.86
14	38.04	61.96	46.76	53.24	43.62	56.38	50.82	39.20	9.98
15					46.09	53.91	48.63	40.86	10.51
16					52.36	47.64	43.06	45.07	11.87

15 bulk grains, and is 20% for the inner parts of 7 grains. All these grains were measured in a few thin-sections from one hand specimen. Thus, the rather heterogeneous modal ratios of the present antiperthitic grains do not favor an exsolution origin.

The bulk chemical composition of the antiperthitic grains was calculated from the modal analyses and average chemical composition of the host and inclusion feldspars (Table 3 and Fig. 6). These are projected in the Ca-Na-sanidine field around the limit of mixable field of natural ternary feldspars on the Or-Ab-An diagram. The Bjørnhamna samples were plotted as Ca-K high albite (SMITH 1974, Figs. 9–16). Ternary feldspars of such compositions are very scarce even in the phenocrysts of volcanic rocks (HARNIK 1969), and are possibly above 700°C under 5000 kg/cm^2 (4.9 Kb) pressure according to the phase diagram (SMITH 1974, Fig. S-3). From metamorphic and plutonic rocks, an andesine-microcline interlocking perthite from Frøyne, Søndeled, south Norway (ANDERSEN 1928), and some meso-perthites of the mangerite and charnockite from Rogaland, south Norway (DAHLBERG 1969), have been reported to have a similar composition.

Most feldspars having a Ca-Na-sanidine composition are meso-perthite and typical antiperthites plot in the composition fields of potash-andesine and potash-oligoclase, for example, those from the enderbite of Nigeria (HUBBARD

1965). However, in the present case grain outlines are defined by plagioclase which is evidently the host even though the inclusions compose more than half the volume. The opposite case was reported from an Uruguayan migmatite (SÁENZ 1965). The present ones can be called an oligoclase mantled meso-perthite.

Some meso-perthites from Rogaland granulite facies rocks have been considered to be of exsolution origin (MICHOT 1961), but some others may be replacement products (DAHLBERG 1969). The Søndeled sample is an irregular patchy micro-perthite and its replacement origin is evident (see Pl. VII, Figs. 2A and 3 of ANDERSEN 1928).

An interesting synthetic study carried out under conditions somewhat higher than the present case was reported by SMITH (HAMILTON, MACKENZIE, and SMITH, unpublished, in SMITH 1974). A gel of composition $Or_{81}Ab_9An_{10}$ (wt%) was heated hydrothermally at 5 Kb and 900°C for 6 hours followed by 10 days at 775°C, and three phases were obtained; potash feldspar typically $Or_{92}An_2$, plagioclase typically Or_7An_{66}, and a glass of $Or_{33-40}An_{20-16}$. The glass, the present author believes, may not solidify as a homogeneous ternary phase, but may further react with the crystalline phases during a prolonged heating or crystallize as two phases during falling temperature. This experiment suggests that homogeneous ternary feldspars of compositions like the present anti-perthites can not be possible even under such high condition present in the experiment.

Accordingly, a homogeneous ternary feldspar of the Ca-Na-sanidine composition is considered to be possible under the conditions of typical granulite facies, as well as in the phenocryst-stage of volcanic rocks, because of high temperature and relatively dry condition, but it is not to be expected in the upper amphibolite facies where the temperature is less than 700°C and the vapor pressure is thought to be commonly very high.

Conclusion

The intimate intergrowth of plagioclase and potash feldspar in a felsic gneiss from the Kennedybreen area is a meso-perthite mantled by oligoclase. These grains were formed in the metamorphic conditions of upper amphibolite facies through replacement of calcic dusty plagioclase by potash feldspar components which were derived from the solid state reactions of decalcification and assimilation of sericite rich dusts of the plagioclase. Homogeneous ternary feldspar of the estimated composition range does not seem likely to have existed under the postulated metamorphic conditions. The irregular orientation of the inclusions, and of their lattice structures, does not support the exsolution and simultaneous crystallization of these intergrowths. Some decalcified plagioclase components might have mobilized and diffused into the initially dusty meso-perthite and formed the rim of the grains, an antiperthite of peculiar composition. Homogeneous ternary feldspar of Ca-Na sanidine composition as in the present examples may be possible in typical granulite facies conditions with high temperature and relatively dry environment. However, in the upper amphibolite facies, the temperature is not high enough, and extremely wet conditions seem to promote replacement and diffusion process in the granitizing rocks.

Acknowledgement

I am very grateful for the assistance of Dr. M. KOMATSU of the Department of Geology, Niigata University, Japan, who kindly carried out the mineral analyses by an electron probe micro analyser.

References

ALLING, H. L., 1938: Plutonic perthites. *Jour. Geol.* **46**, 142–165.

ANDERSEN, O., 1928: The genesis of some types of feldspar from granitic pegmatites. *Norsk Geol. Tids.* **10**, 116–207.

BARTH, T. F. W., 1956: Studies in gneiss and granite II; The feldspar equilibrium temperature in granitic rocks of the pre-Cambrian of south Norway. *Norske Videnskap.-Akad. Skrifter.* Oslo. No. 1.

— 1969: Feldspar. *Wiley-Intersci.* London.

CARSTENS, H., 1967: Exsolution in ternary feldspars I; On the formation of antiperthites. *Contr. Min. Petr.* **14**, 27–35.

DAHLBERG, E. H., 1969: *Feldpars of charnockitic and related rocks, Rogaland, South-west Norway.* Thesis, Univ. of Utrecht.

HARNIK, A. B., 1969: Strukturelle Zustände in den Anorthoklasen der Rhombenporphyre des Oslogebietes. *Schweiz. Min. Petr. Mitt.* **49**, 509–567.

HUBBARD, F. H., 1965: Antiperthite and mantled feldspar textures in charnockite (enderbite) from S.W. Nigeria. *Am. Jour. Sci.* **50**, 2040–2051.

— 1966: Myrmekite in charnockite from south-west Nigeria. *Am. Min.* **51**, 762–773.

KANO, H., 1955: High temperature optics of natural sodic plagioclases. *Min. Jour. Japan.* **1**, 255–277.

MICHOT, P., 1961: Struktur der Mesoperthite. *N. Jahrb. Min. Ab.* **96**, 213–216.

NAIDU, P. R. J., 1954: Minerals of charnockites from India. *Schweiz. Min. Petr. Mitt.* **34**, 203–279.

OHTA, Y., 1969: The geology and structure of metamorphic rocks in the Smeerenburgfjorden area, north-west Spitsbergen. *Norsk Polarinstitutt Årbok* 1967. 52–72. Oslo.

— 1974a: Tectonic development and bulk chemistry of rocks from the Smeerenburgfjorden area, Spitsbergen. *Norsk Polarinstitutt Skrifter* Nr. 158. 69–107. Oslo.

— 1974b: Geology and structure of the Magdalenefjorden area, Spitsbergen. *Norsk Polarinstitutt Skrifter* Nr. 158. 39–67. Oslo.

ORVILLE, P. M., 1963: Alkali ion exchange between vapor and feldspar phases. *Am. Jour. Sci.* **261**, 201–237.

PIWINSKII, A. J., 1968: Studies of batholithic feldspars; Sierra Nevada, California. *Contr. Min. Petr.* **17**, 204–223.

PIWINSKII, A. J. and P. J. WYLLIE, 1970: Experimental studies of igneous rock series; Felsic body suite from the Needle Point Pluton, Wallowa batholith, Oregon. *Jour. Geol.* **78**, 52–76.

SÁENZ, I. M., 1965: Origin of ternary film and string perthites from a Uruguayan migmatite. *Schweiz. Min. Petr. Mitt.* **45**, 103–113.

SEN, K. S., 1959: Potassium content of natural plagioclases and the origin of antiperthites. *Jour. Geol.* **67**, 479–495.

SMITH, J. V., 1974: *Feldspar minerals.* **1** and **2**. Springer Verlag. Berlin.

TUTTLE, O. F. and N. L. BOWEN, 1958: Origin of granite in the light of experimental studies in the system $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O, *Geol. Soc. Am. Mem.* **74**.

URUNO, K., 1963: On the ordering degree of plagioclase. *Sci. Rept., Tohoku Univ.* **8**. Ser. A., 171–220.

YODER, H. S., D. B. STEWARD, and J. R. SMITH, 1957: Feldspars. Washington, *Carnegie Inst. Yearbook*, **56**. 206–214.

PLATES

(The vertical side of all pictures is about 1 mm. The pictures are from the Kennedybreen sample, except for Pl. III-3.)

PLATE I

1. Antiperthitic inclusions in dusty plagioclase (cross).
2. The inclusions are dustier than the host, but the dust is distributed irregularly, more or less regardless of the antiperthitic texture (open).
3. Slightly curved inclusion rods, originally following a crack system. The host plagioclase recrystallized later and the strain has been released (cross).

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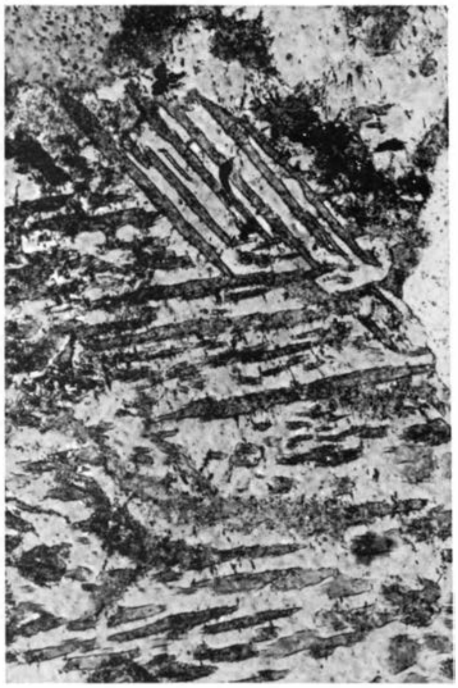

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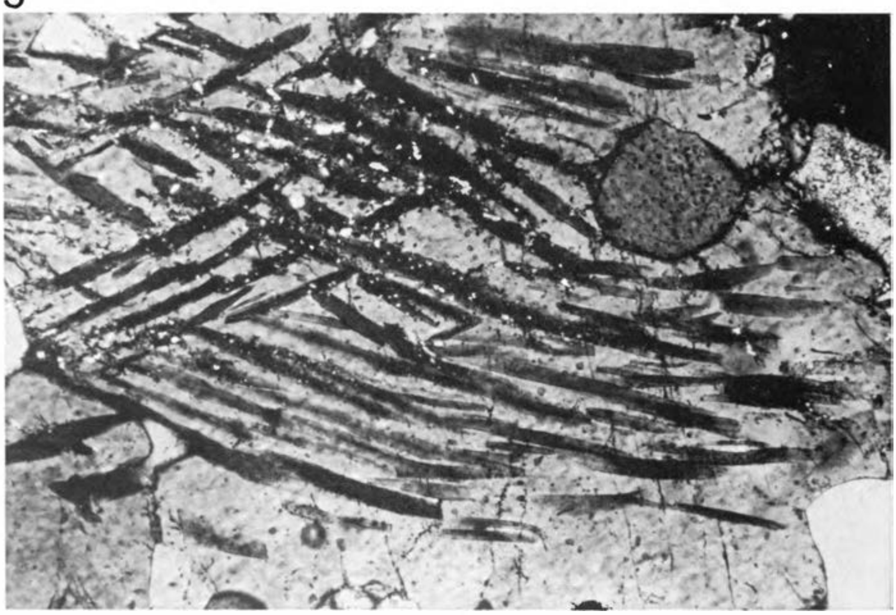

PLATE II

1. Typical antiperthitic grain with three sets of slender rods and a set of beads (cross).
2. Typical antiperthite with two sets of slender rods and a set of irregularly shaped beads (cross).
3. A set of beads arranged parallel to the albite twin lamellae (cross).

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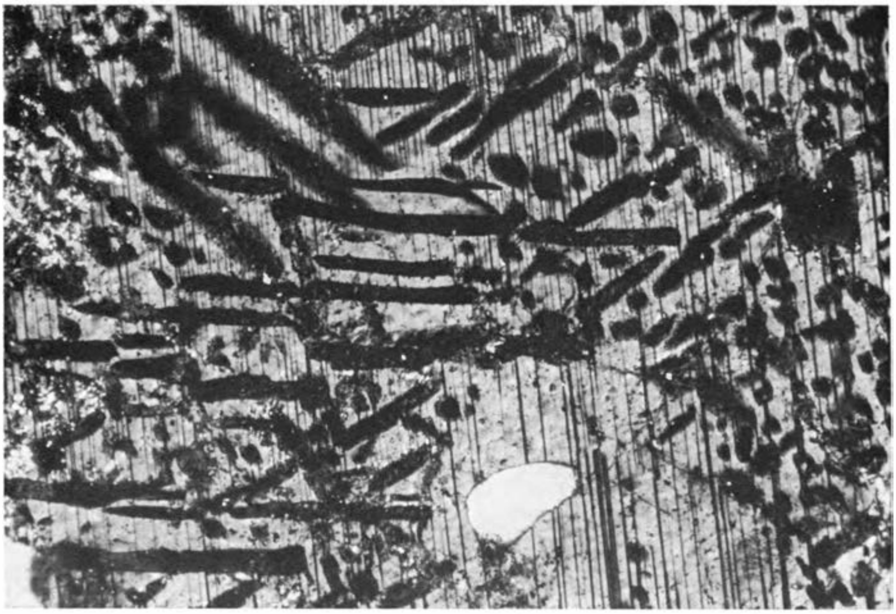

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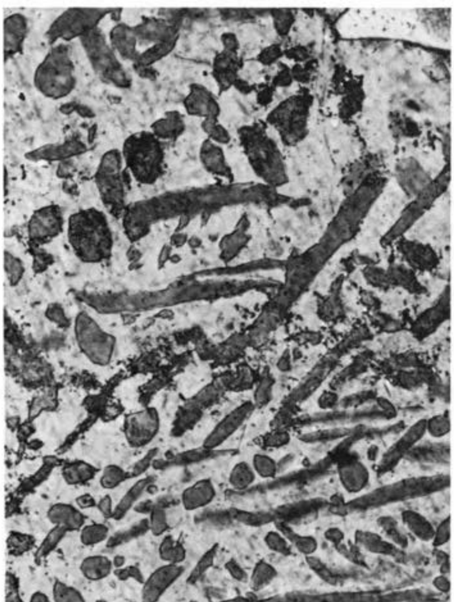

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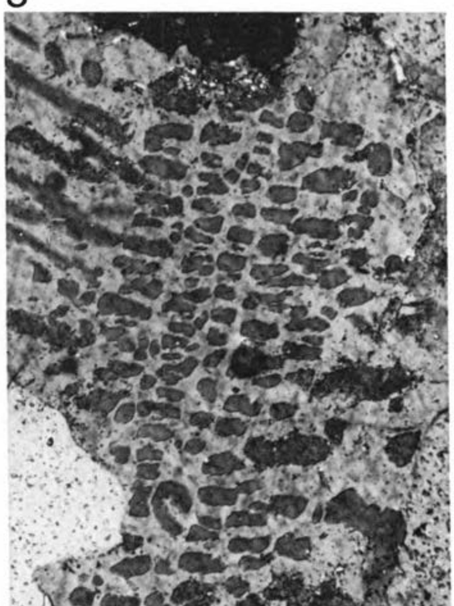
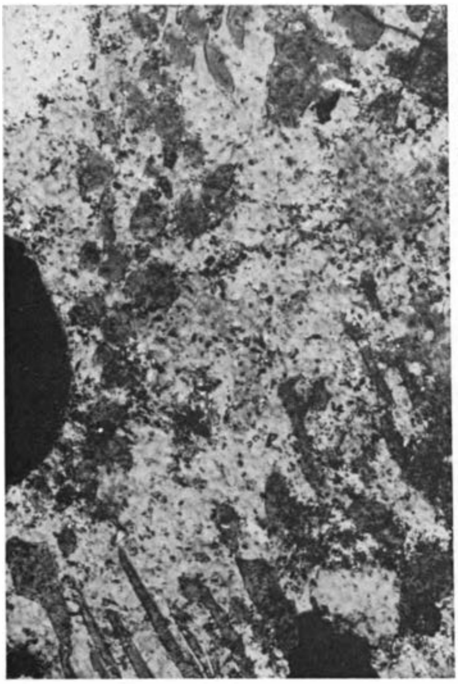


PLATE III

1. Irregular distribution of beads (left side) along a border between two blocks showing slightly different extinction positions (open).
2. Irregular inclusions, in the centre of the picture, acting as a border between three grains (cross).
3. A flame-perthite from the Bjørnhamna sample (cross).

1



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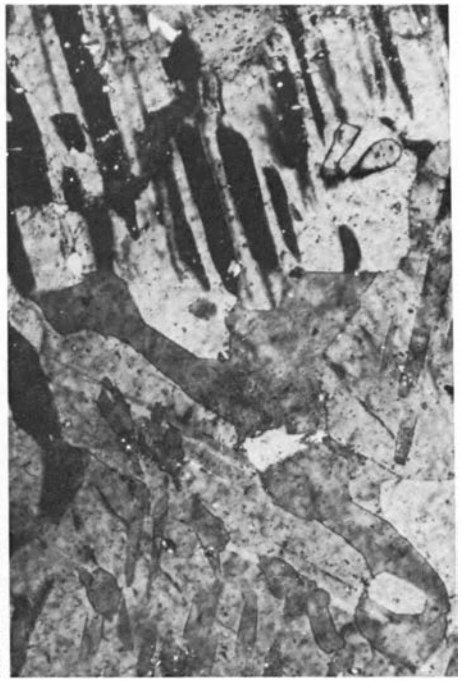

3

The Upper Palaeozoic succession of Bjørnøya[1]

By DAVID WORSLEY[2] and MARC B. EDWARDS[3]

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Abstract

The Upper Palaeozoic succession on Bjørnøya comprises eight formations with a maximum composite thickness of about 1300 metres. It rests unconformably on Hecla Hoek basement, and is overlain disconformably by Triassic shales. The lower formations, of Upper Devonian and Lower Carboniferous age, consist of sandstones and shales with subordinate conglomerates and coals, and were deposited in various alluvial environments. The overlying Upper Carboniferous and Permian formations consist largely of carbonates, with additional sandstones, shales, and cherts; these were deposited in shallow marine and coastal environments. Variations in facies and thickness together with palaeocurrent patterns suggest that Bjørnøya lay near the southern margin of a depositional basin during much of the Upper Palaeozoic.

Introduction

In spite of its small size, Bjørnøya is of considerable geological significance because of its isolated position near the western margin of the Barents Shelf.

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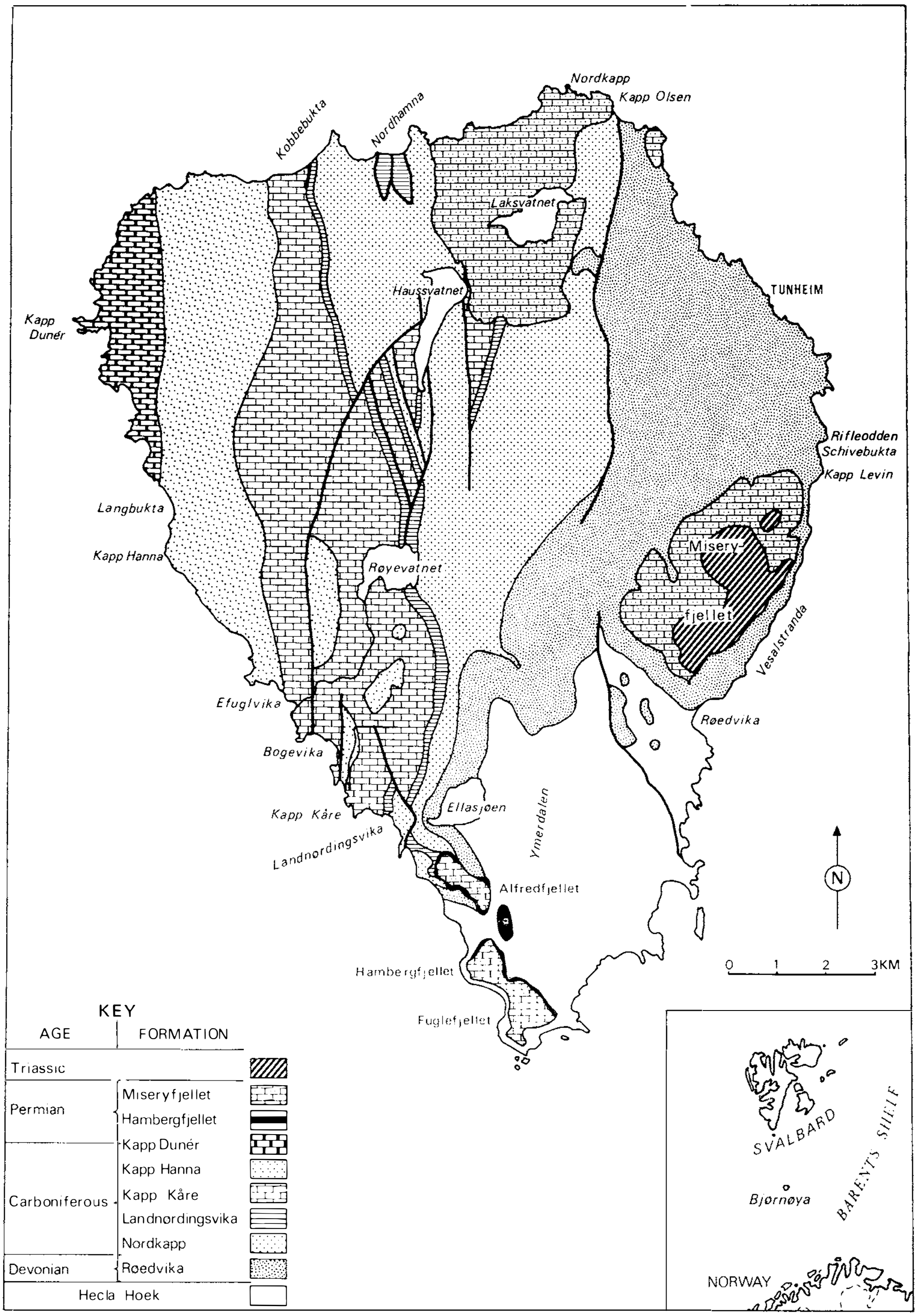

Fig. 1. *Geological map of Bjørnøya, based on* Horn and Orvin *(1928). Place-names referred to in the text are also shown.*

A general geological description of the island can be found in HORN and ORVIN (1928); three geological elements are seen:

3. Triassic – approx. 200 metres of shales and sandstones.
   – *disconformable contact* –
2. Upper Devonian to Permian – described here.
   – *unconformable contact* –
1. Hecla Hoek basement – approx. 1,200 metres of clastics and carbonates of Late Pre-Cambrian and Ordovician age.

The Upper Palaeozoic strata outcrop over most of the island (Fig. 1); until recently, only isolated aspects of their geology had been studied since coal-mining operations were abandoned in 1925. This paper presents preliminary results of an environmental analysis of these strata based on detailed sedimentological sections through much of the succession. The work is part of the Barents Sea Project, a co-operative effort with participation by several Norwegian research institutions. Field work on Bjørnøya was carried out during Norsk Polarinstitutt's expeditions to Svalbard in 1971 and 1973, and was supported by NTNFK (the Continental Shelf Division of the Norwegian Council for Scientific and Industrial Research).

Stratigraphy

The formations described are listed in Fig. 2 together with their thicknesses and approximate ages; the "Series" names established by ANDERSSON (1900) are also shown. CUTBILL and CHALLINOR (1965) introduced formal lithostratigraphical names for the two lower formations on the basis of the account of HORN and ORVIN (1928). KRASILŠČIKOV and LIVŠIC (1974) presented, but did not define, names for the remainder of the succession. Where we consider these names justified we have adopted them and defined them on the basis of our work; however, several of the names introduced by KRASILŠČIKOV and LIVŠIC are inappropriate and are rejected. We have also introduced formal members in two of the formations described.

RØEDVIKA FORMATION

Name

The lower part of the "Ursa Sandstone" of earlier workers was renamed by CUTBILL and CHALLINOR (1965) after Røedvika (Fig. 2) where the lower parts of the formation are exposed; a complete section through the formation is not seen at any single locality.

Lithology and thickness

The formation consists of sandstones and shales with subordinate conglomerates and coals. Bore-hole data (HORN and ORVIN 1928) indicate a thickening over a distance of about 12 km from about 100 metres at Ellasjøen (SW) to about 360 metres around Tunheim (NE).

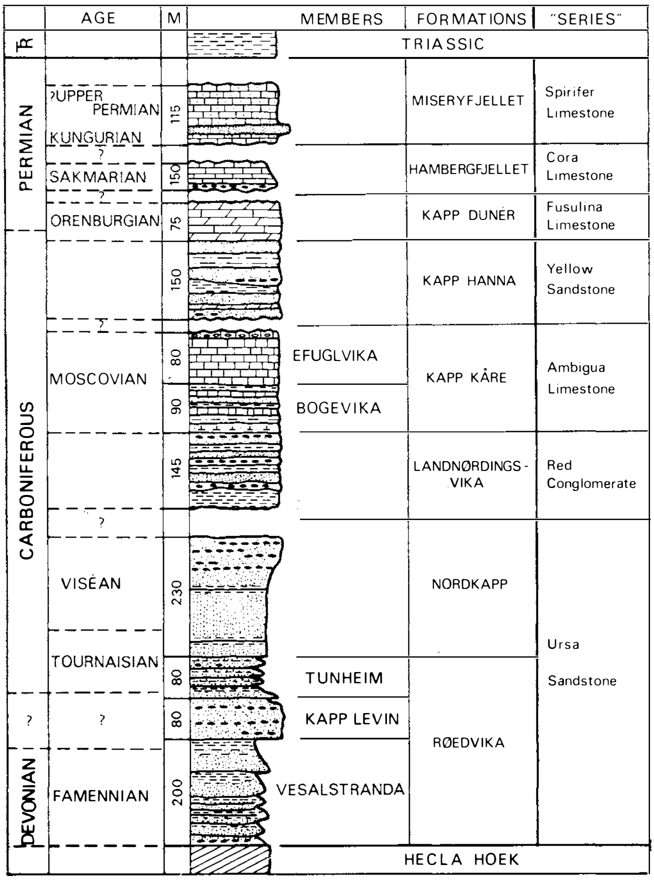

Fig. 2. *Composite section through the Upper Palaeozoic succession of Bjørnøya, with lithology, thickness, and tentative correlation of the formations and members proposed here. The "Series" names used by earlier workers are also shown.*

Boundaries

The formation rests unconformably on the Hecla Hoek with locally developed basal conglomerates. The top of the formation is not exposed, and was somewhat arbitrarily located by HORN and ORVIN (1928) in some of their bore-holes. CUTBILL and CHALLINOR (1965) misquote HORN and ORVIN as having suggested an unconformable relationship between the Røedvika and overlying Nordkapp Formations; HORN and ORVIN (1928, p. 21) merely noted the possibility of such a relationship to explain the formations' geographical variations in thickness, but left this question open. KRASILŠČIKOV and LIVŠIC (1974) suggest that the thickness variation is a result of thrusting of the formation over the Hecla Hoek; although some tectonic deformation of this lower junction may have occurred, exposures do not indicate thrusting of the magnitude necessary to be alone responsible for such large thickness variation. Further, such thrusting cannot explain the lateral variation in thickness of the overlying Nordkapp Formation.

Age

The formation has traditionally been assigned to the Upper Devonian because of its plant and fish macrofossils (e.g. *Archaeopteris* and *Holoptychius*). Although CUTBILL and CHALLINOR (1965) suggested that palynomorphs indicated a Lower Carboniferous age, more extensive palynological studies by KAISER (1970, 1971) indicate that the formation spans the Devonian/Carboniferous boundary, ranging from the Famennian to the Lower Tournaisian.

Sedimentation

The formation was deposited under fluvial conditions. It is here subdivided into three members based on sedimentological studies on the east coast.

VESALSTRANDA MEMBER

This member outcrops along Vesalstranda ("the desolate shore") from Røedvika to just south of Kapp Levin, and here comprises the lower 200 m of the Røedvika formation. The outcrop area's name refers to the unstable scree slopes with continually falling debris. Exposure is generally poor, but a few sections can be measured (see HORN and ORVIN 1928, Plate II).

The member consists of grey and purple sandstones and shales in units up to 25 m thick. Conglomerates are scarce and a few thin coal seams (the Misery series of HORN and ORVIN 1928) occur. Shales contain abundant plant fossils,

Fig. 3. *Cross-stratified sandstones with large scours filled by sandstone and shale. Flow directions to the north. Kapp Levin Member at Kapp Levin.*

and underclays are developed. The arrangement of lithologies in fining-up sequences indicates deposition by meandering rivers. Limited observations on cross-bedding indicate that currents flowed to the W, N, and E.

The underclays, coals, and shales at the top of the member are overlain sharply by conglomeratic sandstones of the Kapp Levin Member.

KAPP LEVIN MEMBER

This member is exposed around Kapp Levin and north to Schivebukta and is about 80 m thick.

Grey cross-stratified sandstones, conglomeratic sandstones, and conglomerates dominate the succession and shale is scarce (Fig. 3). The coarse textures, abrupt changes in grain-size and absence of well-defined fining-up sequences suggest deposition by braided streams. Palaeocurrents towards all directions but SW were recorded.

The coarse deposits which dominate this member are overlain by a 10 m thick shale sequence which marks the junction with the sandstones of the Tunheim Member.

TUNHEIM MEMBER

This member is exposed around Tunheim, the site of the mining camp where coal was produced from 1916 to 1925, and along the coast from Schivebukta to south of Kapp Olsen. The upper series of coal seams in the Røedvika Formation (the Tunheim Series of HORN and ORVIN 1928) occur in this member.

The member is about 80 m thick and consists of grey sandstones and shales with local conglomerates and coals. Sandstones are massive, cross-stratified, and parallel-laminated. As in the Vesalstranda Member, plant fossils are abundant in the shales, and underclays are developed. Well-defined fining-up sequences with sandstone units from 5 to 25 m thick are attributed to deposition by streams meandering across a densely vegetated flood-plain (Fig. 4). Cross-bedding indicates current flow to the NW, N, and NE.

The base of the member is defined by the onset of cyclic sedimentation. The Rifleodden Conglomerate Bed is a useful marker horizon which occurs within approximately 20 m of the base of the member. As indicated previously, the top of the member is not exposed.

NORDKAPP FORMATION

Name

The upper part of the "Ursa Sandstone" was called the Nordkapp Formation by CUTBILL and CHALLINOR (1965) after the northernmost point on Bjørnøya. As with the Røedvika Formation, no complete section exists through the formation at any single locality.

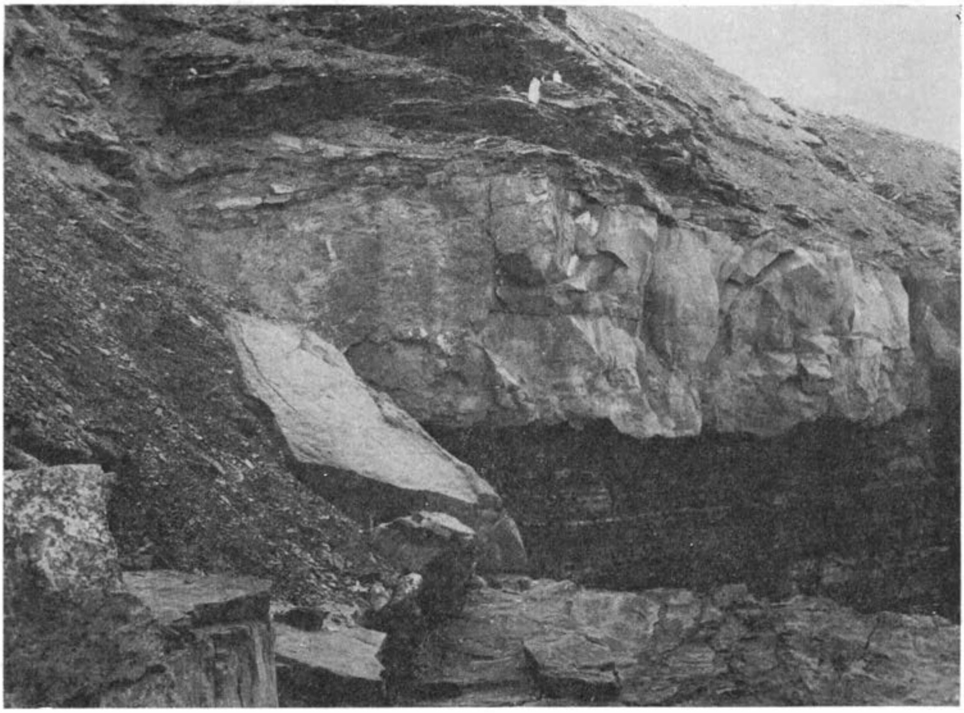

Fig. 4. *Fining-upwards sequence in the Tunheim Member north of Tunheim. The base of the sequence is marked by the erosive contact between a 6 m thick massive sandstone and the underlying shale containing the "A" coal of* HORN and ORVIN (*1928*).

Lithology and thickness

The formation consists of cross-bedded grey sandstones with occasional conglomerates and rare shales with thin coals. The thickness apparently increases northwards over a distance of about 11 km from 110 m at Ellasjøen to 230 m in a bore-hole at Haussvatnet (HORN and ORVIN 1928); faulting obscures the true thickness of the formation in exposures on the north coast.

Boundaries

Although the base of the formation is not exposed, the uniform development of sandstone contrasts with the cyclic development seen in the underlying Tunheim Member.

Extensive conglomerates occur in the upper part of the formation at Landnørdingsvika, just below the first red beds of the Landnørdingsvika Formation.

Age

The formation was first distinguished as a discrete part of the Ursa Sandstone on the basis of plant fossils found in a bore-core from Laksvatnet in 1916; these were dated as Lower Carboniferous by ANTEVS and NATHORST (1917). A microflora from the upper part of the formation at Nordkapp contains elements of the *aurita* assemblage of Spitsbergen; it was assigned to the

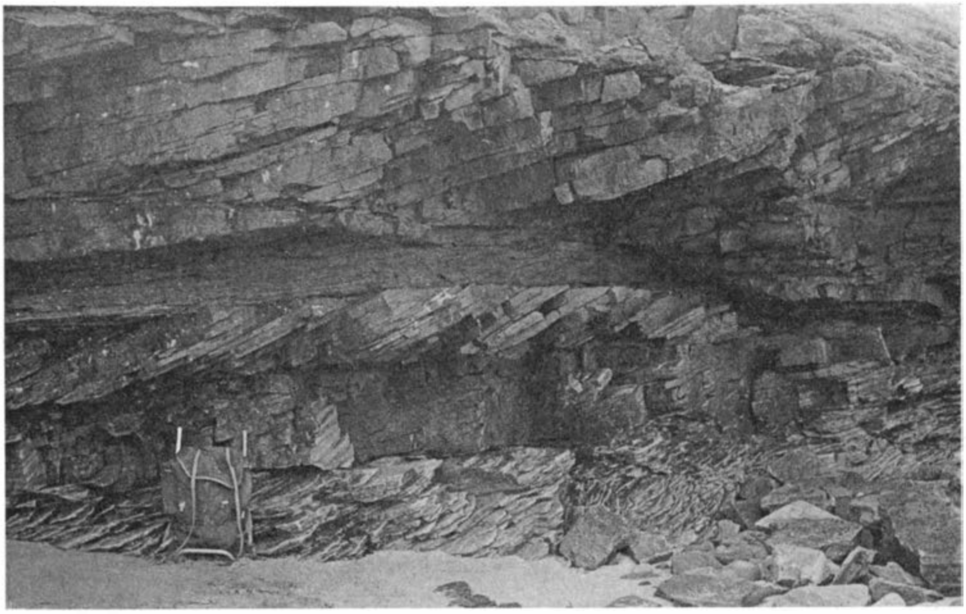

Fig. 5. *Cross-stratification in the Nordkapp Formation east of Nordhamna. The lenticular tabular cross-set in the middle of the picture shows asymptotic bases to the foresets. Uppermost is a large cross-set with reactivation surfaces. Flow directions to the east.*

Viséan by PLAYFORD (1962, 1963) and to the Namurian by CUTBILL and CHALLINOR (1965). KAISER (1970) reassigned this part of the formation to the Viséan. A coal seam of Upper Tournaisian age outcropping south of Ellasjøen probably belongs to this formation and not, as suggested by KAISER, to the Røedvika Formation.

Sedimentation

The uniform cross-bedded sandstones suggest deposition in eastward flowing braided streams (Fig. 5).

LANDNØRDINGSVIKA FORMATION

Name

A complete section through this formation is exposed at Landnørdingsvika. The name replaces "Red Conglomerate Series" of earlier workers.

Lithology and thickness

The lower part of the formation consists of friable red (and occasionally green) mudstones with occasional erosively based sandstone beds up to several metres thick. Cornstones and desiccation cracks are sparsely developed in the mudstones near the base. Conglomerates gradually appear approximately 40 m above the base; these are an important component of the upper part of the formation, mainly at the expense of mudstone. Both sandstone and conglomerate beds are often lenticular. The conglomerates are of fine pebble to fine cobble size, are moderately to poorly sorted, and consist mainly of dolomite, limestone, chert, and sandstone. The formation is 145 metres thick in Landnørdingsvika. HORN and ORVIN (1928) estimated a thickness of about 50 m on the north coast; however a 70 m thick succession in Nordhamna, assigned by them to the overlying Ambigua Limestone, is clearly a lateral equivalent of the Landnørdingsvika Formation in Landnørdingsvika. Thus the formation is at least 120 m thick on the north coast, and although faulting prevents any determination of true thickness, there is no evidence to suggest such large regional variation in the thickness of this formation as previously supposed. However, the northern development represents a more distal facies with little conglomerate and more fine-grained clastic material.

Boundaries

In Landnørdingsvika the base of the formation is placed at the appearance of red mudstones; the top is taken at the last prominent conglomerate bed; this occurs almost simultaneously with the appearance of carbonates in the rhythms typical of the overlying Kapp Kåre Formation. The upper contact on the north coast is obscured by faulting.

Age

Fossils found in the upper part of the formation, and the gradational upper contact, suggest a slightly older age than that of the overlying Moscovian Kapp Kåre Formation. This would indicate an appreciable break in deposition between the Nordkapp and Landnørdingsvika Formations, a conclusion supported by the sedimentological dissimilarity of the two formations.

Sedimentation

The vividly coloured sandstones and mudstones in the lower part of the succession at Landnørdingsvika are arranged in fining-up sequences which suggest deposition on an alluvial plain. The conglomerates in the upper part of the formation are likewise associated with fining-up rhythms and often occur in channels, or clearly erosive beds, so that these are also associated with channel deposition; however, alluvial fan deposits may also be represented. Scattered observations on cross-bedding indicate that currents were highly variable, but flowed mostly towards W, N, and E.

KAPP KÅRE FORMATION

Name

The type section is fully exposed in the cliffs of Landnørdingsvika (access only by boat) and on the coast around Kapp Kåre. The formation here approximates to the "Ambigua Limestone" of ANDERSSON (1900) and later workers; KRASILŠČIKOV and LIVŠIC (1974) renamed the unit as the Kobbebukta Formation, and included the exposures in Nordhamna in this formation (see above). The succession in Kobbebukta is obscured by faulting and we consider it more reasonable to use the south coast exposures as the standard section against which the partial northern exposures can be compared. The formation's earlier name refers to the occurrence of the brachiopod *Composita ambigua.*

Lithology and thickness

The formation is approximately 170 m thick in type section. Other exposures, on both the west and north coast, are fragmentary because of faulting. In type section the lower, Bogevika Member consists of alternations of carbonates, shales, and sandstones. These are overlain by cherty biomicrites assigned to the upper, Efuglvika Member.

Boundaries

The lower boundary in Landnørdingsvika is marked by the disappearance of thick conglomerates and the introduction of carbonates in the succession; isolated thin conglomerates do, however, occur in the lower part of the formation. The upper boundary is clearly marked to the north of Kapp Kåre by intraformational conglomerates which underlie the extrabasinal conglomerates of the Kapp Hanna Formation.

Age

Early workers assigned the Landnørdingsvika, Kapp Kåre, and Kapp Hanna Formations to the Middle Carboniferous. GOBBETT (1963) noted that the brachiopods of the Kapp Kåre Formation suggest a correlation with the Middle Carboniferous (Bashkirian/Moscovian) of the Moscow Basin. On the basis of fusulinids, CUTBILL and CHALLINOR (1965) and FLOOD et al. (1971) placed the formation entirely in the Upper Moscovian. This correlation is supported by studies on corals (FEDOROWSKI 1975) which, however, apparently were collected from intraformational conglomerates high in the formation, and not, as stated by FEDOROWSKI, "from the lower part of the so-called Ambigua Limestone".

Sedimentation

The formation was apparently deposited in lagoonal to open marine conditions. The lower, Bogevika Member represents restricted marginal environments, while the Efuglvika Member represents phases of marine carbonate deposition alternating with periods of silicification and erosion. Current patterns are complex, but the general development of the formation suggests more normal marine conditions to the NW.

BOGEVIKA MEMBER

This member is 90 m thick in type section in the cliffs of Landnørdingsvika and consists of limestones, dolomites, sandstones and shales. Many beds have a characteristic greyish-red colour, although greyish-green and variegated beds

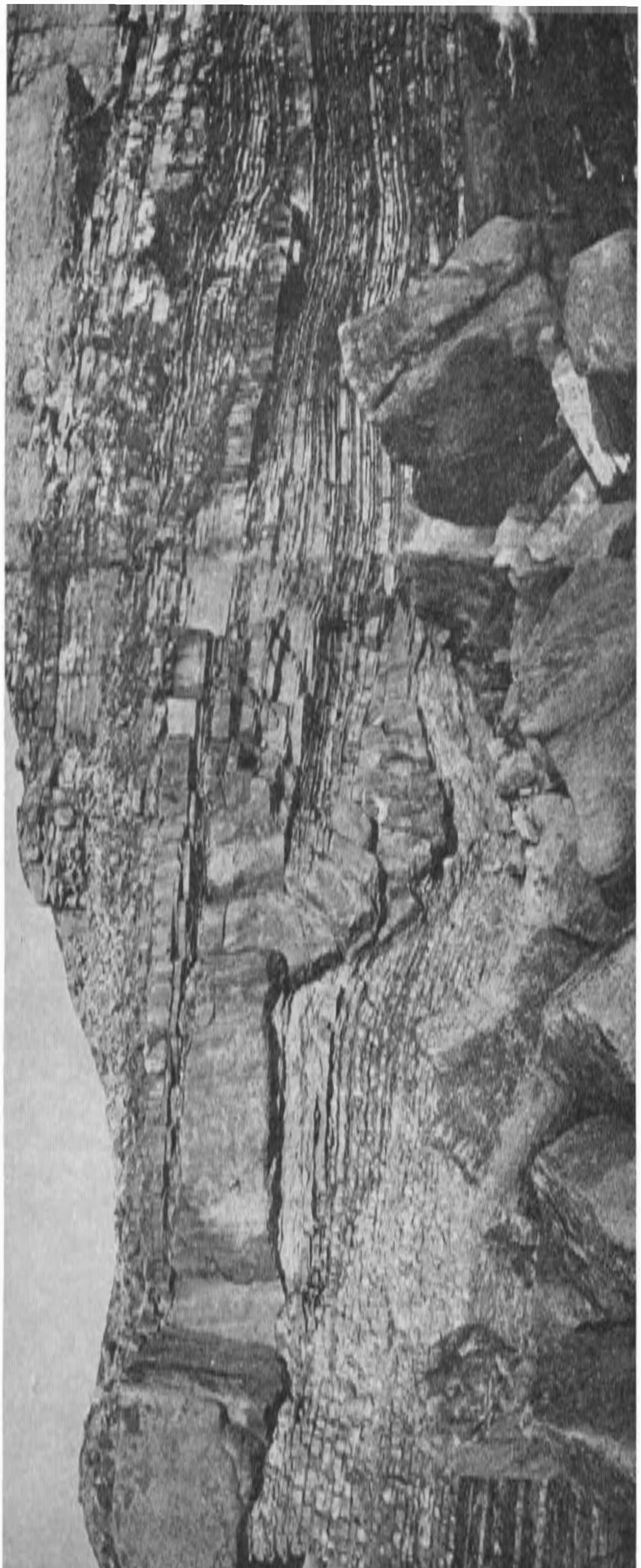

Fig. 6. *Facies variation and sedimentary structures in the upper part of the Efuglvika Member at Kobbebukta. About 20 m of section are exposed. Channels cutting into biomicrites and shales are filled with conglomerates which pass laterally into sandy limestones and shales (to the south).*

also occur. Pale grey biomicrites become more common upwards in the succession, and the junction with the overlying Efuglvika Member is taken where these occur to the virtual exclusion of shales and sandstones.

The upper part of the member is exposed in slightly more accessible cliff-sections in Bogevika, 2 km to the north of Landnørdingsvika. Exposures in the eastern part of Kobbebukta are also assigned to this member, but the succession here is dominated by grey rather than red beds.

The lithologies encountered in these localities often show well-developed rhythmic sequences of limestone, shale and sandstone in 3 to 8 m thick units. These rhythms probably originated in marginal marine environments, and the faunal associations seen suggest variation between marine and brackish water conditions: corals and brachiopods are locally abundant in the limestones and some shales, while shales and sandstones in the upper parts of the rhythms contain bivalves, gastropods, ostracodes, and plant remains. In the upper parts of the member in Landnørdingsvika and Bogevika, limestones with stenohaline faunas alternate with greyish-red shales with bivalves. Oncolitic limestones occur at several horizons.

EFUGLVIKA MEMBER

The member is fully exposed around Kapp Kåre, a promontory marking the western limit of Landnørdingsvika. It is also well exposed in the vicinity of Efuglvika and on the north coast in Kobbebukta.

In the Kapp Kåre section the member consists of 80 m of cherty biomicrites, but the thickness may vary regionally because of differential erosion of the top of the member. Massive cherty biomicrites occur in several metre thick units which are separated by thinly bedded biomicrites; the latter are associated with apparent erosion surfaces. Intraformational conglomerates at the top of the member contain both chert and, less commonly, limestone pebbles.

Exposures in Kobbebukta show a more complex development; several massive conglomerates occur, some of which show channelled bases and abrupt lateral facies changes (Fig. 6). Between the conglomerates are cherty biomicrites with marine faunas. Both chert and, to a lesser extent, fossils are found as intraformational debris in the conglomerates. As on the south coast, early silicification is suggested by the abundance of intraformational chert clasts.

KAPP HANNA FORMATION

Name

The formation outcrops for several kilometres along the north and west coasts. Minor faults, and undulating gentle dips have caused stratigraphic repetition so that a single type section cannot be designated. However, the salient features of the formation are well exposed in the vicinity of Kapp Hanna on the west coast. The formation was earlier called the "Yellow Sandstone".

Lithology and thickness

The formation is approximately 150 m thick and consists of medium-grained well-sorted sandstones with numerous conglomerates, dolomites, and shales. The conglomerates often contain both extra-basinal pebbles and chert clasts which apparently were derived from the underlying Kapp Kåre Formation.

Boundaries

The upper boundary is obscured by faulting on the west coast; on the northwest coast the boundary is taken at the appearance of the massive dolomites of the overlying Kapp Dunér Formation.

Age

The formation's age has been inferred from its relation to the under- and overlying units as the only fossils known until now were crinoid stems and a rugose coral found by HOLTEDAHL (1920). It is hoped that recent finds of corals, bivalves and plant fossils may aid correlation.

Sedimentation

The formation was apparently deposited in coastal and shallow marine environments. The coarse clastic sediments occur both in coarsening upwards sequences and in units with deeply erosive bases; both bar and channel facies are suggested. Fossils found in the shales suggest deposition in brackish lagoons with periodic marine incursions. The cements in the sandstones are varied; calcite, dolomite, and celestite have been identified. The latter is interesting in the context of the evaporitic environments suggested by SIEDLECKA (1972, 1975) in the overlying Kapp Dunér Formation.

KAPP DUNÉR FORMATION

Name

The carbonates formerly assigned to the "Fusulina Limestone" outcrop on the western coast of Bjørnøya over a distance of 8 km. Good exposures through the formation are seen in the cliffs on and around Kapp Dunér.

Lithology and thickness

Exposures indicate a minimum thickness of 75 m for this formation; its top is not seen, and the uppermost beds exposed dip gently seawards. Dolomites dominate the succession, but distinctive grey fusulinid biomicrites are also seen.

Boundaries

The upper boundary with the Hambergfjellet Formation is not exposed, but is clearly unconformable (see below).

Age

CUTBILL and CHALLINOR (1965) and FLOOD et al. (1971) assigned the formation to the Orenburgian zone of *Rugofusulina arctica*, possibly extending upwards into the Asselian.

Sedimentation

HOLTEDAHL (1920) noted "a compact layer, 15 metres thick, of a limestone of a peculiar brecciated character" in this unit. There are in fact three massive lenticular dolomites in the lower part of the exposed succession, and these are exposed for several kilometres along the western coast. Large coral colonies, bryozoan thickets, *Stromatactis* structures, and apparent intraformational conglomerates suggest that these beds represent a series of dolomitised shallow water carbonate banks. They apparently form the base of a partial section through the formation studied by SIEDLECKA (1972, 1975) and FOLK and SIEDLECKA (1974). These authors suggest predominantly sabhka and "schizohaline" (fluctuating hypersaline to fresh water) environments of deposition for the beds in this section. They also note the occurrence of some lagoonal deposits characterised by partially dolomitized biomicrites. The rich fossil content of such biomicrites (e.g. fusulinids, corals, brachiopods, gastropods and echinoderms) clearly indicates normal and probably vigorous marine environments in these lagoons. Likewise coral colonies and bryozoans seen in some of the "hypersaline" dolomite banks indicate either significant periods of normal marine conditions or that the mineralogical criteria used to interpret such hypersaline conditions are in fact a secondary and not a depositional feature of these bodies.

HAMBERGFJELLET FORMATION

Name

This formation is found only in the extreme southwest of the island where it oversteps all older formations from the Hecla Hoek to the Landnørdingsvika Formation (Fig. 7). The most accessible exposures occur on the eastern slopes of Hambergfjellet; lithologies and faunas can also be studied in land-slips immediately underneath these exposures in Ymerdalen. The unit has earlier been called the "Cora Limestone" because of the occurrence of the brachiopod *Linoproductus dorotheevi* (identified by ANDERSSON 1900, as *Productus cora*).

Lithology and thickness

The unit attains a maximum thickness of 50 m on Hambergfjellet, Fuglefjellet and Alfredfjellet; it wedges out eastwards so that the overlying Miseryfjellet Formation rests directly on the Røedvika Formation on Miseryfjellet. Basal pebbly sandstones are overlain by sandy limestones with corals. The middle of the unit consists of rubbly limestones with rich brachiopod faunas, and loose blocks studied indicate that biomicrites dominate the uppermost beds exposed.

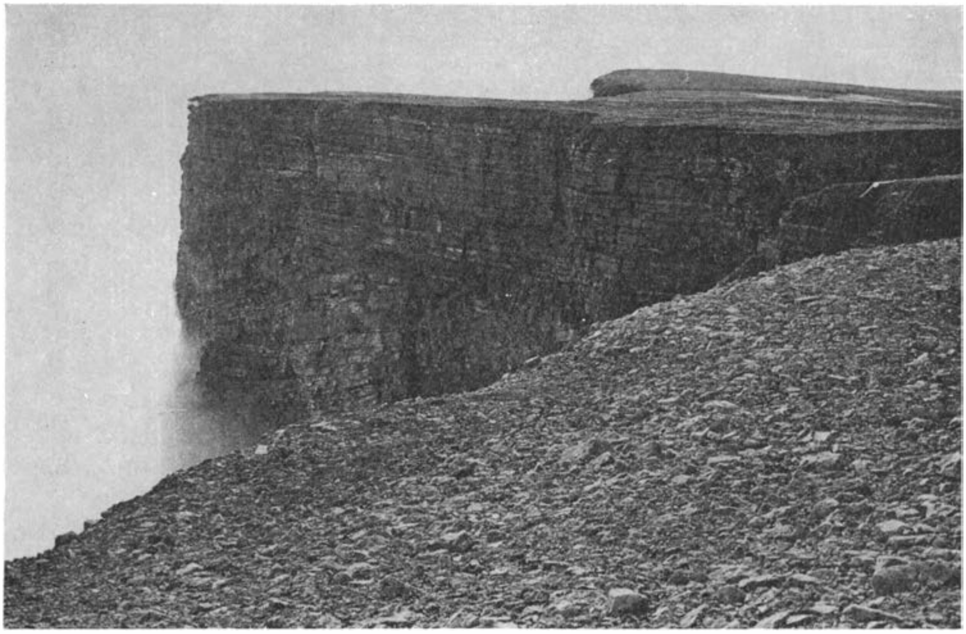

Fig. 7. *Gently dipping limestones of the Hambergfjellet Formation rest unconformably upon faulted sandstones and shales of the Røedvika Formation. About 30 m of the Hambergfjellet Formation are exposed. Western cliffs of Alfredfjellet.*

Boundaries

The formation has unconformable lower and upper boundaries. Deformation and extensive erosion occurred between the deposition of the Kapp Dunér and Hambergfjellet Formations. This erosion exposed Hecla Hoek rocks in the southern part of Bjørnøya and successively younger pre-Permian units westwards in the northern plain. Subsidence and deposition of the Alfredfjellet Formation was followed by warping and denudation prior to the deposition of the Miseryfjellet Formation.

Age

GOBBETT (1963) noted the similarity between the brachiopod fauna of this formation and that of the Upper Wordiekammen Limestone of Bünsow Land in Spitsbergen; he assigned both formations to the Sakmarian. CUTBILL and CHALLINOR (1965) and FLOOD et al. (1971) suggested a correlation with the Artinskian, but did not support this conclusion with any new faunal evidence. On this basis GOBBETT's correlation appears to be more tenable until our material has been evaluated, especially as we have found fusulinids in a loose block apparently derived from this unit (fusulinids have not been seen previously on Svalbard in rocks younger than the Sakmarian).

Sedimentation

The transgressive clastic deposits at the base of the formation are overlain by fossiliferous limestones indicative of normal marine environments.

MISERYFJELLET FORMATION

Name

Sections through the whole formation are only seen on the slopes of Miseryfjellet, although exposure in any single locality is poor. PČELINA (1972) used the name "Laksvatnet Formation" for this unit, but we consider this choice of name to be unfortunate as boreholes at Laksvatnet (HORN and ORVIN) show that only the basal 20 m of the formation occur here and exposure is minimal.

Lithology and thickness

The formation is fully developed only on the slopes of Miseryfjellet where it is approximately 115 m thick. Sandy and partially silicified biosparites dominate, although a 12 m thick quartzitic sandstone with a thin conglomerate at its top occurs 20 m above the base. The formation's lower parts are exposed on the north coast and in the southernmost mountains, and sections studied by SIEDLECKA (1972, 1975) represent the basal 12 to 15 m of the unit.

Boundaries

Basal local conglomerates and calcareous sandstones rest unconformably on various older units. On Miseryfjellet the top of the formation appears to be disconformably overlain by Triassic shales.

Age

The brachiopod faunas of the formation are similar to those of the Kapp Starostin Formation in Spitsbergen, suggesting a Kungurian and Upper Permian age. The upwards extent of deposition into the Upper Permian has not yet been satisfactorily resolved.

Sedimentation

The sandy biosparites of the formation suggest a high energy environment of deposition in shallow marine conditions. The sandstone unit mentioned above shows tabular cross-bedding directed to the south-east, and contains *Skolithos* burrows (see HOLTEDAHL 1926) and bivalves at certain horizons. This body may represent an offshore bank with cross-bedding directed shorewards.

An interesting ecological observation which has yet to be studied in detail is the large size of the brachiopods of the Miseryfjellet Formation compared to their counterparts in Spitsbergen and Greenland (DUNBAR 1955).

Discussion

It is expected that further investigation of material collected in the course of this study will improve correlation between Bjørnøya and Spitsbergen. Meanwhile, several general features of the Bjørnøya succession should be pointed out.

The Late Devonian to Early Permian sequence is relatively complete, with marine deposition first developed in the Moscovian Bogevika Member. The lower parts of the Røedvika Formation may represent the first deposits in Svalbard after the Svalbardian folding phase; corresponding deposits in Spitsbergen have been dated as Tournaisian and younger (PLAYFORD 1962, 1963). Continental conditions also appear to have prevailed longer on Bjørnøya – the Spitsbergen lithological equivalent of the Bogevika Member, the rhythmic Ebbadalen Formation, is of Namurian/Bashkirian age (HOLLIDAY and CUTBILL 1972).

Further studies should investigate whether the conglomerates of the Efuglvika Member and Kapp Hanna Formation represent major breaks in sedimentation. Otherwise, sedimentation rates in the Upper Carboniferous of Bjørnøya were apparently intermediate between the extremes seen in the contemporaneous block and trough deposits of Spitsbergen. The 400 m thick sequence of the Kapp Kåre, Kapp Hanna, and Kapp Dunér Formations was deposited entirely in shallow, often marginal conditions; an arid climate towards the end of the depositional period is suggested by SIEDLECKA (1972, 1975). This long depositional phase was followed by deformation and uplift at some time in the early Permian. Uplift and erosion in the order of 1–2 km has occurred in southern Bjørnøya where the Hambergfjellet Formation rests directly on the Hecla Hoek. In Spitsbergen tectonic activity in the Mid-Carboniferous is marked by a complex system of fault-bounded troughs and blocks which probably represent readjustment after the Svalbardian folding phase. However, post-Moscovian deposits indicate increasing crustal stability (HARLAND 1969) and the early Permian deformation on Bjørnøya is not seen in the central parts of Spitsbergen. Nevertheless, deposits of Namurian to Kungurian age are missing on Sørkappland, while deposition in the same period in Hornsund was apparently discontinuous. It is not yet certain whether these breaks result simply from non-deposition or whether erosion of previously deposited sediments also occurred here.

The two Permian formations on Bjørnøya are much thinner than their counterparts in Spitsbergen. This probably reflects breaks in deposition rather than low sedimentation rates. There was a second, as yet undefined, period of renewed uplift and erosion between the deposition of the two formations; the magnitude of the break in sedimentation above the Miseryfjellet Formation is also uncertain. The Artinskian of Spitsbergen is characterised by the evaporites of the Gipshuken Formation; such deposits are not seen on Bjørnøya, although probable evaporitic diapirs of this age occur further south in the Barents Sea in the Tromsø basin (RØNNEVIK et al. 1975).

This Upper Palaeozoic sequence was deposited entirely in continental and coastal environments. Both thickness and facies changes, and current patterns through much of the succession indicate a general northerly palaeoslope, suggesting that Bjørnøya lay on the southern margins of a depositional basin which is probably preserved in the Barents Shelf between Bjørnøya and Spitsbergen.

References

ANDERSSON, J. G., 1900: Über die Stratigraphie und Tektonik der Bären Insel. *Bull. geol. Inst. Univ. Uppsala* **4**. 243–280.

ANTEVS, E. and A. G. NATHORST, 1917: Kohlenführende Kulm auf der Bären-Insel. *Geol. För. Stockh. Förh.* **39**. 649–663.

CUTBILL, J. L. and A. CHALLINOR, 1965: Revision of the stratigraphical scheme for the Carboniferous and Permian rocks of Spitsbergen and Bjørnøya. *Geol. Mag.* **102**. 418–439.

DUNBAR, C. O., 1955: Permian brachiopod faunas of Central East Greenland. *Medd. Grønland* **110**. No. 3.

FEDOROWSKI, J., 1975: On some Upper Carboniferous Coelenterata from Bjørnøya and Spitsbergen. *Acta. geol. Polon.* **25**. 27–78.

FLOOD, B., J. NAGY, and T. S. WINSNES, 1971: Geological Map Svalbard 1:500.000. Sheet 1G Spitsbergen, Southern part. *Norsk Polarinstitutt Skrifter* Nr. 154A, Oslo.

FOLK, R. L. and A. SIEDLECKA, 1974: The "schizohaline" environment: its sedimentary and diagenetic fabrics as exemplified by late Paleozoic rocks of Bear Island, Svalbard. *Sedimentary Geology* **11**. 1–15.

GOBBETT, D. J., 1963: Carboniferous and Permian brachiopods of Svalbard. *Norsk Polarinstitutt Skrifter* Nr. 127, Oslo.

HARLAND, W. B., 1969: Contribution of Spitsbergen to Understanding of Tectonic Evolution of North Atlantic Region. 817–851 in "North Atlantic Geology and Continental Drift" (M. KAY, ed.). *Am. Ass. Petrol. Geol. Mem.* **12**. Tulsa.

HOLLIDAY, D. W. and J. L. CUTBILL, 1972: The Ebbadalen Formation (Carboniferous), Spitsbergen. *Proc. Yorks. Geol. Soc.* **39**. 1–32.

HOLTEDAHL, O., 1920: On the Palaeozoic Series of Bear Island, especially on the Heclahook system. *Norsk geol. Tidsskr.* **5**. 121–148.

— 1926: A "Pipe-Rock" in the Upper Carboniferous of Bear Island. *Norsk geol. Tidsskr.* **8**. 270–280.

HORN, G. and A. K. ORVIN, 1928: Geology of Bear Island. *Skr. Svalb. og Ishavet* Nr. 15.

KAISER, H., 1970: Die Oberdevon-Flora der Bäreninsel 3. Mikroflora des höheren Oberdevons und des Unterkarbons. *Palaeontographica Abt. B* **129**. 71–124.

— 1971: Die Oberdevon-Flora der Bäreninsel, 4. Mikroflora der Misery-Serie und der flözleeren Sandstein-Serie. *Palaeontographica, Abt. B* **135**. 127–164.

KRASILŠČIKOV, A. A. and JU. JA. LIVŠIC, 1974: Tektonika ostrova Medvežij (Tectonics of Bjørnøya). *Geotektonika* 1974 No. 4. 39–51.

PČELINA, T. M., 1972: Triassovye otloženija ostrova Medvez'ego (Trias deposits of Bjørnøya). **In**: "*Mezozojskie otloženija Sval'barda*" (*Mesozoic deposits of Svalbard*). Eds. SOKOLOV and VASILEVSKAJA NIIGA, Leningrad. 5–20.

PLAYFORD, G., 1962, 1963: Lower Carboniferous microfloras of Spitsbergen. *Palaeontology* **5**. 550–678.

RØNNEVIK, H., E. BERGSAGER, A. MOE, O. ØVREBØ, T. NAVRESTAD and J. STANGENES, 1975: The geology of the Norwegian Continental Shelf. **In**: *Petroleum and the Continental Shelf of North-West Europe* (ED. A. W. WOODLAND). 117–129.

SIEDLECKA, A., 1972: Length-slow chalcedony and relicts of sulphates: evidences of evaporitic environments in the Upper Carboniferous and Permian beds of Bear Island, Svalbard. *J. Sediment. Petrol.* **42**. 812–816.

— 1975: The petrology of some Carboniferous and Permian rocks from Bjørnøya, Svalbard. *Norsk Polarinstitutt Årbok* 1973. 53–72.

Depositional environments in Lower Cretaceous regressive sediments, Kikutodden, Sørkapp Land, Svalbard[1]

By Marc B. Edwards[2]

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Abstract

The change from deposition of marine shales in the Rurikfjellet Formation to variegated continental sediments in the Helvetiafjellet Formation represents a major regression seen in the Lower Cretaceous throughout Svalbard. At Kikutodden, on the south coast of Sørkapp Land, the marine unit includes in its upper part regressive coarsening-up sequences, while the continental unit consists of erosively-based fining-up sequences formed by channel migration on an alluvial plain.

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The relative thinness or absence of corresponding shallow marine deposits between the quiet marine shales of the Rurikfjellet Formation and the continental Helvetiafjellet Formation elsewhere in Spitsbergen may be due to differing subsidence rates, mud accumulation on the delta, or to erosion during the regression.

The similarity of these sandstones, in environment of deposition and stratigraphic relationships, to petroleum-producing sandstones in other areas suggests their potential as reservoir rocks where the effects of the Tertiary orogeny were moderate.

Introduction

In the summer of 1973, the author examined Lower Cretaceous rocks excellently exposed at Kikutodden, south of Keilhaufjellet, Sørkapp Land (Figs. 1 and 2). A profile 215 m long was measured, including the upper part of the marine Rurikfjellet Formation in the lower 155 m, and the lower part of the continental Helvetiafjellet Formation in the upper 60 m (Fig. 3).

The profile was graphically recorded on special forms designed for field use. In addition cross-bedding orientations were measured, and specimens of sandstones were taken for thin-section analysis. Of sedimentological interest are coarsening-up (CU) sequences in the Rurikfjellet Formation and fining-up (FU) sequences in the Helvetiafjellet Formation. This is the first detailed account of the sedimentary structures and environments of deposition of these strata to be published.

This investigation was carried out as part of the Barents Sea Project, involving the cooperation of the Norsk Polarinstitutt, the Continental Shelf Division of NTNF, and other Norwegian research institutions. The purpose of these

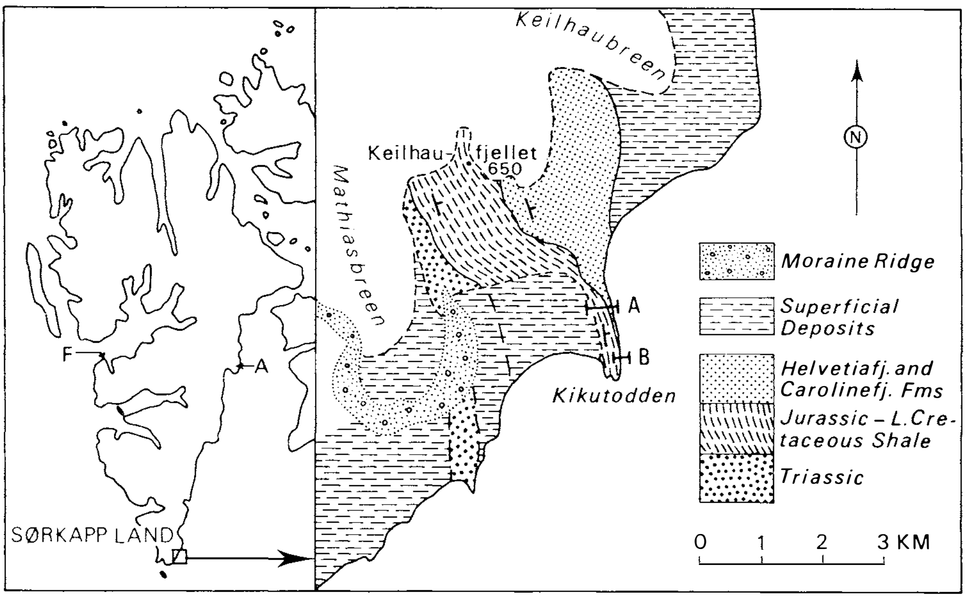


Fig. 1. *Location map (left) and geological map (right) of the study area. Additional localities shown on the left are Festningen (F) and Agardhfjellet (A). On the right, "A" refers to the long measured section (Fig. 4) and "B" refers to the short measured section (Fig. 7).*

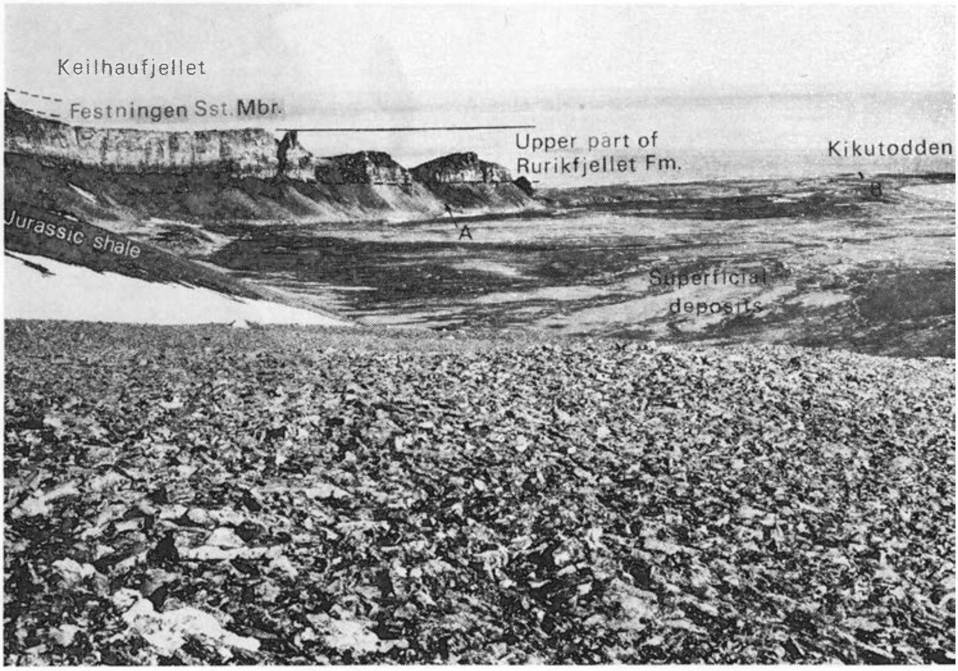


Fig. 2. *View, from the west, of the south end of Keilhaufjellet and Kikutodden. "A" and "B" as in Fig. 1.*

field studies is to obtain stratigraphic, sedimentologic and paleontologic reference material from land areas bordering the Barents Sea. It is anticipated that this data will be essential in evaluating the geological material recovered from the adjacent Barents Shelf.

Rurikfjellet Formation

Throughout Spitsbergen, black shale with clay ironstone nodules is the characteristic lithology of the Rurikfjellet Formation. However, at Keilhaufjellet, and other localities in western Spitsbergen, sandstones, occasionally conglomeratic, are present in the upper part (PARKER 1967). This sandy facies has been termed the '"Ullaberget Series" by ROZYCKI (1959), and has also been noted by other workers (HOEL and ORVIN 1937, PČELINA 1965). The 155 m measured at Keilhaufjellet represents approximately half of the total thickness of the formation.

Sedimentologically, the upper half of the Rurikfjellet Formation includes three CU sequences (Fig. 4, following between pp. 40—41). No body fossils were seen.

Lower CU sequence

The profile begins at the lower limit of exposure in a silty mudstone coarser than the shales typical of the lower part of the Rurikfjellet Formation.

The 50 m visible in the lower fine part of the sequence shows the following upward gradual changes: increase in sandstone grain size from silty very fine-

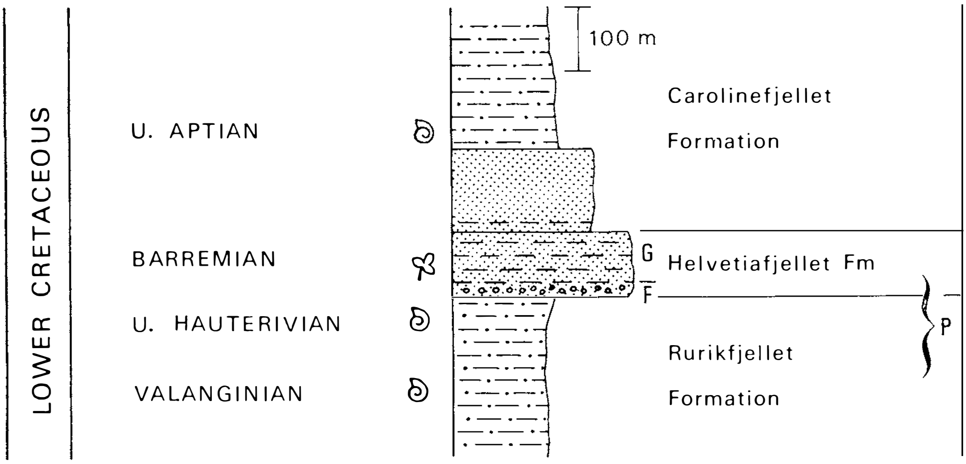


Fig. 3. *Representative profile through part of the Lower Cretaceous sequence of Spitsbergen (based on* PARKER *1967).*

grained to medium-grained, increase in sand/shale ratio from 1/10 to shale absent, increase in sandstone bed thickness from thin (1–5 cm) to medium (c. 25 cm), and ripple cross-lamination and parallel lamination are replaced by cross bedding and parallel lamination with occasional scours.

In the upper coarse part of the sequence cross-bedding is the dominant sedimentary structure, and the weathering of the sandstone is massive. The coarse part consists of three sandstone units: a lower unit with predominant trough cross-bedding and fine gravel conglomerate at the top, a middle unit with thin to medium beds of parallel-laminated and cross-bedded sandstone, and an upper massive unit. A distinctive feature is a vertical rod structure, apparently a rootlet or burrow (Fig. 5). The rods are widely spaced, up to about 1 m in length and several millimeters in diameter. They appear to consist of dark grey, possibly clayey, sandstone not cemented by silica as is the encasing sandstone. It occurs in both cross-bedded and massive sandstones.

Cross-bedding orientations in the lower CU sequence show bimodal, bipolar distributions (Fig. 4) indicating current flow to S-SE, and N-NW.

Middle CU sequence

The base of this sequence rests sharply on the underlying sequence (Fig. 6). The fine part is similar to the lower part of the underlying CU sequence. Similarly it grades up into cross-bedded sandstone (Fig. 4).

A rapid increase in grain size marks the transition to the coarse part, which is a complex of massive and cross-bedded sandstones with several fine-gravel conglomerate horizons. Rod structures are prominent in association with conglomerate-bearing sandstones.

Trough cross-bedding orientations are unimodal and bimodal, indicating current flow mainly to the SE and NW.

Fig. 5. *Rod structures, vertical burrows or rootlets, in cross-bedded and massive sandstones in the upper part of the lower CU sequence, at Kikutodden (see Fig. 4).*

Upper CU sequence

The interval between the topmost exposed sandstone of the middle CU sequence and the base of the Helvetiafjellet Formation is 23 m, most of which is unexposed where the main profile was measured. The upper half of this interval is well exposed near the tip of Kikutodden (Figs. 1 and 2).

The basal 2 m of this profile (Fig. 7), bioturbated dark grey silty mudstone with very fine sandstone lenses and lenticular beds (Fig. 8), is similar in appearance to the basal parts of the lower and middle CU sequences. Through a 1 m transition (Fig. 9) it passes into parallel-laminated and low angle cross-bedded very fine sandstone with irregular mudstone partings (Fig. 10). Eroding into these sandstones is a thin layer of poorly sorted coarse sandstone which is sharply overlain by mottled, greenish grey, silty mudstone, which is pyritiferous and strongly bioturbated, and contains thin, lenticular beds of fine and coarse sandstone (Fig. 11). Silicified wood was found in mudstones below and above the poorly sorted coarse sandstone.

The contact between the Rurikfjellet and Helvetiafjellet Formations is sharp (Fig. 4).

Helvetiafjellet Formation

The two-fold subdivision of this formation into the lower Festningen Sandstone Member and the upper Glitrefjellet Member is persistent over all of

Spitsbergen (Orvin 1940), including the present study area at Keilhaufjellet. The lower member, 20–25 m thick, is recognised at a distance by its whitish, yellow-orange weathering color. At Kikutodden, only the basal 35 m of the c. 80–100 m thick Glitrefjellet Member was observed.

Festningen Sandstone Member

This member consists of medium to coarse-grained quartz sandstone with additional pebble conglomerate at several levels. The pebbles are well rounded and consist mostly of vein quartz and chert. Cross bedding is ubiquitous in sets up to 1 m thick including both tabular (Fig. 12) and trough varieties. Overturned cross bedding (Fig. 13) is rare. Apparent massive beds are seen mainly in association with conglomeratic sandstone. Primary current lineation is visible in some parallel-laminated beds (Fig. 14).

The Festningen Sandstone shows a locally developed FU sequence in the lower 7 m which includes a massive conglomeratic sandstone at the base, cross-bedded sandstone in the middle, and thin-bedded, rippled sandstone with shale intercalations at the top (Fig. 4). The latter is erosively overlain by conglomeratic sandstone. The orientation of cross bedding in the member generally indicates current flow to the SE and E.

Glitrefjellet Member

The basal 35 m of this member consists of alternating sandstone and shale units arranged in FU sequences, with subsidiary conglomerate and coal. Bases

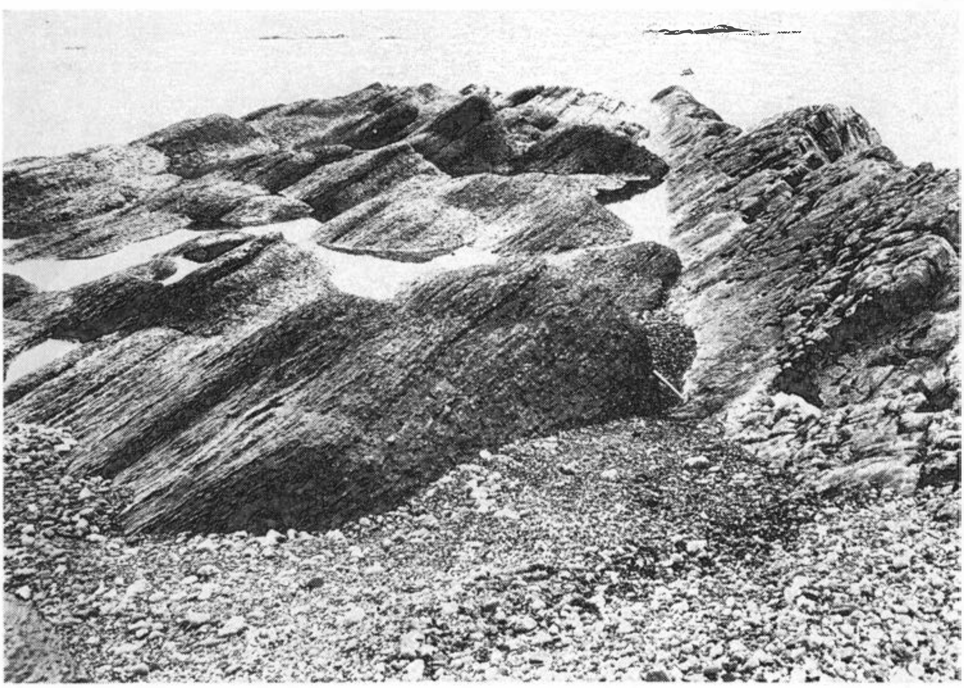


Fig. 6. *Sharp boundary between the lower and middle CU sequences at Kikutodden (see Fig. 4).*

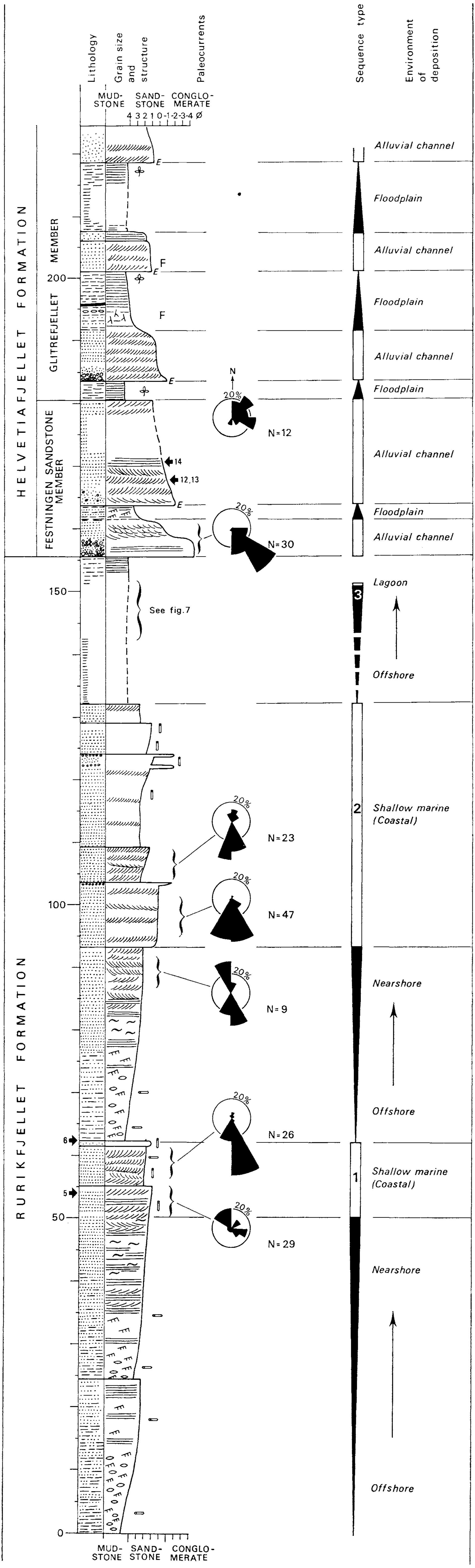


Fig. 4. *Sedimentology of the long measured profile ("A" in Figs. 1 and 2). Legend on p. 41.*

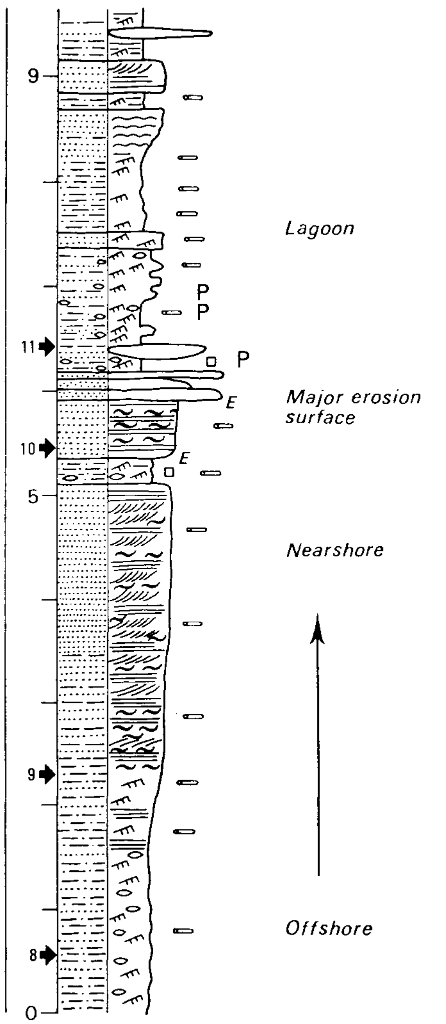
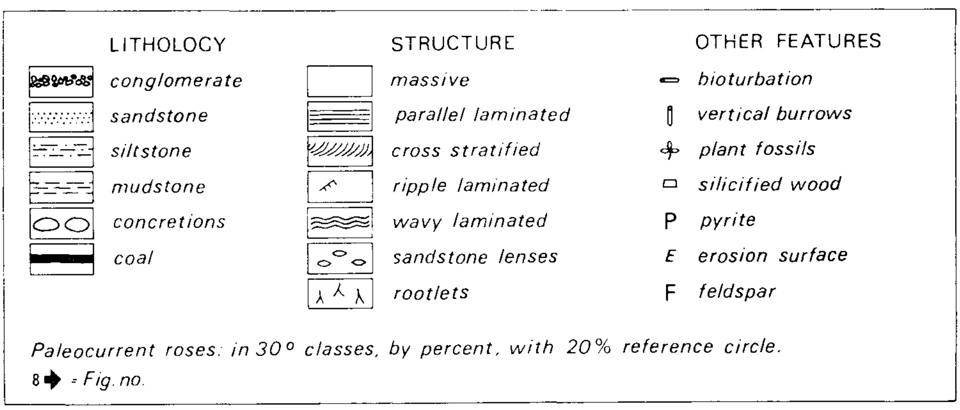


Fig. 7. *Sedimentology of the short profile, through the upper CU sequence ("B" in Figs. 1 and 2).*



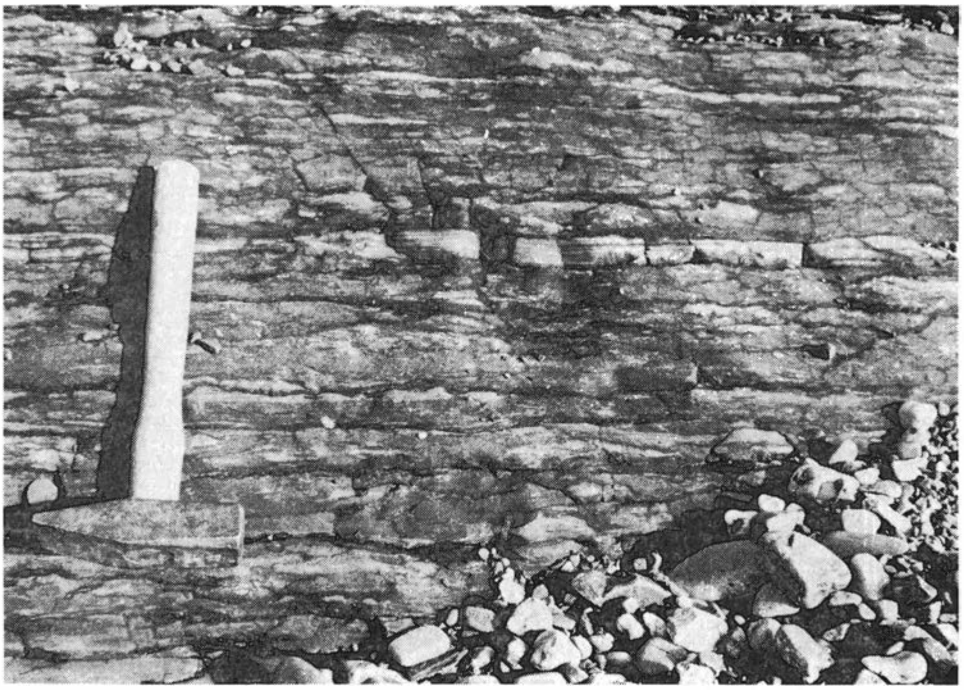


Fig. 8. *The basal facies of the upper CU sequence: bioturbated silty mudstone with lenticular sandstone beds, at Kikutodden (see Fig. 7).*

Fig. 9. *Transitional zone in the upper CU sequence: rippled sandy siltstone with mudstone partings passes up into parallel-laminated and cross-bedded very fine sandstone (see Fig. 7).*

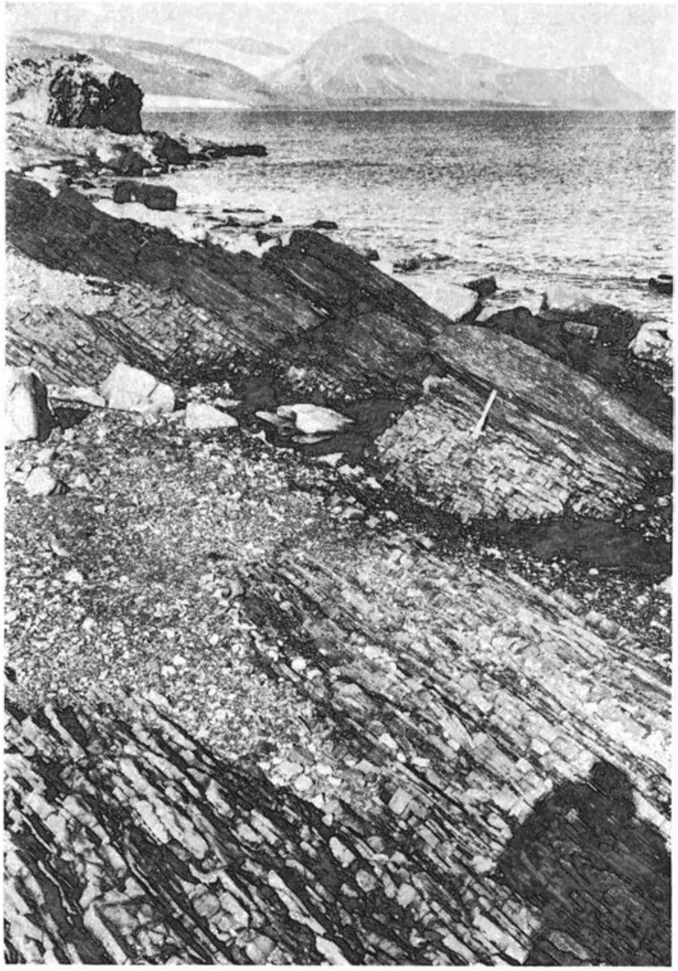


Fig. 10. *Upper part of the upper CU sequence. The coarse sandstone layer is directly beneath the hammer. Below is cross-bedded and parallel-laminated very fine sandstones. Above is mottled silty mudstones with lenticular sandstones. The Festinengen Sandstone is seen in the left background. Kikutodden.*

of sandstones are erosive and often conglomeratic. Medium-scale cross bedding is the dominant structure; parallel stratification is also present.

Sandstone units grade rapidly up into dark shales containing sandstone interbeds, thin coal seams, claystone concretions, rootlets, and plant fossils.

Preliminary measurements of cross-bedding orientations indicate that currents flowed approximately to the SE.

Depositional environment and geological history

The change from marine to continental sedimentation represented across the Rurikfjellet–Helvetiafjellet Formations has generally been attributed to a major regression (Hagerman 1925, Orvin 1940). Although this lithological change is abrupt, it has been considered to be conformable (Hagerman 1925; Parker 1967) in spite of the occurrence of nodules derived from the Rurikfjellet Formation in conglomerates of the Festningen Sandstone (PARKER 1967). The coarse-grained upper part of the Rurikfjellet Formation is thought to be a shallow marine-deltaic deposit formed and preserved during the regression.

Rurikfjellet Formation

Vertical changes in texture and sedimentary structures in the fine parts of the CU sequences reflect a gradual shift from suspension to traction deposition. The structures indicate the increasing effectiveness of waves and currents upwards. Similar sequences have been interpreted as due to shoaling and/or the approach of a shoreline (e.g. MACKENZIE 1965, MASTERS 1967, READING 1970).

The following conditions of sedimentation are suggested for the coarse parts of these cycles; high energy, by massive and trough cross-bedded, medium to coarse, well-sorted sandstone with fine gravel concentrates; tidal, by bimodal, bipolar current regime (KLEIN, 1967); very shallow, or emergent, by rod structures, whether burrows (SEILACHER, 1967) or rootlets. Thus, these sandstones were deposited in a high energy, coastal environment.

The sharp upper surface of the lower CU sequence, overlying a bioturbated sandstone, suggests a rapid change from agitated nearshore marine to quiet offshore conditions with no attendant deposition of sediment. A relative rise in sea-level with a cutting off of the sediment supply is one possible explanation for such a change.

The upper small-scale CU sequence contrasts with the others in that the transitional zone from silty mudstones up into very fine sandstones is relatively thin

Fig. 11. *Close-up of mottled silty mudstone resting sharply on the coarse sandstone layer (see Fig. 7).*

Fig. 12. *Thick, tabular cross-set in the Festningen Sandstone Member at Kikutodden (flow approximately to the E).*

Fig. 13. *Overturned cross-bedding in the Festningen Sandstone Member at Kikutodden. Note Asymptotic base of set. Flow was approximately to the SE.*

(c. 1 m) and in place of an upper coarse part, the fine sandstones are erosively truncated by a thin, poorly sorted sandstone bed. The extensive bioturbation, pyrite, and intercalated various sandstones in the uppermost mottled mudstones distinguish them from the basal silty mudstones. The latter closely resemble the basal parts of the lower two CU sequences and are thought to be offshore quiet water deposits. Those at the top appear to have been deposited in a restricted nearshore environment, most likely a lagoon.

Thus, this CU sequence represents shallowing, but abruptly terminated with erosion, and followed by lagoonal rather than renewed offshore sedimentation. A possible mechanism for the interruption of nearshore by lagoonal sedimentation is the formation of a seaward barrier, as has been shown in Pleistocene sediments by HOYT et al. (1964).

These authors described the establishing of a barrier several kilometres wide and about 10 km offshore as a response to a fall in sea-level of about 3–4 m. During the growth of the barrier in the course of a temporary still-stand of sea-level, a lagoon formed landward of the barrier, and was filled with sediment. We can envisage the fall in sea-level causing the formation of a thin CU sequence, and ultimately sweeping in coarse material in very shallow water, with concommitant erosion. On this coarse pavement, lagoonal deposits were laid down, during the growth of the barrier. This inferred sequence of deposits is thought to closely resemble the sequence occurring at the top of the Rurikfjellet Formation, and to have formed in a similar manner. It is the last stage preserved in the regression before the establishing of continental conditions.

The bipolar cross bedding orientations from the coarse parts of the CU sequences may reflect deposition in one or more sub-environments affected by tidal currents (REINECK 1963). It could not be determined whether these currents flowed parallel, normal, or oblique to the coastline.

Thickening of the Rurikfjellet Formation in the west (PARKER 1967) suggests that tectonic changes may have occurred around the time represented by the Rurikfjellet–Helvetiafjellet Formation boundary. It is therefore not considered justifiable at this stage to compare the paleocurrents of these two formations. Further detailed studies on the relationship between these formations are needed.

In summary, the upper part of the Rurikfjellet Formation was deposited along a coastline dominated by waves and tidal currents. Sand was transported and deposited in the nearshore zone, and possibly in barriers, while silt and clay were deposited in the offshore zone and in lagoons.

Helvetiafjellet Formation

The sediments of the Helvetiafjellet Formation are characterised by the presence of erosively based FU sequences. Continental deposition is attested to by the presence of plant fossils, coals, rootlets and freshwater molluscs (PARKER 1967). Such cycles are a typical product of the lateral migration of a meandering river across a floodplain (e.g. ALLEN 1965). Cross bedding orientations suggest that rivers flowed generally SE or E.

Fig. 14. *Primary current lineation in parallel-laminated beds of the Festningen Sandstone Member at Kikutodden (aligned approximately SE-NW).*

Junction between Rurikfjellet and Helvetiafjellet Formations

The environmental interpretations presented above indicate that some erosion must have occurred along this boundary. While erosion is a normal process beneath deltaic tidal and distributary channels, this does not typically remove a marine CU sequence which may be up to 30–40 m thick in recent deltas (OOMKENS 1970, WEBER 1971). The relatively thin FU sequences in the Helvetiafjellet Formation at Keilhaufjellet suggest that the rivers were too small to have caused deep erosion. Thus the apparent absence of a well-developed CU regressive sequence along this boundary over most of Spitsbergen could signify a relative lowering of sea-level, with an associated drop in fluvial base level and attendant erosion. On the other hand, the presence of a thin CU development at the boundary could suggest either a substantially lower subsidence rate, or a depositional site characterised by mud accumulation during the regression. Such thin sequences occur at Agardhfjellet (not indicated in the type section given by PARKER (1967, Fig. 2)), and at Festningen in Isfjord.

Observations cited by ORVIN (1940, p. 34) suggest a discordance between the marine and continental Cretaceous based on paleontological evidence, in an area where the Festningen sandstone is thought to be absent (Kong Karls Land, eastern Svalbard).

Discussion

Bearing on the age of the sequence

The age of the Helvetiafjellet Formation has generally been inferred from the adjacent fossiliferous marine deposits (Fig. 3). The uppermost part of the Rurikfjellet Formation has yielded Upper Hauterivian ammonites (PČELINA 1965, PARKER 1967). The lower part of the Carolinefjellet Formation has been assigned an Upper Aptian age (PARKER 1967). Following earlier workers, recent studies of the plants and spores in the Helvetiafjellet Formation indicate a Neocomian age, probably Hauterivian-Barremian (PČELINA 1965b, c), although MAYNC (1949) suggested an Aptian age.

From the description of PČELINA (1965a, b) the Hauterivian deposits of central and western localities appear to be somewhat coarser than the older parts of the Rurikfjellet Formation. Thus, they may correspond to the lower part of the present profile.

As mentioned above, the variation in thickness of the regressive sediments may be due to factors other than erosion. Thus it is not possible at this stage to draw any conclusions concerning the age of the sediments based on the sedimentological evidence alone.

Geometry of the Festningen Sandstone

The Festningen Sandstone occurs throughout Spitsbergen wherever the junction between the marine and continental Lower Cretaceous is observed (ORVIN 1940). This wide distribution and a general thickness of 5–25 m gives rise to a sheet-like geometry. The interpretation of the Helvetiafjellet Formation as a series of fluvial channel sandstones, and the observation of a thin FU sequence within the Festningen Sandstone at Kikutodden suggests that the Sandstone is multistory and multilateral.

Nevertheless, the Sandstone is readily distinguished in the field by its lighter weathering color. Thin-sections show that the Festningen Sandstone is locally clay-free, and the overlying sandstones have a higher interstitial clay content. The distinct color might be due to diagenesis. Rivers which deposited the Festningen Sandstone eroded into marine sediments, while later river's were eroding into their own floodplain deposits.

Economic considerations

There is a certain similarity between the present regressive sequence, and regressive sequences in the Upper Cretaceous of the Rocky Mountains which contain petroleum-producing sandstones (WEIMAR 1970) formed in shallow marine and alluvial environments.

The sandstones in the upper part of the Rurikfjellet and in the Helvetiafjellet Formations may be considered as potential reservoir rocks in areas where silica cementation is not too extensive. It is possible that more porous sandstones at this stratigraphic level may exist towards the east and south where the effects of the Tertiary orogeny are substantially reduced.

A study of the gravel on the Spitsbergen Bank, about 200 km south of Sørkapp Land suggested that the Mesozoic formations, including the Helvetiafjellet Formation, extend to the Spitsbergen Bank (EDWARDS 1975), thus strengthening the offshore possibilities.

In this context, the inferred development of a barrier to the S or SE of Sørkapp Land is of interest, if the barrier were preserved during the regression.

Conclusions

At Kikutodden, Sørkapp Land, the upper part of the Rurikfjellet Formation contains shallow marine/deltaic sediments transitional between the lower, quiet marine part of the Rurikfjellet Formation and the continental Helvetiafjellet Formation. The latter was deposited in channels and floodplains on an alluvial plain.

The regional variation in thickness of the regressive coarse sediments may be due to varying rates of subsidence, lateral facies changes, or to erosion during the regression.

The existence of sandstones of the described stratigraphic interval in areas less affected by the Tertiary orogeny is of economic interest. Further work on the Mesozoic paleogeography of Svalbard is required to point out source areas and depositional sites for potential economically significant sandstone bodies.

Acknowledgements

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References

ALLEN, J. R. L., 1965: Fining-upwards cycles in alluvial successions. *Geol. J.* **4**, 229–246.

EDWARDS, M. B., 1975: Gravel fraction on the Spitsbergen Bank, NW Barents Shelf. *Norges geol. Unders.* **316**. 205–217.

HAGERMAN, T. H., 1925: Results of the Swedish expedition to Spitsbergen 1924. II. Stratigraphic and structural investigations within south-western Spitsbergen. *Geogr. Annal.* **7**, 195–221.

HOEL, A. and A. K. ORVIN, 1937: Das Festungsprofil auf Spitsbergen. Karbon-Kreide. I. Vermessungsresultate. *Skrifter om Svalbard og Ishavet.* Nr. 18. 59 p.

HOYT, J. H., R. J. WEIMER, and V. J. HENRY Jr., 1964: Late Pleistocene and Recent sedimentation, central Georgia coast, U.S.A. **In**: *Developments in Sedimentology* (Ed. L. M. J. U. VAN STRAATEN), *Deltaic and Shallow Marine Deposits*. pp. 170–176.

KLEIN, G. DE V., 1967: Paleocurrent analysis in relation to modern marine sediment dispersal patterns. *Amer. Assoc. Petrol. Geol. Bull.* **51**, 366–383.

MACKENZIE, D. B., 1965: Depositional environments of Muddy Sandstone, Western Denver Basin, Colorado. *Amer. Assoc. Petrol. Geol. Bull.* **49**, 186–206.

MASTERS, C. D., 1967: Use of sedimentary structures in determination of depositional environments, Mesaverde Formation, Williams Fork Mountains, Colorado. *Amer. Assoc. Petrol. Geol. Bull.* **51**, 2033–2043.

MAYNC, W., 1949: The Cretaceous beds between Kuhn Island and Cape Franklin (Gauss Peninsula), Northern East Greenland. *Medd. Grønland.* **133**, Nr. 3.

OOMKENS, EPPO, 1970: Depositional sequences and sand distribution in the postglacial Rhone Delta complex. **In**: *Deltaic Sedimentation Modern and Ancient. Soc. Econ. Pal. Min. Spec. Pub.* **15** (Ed. J. P. MORGAN and R. H. SHAVER), pp. 198–212.

ORVIN, A. K., 1940: Outline of the geological history of Spitsbergen. *Norsk Polarinst. Skrifter.* Nr. 78. 57 p.

PARKER, J. R., 1967: The Jurassic and Cretaceous sequence in Spitsbergen. *Geol. Mag.* **104**, 487–505.

PČELINA, T. M., 1965a: On the Hauterivian stage in Vestspitsbergen. *Dokl. Akad. Nauk SSSR.* **163**, 1234–1236.

— 1965b: Stratigraphy and composition of the Mesozoic deposits in central Spitsbergen. *Geology of Spitsbergen, 1965.* 131–154. National Lending Library for Science and Technology (issued 1970).

— 1965c: Mesozoic deposits around Van Keulenfjorden, Vestspitsbergen. *Geology of Spitsbergen, 1965.* 155–181. National Lending Library for Science and Technology (issued 1970).

READING, H. G., 1970: Sedimentation in the Upper Carboniferous of the southern flanks of the Central Cantabrian Mountains, Northern Spain. *Proc. Geol. Assoc.* **81**, 1–41.

REINECK, H. E., 1963: Sedimentgefüge im Bereich der südlichen Nordsee. *Abhandl. Senckenberg. Naturforsch. Ges.* **505**, 1–136.

ROZYCKI, S. Z., 1959: Geology of the north-western part of Torell Land, Vestspitsbergen. *Studia geol. Polon.* **2**, 1–98.

SEILACHER, A., 1967: Bathymetry of trace fossils. *Marine Geol.* **5**, 413–428.

WEBER, K. J., 1971: Sedimentological aspects of oil fields in the Niger Delta. *Geol. Mijnb.* **50**, 559–576.

WEIMER, R. J., 1970: Rates of deltaic sedimentation and intrabasin deformation, Upper Cretaceous of Rocky Mountain region. **In**: *Deltaic Sedimentation Modern and Ancient. Soc. Econ. Pal. Min. Spec. Pub.* **15** (ED. J. P. MORGAN and R. H. SHAVER). pp. 270–292.

Sedimentology of Late Precambrian Sveanor and Kapp Sparre Formations at Aldousbreen, Wahlenbergfjorden, Nordaustlandet[1]

By Marc B. Edwards[2]

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Abstract

The easternmost known exposures of the late Precambrian Sveanor and Kapp Sparre Formations occur north of Wahlenbergfjorden, Svalbard. The Sveanor Formation (174 m) here consists of six massive tillite units, each deposited as a subglacial till, and intercalated with six mudstone units. Four mudstone units have muddy laminae and are interpreted as subaqueous deposits, partly with dropstones indicating ice rafting. Two mudstone units lack any substantial clay fraction, are poorly to non-laminated, and consist of well-sorted angular silt particles. These are interpreted as ancient glacial wind-blown loesses.

The overlying Kapp Sparre Formation (50+ m) begins with 5 m of fine-grained dolomite, which passes up into a shale unit with edgewise dolomite conglomerate beds in the lower part and turbidite sandstones above. The dolomite is interpreted as a transgressive deposit, while the sandstones reflect isostatic uplift of the surrounding land areas.

The sequence is similar to the correlative Polarisbreen Tillite in Ny Friesland, and compares closely with the Smalfjord Formation (lower tillite) and lower part of the Nyborg Formation of Finnmark, North Norway.

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Introduction

Late Precambrian Upper Hecla Hoek sedimentary rocks belonging to the Sveanor and Kapp Sparre Formations crop out north of the inner part of Wahlenbergfjorden, between Aldousbreen and Eltonbreen (Fig. 1, FLOOD et al. 1969). This isolated outcrop of glacial sediments is of special interest as it is the easternmost known tillite exposure on Svalbard, occurring 50 km from the main belt of tillite exposures on Hinlopenstretet, described by KULLING (1934).

During the Svalbard Expedition of 1974, a detailed profile was measured from the top of the Middle Hecla Hoek Ryssø Dolomite through the approximately 175 m thick Sveanor Formation and the overlying 50+ m Kapp Sparre Formation. The object of this paper is to describe the section, discuss its origin, and compare it briefly with successions of other areas.

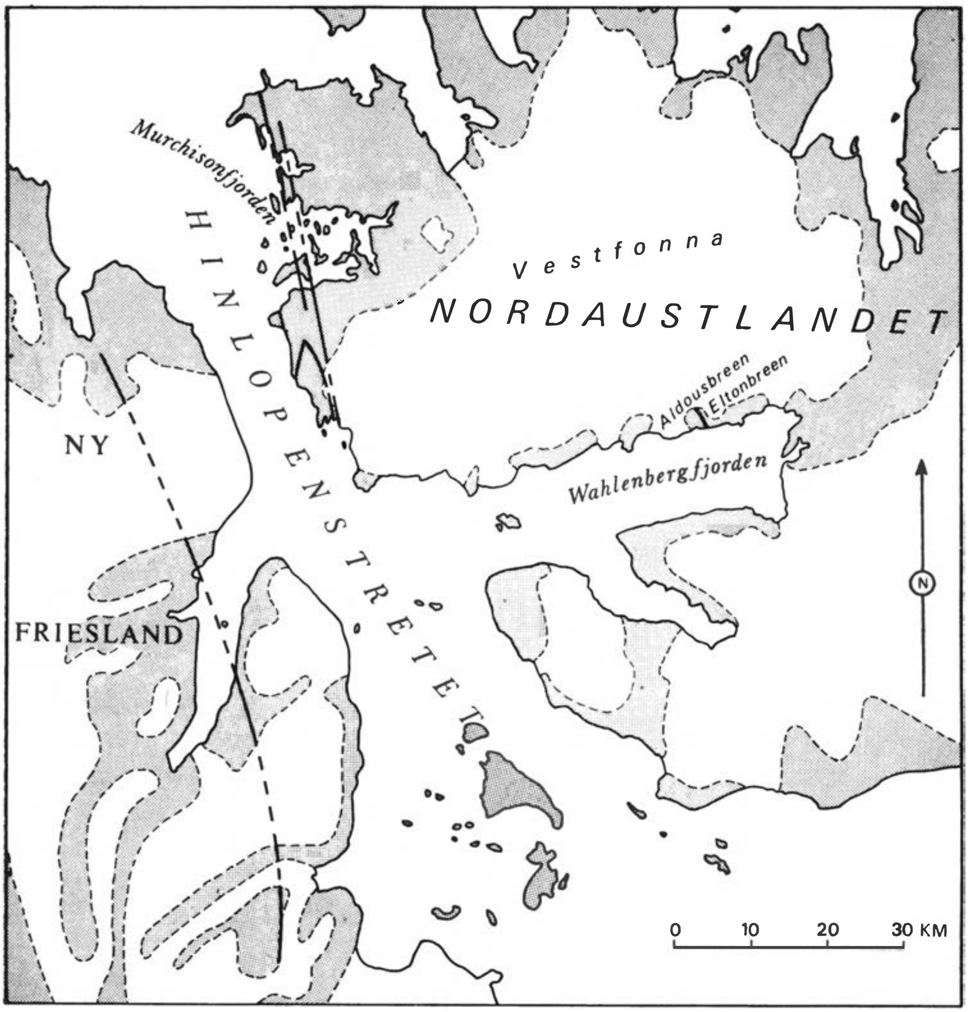


Fig. 1. *Location map. Heavy lines indicate location of late Precambrian tillites in northeastern Svalbard.* (*Based on* WILSON *and* HARLAND *1964;* FLOOD *et al. 1969*).

The exposures occur adjacent to the eastern moraine of Aldousbreen and the flat margin of Vestfonna, associated with numerous small glacial meltwater channels. The rocks are deformed by folds of various scales, and faults with throws up to about 30 m. Accurate measurement of thicknesses in the tillite is hampered both by the deformation and by the scarcity of stratification.

Sveanor Formation

Description

The bulk of the Sveanor Formation can be readily divided into two facies: (1) largely structureless (massive) tillite, and (2) faintly to non-laminated siltstone and mudstone, occasionally with dropstones (Fig. 2).

There are six units of massive tillite (Fig. 3) varying from about 4 to 48 m thick. Grey-green color predominates but purple and brown weathering, grey colors are also present. As a rough estimate, clasts make up less than 5 % of the tillite, and most are smaller than a few centimetres across. They decrease in abundance upwards in the formation. Angular to rounded forms are observed. Most clasts identified in the field are composed of light grey to dark grey dolomite. A few scattered large boulders of coarse red granite and gneiss occur in the upper part of the second tillite unit. Samples of these were taken for radiometric age determination.

Clast types identified in thin-section include recrystallised dolomites, volcanics, and slightly metamorphosed phyllites. The matrix of the grey-green tillites consists of a clay-mica-carbonate mixture with abundant sand and silt grains of quartz, plagioclase and potash feldspar (Pl. 1). Silt grains are generally angular, while sand grains are often rounded. The carbonate content appears to decrease upwards through the formation. Purple tillites have a hematite matrix, with a low carbonate and clay-mica content.

The only sedimentary structures seen in the tillite were a 1½ m thick bed of cross-bedded and parallel-laminated sandstone near the top of the second tillite unit, and a few lenses of sandstone and gravel conglomerate near the top of the sixth tillite unit. An apparent deformation structure is banding, where the bands consist of tillite differing in color and texture. Banding typically occurs both at the base of a tillite unit, and along the boundary between tillites differing in color and texture. The bands are on a scale of centimetres to meters thick, and may be folded.

There are six mudstone units, the lower five 2–4 m thick, the top one 15 m thick. Five of the units are purple, one is grey-green. While the first unit appears massive, the other units are faintly parallel laminated. Outsize dropstones are apparent in two of the mudstone units. One mudstone contains a few isolated sandstone lenses up to about 10 cm thick and 1 m long. They have sharp pebbly bases and gradational tops. Distinctive in the upper mudstone unit are thin beds of conglomerate, with a sharp base and top (Fig. 4). The frequency of dropstones is also very variable in this unit, though generally very low.

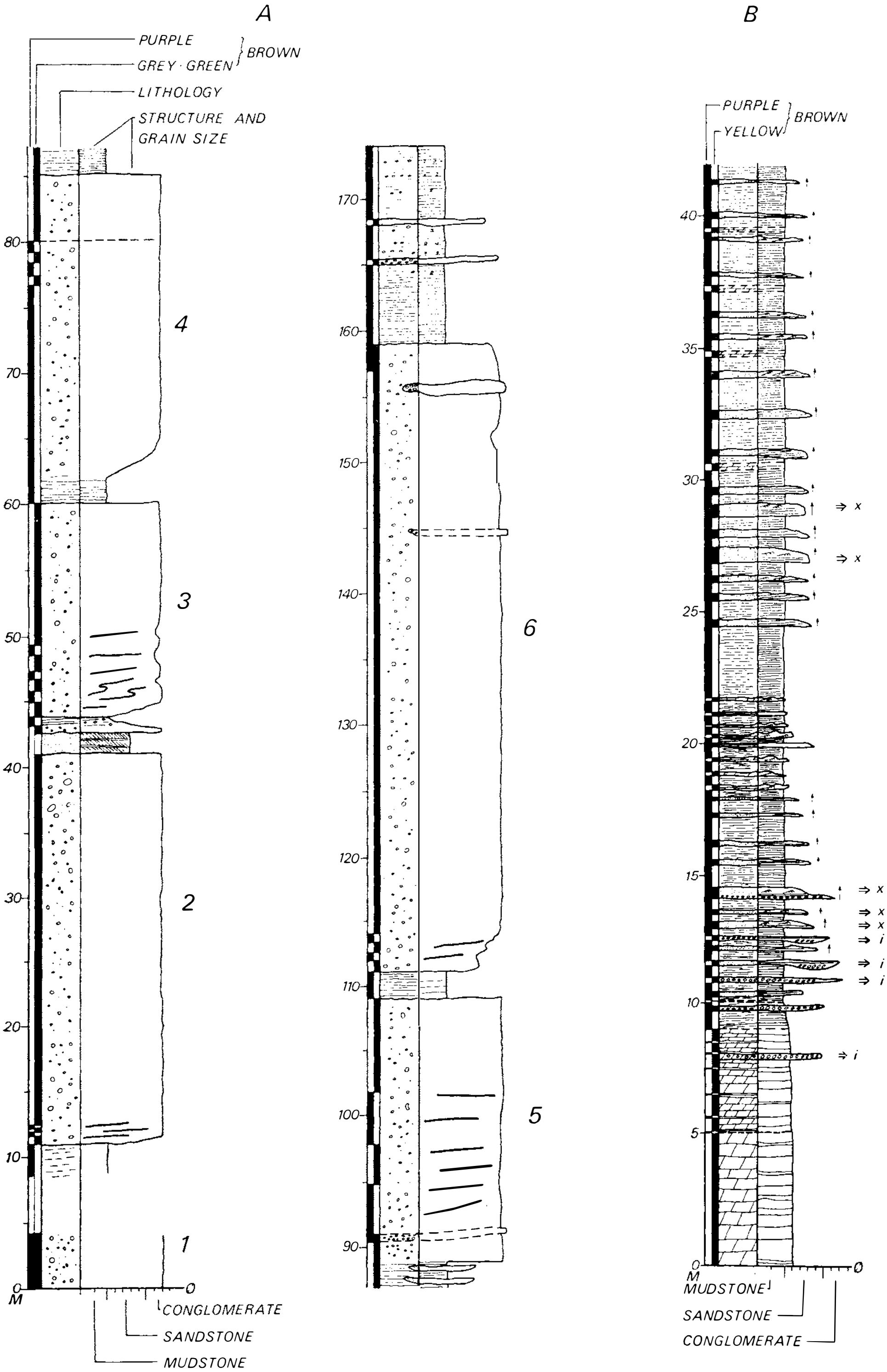
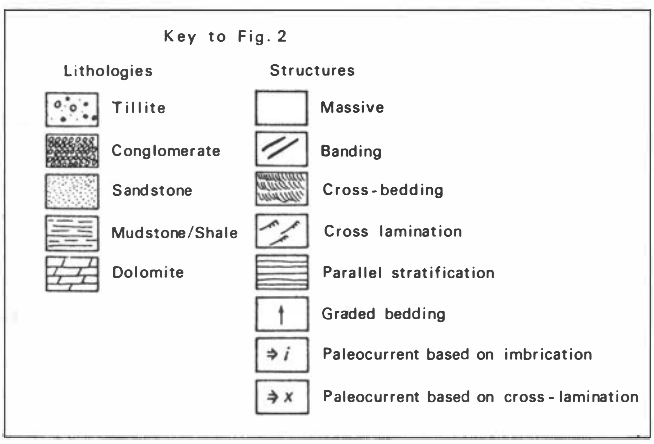


Fig. 2. *Sedimentological profile through Sveanor Formation (A) and Kapp Sparre Formation (B) a Aldousbreen. Note different scales.*

Fig. 3. *Basal part of tillite unit 3, showing dark purple tillite interbanded with overlying grey-green tillite. Note small, scattered dolomite clasts.*

In thin-section, these units show much variation in texture (Pl. 2). Units 2, 3, and 6 contain alternating silty and clayey laminae typical of waterlain mudstones. In the purple units (3 and 6) hematite is abundant in the fine laminae. Units 1, 4, and 5 consist mainly of angular silt grains. In unit 4, laminae of coarse and fine silt are present, with some carbonate-clay matrix. In units 1 and



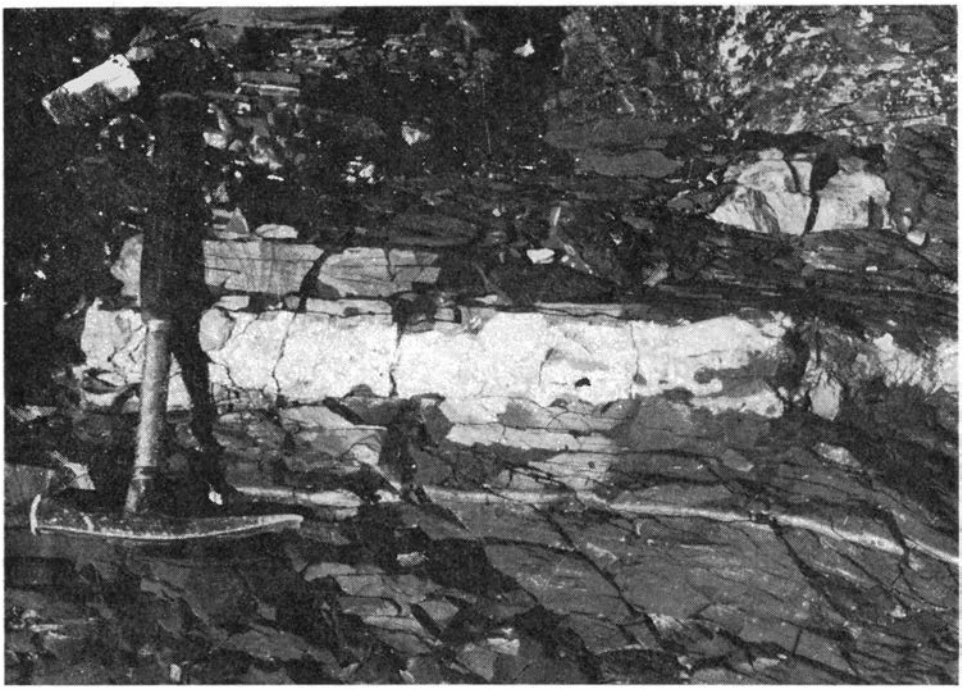


Fig. 4. *Mudstone unit 6, showing faint lamination, and a thin bed of very poorly sorted conglomerate including both dolomite and volcanic clasts.*

5 lamination is not present in thin-section, and the clay content is very low; of the two units the first is better sorted, but both appear to be well-sorted.

The upper mudstone unit is overlain sharply by the dolomite of the Kapp Sparre Formation.

Interpretation

Parallel-lamination in the clayed mudstone units, with occasional dropstones, attests to subaqueous deposition for units 2, 3, 4, and 6, probably marine as suggested by the absence of varves. The well-sorted angular silt in units 1 and 5 suggest deposition as wind-blown glacial loess. The lamination in unit 4 may reflect current reworking of wind-blown silt.

Sharp contacts with massive tillite units, and the absence of dropstones in some mudstone units indicate that there was a significant change in environment between these two facies. Bands in the tillite appear to consist of the main tillite material, and of material reworked from the underlying deposits, whether mudstone or tillite. The absence of continuous lamination or bedding in the massive tillite units, and the deformation of the underlying mudstone units in several cases suggest that this facies was deposited as a subglacial moraine, and that banding formed by subglacial erosion and mixing with englacial debris. Cross-bedded sandstone in the second tillite unit may have formed by englacial or subglacial water flow.

Thus the alternation of the two facies reflects subglacial, subaqueous and subaerial deposition, due to changes in sea-level, and/or advances and retreats of an ice sheet.

Kapp Sparre Formation

Description

About 40 m of this formation was measured in detail. An additional 10 m between the end of the profile and the limit of exposure is similar to that included in the upper part of the profile. The formation rests sharply on the laminated siltstone of the Sveanor Formation. At this locality the Kapp Sparre Formation can be divided into a lower dolomite unit (4½ m) and an upper shale unit (45+ m) (Fig. 2).

The dolomite in the dolomite unit is grey, weathering buff, and is very fine grained. A basal dolomite bed up to ½ m thick is locally parallel-laminated. Bornite and malachite occur in joints in the dolomite. In the landscape, the bed forms a protruding ridge (Fig. 5). The overlying 2 m consists of thin to medium parallel-sided beds of dolomite with occasional purple shale partings. Internally, these are parallel-laminated and massive. The remaining 2 m of dolomite is thin bedded with intercalated purple shale. The bedding is very even and has a striped appearance. One edgewise conglomerate is present near the top of the dolomite unit.

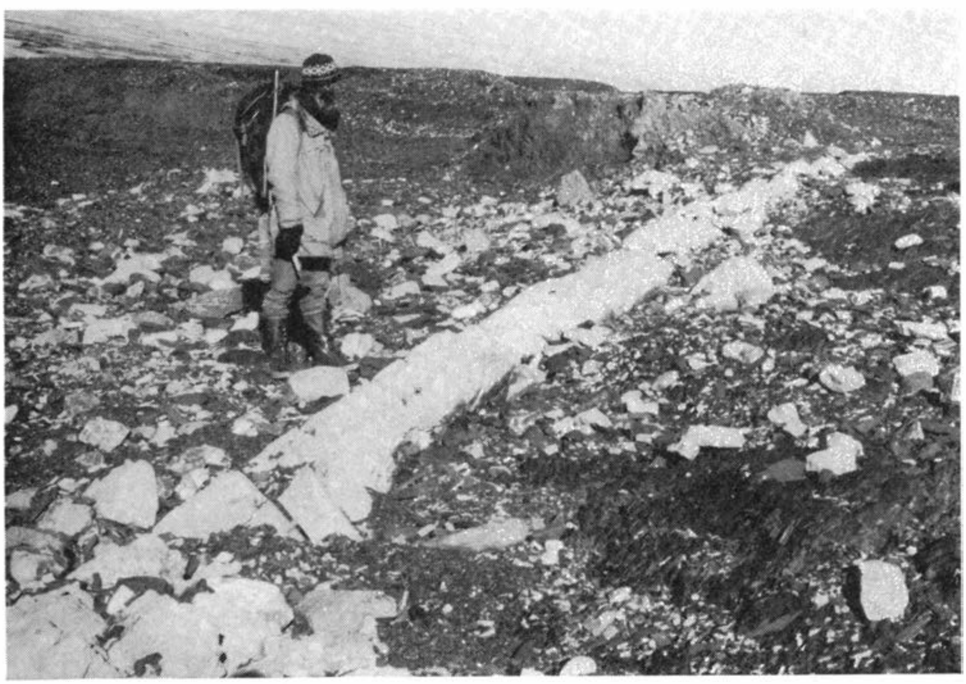


Fig. 5. *The dolomite bed marking the base of the Kapp Sparre Formation, and standing up as a continuos ridge. Laminated siltstone of Sveanor Formation to the right, and shale unit of the Kapp Sparre Formation to the left.*

Fig. 6. *Imbricated, edgewise conglomerates of dolomite occurring in thin beds, intercalated with purple shale in the lower part of the shale unit of the Kapp Sparre Formation. Imbrication suggests that currents flowed from right to left, approximately to N/NW.*

The overlying shale unit rests sharply on the dolomite unit. It is characterised by purple shale with dolomite and dolomite conglomerate in the lower 5 m, and sandstone beds commencing about 15 m from the base.

Edgewise conglomerate beds (Fig. 6) are up to about 15 cm thick, lenticular, often with erosive bases. Pebbles are angular to rounded thin plates of dolomite in a sandy matrix. Pebble imbrication in several beds indicates current flow to N/NW. Conglomerate beds die out upwards and give way to dolosiltites with cross-lamination indicating deposition by traction currents.

Graded red-brown to purple sandstones begin near the base of the member, but increase in importance upwards. They are as much as 30 cm thick, laterally continuous, with erosive bases and Bouma (1962) sequences of sedimentary structures. Cross-laminations dip to the N/NW. In thin-section, the sandstones are poorly to moderately sorted. Grains consist mostly of coarse sparry twinned calcite, recrystallised dolomite, and altered felsites, some porphyritic; quartz is infrequent.

Interpretation

The basal dolomite is probably a marine deposit, but in the absence of critical environmental indicators, the precise origin of the basal dolomite cannot be determined. The sharp contact with the underlying aqueous tillites indicates an abrupt change in climate, or alternatively, a period of erosion or non-deposition.

The overlying dolomite, with siltstone intercalations and partings is a transition to predominantly mud deposition above. The shale-dominated sequence contains two hydrodynamically distinct facies: (1) shales representing deposition of mud from suspension in quiet water, and (2) conglomerates and sandstones representing deposition from periodic traction currents. The edgewise conglomerates apparently reflect reworking of the newly deposited dolomite. The sandstones show the development of a terrigenous source area of clastic debris, and suggest an increased distance of transport. The sedimentary structures in these beds, and their lateral continuity indicates that they are turbidites.

Assuming that deposition of this part of the sequence was taking place during deglaciation, the basal dolomite reflects an initial eustatic rise in sea-level. The overlying dolomite conglomerates suggest isostatic uplift of the basin, or storms eroding the newly deposited material in shallow water. The turbidite sandstones may indicate uplift of the basin margins and/or the transport of available debris on land into the basin.

Comparison with other areas

Svalbard

The sequence at Aldousbreen is closely comparable in many ways to the correlative deposits along Hinlopenstretet, around Murchisonfjorden. According to KULLING (1934) there are alternating tillite and shale units with a variety of clast types, mostly derived from the immediately underlying dolomites, but including a wide variety of exotic clasts. In that area the Kapp Sparre Formation also begins with a dolomite bed, followed by colored shales. An important difference is the absence of basal sandstones as noted in the Sveanor tillite by KULLING (1934).

The Polarisbreen Tillite of Ny Friesland also consists of an variable sequence of massive tillites, shaly tillites and shales (WILSON and HARLAND 1964; CHUMAKOV 1968). CHUMAKOV (1968) described alternating subglacial and subaqueous tillites, as well as sandstone wedges, apparently formed under subaerial freeze-thaw conditions. The sharp base of the dolomite transition upward into red flags with conglomerate and a striped appearance is similar to the base of the Kapp Sparre Formation of Aldousbreen. The orientation of clast long axes and fold structures indicates glacial movement from the WNW (CHUMAKOV 1968) opposite to the current indicators observed in the Kapp Sparre Formation at Aldousbreen.

In the absence of a detailed regional correlation of the upper strata in the Middle Hecla Hoek underlying the Upper Hecla Hoek Polarisbreen and Sveanor Formations, it is not yet possible to determine the position of the base of the tillite formation. The tillite rests sharply on contrasting lithologies of dolomite and marl at Aldousbreen and in Murchisonfjorden, and different stratigraphic units of varying lithology have been included in the base of the tillite formations (KULLING 1934; WILSON and HARLAND 1964; CHUMAKOV 1968; FLOOD et al. 1969).

Finnmark, North Norway

At first glance, the presence of two tillite formations in Finnmark (FØYN 1937; READING and WALKER 1966) suggests that the sequences are not closely comparable. However, of the two tillite formations in Finnmark, the lower Smalfjord Formation is most similar to the Sveanor Tillite. This is a complex of massive tillites, tillitic shales, and shales (EDWARDS 1972). The basal part of the Kapp Sparre Formation is nearly identical to sections described from the base of the interglacial Nyborg Formation in east and central Finnmark (BANKS et al. 1971; EDWARDS 1972). A local basal dolomite grades up into purple shale, locally with edgewise conglomerate, which in turn passes up into a thick turbidite sequence. The sediments overlying the upper (Mortensnes) tillite are dark grey shales having no characteristics similar to the base of the Kapp Sparre Formation.

Thus features of both stratigraphic units support a correlation of the Sveanor Tillite with the Smalfjord Formation, and of the lower parts of the Kapp Sparre Formation and the Nyborg Formation. In view of the presence of an overlying upper tillite in Finnmark, evidence for a glacial episode within the Kapp Sparre Formation and equivalents in Ny Friesland should be sought.

Summary and conclusions

The Sveanor Tillite at Aldousbreen consists of massive tillite deposited as subglacial till, and laminated mudstone, occasionally with dropstones, formed both as proglacial subaqueous deposits, and as wind-blown glacial loesses. The facies alternation indicates changes in sea-level and/or advances and retreats of an ice sheet.

The lower part of the Kapp Sparre Formation consists of a basal dolomite passing up into a turbidite-bearing shale sequence. The succession may represent an initial transgression, followed by isostatic uplift of the source area, supplying terrigenous debris to the basin in the form of turbidity currents.

The formations show close similarity to correlative strata elsewhere in Svalbard. They are also remarkably similar to the Smalfjord (lower tillite) Formation and lower part of the Nyborg Formation of Finnmark, at present 1000 km to the south.

Detailed work on the stratigraphy of the underlying Middle Hecla Hoek, and the Sveanor Formation will reveal the nature of the sub-glacial surface. Further studies on the petrology of tillite clasts, sedimentary environments, and paleoflow and paleocurrent directions are required.

Acknowledgements

The field work was carried out during the Svalbard Expedition of 1974, and I am grateful to the other expedition members for their help, especially my assistant Mr. TRYGVE HANSEN.

I thank Dr. H. G. READING for commenting on the manuscript.

References

BANKS, N. L., M. B. EDWARDS, W. P. GEDDES, D. K. HOBDAY and H. G. READING, 1971: Late Precambrian and Cambro-Ordovician sedimentation in East Finnmark. **In:** *The Caledonian Geology of Northern Norway, Norges geol. Unders.* **269**, 197–236.

BOUMA, A. H., 1962: *Sedimentology of some flysch deposits: a graphic approach to facies interpretation.* Elsevier, Amsterdam.

CHUMAKOV, N. M., 1968: On the character of the late Precambrian glaciation of Spitsbergen, *Dokl. Akad. Nauk SSSR.* **180**, 1446–1449.

EDWARDS, M. B., 1972: *Glacial, interglacial and postglacial sedimentation in a late Precambrian shelf environment, Finnmark, North Norway.* Unpubl. D. Phil. Thesis, Oxford University.

FLOOD, B., D. G. GEE, A. HJELLE, T. SIGGERUD and T. S. WINSNES, 1969: The geology of Nordaustlandet, northern and central parts. *Norsk Polarinstitutt Skrifter*, No. 146.

FØYN, S., 1937: The Eo-cambrian Series of the Tana District, Northern Norway. *Norsk geol. Tiddskr.* **17**, 65–164.

KULLING, O., 1934: The "Hecla Hoek Formation" round Hinlopenstredet. *Geogr. Annaler.* **16**, 161–254.

READING, H. G. and R. G. WALKER, 1966: Sedimentation of Eocambrian tillites and associated sediments in Finnmark, Northern Norway. *Palaeogeog. Palaeoclim. Palaeoecol.* **2**, 177–212.

WILSON, C. B. and W. B. HARLAND, 1964: The Polarisbreen Series and other evidence of late Pre-Cambrian ice ages in Spitsbergen. *Geol. Mag.* **101**, 198–219.

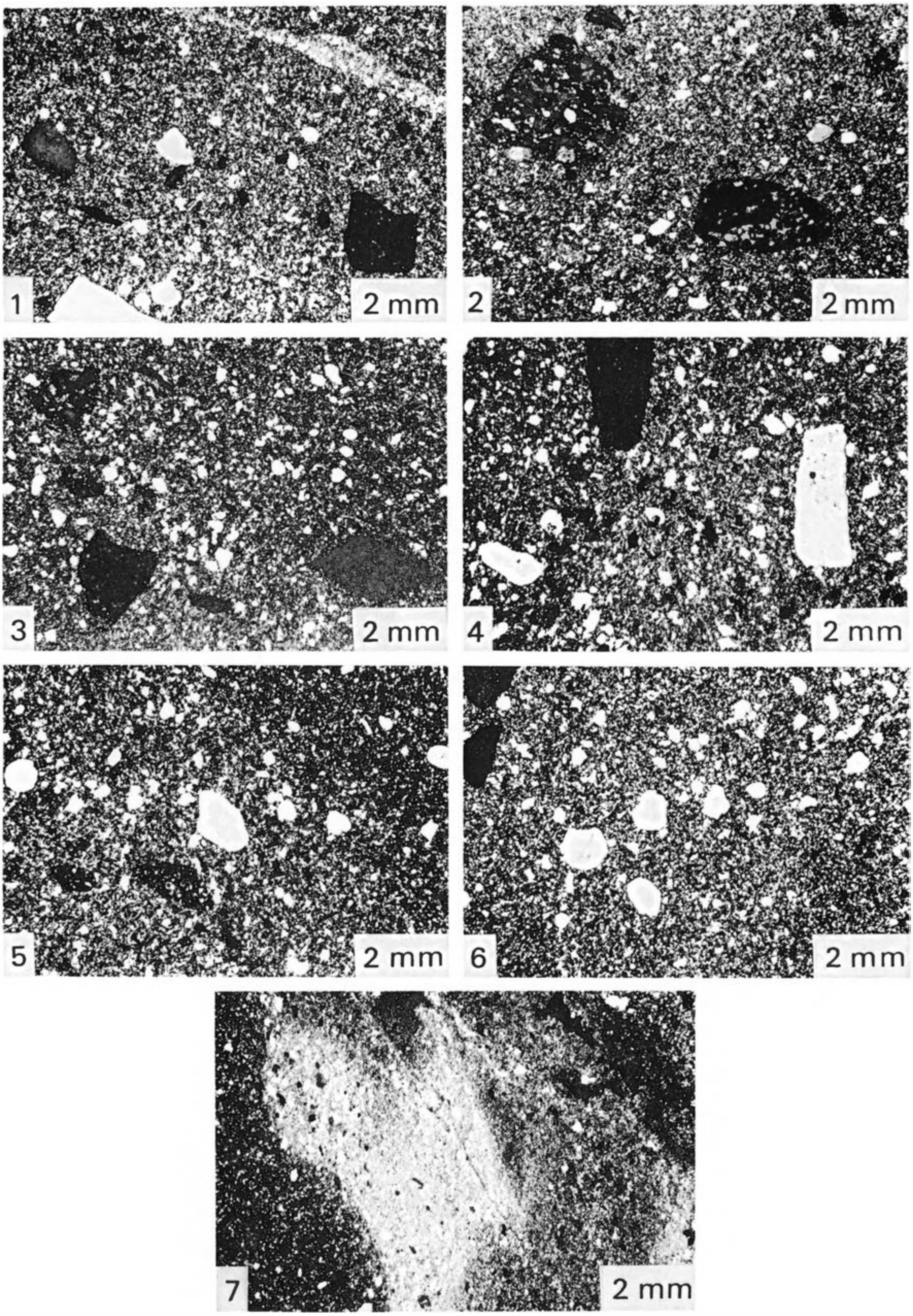
PLATES

PLATE I

THIN-SECTIONS OF SVEANOR FORMATION TILLITES

(Scale given in the lower right of each picture corresponds to the width of the white field.)

1. Tillite unit 1, brown, clasts of dolomite and volcanics. Sample 74 ME A29, plane light.
2. Tillite unit 2, grey-green, clasts of dolomite and volcanics. Sample 74 ME A31, plane light.
3. Tillite unit 3, grey-green, clasts of dolomite and volcanics. Sample 74 ME A1, plane light.
4. Tillite unit 4, top part, grey-green, clasts of chert and volcanics. Sample 74 ME A4, plane light.
5. Tillite unit 5, grey-green. Sample 74 ME A8, plane light.
6. Tillite unit 6, grey-green. Sample 74 ME A10, plane light.
7. Tillite unit 4, basal part, showing banded structure, including purple (dark) and grey-green (light) tillites. Sample 74 ME A2, plane light.



6.

PLATE II

THIN-SECTIONS OF SVEANOR FORMATION SILTSTONES

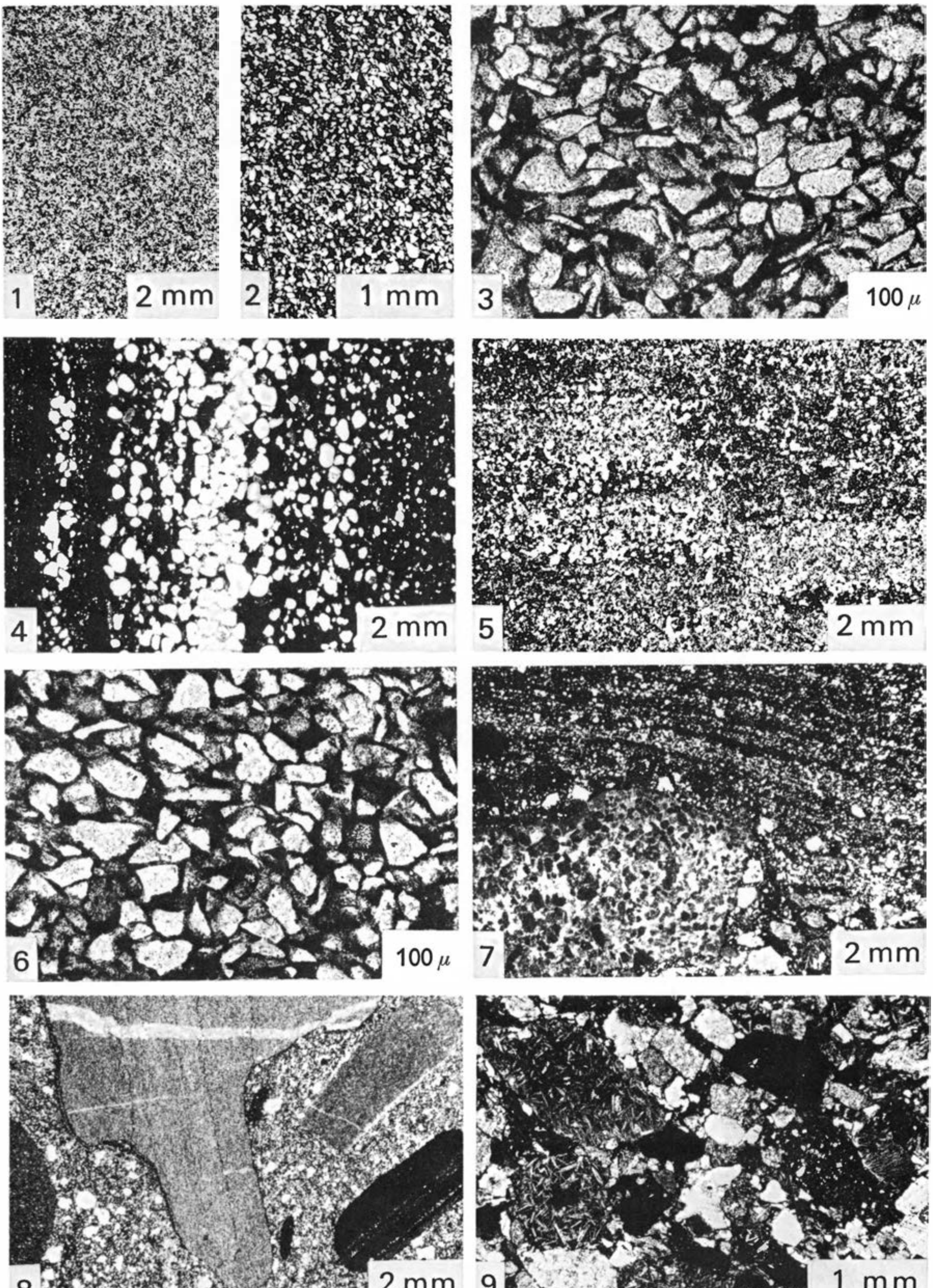
(Scale given in the lower right of each picture corresponds to the width of the white field.)

1.–3. Siltstone unit 1, purple, well-sorted angular silt composed of quartz, plagioclase and potash feldspar. Sample 74 ME A30, plane light.

4. Siltstone unit 3, purple, alternating clayey (hematitic) and sandy laminae. Sample 74 ME A3, plane light.
5. Siltstone unit 4, grey-green, laminated silt, cut by small fault. Sample 74 ME A5, plane light.
6. Siltstone unit 5, purple, well-sorted angular silt composed of quartz, plagioclase and potash feldspar. Sample 74 ME A9, plane light.
7. Siltstone unit 6, purple, finely and coarsely laminated clay (hematitic), silt and sand, large dolomite clast in lower left. Sample 74 ME A14, plane light.
8. Siltstone unit 6, thin conglomerate bed, large dolomite clast is veined, with stylolites, and has broken-looking outline, dark clast on right may be volcanic. Sample 74 ME A11, plane light.

THIN-SECTION OF KAPP SPARRE FORMATION

9. Turbidite sandstone about 30 m above base of formation, showing volcanic grains, with plagioclase laths on left, twinned calcite (lower right), chalcedony (middle right), and scattered dolomite clasts and quartz grains. Sample 74 ME A24, partially crossed nicols.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Microplankton from the Janusfjellet Subgroup (Jurassic-Lower Cretaceous) at Agardhfjellet Spitsbergen · A preliminary report*

By TOR BJÆRKE[1], MARC B. EDWARDS[2], and BINDRA THUSU[3]

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Abstract

Microplankton are recorded for the first time in the type section of the Janusfjellet Subgroup at Agardhfjellet, eastern Spitsbergen. Assemblages are of Upper Jurassic–Lower Cretaceous age, in agreement with previous datings based on megafauna.

An abrupt change in color of organic matter, and improvement in preservation in palynomorphs in a clay-rich interval just above the base of the Lower Cretaceous Rurikfjellet Formation suggest a break in thermal metamorphism. The thermal metamorphism apparently occurred prior to the deposition of the overlying portion of the Rurikfjellet Formation, probably in association with contemporaneous structural and/or intrusive activity.

Introduction

Palynological sampling was carried out at Agardhfjellet during the Norsk Polarinstitutt Svalbard Expedition of 1974 (Fig. 1). The samples cover the Jurassic-Lower Cretaceous Janusfjellet Subgroup at its type section, as well as the top of the underlying Wilhelmøya Formation and the lowermost part of the overlying Helvetiafjellet Formation (Fig. 2). The discovery of well-preserved dinoflagellate assemblages in the Rurikfjellet Formation encourages continued palynological studies, especially in view of earlier unsuccessful attempts at finding workable palynomorphs in the promising lithologies of the Mesozoic of Spitsbergen.

* Contribution No. 64 in NTNF's Continental Shelf Project.

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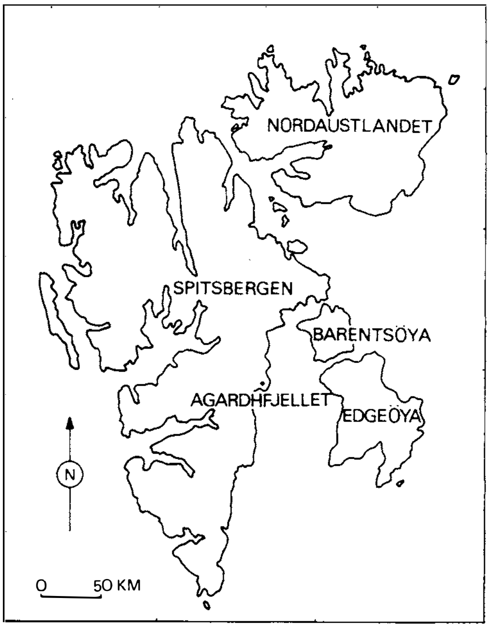

Fig. 1. *Location of Agardhfjellet.*

Sampling

Spot samples of the shaly horizons were collected from the predominantly sandy Wilhelmøya Formation, and channel samples on a two meter sampling interval were collected from the predominantly shaly Janusfjellet Subgroup. All lithologies present in the interval were sampled. As seen in the profile (Fig. 2) important gaps are present in the lower part of the Subgroup, but coverage is almost complete for the rest of the sequence. Samples from the Wilhelmøya Formation were taken along coastal exposures of Agardhfjellet, while the overlying strata were sampled at exposures on the southern part of the steep eastern flank of Agardhfjellet.

Geological setting

The Mesozoic sequence of Svalbard consists predominantly of shales and sandstones with rare conglomerates and coals (see HARLAND 1973). It is a characteristic platform deposit with minor lateral facies and thickness variations. The present biostratigraphical scheme is based on megafossil studies (BUCHAN et al. 1965; PARKER 1967; TOZER and PARKER 1968; NAGY 1970; and others).

Stratigraphical complications occur locally where faulting was intermittently active. In the Agardhbukta area, PARKER (1967) described a dolerite dyke cutting through the Agardhfjellet Formation and truncated at the junction with the overlying Rurikfjellet Formation. A yellow-weathering clay, developed in this area at the base of the Rurikfjellet Formation, presumably formed by weathering of dolerite (PARKER 1967).

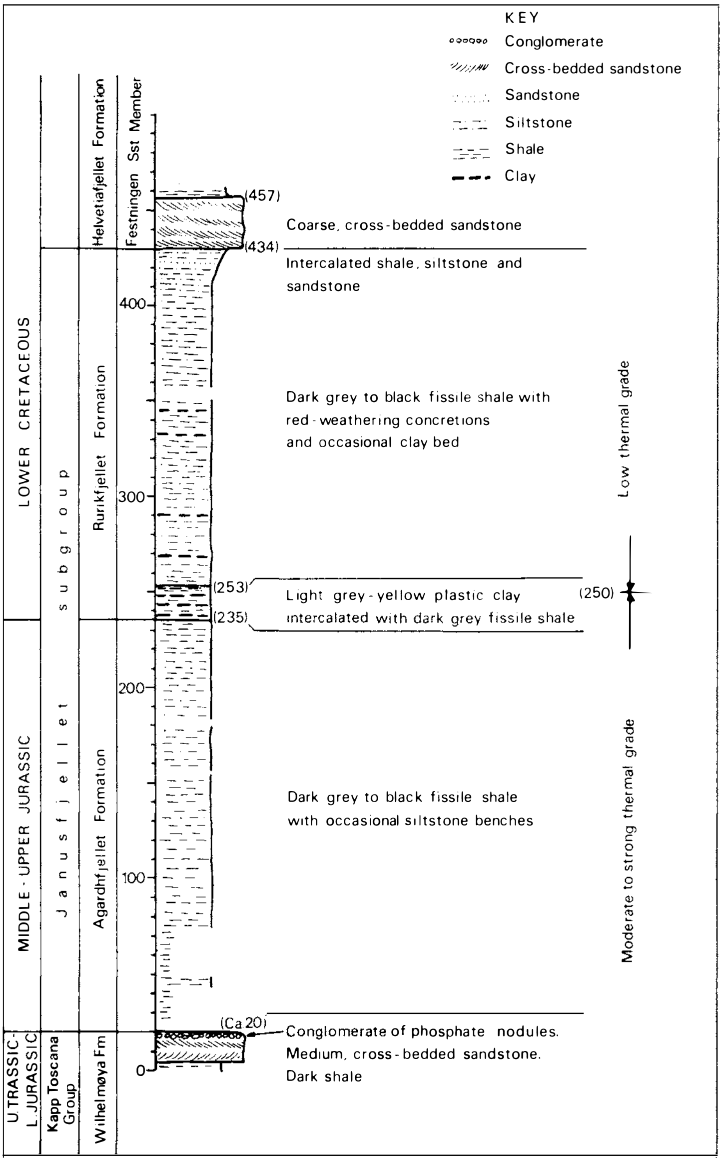

Fig. 2. *Section through the Jurassic–Cretaceous sequence at Agardhfjellet. Thicknesses were determined using both barometer and tape. Stratigraphic nomenclature follows* PARKER (*1967*) *and* WORSLEY (*1973*).

Our observations on the section at Agardhfjellet are essentially the same as those made by PARKER (1967), with two exceptions: 1) Yellow clay beds occur not only along the Agardhfjellet/Rurikfjellet Formation boundary but also as isolated thin beds further up in the Rurikfjellet Formation, up to about 115 m above its base (Fig. 2). These clay beds have sharp contacts with adjacent dark shale. 2) Micaceous siltstones and coarse sandstones, partly unconsolidated and intercalated with dark shale, occur in the upper 15 m of the Rurikfjellet Formation. These strata are sharply overlain by the coarse cross-bedded sandstone of the Helvetiafjellet Formation, the Festningen Sandstone Member. These coarse-grained deposits were considered to represent a regressive sequence between the marine Rurikfjellet Formation and the fluvial Festningen Sandstone Member (EDWARDS 1976).

Palynology

Processing followed standard techniques, using HF, HCl and short oxidation with Schulze's solution. Heavy liquid separation was done on some of the samples using $ZnBr_2$ (sp. gr. 2.0).

Observations on unoxidized residues show a remarkable variation in the preservation and productivity of the samples through the sequence. Below 250 m, including the Wilhelmøya Formation, all samples yielded only black organic matter and occasional dark and badly preserved microplankton with blurred morphological details. This color of organic matter is comparable to the moderate to strong thermal alteration (thermal index 3–4) of STAPLIN (1969). At 250 m an abrupt change in color and preservation of microplankton assemblages takes place. Above 250 m, palynomorphs are excellently preserved, and are lighter in color, comparable to the low thermal grade (thermal index 2) of STAPLIN (1969). As examples, specimens of *S. grossi* and *S. apatelum* below 250 m are dark and poorly preserved, showing blurred morphology, while those above 250 m are light, and excellently preserved as illustrated in the plate.

In general, the assemblages are almost completely dominated by microplankton together with a few bisaccate pollen and spores. Characteristic taxa are illustrated in Plate 1, including *Sirmiodinium grossi* (ALBERTI) WARREN 1973, *Scrinodinium apatelum*[1] COOKSON and EISENACK 1960 and *Imbatodinium villosum* VOZZHENNIKOVA 1967. These taxa were observed from 220 to about 275 m. The upper part of the section between 400 to about 430 m shows the first appearance of *Muderongia* sp. together with *Cicatricosisporites* cf. *australiensis* (COOKSON) POTONIÉ 1956, and *Aequitriradites* sp. Numerous species of *Hystrichosphaeridium* are present throughout the section. The assemblages have an Upper Jurassic-Lower Cretaceous aspect supporting the dating based on megafauna by PARKER (1967).

Discussion

It is generally considered that the color of organic matter is related to heating: darkening occurs with increasing temperature (STAPLIN 1969; BROOKS and SHAW 1971). The different colors of organic matter observed in the Agardhfjellet section are most probably due to differential heating.

[1] *S. apatelum* COOKSON and EISENACK 1960 (p. 249) was transferred by SARJEANT (1969, p. 15) to *Psaligonyaulax* SARJEANT 1966 (p. 136). This transfer is doubtful as no indication of tabulation is observed in our specimens nor did COOKSON and EISENACK (1960, p. 249) record tabulation in their type material. Furthermore VOZZHENNIKOVA (1967, p. 280) suggested the transfer of *S. apatelum* to *Tubotuberella* VOZZHENNIKOVA 1967, p. 279. This taxonomic point will be discussed in a forthcoming publication.

The sharp break in the state of preservation at 250 m occurs in the upper part of the clay-rich interval, whose base PARKER (1967) defined as the boundary between the Jurassic Agardhfjellet Formation and the Cretaceous Rurikfjellet Formation. The lower portion of the section was heated during or after its deposition and before deposition of the upper part of the clay and overlying beds. Apparently, there is a metamorphic break within the lowermost few metres of the Rurikfjellet Formation, close to the Jurassic-Cretaceous boundary.

If the clay beds are a product of volcanic activity in the region, then the distribution of clays in the sequence indicates volcanism from the time of deposition of the top of the Agardhfjellet Formation well into the Rurikfjellet Formation. This interval falls within the time range of intrusive activity, shown by radiometric ages of dolerites in Spitsbergen (GAYER et al. 1966).

The heating inferred from the difference in preservational state of the organic material may have been due to a regional heating event in the Upper Jurassic, possibly related to local structural movements at the time (PARKER 1966), and/or to contact metamorphism associated with intrusion of dolerite dykes and sills of the Agardhbukta area (PARKER 1966). Future studies of other sections in this stratigraphic interval will elucidate the origin and distribution of thermal metamorphism in Svalbard.

Acknowledgements

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We are grateful to other members of the Svalbard Expedition of 1974, especially field assistant Mr. TRYGVE HANSEN. Mr. IVAR RENDAL KRISTENSEN and Mr. KJELL HUSEBY assisted with the sampling at Agardhfjellet.

Cand. mag. EDITH FAYE-SCHJØLL prepared the samples, Mr. GRAHAM BELL assisted in several phases of the investigation, and the manuscript was improved by the comments of Dr. S. B. MANUM, and Cand. real. JORUNN OS VIGRAN.

References

BROOKS, J. and G. SHAW, 1971: The role of sporopollenin in palynology. III International Palynology Conference, Novosibirsk.

BUCHAN, S. H., A. CHALLINOR, W. B. HARLAND and J. R. PARKER, 1965: The Triassic stratigraphy of Svalbard. *Norsk Polarinstitutt Skrifter* Nr. 135. 92 pp.

COOKSON, I. C. and A. EISENACK, 1960: Upper Mesozoic microplankton from Australia and New Guinea. *Palaeontology* **2**. pp. 243–261.

EDWARDS, M. B., 1976: Depositional environments in Lower Cretaceous regressive sediments, Kikutodden, Sørkapp Land, Svalbard. *Norsk Polarinstitutt Årbok* 1974. pp. 35.–50.

GAYER, R. A., D. G. GEE, W. B. HARLAND, J. A. MILLER, H. R. SPALL, R. H. WALLIS and T. S. WINSNES, 1966: Radiometric age determinations on rocks from Spitsbergen. *Norsk Polarinstitutt Skrifter* Nr. 137.

HARLAND, W. B., 1973: Mesozoic geology of Svalbard. Arctic Geology. Ed. M. G. PITCHER, *Amer. Assoc. Petrol. Geol. Memoir 19*. pp. 135–148.

NAGY, J., 1970: Ammonite faunas and stratigraphy of Lower Cretaceous (Albian) rocks in southern Spitsbergen. *Norsk Polarinstitutt Skrifter* Nr. 152. 58 pp.

ORVIN, A. K., 1940: Outline of the geological history of Spitsbergen. *Norges Svalbard- og Ishavs-undersøkelser* Nr. 78. 57 pp.

PARKER, J. R., 1966: Folding, faulting and dolerite intrusions in the Mesozoic rocks of the fault zone of central Spitsbergen. *Norsk Polarinstitutt Årbok* 1964. pp. 47–55.

— 1967: The Jurassic and Cretaceous sequence in Spitsbergen. *Geol. Mag.* **104**. pp. 487–505.

STAPLIN, F. L., 1969: Sedimentary organic matter, organic metamorphism and oil and gas occurrence. *Bull. Canadian Petrol. Geol.* **17**. (1). pp. 47–66.

SARJEANT, W. A. S., 1969: Taxonomic changes, IN: DAVEY, R. J., DOWNIE, C., SARJEANT, W. A. S. and WILLIAMS, G. L., Appendix to "Studies on Mesozoic and Cainozoic dinoflagellate cysts". *Bull. Br. Mus. nat. Hist.* (*Geol.*), Appendix to Suppl. 3. pp. 7–15.

TOZER, E. T. and J. R. PARKER, 1968: Notes on the Triassic biostratigraphy of Svalbard. *Geol. Mag.* **105**. pp. 526–542.

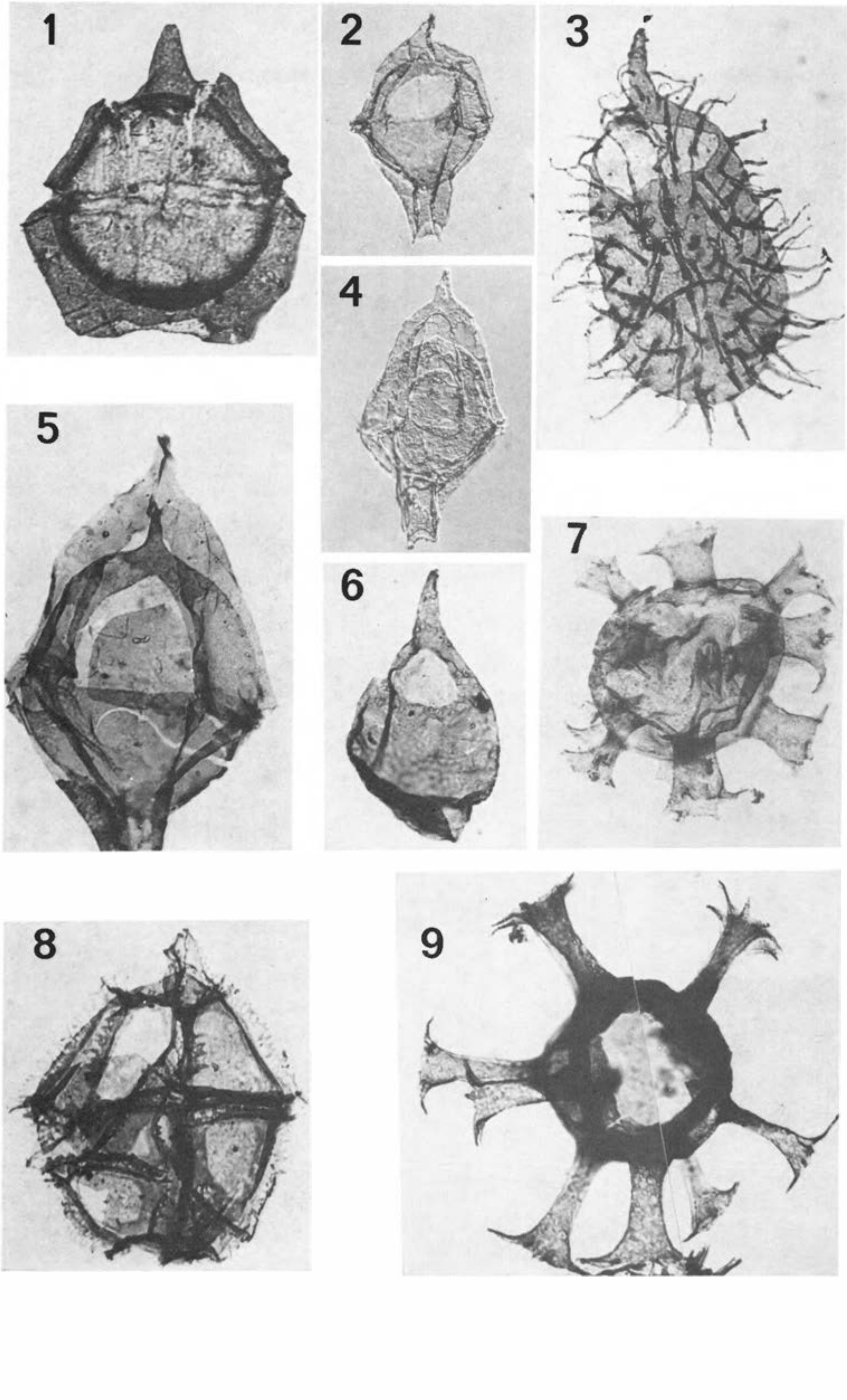
VOZZHENNIKOVA, T. F., 1967: Iskopaemye peridinei yurskikh melovykh i paleogenovykh otlozheniy SSSR. *Akad. Nauk SSSR, Sib. Otd., Inst. Geol. Geofiz.*, Tr., 347 p. (Fossil peridinians of the Jurassic, Cretaceous and Paleogene deposits of the U.S.S.R.)

WORSLEY, D., 1973: The Wilhelmøya Formation – a new lithostratigraphical unit from the Mesozoic of eastern Svalbard. *Norsk Polarinstitutt Årbok* 1971. pp. 7–16.

PLATE 1

1.	*Sirmiodinium grossi* (ALBERTI) WARREN 1973 Sample 74/396, slide 8, coord. 24.2–106.7, ×500.
2, 4, and 5.	*Scrinodinium apatelum* COOKSON and EISENACK 1960 2. Sample 74/389, slide 4, coord. 33.8–105.6, ×300. 4. Sample 74/389, slide 2, coord. 35.6–104.5, ×300. 5. Sample 74/389, slide 8, coord. 35.9–99.8, ×500.
3.	*Imbatodinium villosum* VOZZHENNIKOVA 1967 Sample 74/389, slide 11, coord. 29.3–103.6, ×500.
6.	*Pareodinia ceratophora* (DEFLANDRE 1947) GOCHT 1970 Sample 74/389, slide 1, coord. 34.1–107.2, ×500.
7.	*Hystrichosphaeridium tubiferum* var *brevispinum* DAVEY and WILLIAMS 1966 Sample 74/390, slide 1, coord. 34.6–112.6, ×500.
8.	*Gonyaulacysta cladophora* (DEFLANDRE) DODEKOVA 1967 Sample 74/397, slide 10, coord. 34.6–103.8, ×500.
9.	*Hystrichosphaeridium* sp. Sample 74/390, slide 1, coord. 33.2–104.6, ×500.

Coordinates refer to Leitz Orthoplan Microscope 859913 of the NTNFK palynological laboratory.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Morphology and structure of the Western Jan Mayen Fracture Zone

By G. L. Johnson[1] and J. Campsie[2]

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Abstract

The western portion of the Jan Mayen Fracture Zone is described in regard to its morphology and sedimentary cover. The fracture zone strikes 300° up to the edge of the Greenland Shelf. It seems likely that it is reflected in Greenland subaerial geology. The presence of bottom currents is revealed by drifts of transparent sedimentary material at the base of the fracture zone. The distribution of magmatic activity suggests a relatively deep seated alkaline magma source has been intermittently active.

Introduction

In the autumn of 1974 USNS LYNCH conducted a reconnaissance survey of the western portion of the Jan Mayen Fracture Zone (Fig. 1). The cruise objectives were to: (a) define the morphology of the fracture zone with emphasis toward its intersection with the Greenland continental block, (b) sample the exposed rocks to determine their petrology and petrochemistry, and (c) investigate the sea floor with seismic reflection methods to determine the sediment types and therefore dynamic processes of sedimentation.

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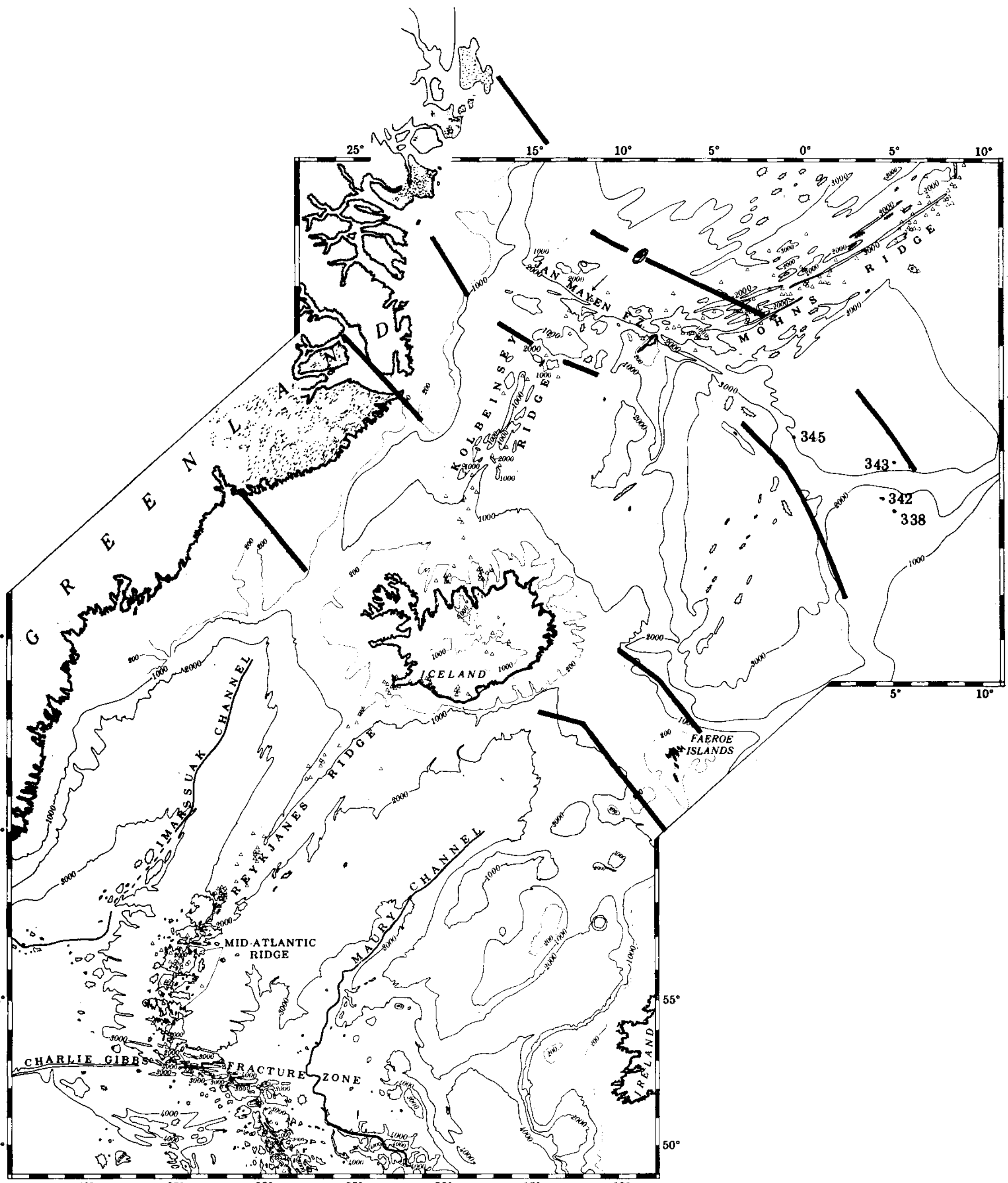

Fig. 1. *Bathymetric chart of the North Atlantic. Stippled area on the east coast of Greenland show area of Tertiary volcanism* (HALLER, *1971*). *Black lines trace regions possibly affected by hot spot activity. Strike of lines parallels flow lines as determined by* TALWANI *and* ELDHOLM *1974 and 1975. JOIDES drill sites are shown.*

The Jan Mayen Fracture Zone was first predicted on seismological evidence (SYKES 1965). The fracture zone offsets the Mid-Ocean Ridge (Kolbeinsey and Mohns Ridges) a distance of over 210 km (120 miles) in a right lateral sense. It apparently extends from the Greenland Continental margin (OSTENSO 1968) to the south flank of the Voring Plateau (ELDHOLM and WINDISCH 1974). JOHNSON and HEEZEN (1967) noted that the fracture zone east of Jan Mayen appears to be a broad band of northwest-southwest en echelon escarpments and ridges. North and west of the island it is a basement deep formed by the northern edge of the Iceland Plateau on the south and an irregular series of basement highs to the north. To the west of Jan Mayen the scarp and singular deep are well defined and are in line with the northnorthwest-southsoutheast elongation of the northern Jan Mayen Insular Shelf, and the faults, volcanic rift zones and dykes striking northwest-southeast on the northern part of Jan Mayen (FITCH 1964, JOHNSON 1968). Just to the north of Jan Mayen a trench is present flanked to the north by a blocky topographic high shoaler than 900 m.

Morphology

Jan Mayen Fracture Zone

The western Jan Mayen Fracture Zone (WJMFZ) is marked by an escarpment which defines the northern boundary of the Iceland Plateau and is therefore the south wall of the WJMFZ. The 1400 meter isobath defines the edge of the plateau. The slope is often precipitous as just to the north of Jan Mayen where the gradient is 1:20 or greater (Fig. 2). The northern extent of the fracture is marked by a series of topographic highs which are either partially emergent (Fig. 2) or buried (Fig. 3, Profiles A and B; Fig. 4, Profile 5; Fig. 5). A large topographic block is present to the north of Jan Mayen (Fig. 6, Profiles 6–8). Dredges on this feature have yielded shales of Tertiary age (JOHNSON 1975) as well as basalt suggesting that like the Jan Mayen Ridge (JOHNSON and HEEZEN 1967; ELDHOLM and WINDISCH 1974), this may be at least a partial continental fragment if the shale was in situ. The feature does have a magnetic signature (AVERY et al. 1968) as would be expected from the recovered basalt, and it is more likely volcanic in nature. An appropriate name for the feature might be "sumit" the Greenlandic for "where did you come from".

The floor of the fracture zone is 20 km wide. It is not flat floored (Fig. 4, Profile 4; Fig. 3; Profile B). The presence of low relief in the form of crests of transparent material suggest the bottom sediments are or have been sculpted by bottom currents. The floor of the fracture zone generally lies at depths in excess of 2200 meters except just north of Jan Mayen and west of 14°W as the continental margin of Greenland is approached.

Profiles 3 and 4 (Fig. 4) show a pair of basement highs which are believed to represent crossings the western extent of the WJMFZ. The picture is complicated however by other basement highs on the northern portion of the Iceland Plateau as shown on profiles 1 and 3 which apparently lie to the south of the WJMFZ. It should be noted that OSTENSO's (1967) seismic reflection data from

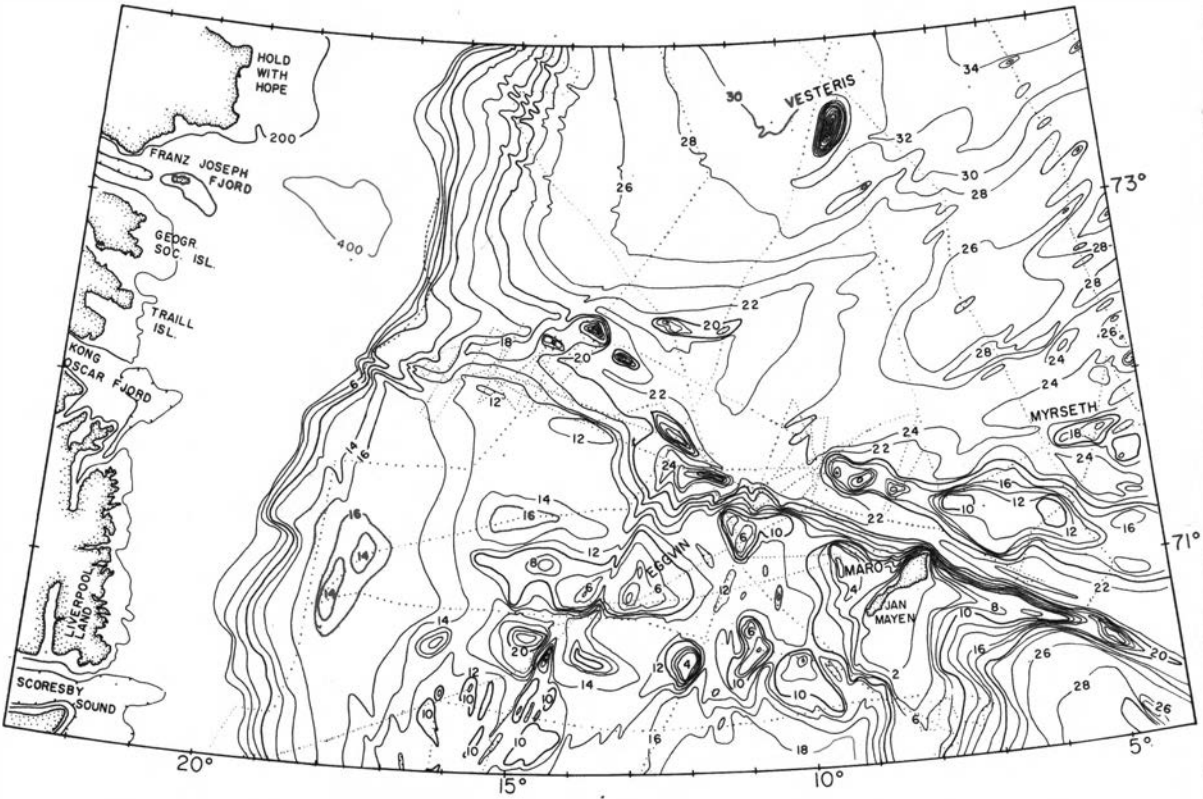

Fig. 2. *Bathymetric chart of the Western Jan Mayen Fracture Zone and northern portion of the Iceland Plateau. Dotted lines show control. Ship's data include* USNS LYNCH *and* R/V VEMA. *Dashed line track of* ARLIS II *from* OSTENSO (1968). Depths are in uncorrected hundreds of meters.

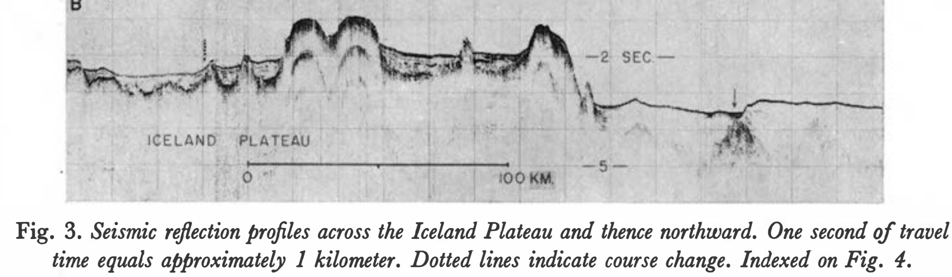

Fig. 3. *Seismic reflection profiles across the Iceland Plateau and thence northward. One second of travel time equals approximately 1 kilometer. Dotted lines indicate course change. Indexed on Fig. 4.*

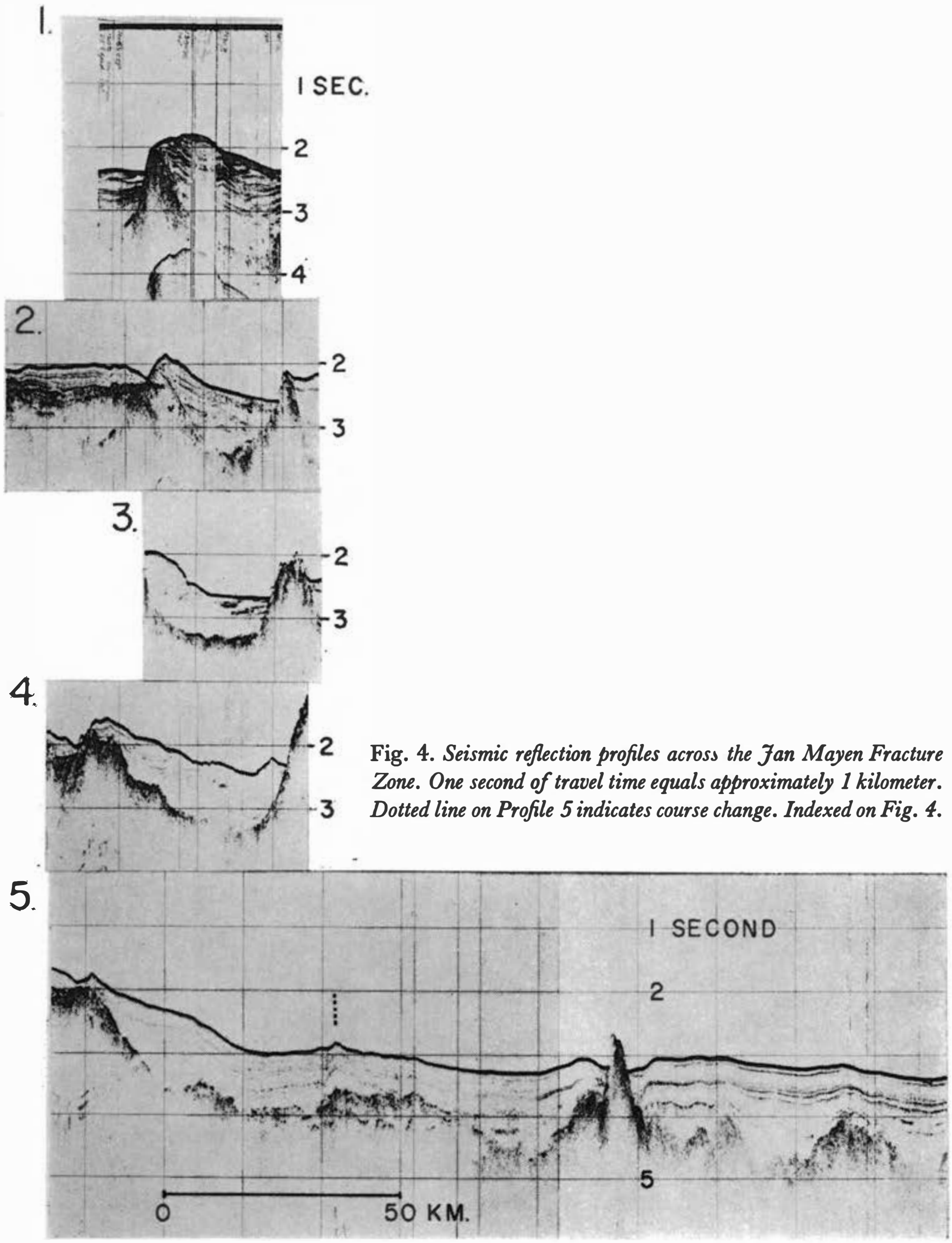

Fig. 4. *Seismic reflection profiles across the Jan Mayen Fracture Zone. One second of travel time equals approximately 1 kilometer. Dotted line on Profile 5 indicates course change. Indexed on Fig. 4.*

ARLIS II also shows a fault scarp on the continental slope to the south of our projection of the WJMFZ; however, we have interpreted this as a possible levee either structural or related to a basement high.

A submarine canyon has flowed along the south side of basement highs to enter the basin to the north of WJMFZ. Strangely, the canyon does not flow down the axis but courses to the northeast and broaches the northern wall of the fracture zone (Fig. 5). The highly reflective nature of the sea floor along

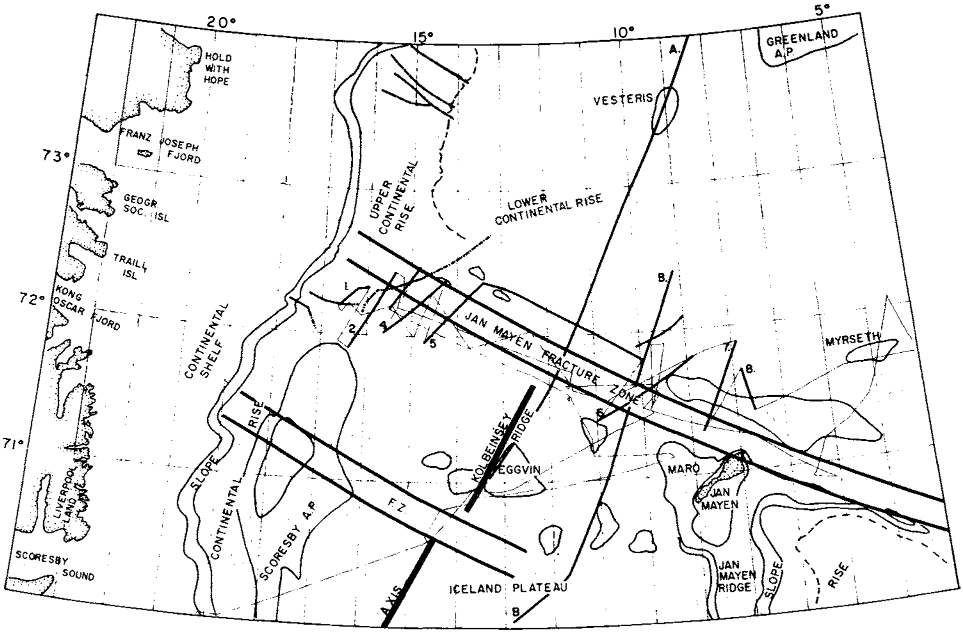

Fig. 5. *Index of seismic reflection profiles. Physiographic provinces are defined. Solid black lines show extent of fracture zones. Dashed lines are submarine canyons.*

the canyon floor can be seen in Profiles 1–3 (Fig. 4) and Fig. 7 which is a 3.5 kHz echogram corresponding to Profile 4. The failure of the canyon to follow the fracture zone axis is clearly seen in the presence of transparent sediments in Profile 4 (Fig. 4). Profile B (Fig. 3) crosses a canyon which apparently belongs to a different system.

Iceland Plateau

The Iceland plateau (Fig. 1) is a generally smooth, flat plateau with a north-south welt raised along its western portion by the Iceland-Jan Mayen Ridge branch of the mid-ocean ridge (Kolbeinsey Ridge) (Johnson et al. 1972). It northern and eastern edges are dominated by flat topped seamounts, the island Jan Mayen and Jan Mayen Ridge.

Up to 600 m of sediment is present on the northern part of the Iceland plateau. The fact that the sediment is transparent indicates it is primarily pelagic in nature. The interbedded reflective layers (Fig. 3, Profile B) may well be volcanic debris from the nearby volcanoes.

The flat topped banks (Eggbin, Marø) (Fig. 3, Profile B) are the apparent eroded remnants of subaerial volcanic peaks.

Intersection of Kolbeinsey Ridge and Fracture Zone

A depression excess of 3000 meters is found at the northern extension of Kolbeinsey Ridge at about 71° 30′N, 12°W (Fig. 2). A seismic reflection line

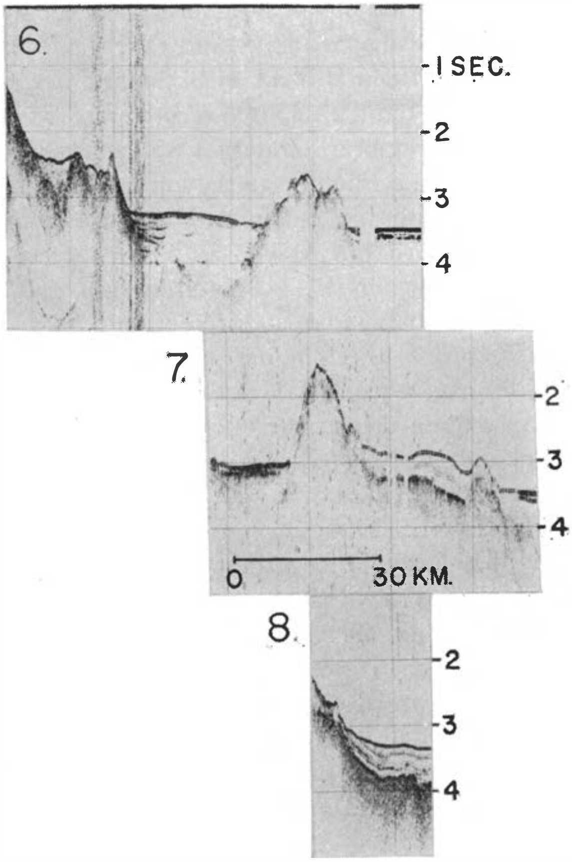

Fig. 6. *Seismic reflection profiles across Jan Mayen Fracture Zone and the northern end of the Iceland Plateau. One second of travel time equals approximately 1 kilometer. Arrow indicates submarine canyon. Profiles are indexed on Fig. 4.*

across the depression (Fig. 3, Profile A) shows a lack of sediment accumulation and an irregular rough bottom indicative of youth and tectonism. The north escarpment of the plateau (south wall of JMFZ) is also rough suggesting faulting. Normally this wall is smooth (Fig. 3, Profile B; Fig. 6, Profile 6).

SLEEP (1969) suggested that where the rift valley of the mid-oceanic ridge is terminated by fractures, depressions of the sea floor should occur. The cause would be the loss of hydraulic head due to increased viscosity of the magma upwelling in the rift valley. The fault wall creates an additional surface for the magma to adhere to in addition to increasing its viscosity by cooling. Figs. 2 and 3 show such a depression where Kolbeinsey Ridge is offset to the east by the Jan Mayen fracture zone.

Structural trends

The Jan Mayen Fracture Zone east of the island Jan Mayen to the south flank of the Vøring Plateau has an average strike of 330° (ELDHOLM and WINDISCH 1974). This parallels the trends of the Senja Fracture Zone as delineated by TALWANI and ELDHOLM 1974.

Our recent seismic reflection and bathymetric data suggest that the western Jan Mayen Fracture Zone extending from just east of Jan Mayen to the Greenland continental block, as delineated by the south wall of the fracture zone, has a WNW-ESE trend (300°) and that the fracture zone might be extrapolated into the continental block of Greenland in the vicinity of Kejser Franz Josephs Fjord (Figs. 1 and 2). This WNW-ESE trend is subparallel to both the Spar and the Tjørnes Fracture Zones, as well as small transform faults on the Reykjanes Peninsula, and fractures to the south of Iceland. This direction is also similar to the Greenland–Iceland aseismic ridge, and additionally to the WNW trending faults on both Jan Mayen and East Greenland. However, it has been conclusively shown by TALWANI and ELDHOLM (1974) that fracture zones which predate the Iceland Plateau strike approximately 330°. If one therefore assumes the fracture zones change strike at the edge of the continental shelf the WJMFZ would project just north of Hold with Hope (Figs. 1 and 2).

An unnamed fracture zone at 70°30'N is parallel to the Jan Mayen Fracture Zone and if projected parallel to the older portion of the Greenland Fracture Zone (330°) (ELDHOLM and WINDISCH, 1974) appears to enter Kejser Franz Josephs Fjord. There is some danger in projections of fracture zones as this one like Spar Fracture Zone does not offset oceanic crust older than m.y. (MEYER et al. 1972, TALWANI and ELDHOLM 1974). The former fracture zone does however lie along the border of sea floor which is predominantly shoaler than 1000 m (Fig. 1) and so may mark a structural boundary. Similarly if a lineament is drawn through Vesteris Bank parallel to the JMFZ to encompass the high blocky topography northeast of Jan Mayen (i.e., Sumit and Myrseth blocks) its western projection would lie just north of the Tertiary basalt province of Shannon Island (Fig. 1).

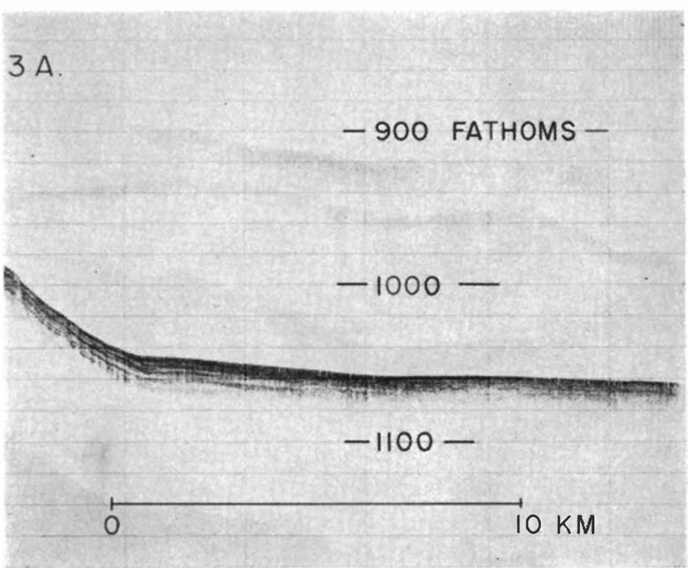

Fig. 7. *3.5 kHz echogram across the floor of Jan Mayen Fracture Zone. Record corresponds to Profile 3, Fig. 3. 900 fathoms = 1646 meters. 1000 fathoms = 1829 meters.*

Magmatic activity

The beginning of active rifting in the North Atlantic area appears to be recorded by intense magmatic activity in the Paleocene of Baffin Island, Greenland, the Faeroes, and Britain (BROOKS 1973a, b). Radiometric dates from all these areas (BEKINSALE et al. 1970) confirm that this activity began about 60 m.y. ago. This date is in close agreement with studies of magnetic anomalies of the intervening ocean (VOGT et al. 1970).

East Greenland Basalts

The areal distribution of East Greenland's extrusive Tertiary igneous rocks are shown in Fig. 1 (HALLER 1971). The coastal basalts are divided into two main groups. The southern basalt plateau province extends from Kangerdlugssuag (68°N) to Scoresby Sund (70°). These basalts are 4–6 km in thickness (HALLER 1971). The northern coastal basalts extend from Kejser Franz Josephs Fjord (73°N) to Shannon Island (75°30′N). These basaltic extrusions are much thinner than those to the south. BUTLER (1959) estimated the thickness did not exceed 700 m. In both instances the northern and southern lava sheets were extruded subaerially accompanied by sinking as interbedded marine beds are found in some locales (HALLER 1971). HALLER (1971) concludes that in the southern field volcanism commenced at the very end of the Cretaceous. By middle to late Eocene time the construction of the plateau was apparently completed. This dating leaves some 10–20 m.y. for the emplacement of the 6 km thick pile of basaltic sheets. BROOKS (1973b) notes the magmatic episode appears to have been extremely limited, being of the order of 10 m.y. and the time of accumulation of the great thicknesses of plateau basalt was probably only a few million years similar to the rate of extrusion of postglacial basalts on Iceland.

East Greenland basalts south of Scoresby Sund are rather uniform in composition and degree of differentiation (FeO*/MgO ratio = roughly 2.0) upwards through the pile. Of course, there are some slight internal variations in chemical character within this sequence. The flood basalts north of Kejser Franz Josephs Fjord on the other hand show an increasing degree of differentiation from the bottom to the top of the pile beginning at about FeO/MgO = 1.7 and ranging to 3.3 at the top (NOE-NYGAARD and PEDERSEN 1975). The age of this basalt sequence is not known with certainty but may be Paleocene-Oligocene. Thus there is a marked magmatic evolutionary difference between the tholeiitic pile south of Kejser Franz Josephs Fjord and that to the north of the fjord. The nunataks at the western end of Kejser Franz Josephs Fjord (KATZ 1952) include neplinites which are indicative of alkaline volcanic activity similar to the Jan Mayen region and the Vøring Plateau.

Jan Mayen and vicinity

In the subarctic, alkaline basalts occur mainly in the Vestmannaeyjar and Snæfellsnes zones of Iceland, Jan Mayen, Kong Oscars Fjord and Kangerdlugssuaq (East Greenland), the Hebridean Province, and the Vøring Plateau. As noted by BROOKS and JAKOBSSON (1974) all these sites are apparently characterized by a thick lithosphere either continental or basaltic. It seems relatively certain that Jan Mayen is located on continental material (JOIDES 1975). DITTMER et al. (1975) have reported on recent analyses of rocks from Eggvin Bank (Fig. 2) which yielded intermediate levels of incompatible elements. There were no alkaline rocks recovered from the ridge axis although basalts with alkalic affinities were recovered from the walls of the Jan Mayen Fracture Zone.

JOIDES sites

Leg 38 of the JOIDES program penetrated the basaltic basement in a number of holes in the Norwegian Sea (JOIDES 1975). Of interest to this study are sites 338, 342, 343 and 345. Subalkalic and alkalic basalt, dolerite basalts, diabase were recovered from holes 338 and 342 and probably hole 343. Drill Site 345 within the Jan Mayen Fracture Zone yielded highly altered basalts with secondary chloritization, zeolitization and albitization (M. TALWANI pers. comm. 1975).

A hot spot?

The reason for the localization of intense magmatic activity along the northwesterly-trending belt from Britain through the Faeroes and Iceland to Greenland and Baffin Bay has been attributed by WILSON (1965) to a "hot spot" or thermal center in the mantle. The nature of such a hot spot is still being debated (for example, SCHILLING 1973a–c, O'HARA 1973, DITTMER et al. 1975). It would appear that initiation of a hot spot may have caused a linear outpouring of basaltic magma along pre-existing lines of weakness (faults). This lineament would extend from the Faeroes to the Scoresby Sund region. At this time the Atlantic was closed or nearly so as drift commenced at about 60 m.y.b.p. The occurrence of these two events suggests a relationship with perhaps the thermal anomaly acting as a "cutting torch".

On Fig. 1 it is possible to draw two swaths of high volcanism. The northern one with an initial pulse about 60 m.y.b.p. and an acceleration commencing 30 m.y.b.p. in the Tertiary (Jan Mayen) fit the volumetric "hot spot" discharge curves of VOGT (1972), SCHILLING and NOE-NYGAARD (1974), and VOGT and JOHNSON (1975). SCHILLING et al. (1974) noted that the Mohns Ridge and the Kolbeinsey Ridge just south of Jan Mayen Fracture Zone have anomalously high La/Sm ratios which support a hot spot source nearby (SCHILLING 1973a–c). The East Greenland basalts differ from typical ocean ridge basalts in that they are richer in Fe, Ti, P and K (FAWCETT et al. 1973; NOE-NYGAARD 1966) in the same way that recent basalts from the central Icelandic volcanic zone (for example: JAKOBSSON 1972, BROOKS 1973b) and 12 m.y. old Icelandic basalts do (J. C. BAILEY and A. NOE-NYGAARD, unpublished). SCHILLING's (1973a) work on the Afar area suggests that such differences are common to hot spot basalts on a worldwide basis.

Jan Mayen may be situated over a region of relatively deep seated melting with production of alkaline basaltic materials (Fig. 1). The northern province of the East Greenland basalts might then correspond with the volcanic (basement) highs of an age of about 60 m.y. found on the seaward edge of the Vøring Plateau (JOIDES 1975). As noted by VOGT (1972), 60 m.y. was a time of intense volcanism on a global scale and probably reflects a time of active plume convection. VOGT and JOHNSON (1975) have suggested that the fracture walls of Charlie and Jan Mayen Fracture Zones reflect two pulses of asthenosphere flow in the late Tertiary. As they note in the Iceland area two ridge jumps are known to have occurred in the late Tertiary (JOHNSON et al. 1972). It is tempting therefore to associate these axial shifts with the two late Tertiary volume discharge maxima (VOGT and JOHNSON 1975) recorded by the fracture ridges. Vesteris Bank (Fig. 3, Profile A) and the other volcanic peaks (Fig. 2 and Fig. 3, Profile B) and Sumit would be manifestations of volcanic activity associated with the postulated Jan Mayen hot spot. The volcanism associated with Jan Mayen would date from the time of the axial shift from the Norwegian Sea to the Iceland Plateau in Middle to Late Oligocene (JOIDES 1975). This increase in plume discharge has been noted on a worldwide scale by VOGT (1972) and VOGT and JOHNSON (1975). There are a number of problems with a Jan Mayen hot spot. BROOKS and JAKOBSSON (1974) note that Jan Mayen has been suggested as a plume site (hot spot); however they discount the notion because to them it is unlikely that one plume in Iceland produces FETI basalts while another so close has such different products. They suggest the light rare earth element enrichment seen in the alkaline rocks from the vicinity of Jan Mayen is probably only a reflection of melting in small amounts at greater depth than seen in the case of tholeiites. NOE-NYGAARD and PEDERSEN (1975) suggest that the flood basalts of the Scoresby Sund region and the northern basaltic fraction could have become separated thus allowing the north of Kejser Franz Josephs Fjord basaltic fraction to follow an extended differentiation trend.

Therefore it seems possible that a relatively deep seated alkaline magma source which has been intermittently active in synchrony with VOGT's (1972) discharge curves has been active in the Jan Mayen region. The Cape Stosch northern basaltic province may well reflect a northern extension of the Scoresby Sund basalts separated by a structural discontinuity such as Jan Mayen Fracture Zone and thus not be related to the deeper alkaline source.

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References

AVERY, O. E., G. D. BURTON, and J. R. HEIRTZLER, 1968: An Aeromagnetic Survey of the Norwegian Sea. *Jour. Geophys. Res.* **73**. p. 4583–4600.

BECKINSALE, R. D., C. K. BROOKS, and D. C. REX, 1970: K-Ar Ages for the Tertiary of East Greenland. *Dansk. Geol. Faren. Medd.* **20**. p. 27–37.

BROOKS, C. D., 1973(a): Rifting and Doming in Southern East Greenland. *Nature, Phys. Sci.* **244**. p. 23–24.

BROOKS, C. K., 1973(b), Tertiary of Greenland – A Volcanic and Plutonic Record of Continental Break-up. **In**: *Arctic Geology* – Second International Symposium on Arctic Geology (ed. M. G. PITCHER) Amer. Assoc. of Petrol. Geol, Tulsa, Oklahoma.

BROOKS, C. K. and S. P. JAKOBSSON, 1974: Petrochemistry of the Volcanic rocks of the North Atlantic Ridge System. **In**: *Geodynamics of Iceland and the North Atlantic Area* (ed. L. KRISTJANSSON), D. Riedel Publ. Co., Boston, p. 139–154.

ELDHOLM, O. and M. TALWANI, 1973: Structure and Development of the Jan Mayen Ridge. *Trans. Amer. Geophys. Union.* p. 324.

ELDHOLM, O. and C. C. WINDISCH, 1974: The Sediment Distribution in the Norwegian-Greenland Seas. *Geol. Soc. Amer. Bull.*, in press.

FAWCETT, J. J., C. K. BROOKS, and J. C. RUCKLIDGE, 1973: Chemical Petrology of Tertiary Flood Basalts from the Scoresby Sound Area. *Meddelelser om Grønland* **195** (6). p. 1–55.

FITCH, F. J., 1964: The Development of the Beerenberg Volcano, Jan Mayen. *Proc. of the Geol. Asso.* **75**. p. 133–165.

HALLER, J., 1971: *Geology of the East Greenland Caledonidos.* Interscience Publishers, New York, 413 p.

JAKOBSSON, S. P., 1972: Chemistry and Distribution Pattern of Recent Basaltic Rocks in Iceland. *Lithos* **5**. p. 365–386.

JOIDES, 1975, Leg 38. *Geotimes* **2**. p. 24–26.

JOHNSON, G. L., 1968: Marine Geology in the Environs of Jan Mayen. *Norsk Polarinstitutt Årbok* 1966. p. 105–111.

— 1975: The Jan Mayen Ridge. **In**: Canada's Continental Margins and Offshore Petroleum Exploration (C. YORATH ed.), *Canadian Society of Petrol. Geol. Mem.* **4**. p. 225-234.

JOHNSON, G. L. and B. C. HEEZEN, 1967: The Morphology and Evolution of the Norwegian-Greenland Sea. *Deep Sea Res.* **14**. p. 755–771.

JOHNSON, G. L., P. R. VOGT, and O. E. AVERY, 1971: Evolution of the Norwegian Basin. ICSU/SCOR Working Party 31 Symposium, Cambridge, 1970, The Geology of the East Atlantic Continental Margin (ed. F. M. DELANY) 1971, *Inst. of Geol. Sciences Report* No. 70/14. p. 53–65.

KATZ, H. R., 1952: Ein Querschnitt Durch die Nunatakzone Ostgrønlands *Medd. om Grønland* **144**. 65 pp.

MEYER, O., D. VOPPEL, U. FLEISCHER, H. CLOSS and K. GERKE, 1972: Results of bathymetric, magnetic and gravimetric measurements between Iceland and 70°N. *Deut. Hydro. Zeit.* **5**. p. 193–201.

NOE-NYGAARD, A. and A. K. PEDERSEN, 1975: Progressive Chemical Variation in a tholeiitic lava sequence at Kap Stosch, Northern East Greenland. *Bull. Geol. Soc. Denmark* **23**. p. 175–190.

O'HARA, M. J., 1973: Non-Primary Magmas and Dubious Mantle Plume Beneath Iceland. *Nature* **243**. p. 507–508.

OSTENSO, N. A., 1968: Geophysical Studies in the Greenland Sea. *Geol. Soc. Amer. Bull.* **79**. p. 107–132.

SCHILLING, J. G., 1973(a): Afar Mantle Plume: Rare Earth Evidence. *Nature, Phys. Sci.* **242**. p. 2–5.

— 1973(b): Iceland Mantle Plume: Geochemical Evidence Along Reykjanes Ridge. *Nature* **242**. p. 565–571.

— 1973(c): Iceland Mantle Plume. *Nature* **246**. p. 141–143.

SCHILLING, J. G., D. R. JOHNSON and T. H. JOHNSTON, 1974: Rare Latitudinal Variations Along the MAR. *Trans. Amer. Geophys. Union* **55**. p. 294.

SLEEP, N. H., 1969: Topography at Intersection of Mid-Ocean Ridges and Transform Faults. Trans. *Amer. Geophys. Union* **50**. p. 181.

SYKES, L. R., 1965: The Seismicity of the Arctic. *Bull. Seism. Soc. Amer.* **55**. p. 501–518.

TALWANI, M. and O. ELDHOLM, 1974: The Margins of the Norwegian-Greenland Sea. **In**: *The Geology of Continental Margins* (eds. C. A. BURK and C. L. DRAKE).

— 1975: Evolution of the Norwegian-Greenland Sea. *Bull. Geol. Soc. Amer.* in press.

VOGT, P. R., 1972: Evidence for Global Synchronism in Mantle Plume Convection and Possible Significance for Geology. *Nature* **240**. p. 338–342.

VOGT, P. R., N. A. OSTENSO and G. L. JOHNSON, 1970: Magnetic and Bathymetric Data Bearing on Sea-Floor Spreading North of Iceland. *Jour. Geophys. Res.* **75**. p. 903–970.

VOGT, P. R. and G. L. JOHNSON, 1975: Transform Faults and Longitudinal Flow below the Mid-Oceanic Ridge. *Jour. Geophys. Res.* **80**. p. 1399–1428.

WILSON, J. T., 1965: Submarine Fracture Zones, Aseismic Ridges, and the International Council of Scientific Union Line – Proposed Western Margin of the East Pacific Ridge. *Nature* **207**. p. 907–911.

Earthquakes in the Svalbard area

By Atle Austegard[1]

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Abstract

In September 1967 a seismic standard station (KBS) was established at Ny-Ålesund, Svalbard. Until January 1974 almost 600 local earthquakes ($\Delta < 5^0$) were recorded by KBS, but less than 20% of these were located using distant stations. Azimuth and epicenter-distance can be estimated from the KBS-records to give approximate epicenters for about one third of the local shocks by using the first P-motion and the difference in S—P-arrival times. Most of the earthquakes in this area are located on the northward continuation of the Mid-Atlantic ridge, but also an active zone in the Storfjord area east of Spitsbergen is found. A local magnitude scale is developed, based on 33 local events which also are determined by ISC.

Introduction

The first study of the local seismic activity in the Svalbard area was performed by a German expedition in 1911–1912. They had a seismograph placed in Adventdalen (Adv.), Spitsbergen (see Fig. 1), and recorded a number of earthquakes in the distance range 160 to 300 km from the station (Tams s.a.).

In 1958 the Seismological Observatory, University of Bergen, established a seismograph station at Kapp Linné, on the southern entrance ol Isfjorden, see Fig. 1. This station had the code ISF (Isfjord) and it was equipped with a Willmore short period vertical seismograph. The station was in regular operation from 1 August. A radio station at the same site did, however, disturb the

[1] Seismological Observatory, Bergen, Norway.

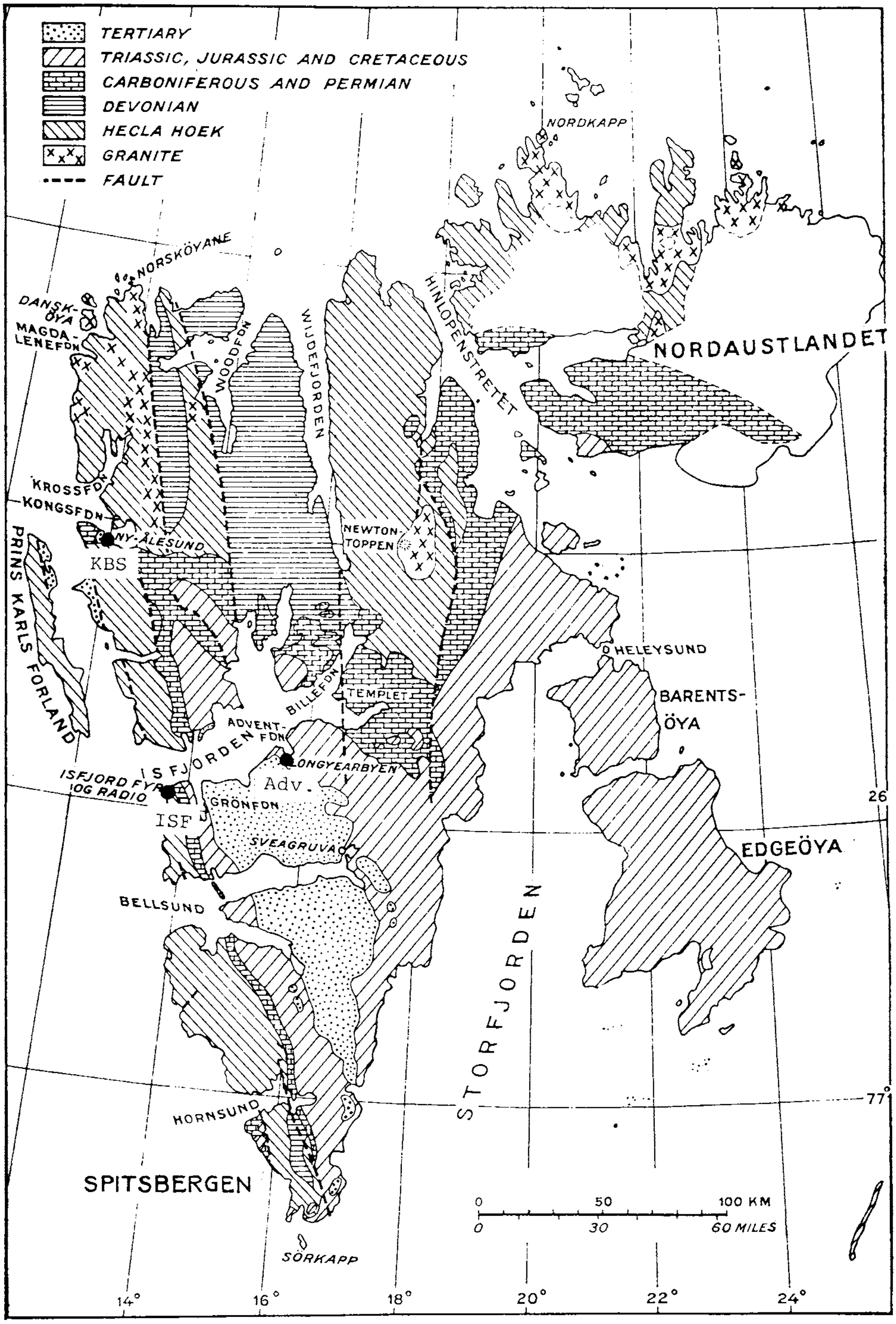


Fig. 1. *Outline of the geology of Svalbard* (*after* WINSNES, HEINTZ *and* HEINTZ *1961*).

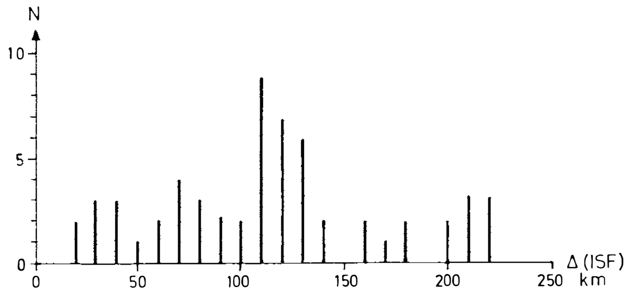


Fig. 2. *Local earthquake frequency versus distance from ISF* (*after* SELLEVOLL *1960*).

recordings, and ISF was therefore closed down 28 February 1963. The recordings from the first 11 months have been analysed by SELLEVOLL (1960). Fig. 2 shows the distance distribution of the local events during this period.

A new seismic station was established in the area in 1967. This station has the code KBS (Kings Bay) and its position is 78°55′03″N, 11°55′26″E, see Fig. 1. KBS is a World Wide Network Standard Station (WWNSS), equipped with 3 short and 3 long period components. It has been in regular operation from 23 September 1967 with some few interruptions.

The earlier studies mentioned above revealed that it is a considerable seismic activity in and around Svalbard, which is not determined by the international seismological network. The purpose of this study is as far as possible to map this local activity by help of the KBS-records and to develop a local magnitude scale for KBS.

Internationally determined epicenters since 1955

The epicenter distribution for the time period 1955–1973 is shown in Fig. 3. Only earthquakes in the interval 30°W–30°E are incorporated. The epicenters are marked by three different symbols according to magnitude classes, and they are taken from the following sources, which are considered to be the most accurate available:

1955–1963: SYKES (1965).
1964–1970: International Seismological Center (ISC), Edinburgh.
1971–1973: Preliminary determinations by USGS (formerly NOAA), Boulder.

Fig. 3 is dominated by the earthquakes which are connected with the northward elongation of the Mid-Atlantic ridge system. In Storfjorden and the eastern part of Spitsbergen we notice a weak seismic zone, while the rest of the area is nearly seismic inactive.

A data base consisting of earthquakes determined by ISC and also recorded by KBS was compiled for further use in the local epicenter and magnitude calculations. Only the greater earthquakes, with 20 or more stations used in the ISC-solution, were included. Thus the data base consists of 40 earthquakes in the distance interval $1° < \Delta(KBS) < 5°$, see Table 1.

Table 1

Data base for computing local magnitude and distance formulas

Date	From ISC-bulletin									From KBS-seismograms		
	H	Lat.(N)	Long	h	m	N	N(m)	Δ (KBS)	Az (KBS)	m (KBS)	S–P	Az
67 10 18	01 11 45.8	79.81	2.90E	42	5.7	293	49	1.90	303	5.78		
11 23	13 42 02.6	80.20	0.70W	16	5.7	277	46	2.63	305	5.28	30.0	307±1
68 01 06	20 10 44.1	80.11	2.90W	33	4.5	38	10	2.96	301	4.74	30.8	321±7
04 07	05 16 24.9	81.52	3.40W	28	5.3	153	26	3.68	322	5.19		318±3
05 11	04 54 23.0	81.20	3.50W	33	4.2	23	5	3.51	318	4.19	40.9	
07 07	00 31 18.7	76.19	9.80E	33	4.4	28	5	2.78	191	4.19	33.3	199±6
08 10	00 43 08.2	76.50	9.00E	33	4.5	51	11	2.51	196	4.65		
10	01 04 42.7	76.50	8.00E	33	4.3	29	8	2.57	201	4.21		
10	04 56 55.8	76.39	9.10E	33	4.5	39	13	2.61	195	4.30		
09 09	09 54 06.5	79.45	3.10E	33	4.5	46	7	1.75	292	4.67	15.0	300±2
12 16	10 06 28.1	79.40	3.00E	33	4.0	27	6	1.76	290	4.40		300±6
30	10 27 10.9	76.32	7.90E	24	4.8	152	18	2.75	200	4.85		
69 02 25	16 30 50.0	76.60	8.80E	33	4.4	31	8	2.42	197	4.09		
04 21	22 28 00.1	74.23	9.30E	33	4.9	107	16	4.75	189	5.13		
08 19	02 26 59.0	74.30	10.40E	75	4.3	30	8	4.66	185	4.09		
11 10	18 15 56.0	77.13	14.60E	10	4.7	76	10	1.88	161	4.95		175±4
70 02 12	05 11 17.9	80.80	5.10W	33	4.5	31	7	3.54	310	4.42	35.2	
04 27	13 46 37.5	80.20	0.80W	4	4.4	20	3	2.65	305	4.43	26.7	
05 03	10 58 03.0	79.66	2.40E	33	3.9	25	4	1.93	297	4.51		
10	05 52 39.2	81.46	5.20W	33	4.4	32	3	3.87	319	4.47	40.0	329±9
19	02 07 40.5	79.16	2.30E	25	4.5	59	11	1.86	282	4.57	19.4	290±1
09 24	18 39 24.6	79.85	5.00E	33	4.5	24	6	1.59	310	4.51	16.0	305±3
10 20	23 29 39.3	74.80	9.60E	33	4.5	39	5	4.18	188	4.84		
21	08 14 14.1	74.62	8.56E	33	5.4	202	31	4.39	192	5.27		207±4
26	20 53 32.6	79.80	2.90E	34	5.6	266	46	1.90	302	5.19		
12 31	08 07 20.6	80.08	1.30W	33	4.5	26	5	2.69	302	4.70	26.7	304±8
71 01 27	20 45 42.1	76.56	6.90E	31	4.7	62	6	2.60	207	4.58	25.0	
28	11 03 49.0	76.40	6.90E	33	4.3	35	3	2.75	206	4.44		
29	08 33 48.0	78.61	6.70E	33	4.6	46	3	1.07	256	4.54	11.6	236±1
31	04 33 26.6	76.61	7.40E	33	4.4	44	5	2.51	205	4.52	29.0	
04 10	06 07 39.4	74.08	9.90E	33	4.4	36	3	4.89	187	4.17		
08 12	23 13 57.0	82.80	5.20W	33	4.6	21	4	4.73	333	4.52	52.0	346±9
22	11 07 21.8	82.96	6.20W	33	4.5	60	7	4.93	333	4.65	49.5	
12 16	18 35 45.3	77.80	18.10E	33	4.9	134	20	1.68	129	5.04		
72 04 16	13 53 08.9	79.48	4.20E	33	4.7	48	7	1.56	295	4.54	14.0	299±1
06 21	03 44 15.6	80.36	2.20E	33	4.4	33	6	2.28	314	4.52	25.5	320±10
11 19	20 10 47.8	80.49	2.40W	0	5.4	207	34	3.01	308	5.39	30.0	308±2
25	20 03 27.4	80.28	2.10W	20	5.6	196	47	2.88	305	5.23	31.0	309±1
12 07	17 30 33.7	81.94	6.40W	0	4.5	38	5	4.28	324	4.68	44.0	319±9
15	19 54 43.4	82.52	6.20W	0	4.8	53	9	4.63	330	4.72	48.0	340±2

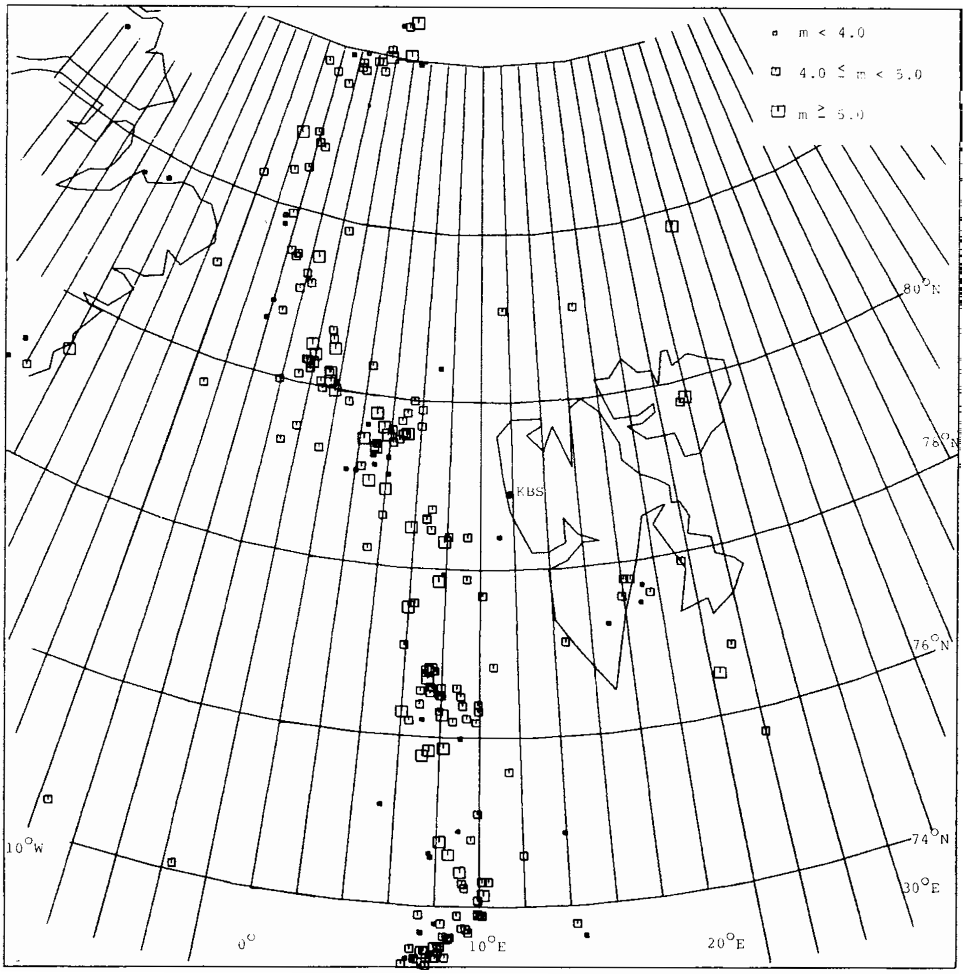


Fig. 3. *Epicenters 1955–1974, given by USGS, ISC and* SYKES (*1965*).

Epicenter-determinations from KBS-records

The S-P arrival time difference is used to find the epicenter distance Δ from KBS. All the earthquakes in Table 1, with a reliable S-P reading at KBS were used in order to find a local S—P travel time table. Fig. 4 shows a plot of these 22 quakes, and also the function

$$S-P = (10.6 \pm 0.5)\Delta \tag{1}$$

(S-P in sec, Δ in degrees), which represents the least square linear fit through origo. This relationship will be applied later in this study.

The procedure followed here is nearly independent of the crust and upper mantle structures and velocities in the area, and is very little influenced by random errors in the epicenter and depth calculated by ISC. Apparently the earthquakes in the area are very shallow. As seen from Table 1 all but one have an estimated depth less than 43 km, but actually 26 of 40 depths are not calculated but assumed to be normal.

The azimuth from KBS to the epicenter is found from the first P-wave motion. The amplitudes are read to the nearest tenth of a millimetre using a magnifying glass, and the N/E-ratio together with the up- or down motion on the Z-component defines the azimuth.

In order to check this procedure, a comparison of the ISC- and the KBS-determined azimuths in Table 1 was done. The 20 actual quakes are plotted in Figs. 5a, b. The bars give the maximum variation in the KBS-azimuth when the N- and the E-amplitude are changed ± 0.1 mm, and represent thus the reading error, but reflect also the size of the inverse amplitude. As can be seen the KBS-azimuths are within $\pm 15°$ of the ISC-azimuths in all but two cases, where the difference is 20°.

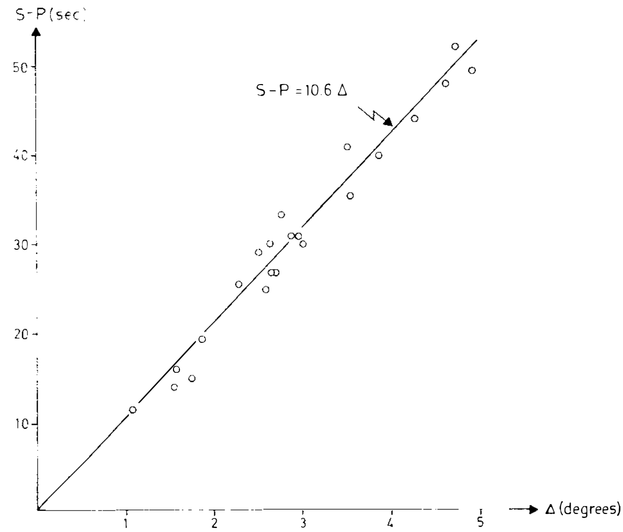


Fig. 4. *S–P arrival time difference versus distance from KBS*·

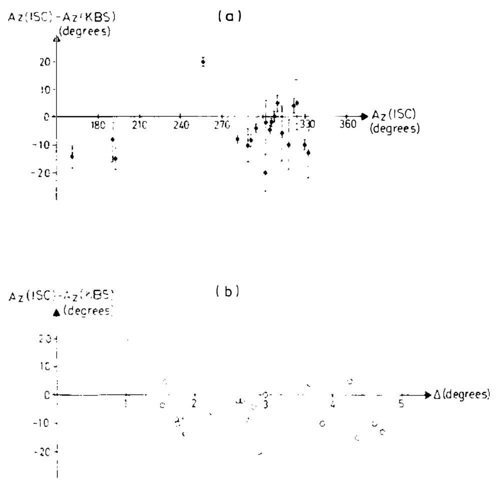


Fig. 5. *Difference between the ISC- and the KBS-determined azimuth versus:*

a) *azimuth from KBS (the bars indicate the uncertainties in the KBS-readings),*

b) *distance from KBS.*

A dip in the sub-station structures and/or uncorrect orientation or magnification of the horizontal instruments may introduce errors in the azimuth-calculations. In order to check this, six well-recorded events in the distance range $5^\circ < \Delta(\text{KBS}) < 14^\circ$ (Novaya Zemlya, Jan Mayen and NW of KBS) were used. Any epicenter error has little influence in this distance range, and the direction of the ray at KBS will still be influenced by a dipping Moho. The azimuths of the six events were, however, in all cases within four degrees of that given by ISC. Thus any significant bias in the procedure is not supported.

The results above are based on the ISC-solutions. A natural question is how accurate these solutions are in the area. HUSEBYE et al. (1975) found a relative epicenter precision of about 20 km when the same event was determined by all recordings (number of stations, N, above 100) and by the twenty most sensitive stations. This, however, must be regarded as a lower limit of the real relative precision between a large event ($N > 100$) and a smaller one ($N = 20$), because the signals from the smaller one are usually not so well-recorded by the 20 stations as in the large event case. Further, their experiment tells nothing about the absolute epicenter accuracy. LILWALL and UNDERWOOD (1970) investigated the effect on the epicenter of large shocks when station corrections were applied in the solution. For the Arctic Ocean they found that the "epicentre network bias" was less than 6 km. However, the source bias is still unknown because no master event is available in the region.

From the above discussion it is believed that an epicenter determined by more than 20 but less than say 40 stations (half of the shocks in Table 1 fall in this category) may be 30–40 km in error. This is comparable to an error in the S-P-difference of about ± 4 sec, or in the azimuth of about $\pm 18^\circ$ ($\Delta = 1^\circ$), $\pm 6^\circ$ ($\Delta = 3$) and $\pm 4^\circ$ ($\Delta = 5^\circ$).

Magnitude-determinations from KBS-records

All earthquakes in Table 1 which had bodywave magnitude determined by five or more stations were used as a data base in developing a local KBS magnitude formula. Usually the magnitude is calculated from the amplitude/period ratio of P-waves. For instance, EVERNDEN (1967) found for crustal- and P_n-phases in the United States relationships of the form $m = a + b \log A/T + c \log \Delta$. In recent years, it is found that the total signal duration, τ, gives a more stable magnitude measure for local shocks. Figs. 6a, b show that this also is true for our data base. The m-log τ plot exhibits not only less scatter than the m-log (A/T) plot, but also a more clear Δ-dependence. Further it contains more points because it is impossible to read the amplitude of the largest shocks.

REAL and TENG (1973) give a summary of existing empirical formulas relating magnitudes and signal duration. They are all of the form

$$M = b_0 + b_1 \log\tau + b_2\Delta \qquad (2)$$

where M in some cases is the surface wave magnitude, in other cases the local Richter magnitude, M_L. They found a similar relation useful for shocks in

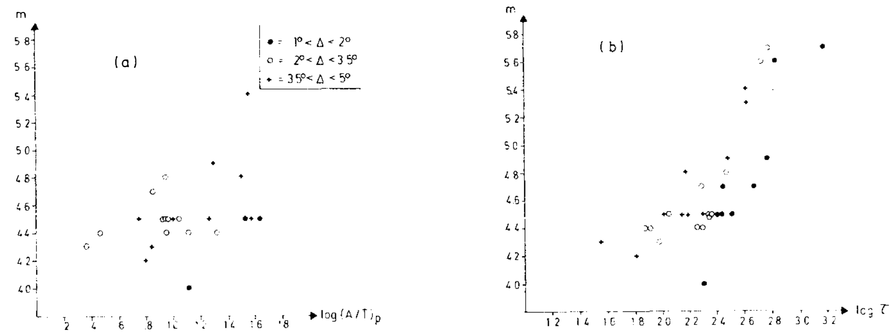


Fig. 6. *The relationship between the ISC-reported body wave magnitude m(ISC) and:*
a) *the max. A/T-ratio in the P-group, measured on the vertical short-period component at KBS,*
b) *the signal duration at KBS.*

Southern California, but for $M_L > 3.8$ (corresponds to $m > 4.6$) they found better agreement between the M_L and the duration magnitudes when $(\log \tau)^2$ was used instead of $\log \tau$.

The dataset mentioned above was used in this study to determine the coefficients in linear expressions by the least square method. Firstly equation (2) was used, resulting in the following relationship

$$m(KBS) = 1.291 + 1.267 \log\tau + 0.151\Delta \tag{3}$$

where the logarithm is taken to the base of ten, Δ is the epicenter-distance from KBS in degrees, and τ is the signal duration in seconds. The total duration is from the first P-onset to the end of the earthquake record, here defined somewhat arbitrary as the point where the amplitude of the signal falls below 1 mm (when the KBS-magnification is 25 k). In some few cases the noise level impeded the τ-eading, but otherwise the noise fluctuations have very little influence on the duration as defined here.

The standard deviation of duration magnitude from the ISC-bodywave magnitude is defined in the following manner:

$$\sigma = \left\{ \frac{1}{N-1} \sum_{i=1}^{N} \left(m(KBS) - m(ISC) \right)_i^2 \right\}^{\frac{1}{2}}$$

where N is the number of earthquakes used (= 33).

Calculations using (3) gave $\sigma(3) = 0.24$.

A second version was also tried, where Δ in (2) was replaced with EVERNDEN's term $\log \Delta$. This resulted in the equation

$$m(KBS) = 1.190 + 1.289 \log \tau + 1.116 \log \Delta \tag{4}$$

and a reduction in σ of 3%. Both (3) and (4) gave too small magnitudes for most of the largest shocks. Trying to reduce this, $\log \tau$ was replaced with a term $(\log \tau)^2$ in a third version. The resulted relationship was

$$m(KBS) = 2.686+0.273\ (\log \tau)^2+1.106 \log \Delta \qquad (5)$$

with a standard deviation $\sigma(5) = 0.21$. This is nearly the same deviation as REAL and TENG (1973) found when comparing duration magnitudes and mean local Richter magnitudes.

The magnitudes calculated by the formulas (3), (4) and (5) are deviating slightly only for the largest and smallest shocks. Further in this study (5) is used, because this formula gave the smallest σ. A more complex equation may reduce the standard deviation slightly, but the data are too sparse to justify any such speculations. In figs. 7a, b the duration magnitudes from (5) are compared to the ISC-magnitudes, and in fig. 7c isolines of the duration magnitude are drawn in the $(\log \tau)^2$, $\log \Delta$-plane. This figure makes it easy to find m(KBS) when τ and S-P are read from the record.

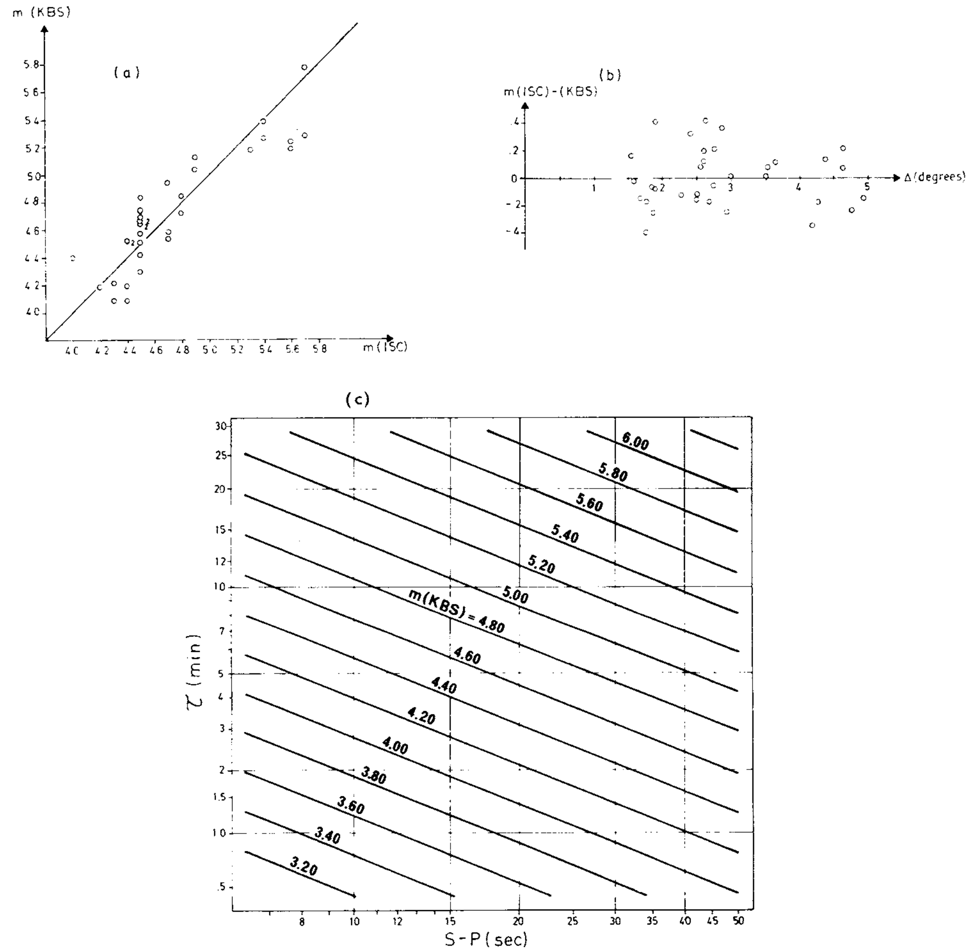


Fig. 7. *The duration magnitudes m(KBS) determined by KBS.*
a) *m(KBS) versus m(ISC).*
b) *m(ISC) – m(KBS) versus distance from KBS.*
c) *Chart for using signal duration and S—P arrival time difference at KBS to find m(KBS).*

The local seismicity around KBS

Using the results obtained above, we are now able to determine earthquake parametres exclusively from the KBS-records. In this way we hoped to obtain a closer knowledge of the local seismic activity. We included only shocks with $\tau > 0.5$ min in this study. It is impossible to determine all these shocks, and the main cause is a not well-recorded first P-onset. While the S—P and τ could be read with reasonable accuracy for nearly all of the investigated shocks, giving the distance and magnitude, the azimuth could be calculated in only one third of the cases.

The local seismicity is distributed roughly in three zones, one on the Knipovich ridge SSW of KBS, one on the Spitsbergen fracture zone WNW of the station, and one in the Storfjord area between Spitsbergen and Edgeøya. The recordings at KBS of shocks in these zones are generally different, while shocks in the same zone give more identical recordings.

Figs. 8a, b, c give typical examples of records from the three zones. Shocks in the Knipovich zone (Fig. 8a) give often a small P-onset followed by a stronger one 1–2 sec later. Therefore rather few shocks are determined compared to the two other zones. Sometimes the S-onset also is difficult to determine. Shocks in the Spitsbergen fracture zone (Fig. 8b) usually exhibit a clear P- and S-onset.

Recordings of earthquakes in the Storfjord area (Fig. 8c) are different from the others in several ways. They are more high-frequent and the P-wave group is dominated by a second arrival with amplitude 5–10 times larger than the

(a)

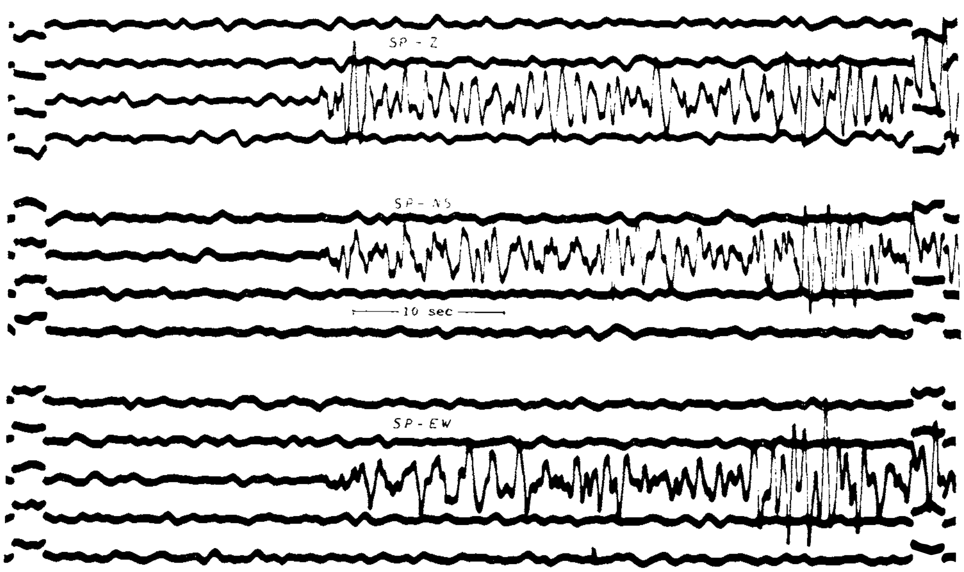
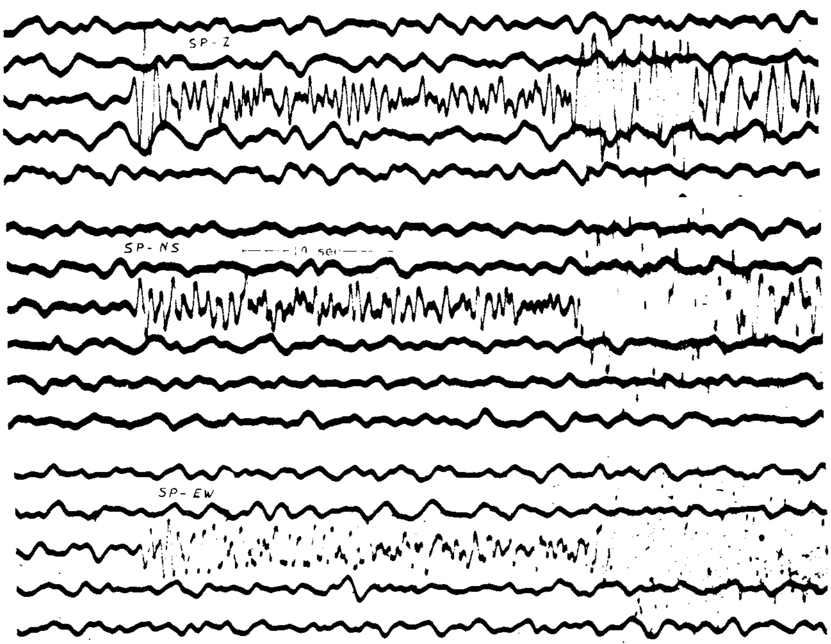


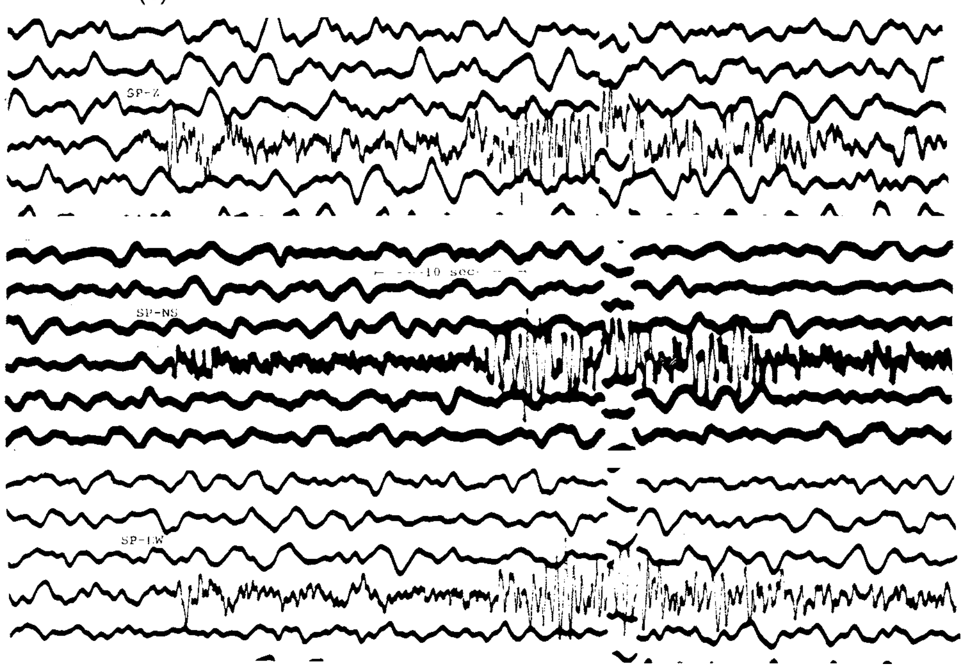
Fig. 8. *KBS-seismograms of an earthquake in:*
a) *the Knipovich zone (710127, H = 204542.8, 76.6N, 6.9E, m(ISC) = 4.7,* $\triangle$ *(KBS) = 2.6°)* (Fig. 8b & c continued next page),

(b)



b) *the Spitsbergen fracture zone* (*671126, H = 113130.6, 80.3N, 2.5W, m(ISC) = 4.2,* $\triangle$*(KBS) = 2.95*^{0}),

(c)



c) *the Storfjord area* (*721205, H = 143402, 77.4N, 18.0E, m(KBS) = 3.9,* $\triangle$*(KBS) = 2.0*^{0}*, not located by other agencies*).

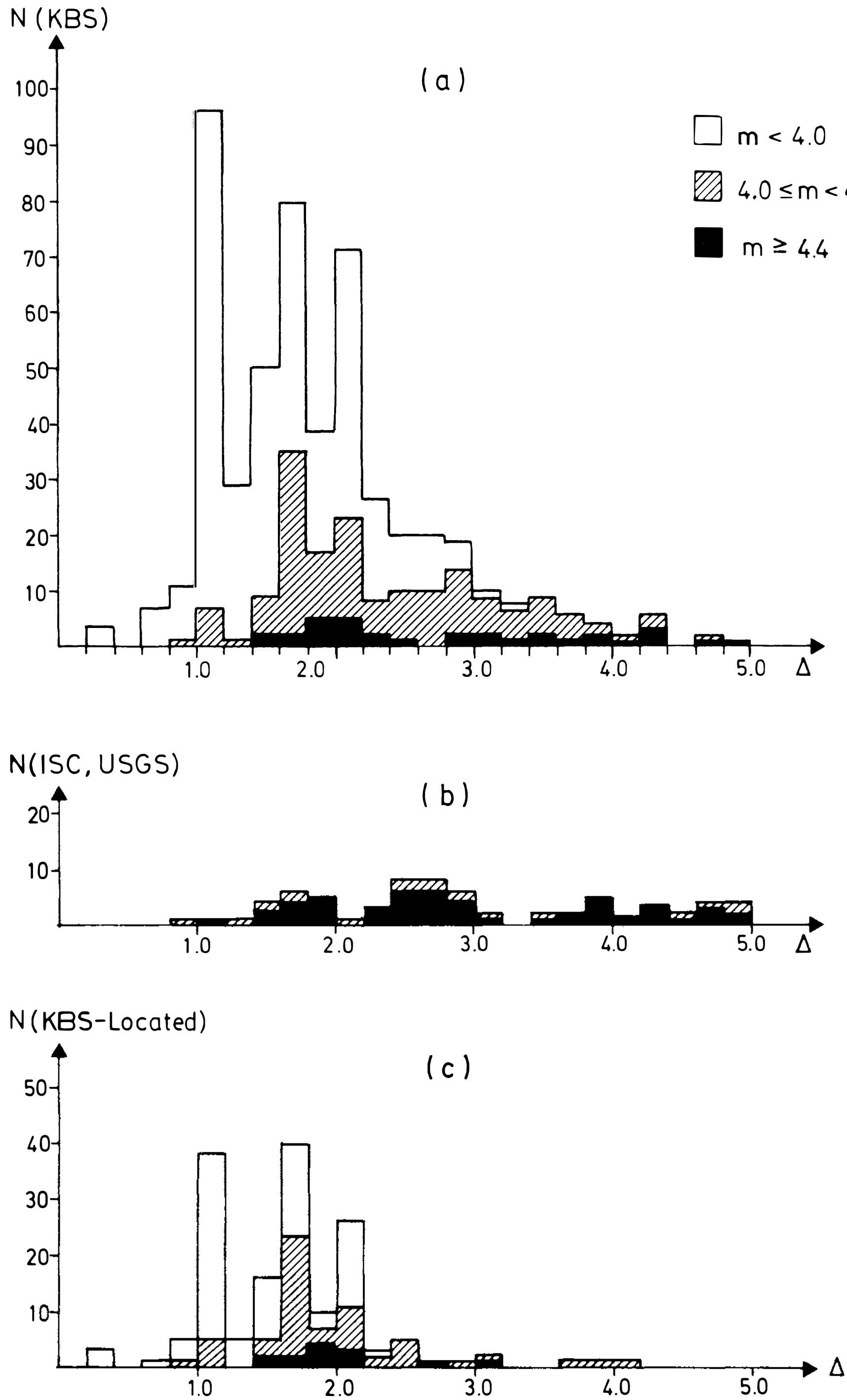


Fig. 9. *Number of local earthquakes versus distance from KBS.*

a) *Shocks recorded by KBS, not reported by ISC/USGS, Sept. 1967–Dec. 1973.*

b) *Shocks reported by ISC/USGS, Sept. 1967–Dec. 1973.*

c) *The shocks in Fig. 9a which are located by KBS.*

first arrival. In contrast to the other two zones, the crust in the Storfjord area is most likely of a continental type (see RYGG 1970), and the two P-onsets are interpreted as P_n and P_g. The arrival time difference P_g–P_n increases from about 2 sec at $\Delta = 2°$ to about 10 sec at $\Delta = 4°$. Because of the small first onset, the P_g-amplitudes are used to determine the azimuth. The S_n-wave is believed lost in the P_g-coda, so the first visible S-wave is interpreted as S_g. The epicenter distance is calculated using the time difference S_g–P_g in (1).

It is not possible to discuss the seismicity in the area thoroughly because of the problems mentioned in the azimuth-calculations. Some results are, however, not influenced by this. Fig. 9a shows a histogram of the number of shocks, recorded by KBS with $\tau > 0.5$ minutes, versus distance from KBS. The histogram does not include earthquakes which are determined by ISC (1967–70) or USGS (1971–73) in the same time interval; they are shown in Fig. 9b. A comparison of the two figures shows that ISC/USGS do not pick up a number of shocks with magnitudes even above 4.4. The distribution of those shocks in Fig. 9a which are located by KBS, are shown in Fig. 9c. We see that most of the shocks with m(KBS) < 4.0 are unlocated, and so are some of the larger more distant shocks.

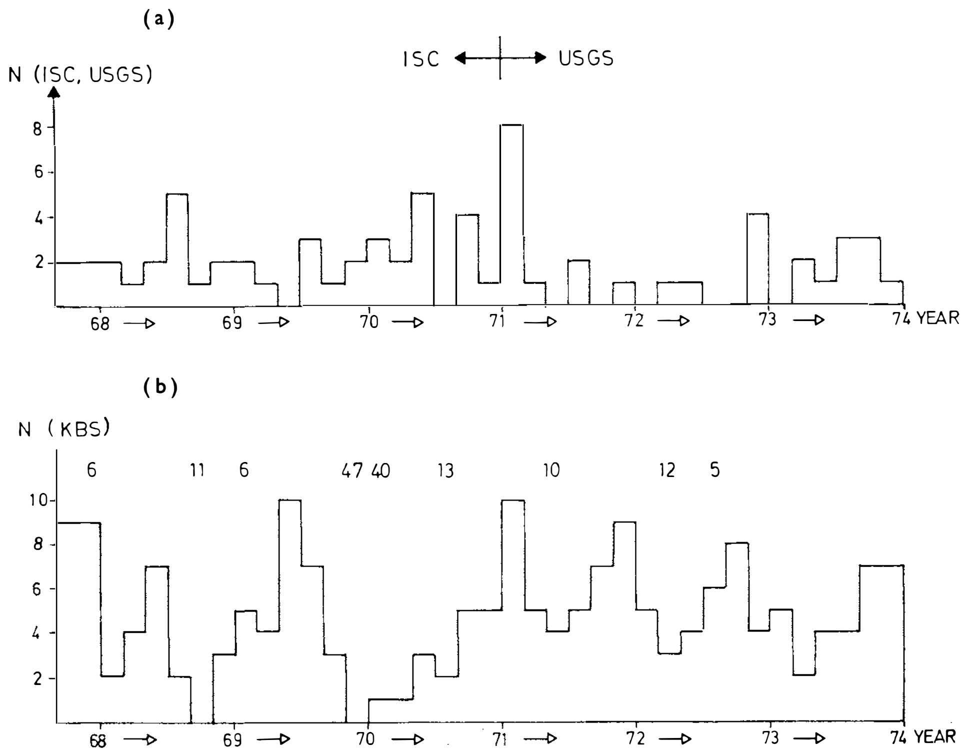


Fig. 10. *Number of local earthquakes with $m \geq 4.0$ versus time.*
a) *Shocks reported by ISC/USGS.*
b) *Shocks recorded by KBS, not reported by ISC/USGS (the numbers represent the amount of days KBS was out of operation).*

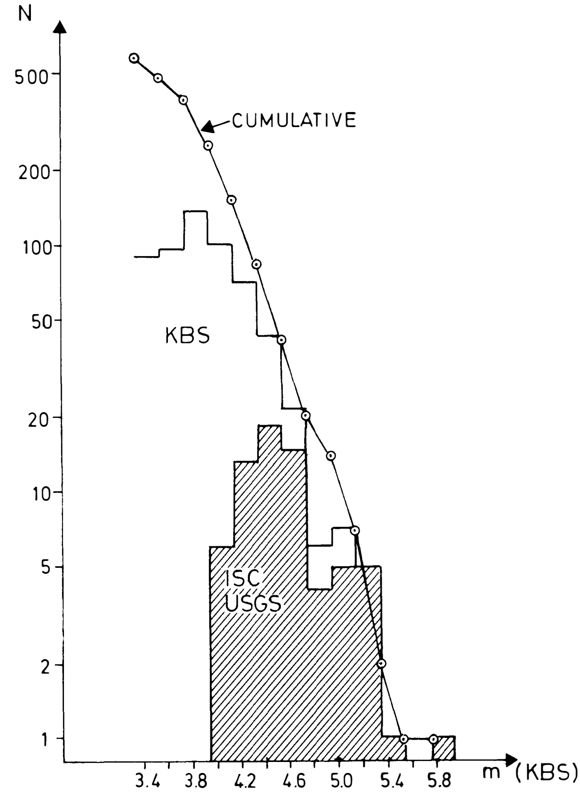


Fig. 11. *Number of local earthquakes versus duration magnitude m(KBS).*

The distribution in time of earthquakes with m≥4.0 is shown in Fig. 10. The gaps in the KBS-histogram are in some degree correlated to the intervals in which the station was out of operation. Such intervals, amounting to more than four days during two months, are numbered in the figure. Any drastic change in the seismicity during the six-years period is not observed.

The histogram in Fig. 11 shows the frequency-magnitude distribution for all earthquakes in this analysis. ISC/USGS report only half of the shocks with m(KBS) about 4.5, and even some shocks with m(KBS) = 5.0 are missed by these agencies. The slope of the cumulative line, b, lies between 1.4 and 1.6, depending on the weights we give the number of the largest shocks. HUSEBYE et al. (1975) found b = 1.26 for the Norwegian and Greenland seas and adjacent continental shelf areas. Some of this discrepancy in the b-values may be a result of using the KBS-magnitudes, which seems to contain a slight bias for the largest shocks, see Fig. 7a.

The geographical distribution of the epicenters only determined by KBS is shown in Fig. 12. Compared to the ISC/USGS-epicenters from the same period, shown in Fig. 13, we can see that the pattern is somewhat different. The Knipovich zone is clear on the ISC/USGS-map, but is not well-determined by KBS, while the opposite is true for the zone in the Storfjord area. The KBS-epicenter locations are accurate within ± 15 degrees in azimuth and ± 30 km in Δ(KBS). This may result in a maximum error in the epicenter of 65 km when Δ(KBS) is 2 degrees. The accuracy generally is increasing with increasing magnitude, and one third of the epicenters in Fig. 12 is correct within 20 km.

HUSEBYE et al. (1975) writes: "In the Svalbard region there may be a weak correlation between seismicity lineations and north-south trending fault lines. However, the seismicity pattern also shows a NE-SW linear trend that continues into the Greenland Sea and intersects the Knipovich Ridge." The present study supports to some degree the former lineations, but not the last trend. Any detailed correlation between known faults (see Fig. 1) and seismic activity in the continental part is, however, impossible to find. The Storfjord area may, however, reflect an old zone of weakness, along which the stress accumulations of today are released.

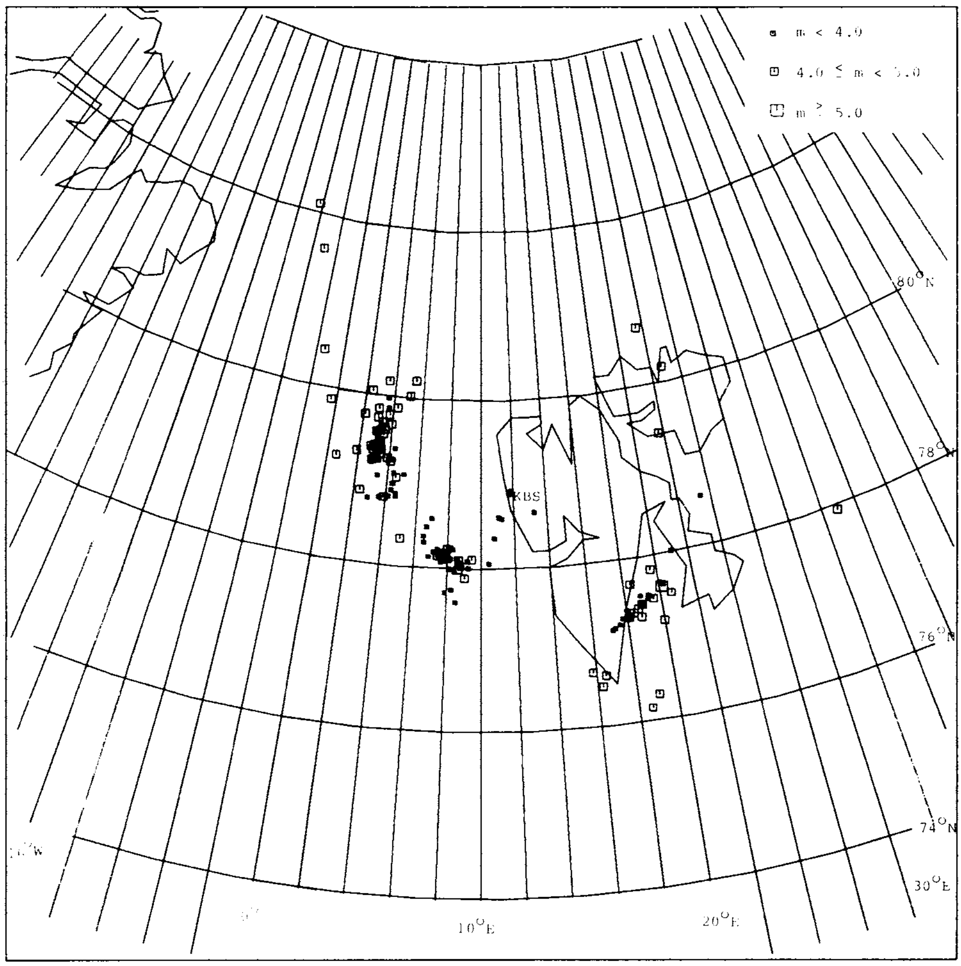


Fig. 12. *Earthquakes located by KBS, not by ISC/USGS, Sept. 1967–Dec. 1973. Geographical distribution.*

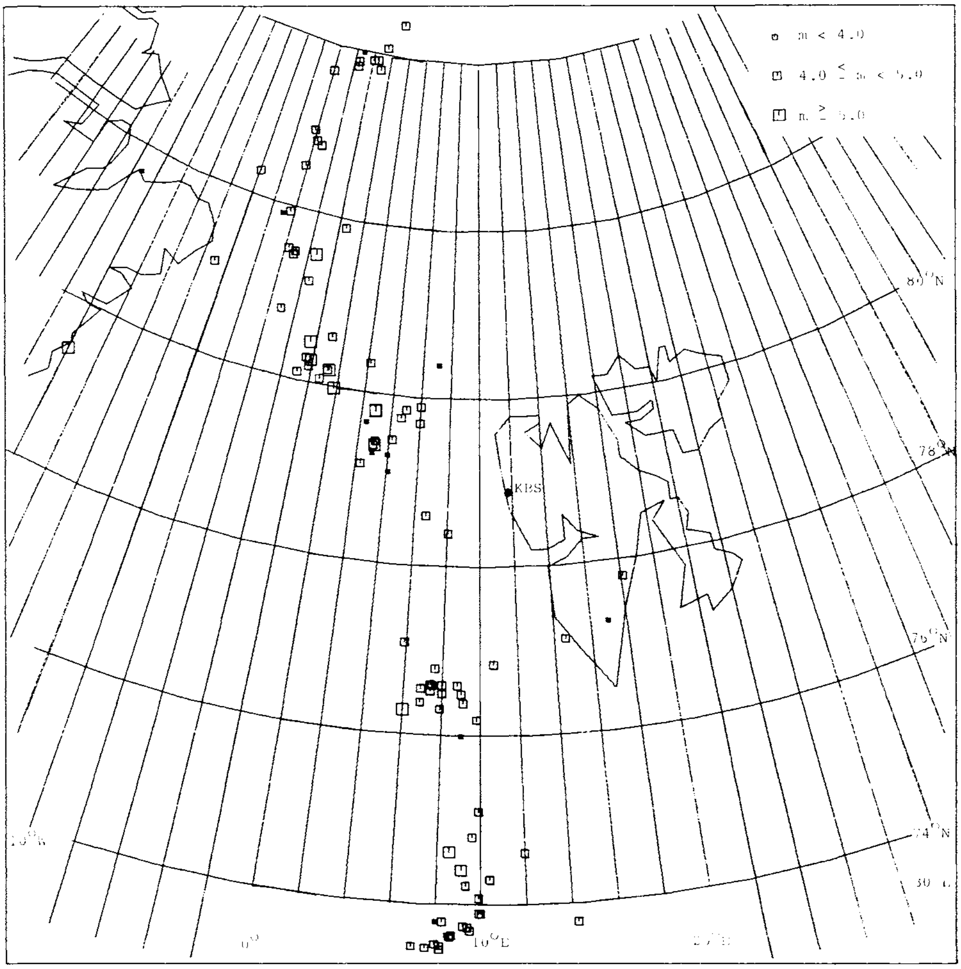


Fig. 13. *Earthquakes located by ISC/USGS, Sept. 1967–Dec. 1973. Geographical distribution.*

Conclusions

By studying ISC- and USGS-bulletins and KBS-seismograms in the time period Sep. 1967–1973, we have arrived at the following conclusions regarding the seismicity in the Svalbard area:

1) The bulletins of ISC and USGS contain only the greater earthquakes. For instance only half of the shocks with m = 4.5 do appear in these bulletins. This implies that we do not get a detailed picture of the seismicity in the area using only these sources.

2) The three-component KBS-station gives additional information about local epicenters, magnitudes and recurrence relations. For instance this study reveals a considerable seismic activity not only along the northward continuation of the Mid-Atlantic ridge, but also to the east on the continental side. Any correlation with known tectonic features are, however, hard to see.

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References

EVERNDEN, J. F., 1967: Magnitude determination at regional and near-regional distances in the United States. *Bull. Seism. Soc. Am.* **57**. 591–639.

HUSEBYE, E. S., H. GJØYSTDAL, H. BUNGUM, and O. ELDHOLM, 1975: The seismicity of the Norwegian and Greenland Seas and adjacent continental shelf areas. *Tectonophysics* **25**.

LILWALL, R. C. and R. UNDERWOOD, 1970: Seismic Network bias maps. *Geophys. J.* **20**. 335–339.

REAL, C. R. and T. L. TENG, 1973: Local Richter magnitude and total signal duration in Southern California. *Bull. Seism. Soc. Am.* **63**. 1809–1827.

RYGG, E., 1970: Rayleigh wave dispersion and crustal structures. The Norwegian Sea and adjacent areas. *Norsk Polarinstitutt Årbok* 1970. 169–177.

SELLEVOLL, M. A., 1960: *Seismisiteten i Svalbard-området.* Jordskjelvstasjonen, Universitetet i Bergen.

SYKES, L. R., 1965: The seismicity of the Arctic. *Bull. Seism. Soc. Am.* **55**. 519–536.

TAMS, E. s.a.: Die seismischen Verhältnisse des Europäischen Nordmeeres und seiner Umwandlung. *Mitt. d. Geogr. Ges., Hamburg*, Bd. XXXIII.

WINSNES, T. S., A. HEINTZ and N. HEINTZ, 1961: Aspects of the geology of Svalbard. *Norsk Polarinstitutt Medd.* Nr. 87, Oslo.

Small-scale drilling in Spitsbergen

By N. J. R. WRIGHT[1] and W. G. HENDERSON[2]

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Abstract

The drilling equipment used by Cambridge geologists in Spitsbergen is described, and technical details given. The procedures which were developed and found to be useful are described and the advantages and limitations of the technique for use with small field parties in Arctic terrain are discussed.

I. Introduction

During the summer of 1972, Cambridge Spitsbergen Expedition 1972, Party C, undertook to investigate two areas of possible coal potential for Store Norske Spitsbergen Kulkompani A/S, Indre Billefjord and Grønfjordbotn (CUTBILL, HENDERSON and WRIGHT in press, CROXTON and PICKTON in press). It was decided to attempt to improve the knowledge of the coal-bearing strata in these areas partly by means of shallow drilling using a hand-held drill. A total of seven holes were drilled, penetrating about 100 m of strata, and detailed information was obtained, which could be fitted into the wider picture achieved through surface studies. The full equipment is now at the Cambridge base buildings in Ny-Ålesund.

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II. Technical details

1. *Equipment*

The drilling equipment used was the Packsack 4 M Drill, supplied by Truco Canada Ltd. It has been designed as a complete system, but modifications have been made both by us and by other operators of this equipment in England (see below).

Drill motor. — This is a standard Chrysler 2-stroke air-cooled engine, developing 8 h.p., onto which has been built a mounting and transmission system. The whole unit weighs about 15 kg. Fuel supply is from a separate 5 gallon (23 litre) tank.

It was found in 1972 that the intense vibration of the motor caused shearing of the mounting, which was kindly strengthened and replaced by engineers of the Store Norske Spitsbergen Kulkompani in Longyearbyen.

Water supply unit. — The circulating water necessary for drilling was supplied by a small gear pump driven by a 2 h.p. Briggs and Stratton 4-stroke engine,

Fig. 1. *Drilling on the north side of Ebbadalen. The man on the left is operating the drill, while the person in the foreground is holdind the «jo-bar». The hole has been put down into loose cover, so a wooden board is being used as a stable platform and to provide an anchorage for the jo-bar chain. The water supply unit is not visible, but the connecting hose pipe can be seen, attached to the drill unit. A piece of guttering is being used to lead the returning water away from the platform.*

weighing 18 kg in all. Connections from the water supply to the pump and from the pump to the drill head are made by flexible hosing.

Although this pump should deliver 23 litres/min at about 9000 gf/cm^2, a more efficient pump would be an advantage. Piston pumps have been used by various teams using this equipment.

Drill bits. — Four grades of diamond bits are supplied by Truco Canada Ltd., suitable for drilling rocks of different hardness. Bit life varies from 30 m to more than 150 m of drilling, depending on the lithology. Tungsten carbine bits are obtainable, suitable for drilling in soft shales, but have not been used by us.

Rods, etc. — Core barrels come in 5 ft (1.5 m) lengths, weighing 7 kg with a short 2 ft (0.6 m) length for starting a hole. At least two 5 ft barrels are needed. Drill rods are also provided in 5 ft lengths and weigh 4.5 kg each. Casing is manufactured in various shorter lengths, and weighs 4.5 kg/m.

Accessories. — These include the "jo-bar" for pressing down on the drill string, clamps for raising it, wrenches for working the joints, various threaded adaptors, "core-fishers" for retrieving lost cores, "rod-fishers" for retrieving a lost drill string and a fairly extensive tool kit for general maintenance.

2. *Technique used (see Fig. 1)*

The drilling technique used was essentially as set out in FARMER et al. (1968). Three operators were necessary at any one time. One person holds the drill motor against the torque and operates the throttle, the second provides the downward force by means of the "jo-bar" and the third is needed to help with the connecting of drill rods, etc., the maintenance of the water and fuel supplies and to assist with the extraction of cores from the barrels. Meanwhile, a geologist will be fully occupied making lithological descriptions of the cores obtained and keeping a general log of the progress made. This logging can alternatively be done by a fifth person.

III. Drilling procedures

The Packsack 4 M drill obtains cores approximately 1″ (2.5 cm) in diameter, which tend to break up into lengths no longer than 15 cm. The amount of core recovered is variable and depends on factors such as the lithology, the extent of fracturing and the amount of "shake" in the drill string. The average recovery in the coal-bearing rocks drilled in Spitsbergen was around 60%, ranging from 0% at worst to more than 90% in some well-lithified sandstones.

In general, soft, fissile rocks such as shales give very poor recovery and it is unusual to obtain a core of coal. It is therefore important that the colour of the returning water be logged accurately against depth. This can give an accurate index of lithological changes and the occurrence of jet-black water can be used as an indicator of the presence of coal. Carbonaceous shales were found to return dark grey to black water. Some attempt was made to sample the returning water for use in palynology.

Another indicator of lithology is the rate of penetration. The hardest sandstones encountered in 1972 drilled at 3 cm/min while shales drilled at about 15 cm/min, and these rates were logged. A qualitative description (fast/medium/slow) is also useful.

Logging was conveniently done in discrete "operations", one operation being the attaching, lowering down, drilling and recovery of an additional length on the drill string. Under each operation, the number and lengths of drill rods, length of core barrel, type and condition of the bit were recorded, and as drilling progressed, the colours of the water and rate of progress were logged. A separate core log was kept, again divided into "operations" resulting in a barrel of core — the percentage recovery, state of the core (long sticks or fragments), lithological descriptions and details of samples taken were all recorded.

IV. Other considerations

1. *Siting of drill hole*

The siting of the drill hole is restricted by the need for a good supply of water. Where heavy transport is available, very long lengths of hose with a back-up pump are commonly used to give flexibility in siting. However, with porterage only relatively short lengths will be taken.

The drill hole can either be put down into loose cover deposits or straight into outcrop, and it was found that the latter was usually preferable. Technically, it is much easier to drill on a firm base, as surface deposits rapidly turn to mud with the returning water, and drilling in drift, etc. requires casing which often works loose and allows material to fall down the hole. For the purposes of our investigations it was also geologically preferable to drill from outcrop as the precise position of the drill hole with respect to the overall stratigraphic section could be fixed. The choice of drill site is therefore further restricted by preference for a fairly flat, firm outcrop. However, the equipment can be used for the purpose of penetrating surface deposits and determining the nature of the bed-rock.

2. *Depth of drilling*

The deepest hole drilled in 1972 was about 30 m, but most were a lot less (about 15 m). The problems of pulling up the drill string, and the danger of getting stuck, increase with depth, and generally 10 m–15 m should be considered the most efficient depth to work. An extra 15 m requires an extra 45 kg of drill rods.

With shallow holes many sites would be required to give complete penetration of a typical geological formation. However, for the investigation of a thin unit (such as a coal-bearing horizon) over a wide area, this depth of penetration is quite adequate.

3. *Problems of Arctic terrain*

Problems common to drilling in any situation are dealt with elsewhere (e.g. FARMER et al. 1968). Some of the problems encountered were peculiar to the using of this equipment in Arctic terrain and will be mentioned here.

The effect of frost shattering on outcropping rocks is developed to a high degree in Spitsbergen, and can create difficulties for the driller. As mentioned above (III), the colour of the returning water is a very useful index, and in general it is not advisable to continue drilling when no water is returning, as it may indicate a blocked bit which, if drilling were continued, would rapidly lead to the jamming of the string. Highly fractured rock tends to lead this returning water away. Also, intense fracturing may allow the sides of the hole to cave in, causing jamming of the drill string. For these reasons it was often found necessary to case the hole down beyond the fractured zone, which in some cases seemed to be up to 10 m deep.

The intense vibration produced by the drill motor can cause movement of seemingly attached outcrop if drilling is attempted on any kind of slope. The general noise and vibration can also loosen boulders, so care is needed in the siting of the hole.

Despite drilling in permafrost, the circulating water does not freeze as long as it is kept flowing or the drill string rotating. If, however, water flow stops, the drill string will freeze in very solidly within about 10 minutes. The first priority, therefore, is to get the drill string out before this happens. The permafrost may in fact help, as the frozen nature of any water in fissures in the rock may help to alleviate water-loss problems caused by fracturing. It also, probably, makes the soft shales more competent; it is interesting to note that the drillers for the Scottish Spitsbergen Syndicate experienced considerable difficulties with icing-up but, having solved the problem by pre-heating the water, later complained of "running" of the black shales (e.g. CAMPBELL 1919). This effect was probably due to the melting of the frozen shales by the hot circulating water.

We found that the hole could be left to ice-up overnight, as the ice could be quickly drilled out again.

4. *Environmental considerations*

The equipment has many advantages for use in terrain such as the Spitsbergen tundra, which is so sensitive to environmental damage. The small scale nature of the operation requires only a few people and the equipment can be transported by foot into areas where wheeled or tracked vehicles would cause permanent damage. Also, because each drill site is only occupied for a few hours or days, very little mess is created. Drill sites can, in fact, be very hard to re-locate.

5. *Transport*

The drilling equipment breaks into manageable units and in 1972 was portered inland. The basic equipment for a short hole weighs about 125 kg, the heaviest single item being 16 kg, and can therefore be pack-carried to relatively inaccessible locations. However, the awkward shape of some items (drill rods for example), the total weight and the need to supply about 15 kg of fuel for each day's drilling sets limits to the distance possible by foot with a small party.

In the absence, therefore, of motorised land or air transport, drilling is confined to areas with fairly easy access to the coast.

6. *Economic considerations*

Provided sites are accessible to boat or air transport, a four-man crew can operate this equipment quite effectively. The running costs of the equipment are not high. Regular servicing of both engines is required, but this need not be in excess of normal small engine servicing costs. The cost of transporting, maintaining and operating a Packsack 4 M drill for a field season could perhaps be compared to the cost of putting one extra man into the field for the same period.* A team of, say, five men could therefore undertake a reduced programme of ordinary field work and integrate it with the results of a shallow drilling programme for (approximately) the cost of putting six men into the field. The system can therefore be highly cost-effective in terms of geological information obtained.

V. Conclusions

Two types of situation exist under which drilling might be carried out, and they affect the type of drilling that it would be reasonable to attempt.

Firstly, a situation where transport is available. This might be the investigation of a shore-line exposure with boat transport, the use of a soft-wheeled amphibious vehicle inland, transportation by helicopter, or possibly movement over ice by motorised sledges. In this situation, a fairly deep hole could be attempted; there is no reason why this equipment would not reach depths of up to 60 m as other workers have reached depths of up to 85 m (FARMER et al. 1968) with similar equipment. There are many accessories, such as a small derrick and a jacking system for extracting stuck drill strings, which would perhaps be desirable for such an undertaking. These could only be used if transport were available.

Secondly, in a situation where all the equipment has to be carried on foot, weight is the limiting factor and this restricts the depth of hole to be attempted. No more than 20 m of rods should be necessary, although a stockpile of spares must be available. Under these conditions, the drilling should be confined to a number of shallow holes, stratigraphically linked, if necessary, up a stream section for instance. Even under this constraint, useful results can be obtained by a fairly small team, investigating problems such as the details and extent of coal-bearing strata or the extent of other mineral seams. The equipment can

* This rough figure does not, however, take into account depreciation on the equipment which is high in view of the limited life of many of the items.

also be used as a system for obtaining fresh samples of otherwise unexposed or badly weathered rocks, for petrological study, using a series of very shallow holes.

References

CAMPBELL, A. F., 1919: Report and Notes on Prospecting, Mining and Boring work . . . in Bünsow Land, West Spitsbergen. *Scottish Spitsbergen Syndicate* (unpublished) Ms. 71.

CROXTON, C. A. and C. A. G. PICKTON, 1976: The Van Mijenfjorden Group (Tertiary) of South-West Nordenskiöld Land. *Norsk Polarinstitutt Skrifter* Nr. 164 (in press).

CUTBILL, J. L., W. G. HENDERSON and N. J. R. WRIGHT, 1976: The Billefjorden Group (Early Carboniferous) of Central Spitsbergen. *Norsk Polarinstitutt Skrifter* Nr. 164 (in press).

FARMER, N., J. M. JONES and D. G. MURCHISON, 1968: Small-scale drilling operations for research purposes. *Q. J. Eng. Geol.* **1**, pp. 195–205.

Adaptation to marine life in Spitsbergen birds; a physiological demonstration

By Hans Staaland[1]

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Abstract

It is shown that most breeding birds in Spitsbergen have large salt glands which indicate adaptation to marine life. These findings are discussed in relation to ecological conditions in high arctic areas; low productivity in terrestrial habitats, the importance of marine food chains, in particular during cold spells, spring and autumn.

Introduction

In the high Arctic there is a close connection between marine and terrestrial life, man as well as animals to a large extent depend on sea for food and survival (see Irving 1972).

Among the birds particularly the order Charadriiformes and to a lesser extent the Anseriformes are well developed in the Arctic, whereas the largest order of birds, the Passeriformes, only have 4–5 genuine high Arctic species. The marine affinity of the Arctic birds can be demonstrated by studying their ecology and behavior on their breeding and feeding grounds. However, it would also appear that most Arctic birds seem physiologically adapted to a marine life, even those breeding and feeding on the tundra far from the sea. This can, for example, be shown by examining the development of their (nasal) salt glands (Staaland 1967).

The purpose of the present paper is therefore to demonstate the marine adaptation of the Spitsbergen avifauna by examining the development of the salt glands in these birds.

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Material

The material used in the present study has been compiled from various sources. Some birds were collected in the Kings Bay area of Spitsbergen in July–August 1974. Other birds were collected in South Norway as early as 1965–66 and has previously been used in another study (STAALAND 1967). Some Shore birds were also collected on Revtangen, Jæren in South West Norway during the autumn migration in September 1973. Other data has been compiled from the works of LOWE (1922), SCHIØLER (1925–28) and BOCK (1958). Data regarding the bird fauna of Spitsbergen has largely been based on LØVENSKIOLD (1964) and to some extent on own observations and personal communications from THOR LARSEN, Norsk Polarinstitutt.

Results and discussion

It has repeatedly been demonstrated that marine birds possess the capability of extrarenal excretion of excess salt obtained from food or by drinking sea water by means of their intra- or supraorbital nasal (salt) glands. Furthermore it has been confirmed that the more marine birds have more concentrated secretion and also a higher capacity of salt secretion than those species which usually are found in estuares, brackish water areas, freshwater or are terrestrial. The concentrating capability seems to be related to micro-structures (i.e. the length of the secretory tubules) (STAALAND 1967), whereas the volume of secretion is largely related to the sizes of the salt glands (BENTLEY 1971). A fairly good demonstration of the salt secreting capacity of the salt glands in a bird is therefore obtained just by examining the development of the salt glands. This can easily be done by observing the glands in situ or by examining the size of the impressions they leave when removed from the frontal bone of the skull.

Fig. 1 demonstrates the salt gland sizes of the common and regularly breeding birds of Spitsbergen (except for the Ivory Gull). The Ptarmigan and the Snow Bunting belong to genera which apparently do not have salt glands. The Ptarmigan is a resident herbivore whereas the Snow Bunting contrary is migratory, and one of the few Passerines living under Arctic conditions. Thus except for these two birds, it seems that not only typical marine groups of birds like Auks and Gulls, but also all common Shore birds occurring in Spitsbergen during the summer have large salt glands. These species do not usually breed in direct association with the sea (see SUMMERHAYES and ELTON 1928, LØVENSKIOLD 1964).

When comparing the size of salt glands in Spitsbergen Shore birds with those of species breeding for example in Scandinavia, it might appear that only species with well developed salt glands breed and maintain a population on Spitsbergen. This is evident even within a single genus like *Calidris*. For example Temminck's Stint, Dunlin and Purple Sandpiper breed in high mountain areas in Norway, e.g. at Finse in South Norway, in areas and habitats with an arctic-alpine character (LIEN et al. 1974). Yet only the Purple Sandpiper and the Dunlin with large salt glands occur in Spitsbergen. Other examples can be

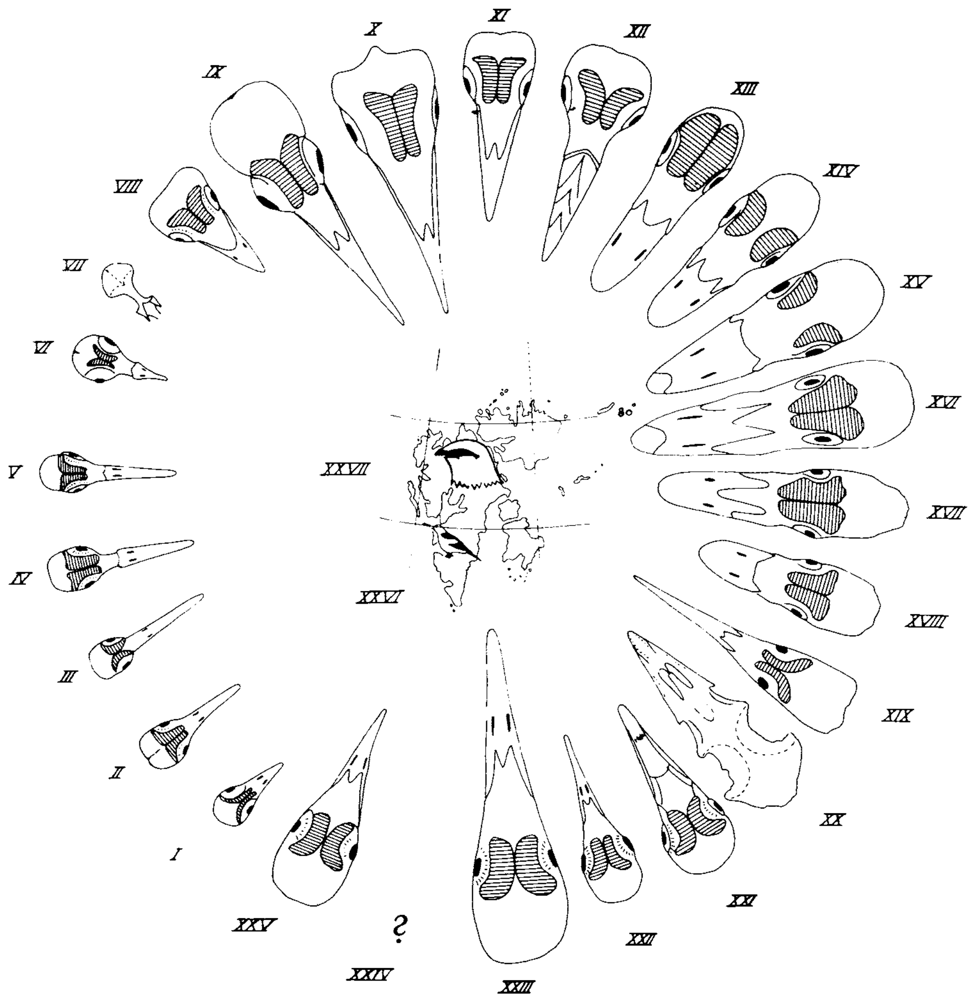

Fig. 1. *Salt glands in birds regularly breeding in Spitsbergen.*
I. Grey Phalarope, *Phalaropus fulicarius* (chick, few days old); II. Sanderling, *Crocethia alba*; III. Dunlin, *Calidris alpina*; IV. Knot, *Calidris canutus*; V. Purple Sandpiper, *Calidris maritima*; VI. Ringed Plover, *Charadrius hiaticula*; VII. Turnstone, *Arenaria interpres*; VIII. Little Auk, *Plotus alle*; IX. Guillemot, *Uria aalge*; X. Brünnich's Guillemot, *Uria lomvia*; XI. Black Guillemot, *Cepphus grylle*; XII. Puffin, *Fratercula arctica*; XIII. Brent Goose, *Branta bernicla*; XIV. Barnacle Goose, *Branta leucopsis*; XV. Pink-footed Goose, *Anser fabalis brachyrhychus*; XVI. Eider, *Somateria mollissima*; XVII. King Eider, *Somateria spectabilis*; XVIII. Long-tailed Duck, *Clangula hyemalis*; XIX. Red-throated Diver, *Gavia stellata*; XX. Fulmar, *Fulmarus glacialis*; XXI. Arctic Skua, *Stercorarius parasiticus*; XXII. Arctic Tern, *Sterna paradisea*; XXIII. Glaucous Gull, *Larus hyperboreus*; XXIV. Ivory Gull, *Pagophila eburnea*; XXV. Kittiwake, *Rissa tridactyla*; XXVI. Snow Bunting, *Plectrophenax nivalis*; XXVII. Ptarmigan, *Lagopus mutus*; Nos. XIII–XIX redrawn after SCHIØLER (1925–28), simplified; VII redrawn after BOCK (1952). The other based on own collection. Nos. XII and XXI: — the dotted lines indicate the impression in the skull after removing the salt glands.

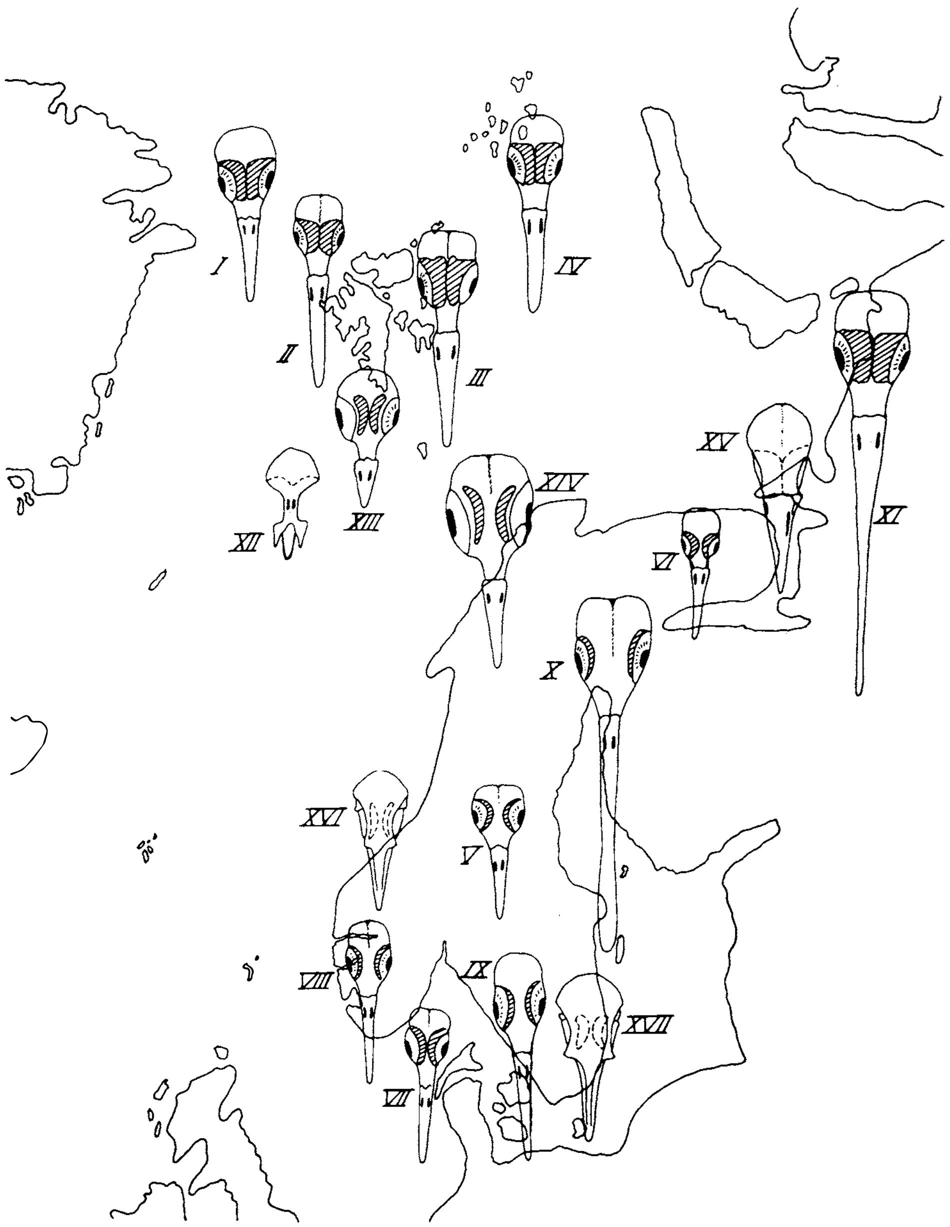

Fig. 2. *Sketches of heads from shore birds showing their salt glands, or impressions in the frontale bone after removing the salt glands.*

I. Sanderling, *Crocethia alba*; II. Dunlin, *Calidris alpina*; III. Knot, *Calidris canutus*; IV. Purple Sandpiper, *Calidris maritima*; V. Temminck's Stint, *Calidris temminkii*; VI. Little Stint, *Calidris minuta*; VII. Common Sandpiper, *Tringa hypoleucos*; VIII. Wood Sandpiper, *Tringa glareola*; IX. Greenshank; *Tringa ochropus*; X. Snipe, *Capella gallinago*; XI. Bar-tailed Godwit, *Limosa lapponica*; XII. Turnstone, *Arenaria interpres*; XIII. Ringed Plover, *Charadrius hiaticula*; XIV. Golden Plover, *Pluvialis apricaria*; XV. Grey Plover, *Squatarola squatarola*; XVI. Dotterel, *Eudromias morinellus*; XVII. Lapwing, *Vanellus vanellus*; XII, XV, XVI, and XVII from Lowe (1922) and Bock (1958).

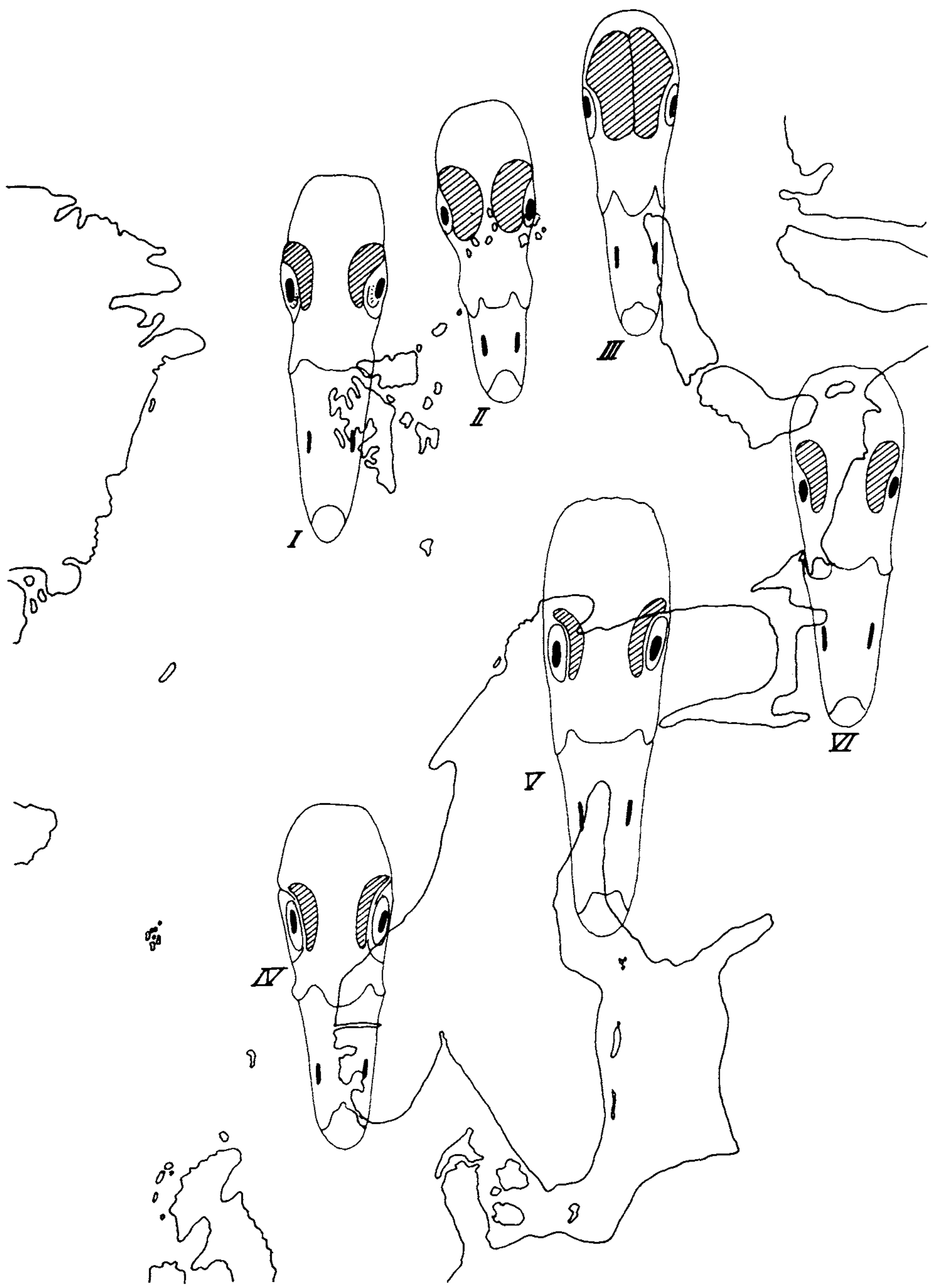

Fig. 3. *Salt glands of geese. Redrawn and simplified from* SCHIØLER (*1925–28*).
I. Pink-footed Goose, *Anser fabalis brachyrhynchus*; II. Barnacle Goose, *Branta leucopsis*; III. Brent Goose, *Branta bernicla*; IV. Grey Leg Goose, *Anser anser*; V. Bean Goose; *Anser fabalis fabalis*; VI. White-fronted Goose, *Anser albifrons*.

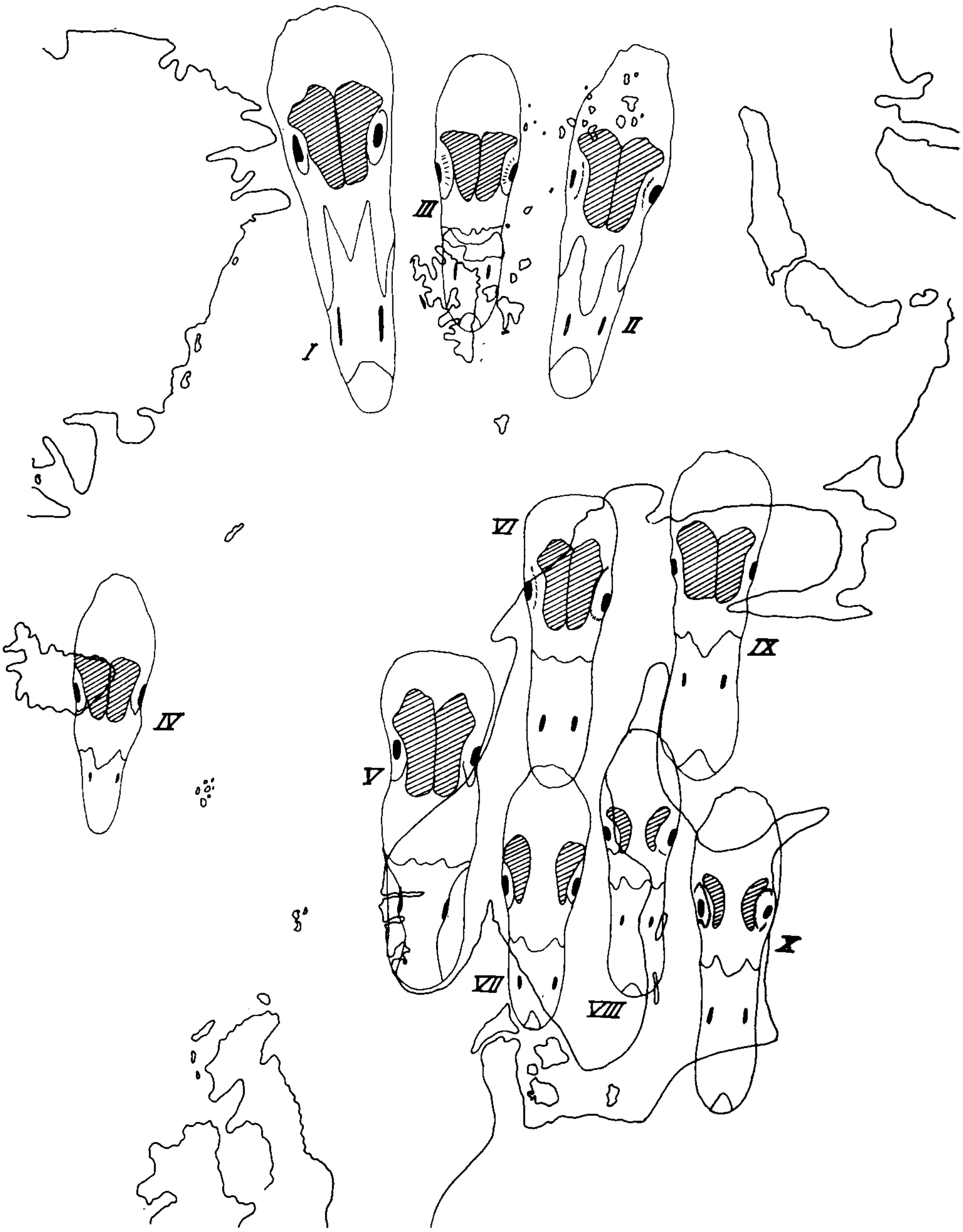

Fig. 4. *Salt glands from the common North European Diving ducks. Redrawn and simplified from* SCHIØLER (*1925–28*).

I. Eider, *Somateria mollissima*; II. King Eider, *Somateria spectabilis*; III. Long-tailed Duck, *Clangula hyemalis*; IV. Harlequin, *Histrionicus histrionicus*; V. Common Scoter, *Melanitta nigra*; VI. Velvet Scoter; *Melanitta fusca*; VII. Golden Eye, *Bucephala clangula*; VIII. Tufted Duck, *Fuligula fuligula*; IX. Scaup, *Fuligula marila*; X. Pochard, *Aythya ferina*.

found within the Plovers. The Dotterel and the Golden Plover (with small salt glands) and the Ringed Plover (large salt glands) all breed in high mountain areas in South Norway, but only the Ringed Plover regularly breeds in Spitsbergen. Other Shore birds (Fig. 2) might as well support these demonstrations.

To some extent the same trend can also be demonstrated by observations on Geese and Ducks (Figs. 3 and 4). Even within the Bean Goose, *Anser fabalis*, the subspecies, *brachyrhynchus* (Pink-footed Goose), which breed in Spitsbergen appears to have larger salt glands than the subspecies *fabalis* breeding in northern Scandinavia. Also the three common ducks in Spitsbergen seem physiologically adapted to a marine life, and ducks which occasionally have bred (Common Scoter, Pintail and Teal) seem to have rather large salt glands (SCHIØLER 1925–28). Of about 12 species which occasionally have bred in Spitsbergen, only three or four (Wheatear, Redpoll, Great Snipe, and Golden Plover) are land birds.

Contrary a large number of Passerines (without salt glands) or species with small salt glands like Dotterel and Wood-cock have been observed just once or a few times in Spitsbergen.

The finding of large salt glands in Arctic birds is probably not confined to Spitsbergen species. As it will appear from Figs. 2–4 even species breeding in Northern Siberia like Bar-tailed Godwit and Grey Plover, White-fronted Goose, etc. have large salt glands. And the Shore birds: Knot, Dunlin, Sanderling, Purple Sandpiper, Turnestone, Ringed Plover, are species which breed in the extreme north, and all have nearly circumpolar distribution.

Such findings as those presented might be just a coincidence, but might also be related to ecological conditions in high Arctic areas. With respect to the Spitsbergen avifauna the distance between the European continent and Spitsbergen is considerable (North Cape, Norway to South Cape, Spitsbergen is about 660 km) with only the small Bjørnøya half way as the only theoretical resting place for a land bird. It might be an advantage for birds during long oceanic flights to have salt glands, thus making drinking of sea water theoretically feasible. On the other hand Wheatear and other Passerines without salt glands frequently reach Spitsbergen and cross the North Atlantic from Iceland and Greenland to Norway (PETERSON et al. 1966, LØVENSKIOLD 1964).

A comparison between the bird fauna of Spitsbergen with that of Iceland, another isolated oceanic island, also reveals that at least 30% of the breeding birds on Iceland are Passerines, or birds with extremely small salt glands like Snipe and Golden Plover (see e.g. PETERSON et al. 1966). The distance between Spitsbergen and the European continent may be no barrier therefore for the distribution of terrestrial birds, although it might exclude some species.

In Spitsbergen Snowy Owl, Gyr Falcon, Raven or other arctic predatory birds have never been found breeding, although frequently observed. This might be explained by the absence of all kinds of voles and lemmings on these islands. The Long-tailed Skua, which to a large extent feeds on small mammals during the breeding season, has bred on a few occasions, however, but this is apparently a bird adapted to an oceanic life, since outside the breeding season it roams the open seas (SUMMERHAYES and ELTON 1928, LØVENSKIOLD 1964).

Another category of birds might be those which can survive on seeds, buds and plant material often found on ridges or places blown free of snow even during cold spells or snow falls. Such birds are the Ptarmigan, Snow Bunting and Arctic Redpoll. During such weather conditions birds feeding on terrestrial arthropods, green plant material, fresh water organisms etc. might succumb if they did not have a refuge at the sea.

These situations might occur on several occasions during the life cycle of the birds in Spitsbergen or other Arctic areas. Except for a few species all the arctic birds are migratory; they may arrive in the spring before lakes and land areas are free from snow cover and ice, and snow can fall before they leave in the autumn. Even during the short summer sudden snow fall may be hazardous not only to nests and young birds, but also to adults. On these occasions the sea or sea shore may be a place to survive for the adult population at least. In summers with bad weather conditions it is also well known that "non-breeding" occurs (SUMMERHAYES and ELTON 1928); then most of the adult population might survive due to the always surplus marine food supply. It seems likely also that the available food for many birds in terrestrial habitats might always be so low that a marine food chain is of great importance for the survival of birds in these areas even during favourable weather conditions.

Similar situations, sudden snow fall, cold spell, late spring, non-breeding, etc. may also occur in southern high alpine-arctic areas (e.g. in South Norway), but here there is always a comparatively short distance to low altitudes, with

Table 1

Breeding birds on Ellesmere Island (based on SNYDER *1957,* PARMELEE *and* MACDONALD *1960). X = birds which are known to have large salt glands or are known to be oceanic outside the breeding season.*

Raven	*Corvus corax*		Long-tailed Skua	*Stercorarius longicaudus*	X
Wheatear	*Oenanthe oenanthe*		Glaucous Gull	*Larus hyperboreus*	X
Arctic Redpoll	*Acanthis hornemanni*		Herring Gull	*Larus argentatus*	X
Lapland Bunting	*Calcarius lapponicus*		Ivory Gull	*Pagophila eburnea*	X
Snow Bunting	*Plectrophenax nivalis*		Kittiwake	*Rissa tridactyla*	X
Ptarmigan	*Lagopus mutus*		Sabine's Gull	*Larus sabini*	X
Gyr Falcon	*Falco rusticolus*		Arctic Tern	*Sterna paradisea*	X
Snowy Owl	*Nyctea scandiaca*		Brünnich's Guillemot	*Uria lomvia*	X
Ringed Plover	*Charadrius hiaticula*	X	Black Guillemot	*Cepphus grylle*	X
Grey Plover	*Squatarola squatarola*	X	Little Auk	*Plotus alle*	X
Turnstone	*Arenaria interpres*	X	Fulmar	*Fulmarius glacialis*	X
Knot	*Calidris canutus*	X	Brent Goose	*Branta bernicla*	X
Purple Sandpiper	*Calidris maritima*	X	Snow Goose	*Chen hyperboreus*	
Baird's Sandpiper	*Calidris bairdii*		Eider	*Somateria mollissima*	X
Sanderling	*Crocethia alba*	X	King Eider	*Somateria spectabilis*	X
Grey Phalarope	*Phalaropus fulicarius*	X	Long-tailed Duck	*Clangula hyemalis*	X
Arctic Skua	*Stercorarius parasiticus*	X	Red-throated Diver	*Gavia stellata*	X

more favourable weather conditions. Contrary, a trans-oceanic flight from e.g. Spitsbergen might not be possible unless there is a physiological preadaptation for migration.

Analyses of the bird fauna of other high Arctic areas exhibit similar patterns, e.g. that of Ellesmere Island (Table 1). This island, located between about 76° and 82° north at the west coast of Northern Greenland, has an avifauna similar to that of Spitsbergen. One main exception is that Snowy Owl, Gyr Falcon, Raven and Long-tailed Skua are breeding. This is probably possible since Lemmings, Arctic Hare, Weasels etc. are found here (PARMELEE and MACDONALD 1960). Two typical North American birds, Snow Goose and Baird's Sandpiper, are also found on Ellesmere Island. Other differences are that Lappland Bunting and Arctic Redpoll are among the more common breeding birds. For these birds it might also be of importance that unlike Spitsbergen, Ellesmere Island is close to other large islands like Baffin Island and Greenland.

The present hypotheses are made on the assumption that the birds in high Arctic areas need a stable food reserve, which is only partly influenced by weather conditions. For birds which cannot rely on abundant supply of Microtines or seeds/buds, etc. the stable food available is mostly marine organisms.

According to this hypothese species possessing functional well developed salt glands (an adaptation to marine life) might be preadapted to survive in high Arctic areas. The Charadriiformes and Anseriformes are birds with generally well developed salt glands, and hence these groups of birds might have inherited properties important for survival in Arctic areas like Spitsbergen. Other explanations might as well be possible, but to further confirm the present or other hypotheses would probably need thorough studies on the bird fauna of other Arctic (or Antarctic) areas.

Acknowledgements

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References

BENTLEY, P. J., 1971: *Endocrines and Osmoregulation.* Springer-Verlag, New York, Heidelberg, Berlin. 300 pp.

BOCK, W. J., 1958: A generic review of the Plovers (Charadrinae, Aves). *Bull. Mus. Comp. Zool. Harv.* **118**. 27–97.

IRVING, L., 1972: *Arctic Life of Birds and Mammals.* Springer-Verlag, Berlin, Heidelberg, New York. 192 pp.

LIEN, L., E. ØSTBYE, O. HOGSTAD, K. M. HAANDE, P. S. HAANDE, A. HAGEN, H. J. SKAR, A. SKARTVEIT, and D. SVALASTOGA, 1974: Bird surveys in the high mountain habitats at Finse and Stigstuv, Hardangervidda, South Norway, 1967–72. *Norw. J. Zool.* **22**. 1–14.

LØVENSKIOLD, H. L., 1964: Avifauna Svalbardensis. *Norsk Polarinst. Skrifter* Nr. 129. 460 pp.+ XVIII plates.

LOWE, P. R., 1922: On the significance of certain characters in some Charadrine genera with a provisional classification of the order Charadriiformes. *Ibis* **4**. 425–495.

PARMELEE, D. F., and S. D. MACDONALD, 1960: The birds of west-central Ellesmere Island and adjacent areas. *Bull. Nat. Mus. Can.* **169**. 1–103.

PETERSON, R. T., G. R. MOUNTFORT, and P. A. D. HOLLOM, 1966: *A field Guide to the Birds of Britain and Europe.* Houghton Mifflin Company, Boston and The Riverside Press, Cambridge.

SCHIØLER, E. L., 1925–28: *Danmarks Fugle I & II.* Gyldendals Boghandel, København.

SNYDER, L. L., 1957: *Arctic Birds of Canada.* Univ. of Toronto Press, Toronto. 310 pp.

STAALAND, H., 1967: Anatomical and physiological adaptations of the nasal glands in Charadriiformes birds. *Comp. Biochem. Physiol.* **23**. 933–944.

SUMMERHAYES, V. S. and C. S. ELTON, 1928: Further contribution to the ecology of Spitsbergen. *J. Ecol.* **16**. 193–268.

On the salt excretion in the Little Auk, *Plotus alle* (L.)

By Hans Staaland[1]

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Abstract

The Little Auk has relatively larger salt glands than other sea birds; this is partly an adaptation to the high salt content of its food, but may also be an effect of its small body size. Also the kidneys are relatively large, and in all the auks examined the anterior lobes counted for about 50% of total kidney weight.

The concentrations of sodium, potassium and chloride were determined in salt gland and cloacal fluids after acute salt loads. It appeared that the potassium concentrations of salt gland fluid was higher than usually found in marine birds. The secretory rate of the salt gland was considerably lower than previously reported, but it is nevertheless assumed that the Little Auk can subsist on water gained from its food, mainly *Calanus* and other planctonic crustaceans.

Introduction

The Little Auk, *Plotus alle* (L.), is a high-arctic sea bird of the North Atlantic and adjacent seas. They breed in eastern Canada, Greenland, Spitsbergen, Franz Josef Land and Severnaya Zemlya. Often they breed in extremely large colonies, some counting several hundred thousand (Norderhaug 1970). Outside the breeding season the Little Auk is an oceanic bird. The Spitsbergen population migrates to the coast of Greenland, but Little Auks belonging to other populations reach e.g. the North-Sea and the Norwegian coast (Norderhaug 1967). Only during heavy storms the Little Auk can be found inland (Fisher and Lockley 1954).

The Little Auk nests in crevices on mountain slopes, under boulder, rock

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falls, etc. and their nests and young are therefore difficult to reach. Sometimes they nest close to the sea, but frequently also a long distance from the sea, even on nunataks on the inland glaciers. The Little Auk mostly feed on planctonic crustaceans (95% or more of its diet), in Spitsbergen mainly *Thysanoessa* and *Calanus* (SUMMERHAYES and ELTON 1928, LØVENSKIOLD 1964, NORDERHAUG 1970). The Little Auk carries this food in a throat pouch to their nestlings.

It is usually assumed that marine invertebrates contain more salt than marine fishes, and hence a species feeding on planctonic crustaceans might have a higher burden on their osmoregulatory capacity than fish eating species. Furthermore, the Little Auk is the smallest of the Atlantic Auks, mean body weight about 160 g (NORDERHAUG 1970), and one of the smallest sea birds of this area. This may also enhance its osmoregulatory demands compared to other sea birds.

Marine birds and reptiles are believed to excrete a larger part of the salt they obtain from food and drinking water by means of their salt glands (SCHMIDT-NIELSEN 1960, STAALAND 1967, BENTLEY 1971). It has furthermore been assumed that those species living in oceanic areas and feeding on marine invertebrates have the largest capacity of salt secretion and the largest salt glands.

The Little Auk may therefore be a species with extreme adaptation to marine life. Of special interest would probably be a study of the salt and water balance of the nestlings. They seem to depend on water derived from food only.

The purpose of the present paper is to examine the salt glands and their function in the Little Auk. Also other Auks (and sea birds) in Spitsbergen to a large extent feed on Crustaceans (SUMMERHAYES and ELTON 1928, LØVENSKIOLD 1964), for comparison also some data regarding the gross anatomy and size of kidneys and salt glands of these birds have been included.

Materials and Methods

Little Auks, *Plotus alle*, were collected by "flygustong" at the bird cliffs on Ossian Sarsfjellet and Stuphallet in the Kings Bay area of North-West Spitsbergen in July–August 1974. Within a few hours the birds were brought to Ny-Ålesund. Here they were put into small cages which allowed quantitative sampling of cloacal fluids. They were kept in this cage for half an hour before they were given a salt load by means of a stomach tube (2 ml 10% NaCl). Discharge of fluid from the salt glands appearing in the nostrils was quantitatively collected by a micropipette and stored in stoppered polyethylene tubes. Cloacal fluids were sampled into small glass vials. Both salt gland secretion and cloacal fluids were sampled for each half hour period, and each experiment lasted for 3 hours. The birds was then allowed to rest for 12 hours in the dark, and a new similar experiment was then performed. No food was given. After this experiment the birds were sacrificed, and salt glands and kidneys were exposed and fixed in situ in 4% formol.

Other specimens of Little Auks, as well as Black Guillemot, *Ceppus grylle mandti*, Brünnich's Guillemot, *Uria lomvia*, and Puffin, *Fratercula arctica grabae*, were shot in Kings Bay on 15 and 17 July, 1974. Two Kittiwakes, *Rissa tridactyla*, were shot near Ny-Ålesund on 6 August, and four Purple Sandpipers, *Calidris maritima*, were shot near Ny-Ålesund on 16 July and 6 August. In all these specimens salt glands and kidneys were fixed as described for the Little Auk.

Samples of *Calanus* were collected by a plancton net in Kings Bay near Ny-Ålesund (S‰ = 22–27). The samples were dried on filter paper and transferred to well sealed glass vials. These samples as well as all other samples were transported to the Department of Zoology, Agricultural University of Norway, for further analyses during the autumn of 1974.

Calanus was dried for 24 hours at 105°C to estimate the water content, then ashed at 550°C. The ash was dissolved in distilled water. The quantities of salt gland secretion and cloacal fluid were determined by weighing.

Chloride in all fluids and solutions was determined by titration (Schales and Schales 1941), and sodium and potassium in dilutions by means of an Eel Flame photometer.

Drawings were made of salt glands and kidneys in situ. These organs were then carefully dissected and placed in 4% formol in separated vials. The kidneys were divided into their different lobes. Salt glands and kidney lobes were dried carefully between two pieces of filter paper and all samples were then weighed on a Mettler balance. Body weight of all birds were recorded to the nearest g in the field.

Results

Gross anatomy and sizes of salt glands and kidneys. — In all the species examined the salt glands have the usual supraorbital localization and the glands cover almost the entire frontal bone between the eyes (Fig. 1). Relative to the body weight the salt glands are largest in the Little Auk and the Kittiwake, smallest in the Purple Sandpiper (Table 1). The Little Auk and the Puffin had the relatively largest kidneys, and in all the Auks, the two posterior lobes of the kidneys are considerably larger than in the Kittiwake and the Purple Sandpiper (Fig. 1, Table 1). The relatively larger kidneys in the Auks seem therefore mainly to be a result of large anterior lobes which in these birds account for about 50% of the kidney weight. Logaritmic plots of kidney and salt gland weights against body weights seem to exhibit a linear relationship for the Spitsbergen Auks (Fig. 2).

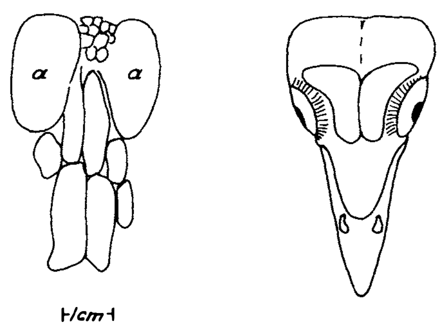

Fig. 1. *The kidneys and salt glands in the Little Auk. a : anterior lobes of the kidneys.*

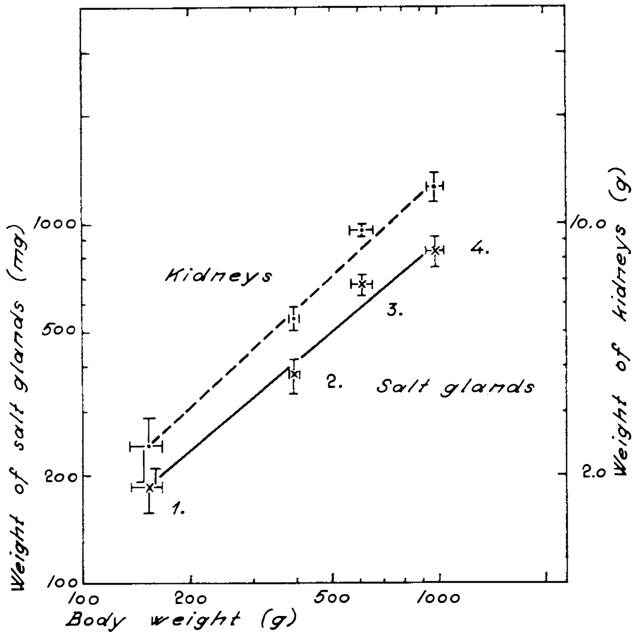

Fig. 2. *Salt gland and kidney weights in relation to body weight. Mean weights ± standard deviations of the means. 1. Little Auk; 2. Black Guillemot; 3. Puffin; 4. Brünnich's Guillemot. The straight lines are fitted by the method of least squares.*

Table 1
Relative sizes of salt glands and kidneys in some Spitsbergen birds.
(Number of specimens in parenthesis.)*

Species	mg salt gl./g.B.W.	mg kidney/g.B.W.	2 anterior kidney lobe/kidney
Black Guillemot (5)	0.96	13.79	55.5%
Brünnich's Guillemot (5)	0.85	12.73	58.0%
Puffin (5)	1.11	15.85	49.9%
Little Auk (9)	1.23	15.87	57.5%
Purple Sandpiper (4)	0.57	11.30	37.6%
Kittiwake (2)	1.41	11.23	38.4%

* All calculations: Mean weights of salt glands or kidneys/mean body weight.

Table 2
Main components of salt gland secretion in the Little Auk (m M/1 secretion). Each figure represents the average of four experimental series, each with samples from 5 collecting periods.

	Na	K	Cl
First experimental period	723	80	846
Second experimental period	647	105	881

Physiological measurements. — The concentration of the secretion from the salt glands in the Little Auk (Table 2) is within the same order of size as found in other sea birds (see e.g. BENTLEY 1971). It might, however, appear that the potassium concentrations are higher than those usually found in sea birds (SCHMIDT-NIELSEN 1960), but equal high or higher concentrations have frequently been found in reptiles (HOLMES and MCBEAN 1964, DUNSON 1969) or in raptorial birds (CADE and GREENWALD 1966). There seems to be relativety small differences in the concentrations of the secretion between the two experimental series.

Before salt loads were administered no fluid could be collected from the nostrils. However a clear drop of fluid (assumed to be salt gland secretion) on the beak was observed on Little Auks in the field. The secretion from the salt glands usually started within 15–20 minutes after the salt load. In the first series of experiments the secretory rate reached a maximum about one hour after the salt load was given (Fig. 3), but seemed to decrease after about 2 hours. In the second series the fluid rate seemed more or less stable throughout the experimental period, but was always on a lower level than in the first experiment. In the first hour after a salt load usually a large volume of cloacal fluid appeared, but during the rest of an experimental period the discharge of cloacal fluid almost ceased (Fig. 3). This is in agreement with earlier findings (STAALAND 1968). Mean concentrations of sodium, potassium and chloride are shown in Table 3. As can be seen the potassium concentrations are usually lowest, and seem to decrease after salt loads. The concentrations of sodium and chloride, on the other hand increase to the maximal levels usually found in birds (BENTLEY 1971). Water and mineral content of the food is given in Table 4.

Discussion

The sizes of the salt glands in the Spitsbergen Auks seem to be larger than in most other birds as far studied (STAALAND 1967, HUGHES 1970a, 1970b). This

Table 3

Concentrations of sodium, potassium and chloride in cloacal fluid from the Little Auk after acute salt loads. Concentrations in mM/1 and the figures represent the mean values from all measurements.

	Before the salt load $-\frac{1}{2}$–0 hr	After the salt load 0–$\frac{1}{2}$ hr	$\frac{1}{2}$–1 hr	1–$1\frac{1}{2}$ hr	$1\frac{1}{2}$–2 hr	2–$2\frac{1}{2}$ hr
First experimental period						
Na	65	208	137	—	235	—
K	41	12	23	—	30	—
Cl	23	339	190	—	184	—
Second experimental period						
Na	173	319	183	—	—	—
K	176	22	27	—	—	—
Cl	41	490	181	—	—	—

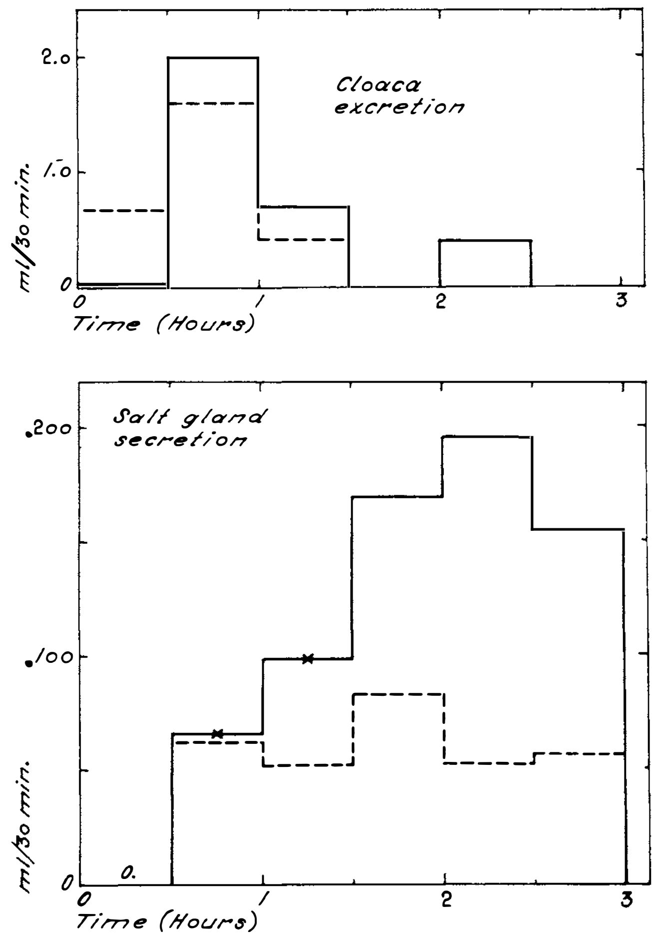

Fig. 3. *Volumes of fluids collected from the salt glands and the cloaca. Fully drawn lines first experimental series, dotted lines the second experimental series. Each series represents the means of 4 different experiments.*

Table 4
Water and mineral content of Calanus *sp. collected in Kings Bay, Spitsbergen. n = 10.*

g water/100 g wet weight	mM/kg tissue water Na	K	Cl
80.0±2.8	145±24	49±10	202±37

might reflect that these Auks mainly feed on marine crustaceans. Salt glands are generally developed in accordance with the ecology of the birds, species living in marine habitats and feeding on marine invertebrates are believed to have the largest glands (see e.g. STAALAND 1967). Usually, however, it may be rather difficult to compare the sizes of these organs in different birds since the relative sizes of these glands may vary with body size, and hence for metabolic reasons, a smaller bird might be expected to have relatively larger glands than a bigger. Furthermore the salt gland sizes are not only inherited, but also influenced by the salt content of the food a particular specimen eats (SCHMIDT-NIELSEN and KIM 1964). The Spitsbergen Auks, however, could be assumed to live under similar ecological conditions, feed on similar diets, and also of importance might be their similar body shapes. Although the Little Auk has the largest salt glands in relation to body weight (Table 1), a logaritmic plot (Fig. 2) shows that the salt gland sizes in the Auks fit to an equation $\lg y = 0.83 \lg x + 0.46$ (y = salt gland weights in mg, and x = body weight in g).

The sizes of the kidneys in birds possessing salt glands have been shown to be larger than in birds without salt glands. HUGHES (1970a) found that the kidney size in such birds was related to body size according to the equation $\lg y = 0.88 \lg x — 1.59$ which agree to the present findings: $\lg y = 0.91 \lg x — 1.61$ (y = weights of kidneys in g, and x = body weight in g).

However, the secretory rate of the salt glands in the Little Auk seems much lower than previously reported for sea birds (Fig. 3, Table 5). HUGHES (1970b) reports a secretory rate of 0.29 ml/min kg body weight for the Puffin. Using the values obtained for the Little Auk would indicate a secretory rate of about 0.03 (high rate) or 0.014 (low rate) ml/min kg body weight. This is only comparable to the secretory rate of the Humbolt Penguin, *Speniscus humboldti*, 0.06 ml/min kg body weight (HUGHES 1970b). There are no obvious reasons for these findings. One explanation might be that the salt glands of the Little Auk were in more or less continuous use before they were exposed to experimental procedures. This might to some extent deplete the energy reservoir of the glands. In favor of this hypothesis is that in the second experimental series lower secretory rates were observed (Fig. 3). In other experiments reported the experimental birds have usually been kept in captivity for some time and they may have been fed on fish and/or have had access to fresh water. In the present study the birds might likely have eaten just *Calanus* with a much higher salt content than fish. Even though the secretory rate is not so high as could have been expected from previous reports (see HUGHES 1970b), the salt gland of the Little Auk may nevertheless have the capacity to excrete the salt from a rather large amount of *Calanus* per day (Table 4). Calculations based on data given in Tables 4 and 5 indicate that with the highest secretory rate, the sodium in about 42 g of *Calanus* can be excreted per day. For the lower rate the sodium

Table 5

Average secretory capacity of the salt glands in the Little Auk calculated on a 24 hr basis for the two experimental series.

	Volume of secretion (ml)	m Eq Na	K	Cl
First experiment	6.6	4.9	0.5	5.6
Second experiment	3.0	1.9	0.3	2.6

from about 16 g *Calanus* can be excreted each day. Using the chloride concentrations for the calculations similar values can be found.

No data regarding food consumption in adult Little Auks are available, but NORDERHAUG (1970) estimated that the food consumption of chicks in the last week before they abandoned the nest was about 30g plankton per day. According to Table 3, 30 g of *Calanus* contains about 3.5 mEq sodium, 1.2 mEq of potassium, and 4.8 mEq of chloride.

As can be seen from Table 5 if the salt glands secrete with the highest rate, this amount of sodium and chloride can easily be excreted per day. 30 g of *Calanus* furthermore give a water yield of about 24 g free water+metabolic water. Metabolic water amounts to about 1.07 g per g fat and 0.5 g per g protein (SCHMIDT-NIELSEN 1964). Thus the water yield may be somewhere between 25 and 30 g per day. The evaporative water loss is usually about 5% per day (at 25°C), *i.e.* about 8 g in a bird weighing 150 g. Similarly water loss in urine and faeces amount to 5–6% of body weight, or 7.5–9 g per day in the Little Auk (see BENTLEY 1971). With sodium concentrations of about 700 mM/l in salt gland secretion, the sodium in 30 g (3.5 mEq) *Calanus* could be excreted in about 5 g water. Using these estimates (8 g evaporation+9 g cloacal excretion+5 g salt gland excretion), the water requirements would be about 22 g per day. Remembering that both nestlings and adult Little Auks live in cool-moist burrows or mostly swim and dive in cold sea water, it seems likely that the water requirement is less than these calculations indicate. The Little Auk might therefore subsist on the metabolic and free water of their food. The relatively high concentrations of potassium in salt gland secretion may also decrease the need of drinking sea water to compensate for differences in sodium/potassium ratios in salt gland secretion and food (see HOLMES and MCBEAN 1964). It should also be noted that some sodium and potassium are excreted in the urine (Table 3) which to some extent decrease the need for extrarenal excretion.

In conclusion the Little Auk in Spitsbergen has relatively larger salt glands and kidneys than other Auks of the same area. This is probably an effect of its smaller size. Although the secretory capacity of salt glands in the present study was found to be lower than previously reported for other sea birds, the salt secreting capacity of these glands in the Little Auk nevertheless seem to be sufficient to excrete the salt from the daily food intake.

Acknowledgements

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References

BENTLEY, P. J., 1971: *Endocrines and Osmoregulation.* Zoophysiology and Ecology, Vol. I. Springer-Verlag, New York, Heidelberg, Berlin. 300 pp.

CADE, T. J. and L. GREENWALD, 1966: Nasal salt secretion in falconiformes birds. *Condor* **68.** 338–350.

DUNSON, W. A., 1969: Electrolyte excretion by the salt gland of the Galapagos marine iguana. *Am. J. Physiol.* **216**. 995–1002.

FISHER, J. and R. M. LOCKLEY, 1954: *Sea-birds.* Collins, London. 320 pp.

HOLMES, W. N. and R. L. MCBEAN, 1964: Some aspects of the electrolyte excretion in the green turtle, *Chelonia mydas mydas* L. *J. exp. Biol.* **41**. 81–90.

HUGHES, M. R., 1970a: Relative kidney size in non-passerine birds with functional salt glands. *Condor* **72**. 164–168.

— 1970b: Some observations on ion and water balance in the Puffin, *Fratercula arctica. Can. J. Zool.* **48**. 479–482.

LØVENSKIOLD, H. L., 1964: Avifauna Svalbardensis. *Norsk Polarinst. Skrifter* Nr. 129, 460 pp. + XVIII plates.

NORDERHAUG, M., 1967: Trekkforhold, stedstrohet og pardannelse hos alkekonge på Svalbard. *Fauna* **20**. 236–244.

— 1970: The role of the Little Auk, *Plotus alle* (L.), in arctic ecosystems. IN: HOLDGATE, M. W. (ed.) *Antarctic Ecology* I. 558–560.

SCHALES, O. and S. SCHALES, 1941: A simple and accurate method for determination of chloride in biological fluids. *J. biol. Chem.* **140**. 879–884.

SCHMIDT-NIELSEN, K., 1960: The salt secreting glands in marine birds. *Circulation* **21**. 955–967.

— 1964: *Desert animals.* Clarendon Press, Oxford.

SCHMIDT-NIELSEN, K. and Y. T. KIM, 1964: The effect of salt intake on the size and function of the salt glands of ducks. *Auk* **81**. 160–172.

STAALAND, H., 1967: Anatomical and physiological adaptations of the nasal glands in Charadriiformes birds. *Comp. Biochem. Physiol.* **23**. 933–944.

— 1968: Excretion of salt in Waders, Charadrii after acute salt loads. *Nytt Mag. Zool.* **16**. 25–28.

SUMMEHAYES, V. and C. S. ELTON, 1928: Further contributions to the ecology of Spitsbergen. *J. Ecol.* **16**. 193–268.

Monthly general rhythm pattern variations in the Nordenskiöld-Sabine Land population of the Svalbard reindeer
(*Rangifer tarandus platyrhynchus*)[1]

BY ERIK S. NYHOLM[2]

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Abstract

Records totalling 74,080 minutes were made of the activity of 105 Spitsbergen reindeer at all times of the day and night (Fig. 2) in Adventdalen and Sassendalen and on the north shore of van Mijenfjorden (Fig. 1) in 1964, 1965 and 1968–1969. Active and rest period durations were measured to an accuracy of one minute and calculated as percentage of total observation time. The average distribution of activity is depicted in Fig. 5 and the sex- and age-specific averages in Fig. 6.

The females spend more time eating in the summer than in the winter ($t = 32.21$, $P < 0.001$), while they are walking for longer periods of time in the winter ($t = 7.89$, $P < 0.001$). Similarly the calves (<1 yr.) spend more time walking in the winter than in the summer ($t = 6.64$, $P < 0.001$). The males also seem to be more active walking in the winter than in the summer (2 mths x: winter 7.25 ± 1.85, summer 4.38 ± 1.26). In the summer, when very young, the calves are standing more often than the adult males ($t = 4.12$, $P < 0.01$).

It is understandable that the reindeer should require large amounts of food in the summer, as they possess a fat layer some 4–6 cm thick, which constitutes an essential store of energy for the winter. The winter increase in walking seems to be related to the occurrence of patches of hard, crusty snow and to the irregular distribution of food-plant communities on the edge of bare, windswept areas.

Introduction

The period 1960–1970 has seen a sharp increase in number of papers devoted to activity patterns for animals, and more and more detailed descriptions have been made of such species as for example the Norwegian wild reindeer (GAARE et al. 1970, THOMSON 1971, 1973). No previous work is to be found, however, on the activity patterns and rhythms of the Svalbard reindeer.

[1] This work forms Part 7 of the series "Ecological observations on the High Arctic animals", describing the results of the Finnish Zoological Svalbard Expeditions (FZSE) under the leadership of the author.

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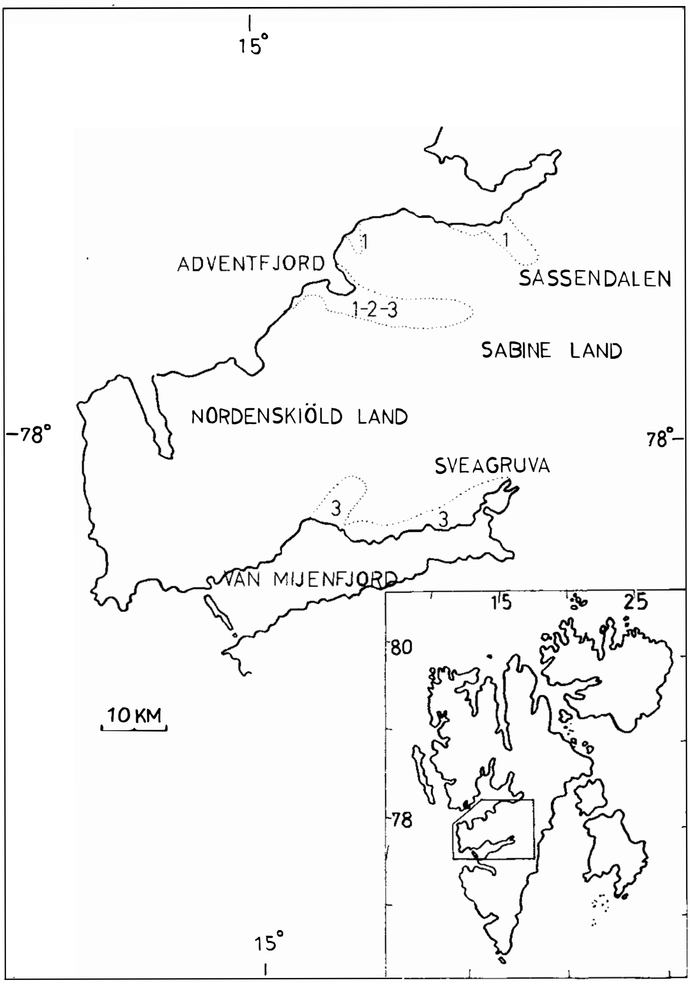

Fig. 1. *The study areas in 1964 (1), 1965 (2), and 1968–69 (3).*

My own work on the ecology of this species in 1964–1972 included studies of its activity and rhythms in an attempt to discover sex-specific, age-specific, and individual differences in behaviour within the population, and particularly the monthly variations in the time devoted to the various classes of locomotor activity.

Material and methods

The activity studies were carried out in the summer of 1964 and 1965 and during a winter stay in 1968–1969, and were focussed on the Nordenskiöld-Sabine Land reindeer population (Fig. 1), the most flourishing of the four separate populations in Svalbard (Lønø 1959).

Field observations:

Vicinity of Adventdalen: 24.6.–6.7.1964, 9.7.–14.7.1965.
Adventdalen-Sassendalen: 10.7.–14.7.1964, 25.7.–20.9.1968.
Adventdalen-van Mijenfjorden: 28.9.1968–20.6.1969.

The size of the material assembled was as follows:

Completed rhythm caras	Total observation time (minutes)	Total fieldwork time (days)	Individuals studied adult ♂	♀	juv. ∅
149	74,080	112	32	45	28

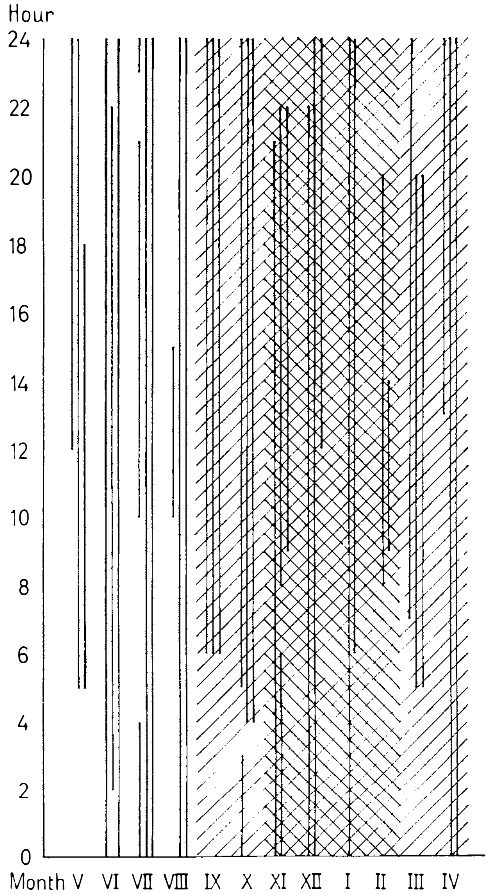

Fig. 2. *Monthly maximum durations of observation per 24 hours in 1964, 1965, and 1968–69. Spring and autumn (light and darkness) = /////, winter (darkness) = ////XX, ♂ ♀ ∅.*

It is relatively easy to study the Svalbard reindeer as it has no natural enemies and therefore is not frightened. Observations were made at all times of the day and night (Fig. 2), following the animals on foot in the summer and on skis or by motor sledge in the winter. Binoculars with a magnification of 7×50 or 8×40 were used, together with a Dynalit spot-lamp at darkness. This latter had an accurate observation range of 350 m and a discrimination range, for locating the reindeer, of 500 m. When doing fieldwork in bad weather a Karelian Bear-dog was used to follow the movements of the reindeer.

The activity and rhythm observations were timed using a watch and two summing second chronometers, enabling the durations of various activities to be recorded separately over the same period of time. Field notes were made using a clipboard with specially designed rhythm cards based on standard Paragon notched index cards (703103 Speedex 58201a).

The rhythm investigations included the determination of *general rhythm patterns*, for which the activities of individuals or herds were marked on the cards under six headings: lying, standing, grazing, walking, trotting-running, other activities (butting etc.). The *specialized rhythm samples* timed with the second chronometer subdivided these general categories into more detailed activities, e.g. lying: rest, rumination, sleep (Fig. 3).

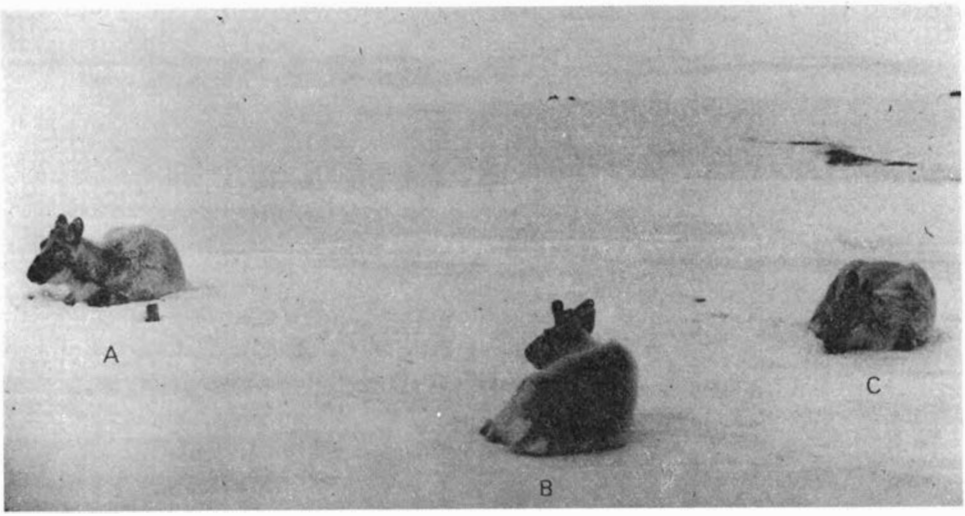

Fig. 3. *Phases in the 'lying down' rhythm of male reindeer at van Mijenfjord, 1969. A – resting, B – rumination, C – sleep.* *Photo:* ERIK NYHOLM

These activities were marked on the cards using the following symbols:

- rest period
  - lying = ———
    - rest = RE
    - rumination = RU
    - sleep = SL
    - defecation = DE
    - urination = U
  - standing = IIIIIII
    - suckling, sucking = SU
    - scratching = SC
    - scraping the horns = SCH
    - drinking = DR
- activity period
  - grazing = mm
    - feeding = F
    - digging (> 5 cm. snow) = D
    - pounding (<5 cm. snow) = P
    - movement (<10 steps) = M
  - walking (> 10 steps) = - - - - -
  - trotting-running = ...
  - other activities = xxxxxxx
    - butting = B
    - mating = MA
    - giving birth = GB
    - play = PL

General and specialized rhythm data were collected for as many easily identifiable or marked individuals as possible for as long sequences as conditions permitted (see Fig. 2). The animals were approached slowly upwind and were allowed to satisfy their curiosity and calm down completely before any readings were taken.

General rhythm measurements were also performed for herds or groups in connection with weekly censuses, the number of animals engaged in each activity being recorded with five-minute intervals. This short interval was possible because of the small size of the herds and groups (NYHOLM 1976). THOMSON (1971) had to record with 15 min. intervals in Norway, where the herds are larger.

The activity symbols were entered on the first page of the rhythm card beginning at the appropriate time of day, and the duration of each activity in seconds was noted alongside. The specialized rhythm letters were then placed beside the general symbols, although specialized rhythms were not recorded in every case.

These field observations were complemented with detailed meteorological readings taken at the field station and with micro-climate recordings and measurements of snow made at each site.

The durations of the general rhythm periods and the various activities appropriate to the rest and active periods were recorded to the nearest minute and calculated as percentages of total observation time.

Results

General

The Svalbard reindeer move about individually, in families (Fig. 4) or in small groups, and only when in rut do they form herds of ten or more. After the October rut the males and females form separate groups and

Fig. 4. *A 'reindeer family' – hornless male, horned female, and a calf – at van Mijenfjorden in April 1969.*
Photo: ERIK NYHOLM

move to different areas, the calves remaining with their mothers until the following spring. A group may remain constant in composition for several months, or may equally well change from day to day (NYHOLM 1976).

Although the reindeer have no natural enemies, observations suggest that they may be disturbed by the presence of an Arctic fox (*Alopex lagopus*) or polar bear (*Ursus maritimus*). Similarly, a harsh, cold wind seems to predispose them for periods of lying down or standing.

General rhythm

The average percentage distribution of the general rhythm pattern of the reindeer in different seasons of the year, involving lying, standing, grazing, walking and "other activities", is presented in Fig. 5. Summer and winter are defined as lasting for 4 months and spring and autumn for 2 months each.

The proportion of the observation time occupied by forms of *lying* is highest in the summer, especially in June (Fig. 5) when it exceeds the average for the year by 10.5%, while it is lower in the autumn and the winter, reaching a minimum in October (12.9% $< \bar{x}$). A second trough, though only departing from the average by 1.7%, occurs in the last month of the darkness period, February.

The first peak in the proportion of *standing* time (Fig. 5) appears in June, although it only rises 1.6% above the average, and a second peak of a similar order (1.9%) occurs at the beginning of the period of darkness, in November. The average figures for standing-type activity fall to a level somewhat less than 2% (0.8–1.1%) below the overall average in spring, in March and April.

The peak of the *grazing* time occurs in August, with a 7.8% positive deviation, and the minimum at the beginning of the period of darkness in November (4.6% $< \bar{x}$). A secondary negative trend in grazing (3.4%) occurs in June.

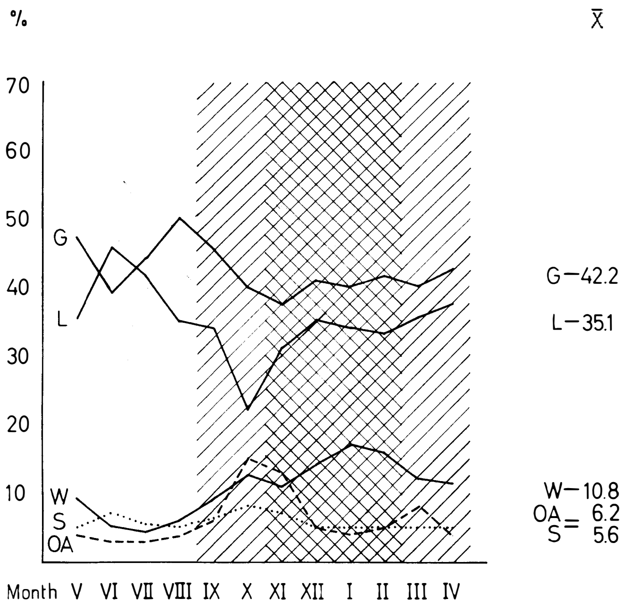

Fig. 5. *Monthly averages for general rhythm components in a material of 105 reindeer. Spring and autumn (light and darkness) = /////, winter (darkness) =* ⨯⨯⨯, *L – lying, G – grazing, W – walking, S – standing, OA – other activities.*

Walking is a common activity in October (4.3% > x̄), with another considerable increase in January, during the darkness period, when it rises to 6.2% above the average. It is at a minimum in June and July, the average values for these months falling 5.6% and 6.3%, respectively, below the average for the whole year.

The group of "*other activities*" includes trotting, running, etc. The peak here occurs at the rut in October and November (9.1% and 7.0% > x̄, respectively). The figure for March also lies slightly above the average (1.9%). The minimum period spans June, July and August (3.0%, 3.1%, and 2.4% < x̄ for the three months, respectively).

Comparison of general rhythm patterns by age and sex

The general activity patterns for males, females and calves are depicted in Fig. 6. The differences between the summer and winter periods for the females statistically did no more than indicate a tendency in the case of lying, standing and trotting-running activities ($t = 0.66—1.67$, $P < 0.1$), but in the case of grazing and walking they were significant ($t = 32.21$, $P < 0.001$ and $t = 7.89$, $P < 0.001$, respectively).

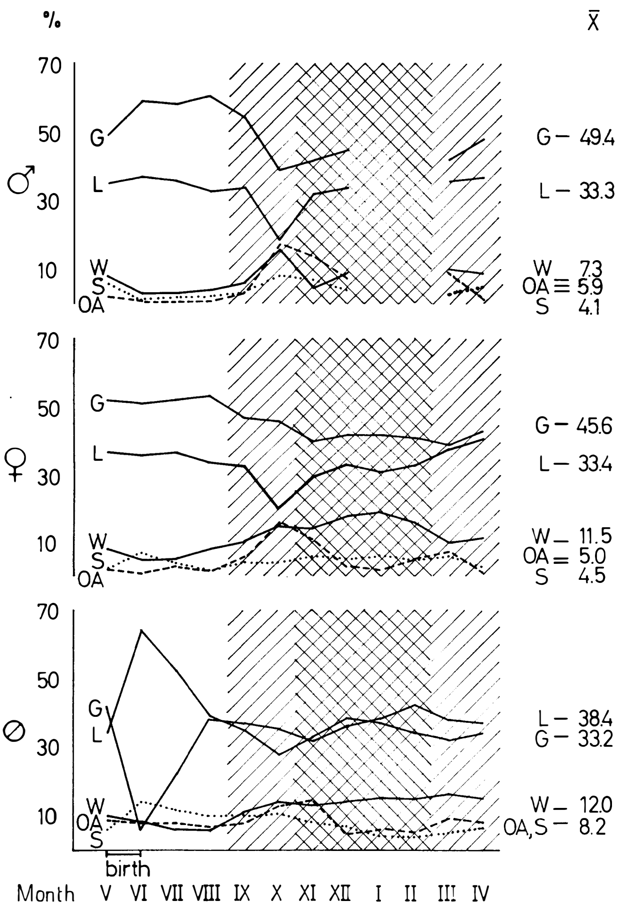

Fig. 6. *Monthly averages for general rhythm components in male (n = 32), female (n = 45), and juvenile (n = 28) reindeer. Symbols as for Fig. 5.*

A corresponding comparison in the case of the calves showed that the differences between summer and winter also indicated only tendencies in the case of lying, grazing and trotting-running ($t = 1.23$—1.70, $P < 0.1$), but that the calves spend more time standing around in summer than in winter ($t = 2.55$, $P < 0.05$), and more time walking in winter ($t = 6.64$, $P < 0.001$).

No comparison was possible in the case of the males due to the insufficiency of the data (see Fig. 6).

There were only slight differences in activity between the males and the females during the summer:

($P < 0.1$):	lying	$t = 0.58$
	standing	$t = 0.75$
	grazing	$t = 1.81$
	walking	$t = 0.83$
	other activities	$t = 1.00$

The only significant difference ($t = 3.04$, $P < 0.05$) was found in the proportion of trotting-running activity, which was more prominent in the females than in the males.

The differences between the females and the calves in lying, walking and trotting–running activities were similarly only slight ($P < 0.1$), but those noted in standing, grazing and "other activities" were significant ($P < 0.05$):

standing	$t = 3.38$
grazing	$t = 3.20$
other activities	$t = 2.76$

The differences in activity between the males and the calves were clearer than those between the males and the females, as only those concerning lying and walking remained slight ($P < 0.1$), while those for grazing, trotting–running, and other activities were significant ($P < 0.05$):

grazing	$t = 3.40$
trotting–running	$t = 2.65$
other activities	$t = 2.59$

There was a significant difference in the case of standing ($t = 4.12$, $P < 0.01$), with the calves standing more often than the adult males.

The age-specific and sex-specific comparison for the winter period must again be restricted to that between the females and the calves, in which only tendencies were to be observed ($P < 0.1$), with the exception of the category of lying, in which the calves were lying down significantly more often than the females ($t = 2.50$, $P < 0.05$) (Nyholm 1975).

Discussion

The high Arctic conditions of Svalbard, with a mean summer temperature of about +4°C, exclude the blood-sucking insects of the Culucidae, Simulidae and Tabanidae families and the warble fly (Oedemagena tarandi) and nostril fly (Cephenomyia trompe) which harrass reindeer and wild reindeer in Northern Europe and North America (THOMSON 1971) and in Siberia (ALARUIKKA 1959). Since the Svalbard reindeer is protected by law all year round and has no natural enemies, it would not be right to attempt a comparison of its activity patterns with those of for instance the Norwegian wild reindeer, which is hunted (THOMSON 1971) and has several natural enemies. On the other hand, a monthly comparison between the sexes and age-groups within this one population offers some interesting details of information.

During the *summer* there were slight differences in activity between the sexes and age-groups (adults > 1 yr. and juv. < 1 yr.), although standing and "other activities" were more common among the calves (< 1 yr.) than among the females ($t = 3.38$, $P < 0.05$ and $t = 2.76$, $P < 0.05$, respectively) and the males ($t = 4.12$, $P < 0.01$ and $t = 2.59$, $P < 0.05$). Trotting and running were also significantly more frequent among the calves than among the males ($t = 2.65$, $P < 0.05$). Conversely, the calves were less active in grazing than the males ($t = 3.40$, $P < 0.05$) and than the females ($t = 3.20$, $P < 0.05$). Between males' and females' grazing activities in summertime there was only a slight difference in favour of the males ($t = 1.81$, $P < 0.1$), while the females ran and trotted significantly more than the males ($t = 3.04$, $P < 0.05$).

The high level of standing-type activity in the summer period appears to be related to the suckling phase of the calves and to the high frequency of defecation due to the substantial food intake of the adults.

In the *winter* the difference between the females and calves were only slight, except in the case of lying, where the calves spent significantly more time ($t = 2.5$, $P < 0.05$).

The minimum for grazing in November appears to be due to the final stages of the rut and to the coldness on the snow in the high winds, force 5 beaufort or more, which occurred in the winter of 1968–1969, as seen in the following table (author's own unpublished material):

	Days	Force 5 beaufort (8.0–10.7 m/sec)	Force > 5 beaufort (> 10.7 m/sec)	High winds
November–February	120	17	30	47 days
Observation days	41	7	8	15 days

The increased incidence of walking in the winter period seems to be the result of the occurrence of snow patches and the scattered location of the food-plant communities at the edges of the bare, windswept areas.

A comparison between the *summer* and the *winter* material shows that the differences in respect of lying, standing, trotting–running and "other activities" for the females were slight only ($P < 0.1$), while grazing was more important in the summer ($t = 32.21$, $P < 0.001$) and walking in the winter ($t = 7.89$, $P < 0.001$).

There were only slight differences in the case of lying, grazing, trotting–running and "other activities" for the calves, but they were found to stand around more in the summer than in the winter ($t = 2.55$, $P < 0.05$), whereas they were significantly more active walking in the winter ($t = 6.64$, $P < 0.001$).

The higher grazing activity noted in the summer is quite logical, since they need to develop their 4–6 cm thick fat layer as an auxiliary nutrient supply for the winter (LØNØ 1959, author's own unpublished material). As the snow becomes harder in the winter they are obliged to search for food over a wider area, while the weaning of the calves in the early spring also increases the walking activity and the consumption of energy.

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References

ALARUIKKA, Y., 1959: Poronhoito suomensukuisten kansojen keskuudessa. *Rovaniemi.* 1–47 pp.

GAARE, E., T. SKOGLAND, and B. R. THOMSON, 1970: *Villreinens næringsvaner og adferd, Hardangervidda jan.-juli 1970.* Report of Norwegian IBP & Statens viltundersøkelser, Trondheim, Norway (mimeo). 97 pp.

LØNØ, O., 1959: Reinen på Svalbard. *Norsk Polarinstitutt Medd.* Nr. 83. 1–31 pp.

NYHOLM, E. S., 1975: Huippuvuorten peura (Rangifer tarandus platyrhynchus VROLIK). *Poromies* **5**. 2–6.

— 1976: *Structure and its variations of the reindeer population in West-Spitsbergen van Mijenfjord in 1968–1969.* (*Manuscript*).

THOMSON, B. R., 1971: *Wild reindeer activity, Hardangervidda July-Dec. 1970.* Report of Norwegian IBP–Statens viltundersøkelser, Trondheim, Norway (mimeo). 83 pp.

— 1973: *Wild reindeer activity Hardangervidda 1971.* Report of Norwegian IBP–Statens viltundersøkelser, Trondheim, Norway (mimeo). 76 pp.

Population size and reproduction of the reindeer (*Rangifer tarandus platyrhynchus*) on Nordenskiöld Land, Svalbard

By EINAR ALENDAL[1] and INGVAR BYRKJEDAL[1]

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Abstract

From ground surveys in July and August, 1973 and 1974, the reindeer population on Nordenskiöld Land, Spitsbergen, was found to consist of approximately 6000 animals.

The area north of the watershed was surveyed in 1973 and with a fertile area of somewhere between 304 and 412 km², a density of between 7.9 and 5.9 reindeer per km² fertile area was found (n = 2415). The area south of the watershed and the coastal area west of Fridtjovhamna-Grønfjorden were surveyed in 1974, and with fertile areas of between 387 and 464 km², and 251 and 285 km², respectively, the reindeer densities, accordingly, were to be found between 6.5 and 5.4 (n = 2510), and 2.2 and 1.9 (n = 542).

The calf production in 1973 was 15.9 per cent (north of the watershed on Nordenskiöld Land), but only 5.9 per cent in 1974 (south of the watershed). This might be ascribed to the severe food situation in late winter 1974. In the coastal area west of Fridtjovhamna-Grønfjorden, however, the calf percentage was 17.2 in 1974. Calf percentages and sex ratios should be calculated from a large number of animals, since the population is more or less segregated into "bull-areas" and "cow/calf-areas" during the summer.

Lichens, which have a very slow regeneration after heavy grazing, are unimportant or negligible as food in most parts of Svalbard. Therefore the Svalbard reindeer will have almost the same biomass of forage to subsist on every year, and we find it unlikely that a crash die-off will occur after the carrying capacity has been reached.

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Introduction

The gradual recovery of the reindeer in Svalbard from next to extinction in the 1920's (WOLLEBÆK 1926) to a recent population of several thousand animals, has been reviewed by LØNØ (1959a) and NORDERHAUG (1969a, 1969b, 1972). The most important range is Nordenskiöld Land – Sabine Land, Spitsbergen, which comprises a considerable area of vegetated ground. From ground surveys in 1971 and ground and air surveys in 1972, GOSSOW and THORBJØRNSEN (1974) suggested that sooner or later the population density may become critical in this area, and therefore recommend regular counts.

The present paper deals with ground surveys in the summers of 1973 and 1974, covering Nordenskiöld Land. In 1973 both authors participated in the survey, while the survey in 1974 was done by EINAR ALENDAL, with field assistance by PAAL H. PETERSEN.

Study area

The study area is shown on Fig. 1. It is divided into three parts; part A was surveyed in 1973, and parts B and C in 1974. Most of the area consists of barren mountains, steep unvegetated slopes, and glaciers. Extensive vegetation is only found at low altitudes along the fjords and in the valleys. The vegetation consists mainly of grasses, sedges, rushes, and mosses, lichens constituting only a minor and insignificant quantity. Even within the vegetation range there is unproductive ground, like broad, stony, half dried watercourses, exposed rock, areas of poor vegetation due to heavy wind exposure, etc. In most places the upper limit of the vegetation is rather sharply defined.

When estimating the productive area in Spitsbergen, NORDERHAUG (1969) regarded 100 m a.s.l. as an average altitudinal range for vegetation. In the western part of Nordenskiöld Land, the upper limit for vegetation is well below 100 m a.s.l., possibly only about 50 m a.s.l. in area C. In the eastern part, however, it goes higher, with an average altitude probably between 100 and 150 m a.s.l. In some of the interior valleys a few grazing reindeer were found even as high up as 300 m a.s.l.

In this study we have calculated the areas below the contour line for 50 and 100 meters in area C; below 100 and 150 meters in A and B, thus obtaining a minimum and a maximum productive area, between which the actual fertile area probably is to be found. Measurements were made with a planimeter on the maps "Adventdalen", "Isfjorden", "Van Mijenfjorden", and "Braganzavågen", in scale 1:100 000 (issued by Norsk Polarinstitutt).

Methods

The surveys were carried out on foot in the period 23 July–27 August 1973 (area A), and 23 July–26 August 1974 (areas B and C), covering all the potential reindeer habitats. In order to cover the wide lower parts of large valleys, we had to do separate surveys on each side of the valley, by walking up on one side, and down the other. Almost all valleys, however, could be covered by passing the valley once. Apart from recording of animals encountered along the census paths, the terrain was thoroughly scanned with binoculars (8 × 30, 7 × 50) regularly and with short intervals, thus revealing reindeer with strongly cryptic colour. For long distance observations a telescope (20, 30, 40, 50 × 100) was used.

During the summer the reindeer will be found grazing on the richer vegetation, which is found along the bottom of the valleys and along the plains of the fiords. These areas are easily surveyed, since the topography permits an excellent overlook. From a census path at some altitudes the vision is practically unimpeded. Thus in the major parts of the surveyed area, all the animals must have been discovered. In a few places where the landscape consisted of summits and ridges, some animals probably remained undetected. The approach of the observers did not confuse the counts, as animals at close range would only run or walk a short distance (50–100 m) and start grazing again.

In cases where neighbouring valleys had to be surveyed with several days intervals, some animals might in the meantime have moved from one valley to the other. Some of these animals may have been recorded twice, while others may not have been recorded at all. This source of error is difficult to estimate. But we feel it justifiable to assume that about 90 per cent of the population within the study area was recorded.

In addition to counting the number of animals and recording the calves, attempts were made to distinguish between sexes. Older bulls were easily identified by body size and colour, and especially by the size and form of the antlers. Cows and younger bulls often looked very similar, in which case presence of preputium could be the only reliable guide for sex identification. This method was often practicable only by use of binoculars or a telescope at close range.

Natural "flock sizes" were recorded before the appearance of the observers had influenced the behaviour of the animals. We also recorded all reindeer carcasses and skulls found, and tried to judge if the animals had died within the last 1½ years or earlier.

Results

Distribution and population size

The distribution of the reindeer is shown on Fig. 1 (yearlings and older) and Fig. 2 (calves). Number of observed animals in the different valleys and coastal plains can be seen from Tables 1, 2, and 3. The densities within areas A, B, and C are shown in Table 4.

In the areas A and B there was a tendency for bulls to be more numerous in the areas along the fiords, while cows with calves showed a more inland distribution. Concentrations of cows with calves were found in several remote side-valleys. Area C consists of a coastal plain, more or less isolated from A and B by high mountains and glaciers. No fertile valleys are accessible, and therefore the bulls and the cows with calves were found scattered over the plains.

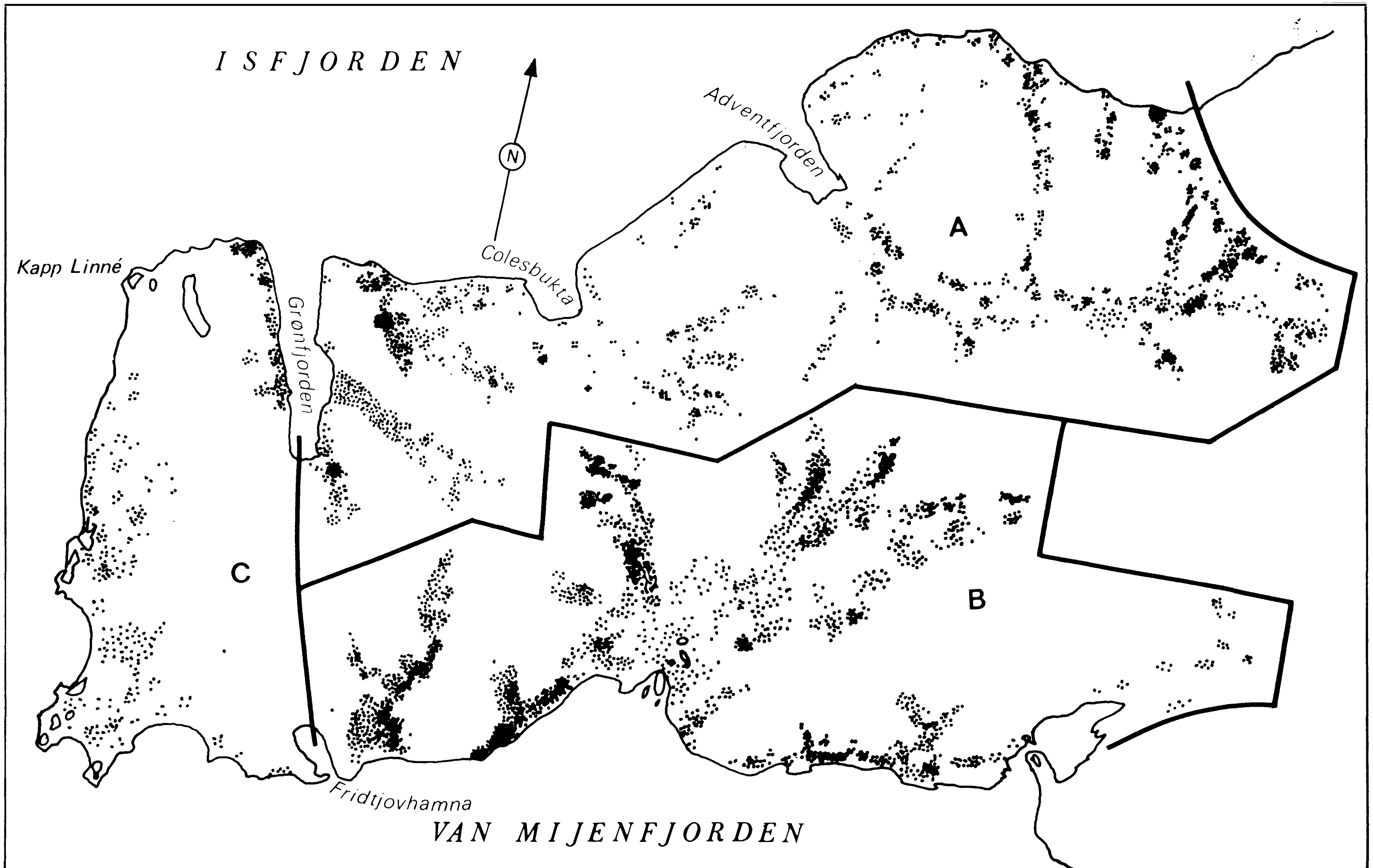

Fig. 1. *Distribution of observed reindeer older than calves in the summer 1973 (area A) and 1974 (areas B and C). Each dot indicates one animal.*

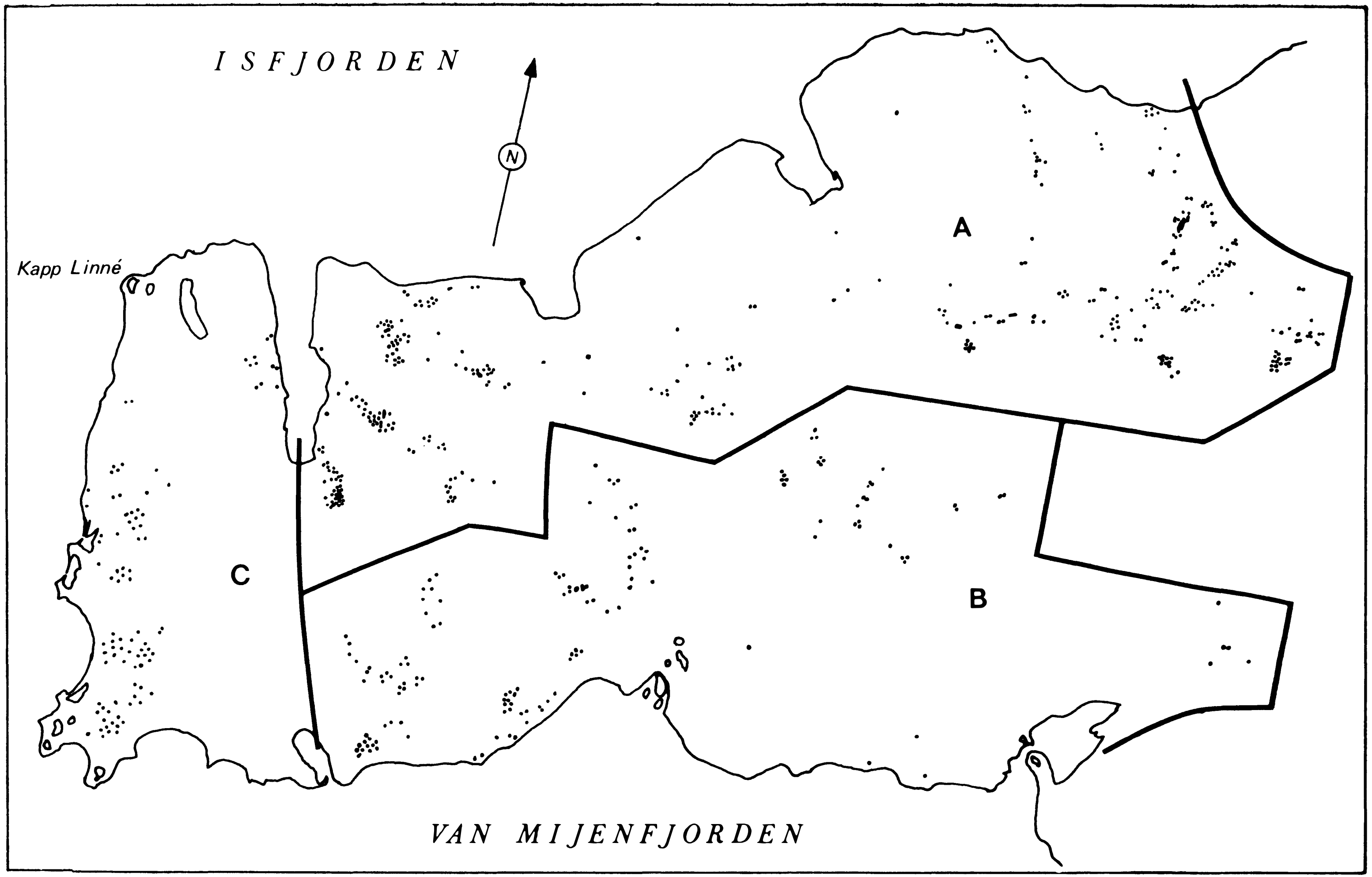

Fig. 2. *Distribution of calves observed in the summer 1973 (area A) and 1974 (areas B and C). Each dot indicates one calf.*

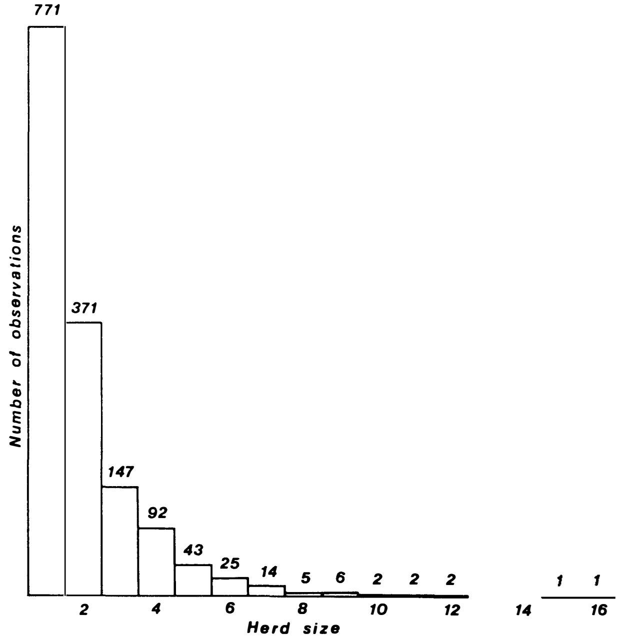

Fig. 3. *Herd size frequency of 2976 reindeer observed in the areas B and C on Nordenskiöld Land the summer of 1974.*

However, the plains west of Grønfjorden, Starostinaksla-Aldegondabreen, seem to be a typical "bull-area". The lack of reindeer in the area Griegbekken-Starostinaksla and in Linnédalen may be due to the three loose Greenland dogs at the weather station Isfjord Radio.

A total of 5467 reindeer were observed within the study area, and 110 were seen at a distance northwest of Sassenelva. Assuming a census efficiency of about 90 per cent, the total population amounts to slightly over 6000 animals, provided that the number of reindeer in area A was approximately the same in 1974 as in 1973.

The reindeer in Svalbard do not occur in large herds. Single animals or a few individuals together are mostly seen (Fig. 3). Usually the groups seemed to be no more than unattached animals grazing in proximity of each other.

Table 1

Observations of reindeer north of the watershed (area A) 23 July–27 August 1973.

Date	Locality	Total No. observed	Calves	
			No.	%
	Sassendalen SV of the river			
23/7	Sveltihel-Deltadalen	33	3	9.1
26/7	Deltadalen-Eskerdalen	68	13	19.1
25/7	Eskerdalen-Vendomdalen	40	2	5.0
25/7	Vendomdalen	116	28	24.1
24/7	Trehøgddalen	32	4	12.5
24–25/7	Brentskardet+Eskerdalen	175	29	16.6
24/7	Juvdalen	19	5	26.3

Date	Locality	Total no. observed	Calves	
			No.	%
23/7	Deltadalen	108	24	22.2
26/7	Lusitaniadalen	30	4	13.3
26/7	Sveltihel	38	5	13.2
27/7	Flowerdalen	41	3	7.3
28/7	Vindodden-Elveneset	2	0	
30/7	De Geerdalen	127	12	9.4
1/8	Wimandalen	13	0	
1/8	Wimandalen-Konusdalen	25	3	12.0
4/8	Konusdalen	3	0	
3/8	Konusdalen-Carolinedalen	14	0	
3/8	Carolinedalen	3	0	
3/8	Louisdalen	11	0	
4/8	Hanaskogdalen	20	1	5.0
5/8	Mälardalen	12	0	
30/7	Helvetiadalen	29	3	10.3
9/8	Arnicadalen	7	2	28.6
9/8	Janssondalen	22	9	40.9
11/8	Foxdalen	31	9	29.0
11/8	Bolterdalen	15	0	
14/8	Todalen	28	2	7.1
12/8	Endalen	1	0	
	Adventdalen			
7–12/8	Adventbukta-Helvetiadalen (Not obs. Endalen-Todalen SV of the river)	162	8	4.9
9/8	Helvetiadalen-Drønbreen	108	19	17.6
9/8	SE of Drønbreen	48	11	22.9
15/8	Adventbukta-Bjørndalen	0		
16–17/8	Bjørndalen	20	0	
17/8	Fuglefjella's NW-side	2	0	
17/8	Grumantdalen	4	1	25.0
12–13/8	Fardalen	53	3	5.7
13/8	Bødalen	39	8	20.5
27/8	Ringdalen	26	7	26.9
25/8	Trodalen	1	0	
25/8	Synndalen	6	1	16.7
22/8	Lailadalen	21	1	4.8
25–26/8	Colesdalen			
	West of 15°20′	22	1	4.5
	East of 15°20′	52	11	21.2
25/8	Rusanovodden-Russekollen	9	0	
23–24/8	Fossildalen-Hollendarbukta	83	13	15.7
22–23/8	Hollendardalen	281	51	18.1
23/8	Iradalen	1	0	
21–23/8	Hollendarbukta-Larvika	45	1	2.2
20/8	Grøndalen	230	42	18.3
20/8	Skarddalen	17	7	41.2
20/8	Grøndalen-Grønfjorddalen	11	1	9.1
19/8	Grønfjorddalen	111	37	33.3
	Total	2415	384	15.9

Table 2

Observations of reindeer south of the watershed (area B) 23 July–17 August 1974

Date	Locality	Total No. observed	Sex			Calves	
			M	F	U	No.	%
1/8	Kjellströmdalen, lower part	31	5	2	22	2	6.5
1/8	Lundströmdalen, lower part	23	5	4	11	3	13.0
4–6/8	Sveagruva-Litledalselva	228	83	19	124	2	0.9
5/8	Nordenskiölddalen	51	12	8	30	1	2.0
5/8	Urdkolldalen	34	11	11	12	0	
5/8	Langnesdalen	14	5	2	7	0	
4/8	Litledalen	19	6		13	0	
	Reindalen						
25/7	From Tverrdalen-Slakkbreen to Marthabreen	185	17	44	113	11	5.9
2+4/8	Slakkbreen-Litledalselva	208	75	15	117	1	0.5
25/7+11/8	Tverrdalselva-Kalvdalselva	216	98	22	92	4	1.9
24/7	Tverrdalen	99	13	12	67	7	7.1
23/7	Gangdalen	125	29	22	67	7	5.6
23/7	Tufsdalen	35	6	7	17	5	14.3
9/8	Semmeldalen	211	36	27	134	14	6.6
9/8	Skiferdalen	5	1	1	3	0	
9/8	Stigdalen	3			3	0	
9/8	Istjørndalen	59	4	6	45	4	6.8
9/8	Passdalen	28	8	2	17	1	3.6
11/8	Kalvdalen	63	10	17	24	12	19.0
12/8	Kalvdalselva-N.E.C.-hytta	79	17	7	50	5	6.3
13/8	N.E.C.-hytta-Vassdalselva	87	7	7	66	7	8.0
15/8	Vassdalen	88	4	12	62	10	11.4
15/8	Vassdalselva-Camp Morton	119	20	11	83	5	4.2
17/8	Berzeliusdalen	452	120	49	244	39	8.6
17/8	Aurdalen	48	1	7	33	7	14.6
	Total	2510	593	314	1456	147	5.9

Table 3

Observations of reindeer west of Fridtjovhamna-Grønfjorden (area C) 19–26 August 1974.

Date	Locality	Total No. observed	Sex			Calves	
			M	F	U	No.	%
19/8	Fridtjovhamna-Ytterdalselva	14	14	0	0	0	
19/8	Ytterdalen	1	1	0	0	0	
21/8	Ytterdalselva-Silderåa	96	33	32	9	22	22.9
22/8	Silderåa-Grønsteinelva	97	28	23	22	24	24.7
23/8	Grønsteinelva-Orustelva	102	26	36	12	28	27.5
23/8	Orustdalen	4	2	1	0	1	25.0
24/8	Orustelva-Griegbekken	61	38	8	8	7	11.5
24–26/8	Griegbekken-Starostinaksla and Linnédalen	0					
25/8	Starostinaksla-Aldegondabreen	155	115	13	20	7	4.5
25/8	Kongressdalen	12	2	4	2	4	33.3
	Total	542	259	117	73	93	17.2

Table 4

Estimated productive areas, observed population sizes, and densities of reindeer between Isfjorden and Van Mijenfjorden, with eastern boundary Sassenelva, 17°30'E, and Kjellströmdalen's SE-side.

Area	Total number observed	Area (km^2) below different contour lines			Animals/km^2 prod. area
		50 m	100 m	150 m	
A*	2415		304	412	7.9–5.9
B	2510		387	464	6.5–5.4
C	542	251	285		2.2–1.9
Total	5467		976		5.6

* 110 reindeer on the NE side of Sassenelva not included.

Calf production

Calf percentages for each of the areas A, B, and C are given in Tables 1 and 2, as percentages of the total number of observed animals within each area. The calf percentages of area A (15.9%) cannot be directly compared to those of B (5.9%) and C (17.2%), since A was surveyed a year before B and C. In area C the bulls outnumbered the cows, hence a calf percentage of 17.2 implies that a high proportion of the cows had calves.

Mortality

Records of reindeer carcasses and skulls are given in Table 5. The causes of death are unknown in almost all instances.

Mortality due to accidents may occur. Three bulls were seen with major leg injuries, and seven animals had died with their antlers entangled in wire. Eight pairs of bulls had died with their antlers completely locked after a combat. In addition, two bull skeletons were found with a single antler beam from a combattant fastened to their antlers. One of these must have died from starvation, since the position of the antler beam must have made grazing impossible.

Illegal shootings occur, although the reindeer in Svalbard has been protected since 1925. Hides and other remains of seven shot animals were found (Hatten 2 individuals, Sundodden (Akselsundet) 1 individual, Carolinedalen 1♂ (probably shot in June or July 1973), Hanaskogdalen 1♀, Blåhuken 2♂♂

Table 5

Reindeer carcasses, skeletons, and skulls found within the study area.

Year	Area	Carcasses and skeletons $< 1\frac{1}{2}$ years since death					Skeletons and skulls $> 1\frac{1}{2}$ years since death			
		M	F	U	Calf/yearl.	Total	M	F	U	Total
1973	A	12	5	20	7	44	17	12	28	57
1974	B+C	22	6	20	5	53	40	11	16	67

Table 6
Escaped dogs during the years 1963–74.

Year	Date	No. dogs Seen	No. dogs Shot	Locality	Killed reindeer	Source
1963	15/4	2		Gangdalen		1
1963	25/6		1		14 at Indre Hiorthhamn	3
1963	29/6	1		De Geerdalen	20 at Indre Hiorthhamn-De Geerdalen	4
1966		Some				1
1967	24/3	3	2	Pluto, Reindalen		1
1967	25/3	1		Fardalen		1
1967	31/3	1	1	Blåhuken		1
1967	10/4	3		Passdalen		1
1967	4/5	2	1	Semmeldalen		1
1967	7/5	4	4	Hollendardalen		1
1967			1			1
1968		1		Isfjordområdet		1
1970	17/2	1		Adventdalen	Several in Adventdalen	1
1970	6/3	2	2	Eskerdalen	Abt. 50, Adventdalen-Sassendalen (O. VIK SOLHEIM, pers. comm.)	1
1970	2/5	2		Grøndalen	Some	1
1972	30/3	1	1	Reindalen	Several killed and injured (O. VIK SOLHEIM, pers. comm.)	1
1972	/4	1		De Geerdalen		1
1972	23/5	3		Grøndalen		1
1973	14/5	4		Grøndalen		2
1974	9/4	2		Colesbukta	2 in Colesbukta	2
1974	21/7	6		Colesbukta		2

[1] and [2] Files of the Sysselmann's office, Longyearbyen, communicated by G. KROGSTAD and A. KOLBU, respectively.
[3] T. SKAUG in the hut name-book at Indre Hiorthhamn.
[4] HOLEN in the hut name-book of De Geer-hytta.

(shot in the winter 1973/74)). Four other animals had probably also been shot (Semmeldalen, Storheia, Grøndalen, and Skarddalen). One of these was found with shotgun pellets in the lower jaw.

Escaped dogs have occasionally killed considerable numbers of reindeer. A historical review has been given by LØNØ (1959). More recent data are listed in Table 6. Some of the dogs referred to in this table may, according to what was said in Longyearbyen, only be dogs that had made occasional excursions away from their owners or the settlements.

It is difficult to get an estimate of the mortality rate from the number of carcasses and skeletons found, and estimates of sex-ratios should be made with precaution. Dead animals will disappear from the tundra within a certain time limit, due to Arctic foxes (*Alopex lagopus*) and Glaucous gulls (*Larus hyperboreus*), and remains may become buried in the soil or washed into the sea during the melting period. Some animals that had died during the winter had dried up, and were not much macerated by foxes. On the other hand, animals that died during the summer were cleaned for soft parts by foxes and gulls within an astonishingly short period of time. Skeletons and antlers of big bulls are probably more resistent to decomposition than those of the cows. Besides, big antlers make the remains of dead bulls visible at quite a distance. Thus bulls tend to be overrepresented. The popularity of big antlers as collecting items among tourists and residents might partly be responsible for the lower bull/cow-ratio for carcasses and skulls found in area A, where most of the human activities are found.

Discussion

As mentioned, the sexes were more or less segregated into "bull-areas" and "cow/calf-areas" during our observation periods. NORDERHAUG (1970), OOSTERVELD (1973), and HJELJORD (1975) made the same experience in the summer on Edgeøya. The reason for this segregation is unknown. On Edgeøya the cows with their calves, often accompanied by juveniles, leave for higher plateaus and more interior valleys after June, while the bulls remain on the coastal plains for some time (OOSTERVELD 1973). Segregation of bulls and cows with calves in different areas in the summer is also the rule on Hardangervidda, South Norway (KJOS-HANSSEN 1973). The sexes of the barren-ground caribou west of Hudson Bay are to a large extent separated during the winter (PARKER 1972).

GOSSOW and THORBJØRNSEN (1974) comments upon the sex ratio of the reindeer in Svalbard, finding males to be in the majority. Our data from areas A and B are too scanty to permit any conclusions (Table 3). However, if the reindeer in area C is not a stationary sub-population, the male surplus there may only be a temporary feature. Although area C looks rather isolated, it is accessible from area A along Grønfjorden, and from area B across Fridtjovbreen north of Akselsundet. If area C is a favoured summer range for bulls of the western parts of area A (and B), the observed sex ratio in area C is not representative. We would like to stress the importance of determining sex ratios from sufficiently large samples, to allow for seasonal segregations and movements. As pointed out by HJELJORD (1975), this also applies when determining calf percentages.

Calf percentages around 20 have been regularly recorded in Svalbard. When counting muskoxen and reindeer in greater parts of area B in July 1959, LØNØ (1959b) saw 83 reindeer, of which 25.3 per cent were calves. During aerial surveys in July 1972 in greater parts of the areas A (and some area east of A) and B, GOSSOW and THORBJØRNSEN (1974) observed 13.5 and 24 per cent calves out of 1510 and 1462 animals, respectively. Their calf percentage of 13.5 is probably not fully representative for area A, since they missed some of the important calf areas here. Aerial and ground surveys of the reindeer on Barentsøya (n=484) 25–30 July 1969, and aerial surveys on Edgeøya (n=1448) 14–20 August 1969, showed calf percentages of 17.8 and 20.0, respectively (NORDERHAUG 1970).

The present study shows a calf percentage in area B (n=2510) of 5.6, while the calf percentages in areas A (n=2415) and C (n=542) of 15.9 and 17.2, respectively, correspond roughly to those found in earlier studies in Svalbard. When comparing these figures and, from what is known about calf percentages of reindeer and caribou in other parts of the world (see PARKER (1972) for a shorter review), the calf recruitment in area B was very low. Areas A and B look very similar in topography and vegetation, so differences in calf percentages can hardly be explained by differences between the areas in habitat quality. The differences in calf percentages probably represent a different reproduction success in the years 1973 and 1974. The reindeer in area C showed a good reproduction in 1974, thus the low reproduction probably only affected the interior of Nordenskiöld Land. Table 5 gives no information about the rate of the calf mortality, as dead calves are quickly eaten by Arctic foxes and Glaucous gulls, and the remains are not easily discovered.

Temperatures above 0°C may occur in any month of the winter, often in coincidence with periods of precipitation, favouring hard snow and icing in subsequent cold periods, making the forage less accessible. During the years 1973–74 such weather situations occurred several times, but precipitation was relatively scarce, except in the late winter 1974 when, judged from the weather data, the food situation seems to have been especially severe in the interior of Nordenskiöld Land. This is in accordance with information from BJØRN HENNINGSEN (in lit.), who was a resident in Longyearbyen at that time. During 2–9 March, daily maximum temperatures rose to above 0°C at Isfjord Radio (area C) as well as in Longyearbyen (area A), and the total precipitation was recorded at 40.8 mm and 51.9 mm, respectively. However, while the maximal precipitation recorded at Isfjord Radio on one single day was 13.2 mm, Longyearbyen had 34 mm. After this period, maximum temperatures remained below 0°C until the middle of May (interrupted by one day in late March). (Weather data from Det Norske Meteorologiske Institutt).

Since we have no data from the calving period (which, according to OOSTERVELD (1973), occurs after mid-May), or the subsequent weeks, we will only forward the hypothesis that a combination of hard snow and icing making scarcely any forage available, bad physical condition of the mothers, and frost and wind chill after the pelage of calves becomes wet, were the reasons for the low calf percentage in area B. HART et al. (1961) have for instance shown that calves that were exposed to cold without protection, combined with wind and precipitation eventually became hypothermic and died.

While the densities of reindeer in areas A and B were found to be nearly similar, area C had a markedly lower density. This might be ascribed to a less dense vegetation cover in area C. The vegetation communities also differed from those in areas A and B.

NORDERHAUG (1969b) gives a table of summer observations of the density of reindeer in different parts of Svalbard, 1958–68, showing a density of 0.06–1.6 reindeer per km² in the area below 100 m a.s.l. in different parts of Nordenskiöld Land. In greater parts of A (and some area east of A) and B, Gossow and THORBJØRNSEN (1974) found 5.5 and 3.9 reindeer per km² below 100 m a.s.l. in July 1972, whereby they concluded that the population is still growing. Our data show an even greater density, 7.9 for area A and 6.5 for area B below the 100 m contour line. But since different censusing techniques have been employed, comparison should be done with some reservation. On Barentsøya and Edgeøya where the productive areas reach on the average 200 m a.s.l., NORDERHAUG (1970) found 1.2 and 1 reindeer per km² estimated reindeer habitat, respectively, in the summer of 1969. Here the population level seems to have stabilized (HJELJORD 1975). These figures agree with the density of the stationary reindeer populations (0.01–1.6 reindeer per km² productive area) on 15 of the Arctic islands of Canada recorded by several authors (in NORDERHAUG 1969b).

The question arises when Nordenskiöld Land will reach its carrying capacity, and how a density dependent regulation will affect the reindeer population. Drastic population crashes have been witnessed in other reindeer populations as on two Arctic islands in the Bering Sea, St. Paul Island (SCHEFFER 1951) and St. Matthew Island (KLEIN 1968). Maximum density before the crashes were 18.2 and 17.5 per km² on St. Paul Island and St. Matthew Island, respectively. On both islands the crash came during winters with unfavourable climatic conditions, and after the very important lichen forage had been almost completely eliminated during some winters of heavy grazing pressure.

The populations on these two islands differ from Svalbard in at least two important respects: the reindeer stocks had been introduced by humans, while in Svalbard the reindeer population is natural, having adapted itself to the environments by natural selection and, in Svalbard the reindeer subsist on grass-like plants, forbs, and woody plants during the whole year. Lichens are so scarce that they are of little or almost negligible importance as winter forage. PALMER (1934, in SCHEFFER 1951) states that "quadrat observations made on the coastal tundras indicate that recovery of lichen range following full cropping may take possibly 15 or 20 years". The vegetation in Svalbard, on the contrary, will grow up to the same height every year, thus giving the reindeer population the same biomass to subsist on. In the winter the pastures are usually covered with ice (LØNØ 1968), preventing the reindeer from making any damage to the roots of the plants. These facts make it improbable that large die-offs will occur, and cause any drastic reduction in the reindeer populations in Svalbard. As long as the reindeer is protected, the number will be relatively stable with a somewhat higher mortality in severe winters. Since there are no natural predators in Svalbard, intraspecific competition for available winter forage may benefit the population genetically. However, interspecific competition for food seems to have a negative effect on the small muskox population on Nordenskiöld Land (ALENDAL 1975).

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References

ALENDAL, E., 1976: The muskox population (*Ovibos moschatus*) in Svalbard. *Norsk Polarinstitutt Årbok* 1974.

GOSSOW, H. and S. R. THORBJØRNSEN, 1974: Air and ground survey of reindeer in Nordenskiöld Land and Sabine Land, Spitsbergen. *Norsk Polarinstitutt Årbok* 1972. 83–88.

HART, J. S., O. HEROUX, W. H. COTTLE, and C. A. MILLS, 1961: The influence of climate on metabolic and thermal responses of infant caribou. *Can J. Zool.* **39**. 845–856.

HJELJORD, O., 1975: Studies of the Svalbard reindeer. *Norsk Polarinstitutt Årbok* 1973. 113–123.

KJOS-HANSSEN, O., 1973: *Utbredelse og reproduksjon hos reinen på Hardangervidda.* Unpubl. Thesis. Univ. Bergen. 218 pp.

KLEIN, D., 1968: The introduction, increase, and crash of reindeer on St. Matthew Island. *J. Wildl. Mgmt.* **32**. 350–367.

LØNØ, O., 1959a: Reinen på Svalbard. *Norsk Polarinstitutt Medd.* Nr. 83. 31 pp. (Reprint of *Fauna* **12** (2), 1959).

— 1959b: *Telling av moskusdyr og rein på Svalbard 1959.* Typewritten report. Files of Norsk Polarinstitutt. 4 pp.

— 1968: Nye opplysninger om reinen på Svalbard. *Fauna* **21** (1). 32–36.

NORDERHAUG, M., 1969a: Svalbard-reinens utbredelse i 1960–årene. *Fauna* **22**(2). 132–139.

— 1969b: Svalbard-reinen i 1960–årene. Beiteareal og bestand. *Fauna* **22**(4). 253–264.

— 1970: Investigation of the Svalbard reindeer (*Rangifer tarandus platyrhynchus*) in Barentsøya and Edgeøya, summer 1969. *Norsk Polarinstitutt Årbok* 1969. 70–79.

— 1972: Distribution of the Svalbard reindeer (*Rangifer tarandus platyrhynchus*) in 1969–70. *Norsk Polarinstitutt Årbok* 1970. 53–58.

OOSTERVELD, P., 1973: *Reindeerstudies on Edgeøya.* Unpubl. preliminary report. Res. Inst. Natmgmt., Leersum. 20 pp.

PARKER, G. R., 1972: Biology of the Kaminuriak population of barren-ground caribou. Part 1: Total numbers, mortality, recruitment, and seasonal distribution. *Can. Wildl. Serv. Rept. Ser.* No. 20. 95 pp.

SCHEFFER, V. B., 1951: The rise and fall of a reindeer herd. *Sci. Monthly* **73**. 356–362.

WOLLEBÆK, A., 1926: The Spitsbergen reindeer (*Rangifer tarandus spetsbergensis*). *Resultater av de norske statsunderstøttede Spitsbergenekspedisjoner.* **1** (4). 1–71.

Vegetasjon, mikrofauna og rein på Reinsdyrflya

Vegetation, microfauna, and reindeer at Reinsdyrflya

AV INGVAR BRATTBAKK, ARNE FRISVOLL og ERLING SENDSTAD[1]

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Abstract

Some notes on the vegetation, reindeer, and soil fauna at Reinsdyrflya, a peninsula in northwestern Spitsbergen, are given. Reindeer (*Rangifer tarandus platyrhynchus*) were observed grazing on *Poa alpina* var. *vivipara*, *Oxyria digyna*, and *Stereocaulon*. Overgrazing during the summer season is probably not a limiting population factor. The detailed decomposition chain of the ecosystem is practically unknown, but Tullgren funnel studies of the upper 3 cm of soil yielded an estimated total of about 35,000 *Collembola* per square metre. Based on present knowledge this seems to be a normal density for Spitsbergen.

Innledning

På nordkysten av Spitsbergen ligger Reinsdyrflya (79°58'N, 13°30'Ø), en stor halvøy nordvest for Woodfjorden (Fig. 1). Fra de 470 m høye Sebrafjella i øst til Woodfjorden i vest er avstanden 17 km, og fra Worsleyhamna i sør til

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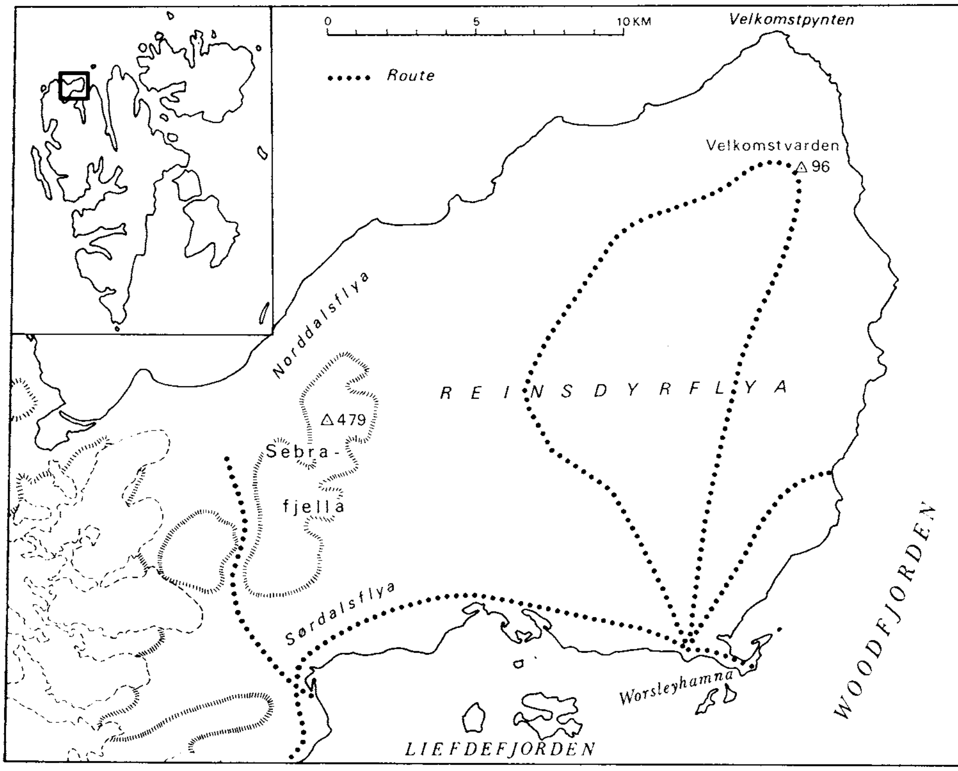

Fig. 1. *Kart over Reinsdyrflya med marsjruter inntegnet.* Map of Reinsdyrflya, northern Spitsbergen, with localities investigated.

Velkomstpynten i nord er det 20 km. Reinsdyrflya med de naturlig tilliggende lave områdene sør og nord for Sebrafjella — Sørdalsflya og Norddalsflya — dekker 340 km^2.

Topografien viser et flatt, bølget landskap. I nordøst ligger Velkomstpynten på 96 m o. h.: dette er det høyeste punktet på flya. I et så flatt landskap med permafrost må det nødvendigvis bli dreneringsproblemer. Vannet dreneres ikke ned i grunnen, men samles i forsenkningene til grunne dammer, tjern og våtmarksområder. Bekker og elver har lite fall og er heller ikke særlig store om sommeren, men i en hektisk smelteperiode om våren synes de å ha ganske stor vannføring.

Berggrunnen på flya er sedimenter fra tidlig Devon og tilhører Woodfjord-serien som har en mektighet på inntil 3000 m. Dette er «Old Red Sandstone» og den er trolig avsatt under svært tørre forhold, kanskje ørkenklima. Den rødbrune fargen kommer av jernoksyder (ORVIN 1969). Denne røde sandsteinen er løs og forvitrer lett, og gir da en rødbrun leire som ser ut til å gi et godt næringssubstrat for plantene.

SUMMERHAYES & ELTON (1928) delte Svalbard inn i fire klimasoner på grunnlag av vegetasjonen. I dette systemet lar de Reinsdyrflya komme i sone 2 —

Dryas-sona. Nordaustlandet faller til sammenligning i den mest karrige, sone 1. Vårt inntrykk av vegetasjonen på Reinsdyrflya er at også store deler av denne tilhører sone 1.

Undersøkelser av vegetasjonen på Reinsdyrflya

De følgende notater om vegetasjonen på Reinsdyrflya er et resultat av turer foretatt i august 1974 (Fig. 1). Det ble gjort få inngående noteringer eller analyseringer, og opplysningene må derfor tas som et foreløpig inntrykk.

Alt etter hvilke planter som vokser i deler av et område, kan en gruppere områdets vegetasjon i vegetasjonstyper. Følgende klassifisering av vegetasjonen på Reinsdyrflya synes å passe i denne sammenhengen. Nomenklaturen følger for karsporeplanter (*Pteridophyta*) og enfrøbladede (*Monocotyledoneae*) Rønning 1972, for tofrøbladede (*Dicotyledoneae*) Rønning 1964, og for moser (*Bryophyta*) og lav (*Lichenes*) Ursing 1962.

1. *Strandenger med dvergstarr* (Carex ursina)

Dvergstarr danner tette, halvkuleformete tuer som sikkert tåler et sterkt beitetrykk. Der det er mye strandeng utgjør disse et skattet beiteområde for reinen, men strandenger med dvergstarr er sjeldne på Reinsdyrflya. De fantes særlig omkring Worsleyhamna.

2. *Grunne dammer og små tjern med en vegetasjon av hengegras* (Arctophila fulva) *og — i noe mindre grad — småtundragras* (Dupontia pelligera) og *sabinegras* (Pleuropogon sabinei)

Disse er best utviklet i perifere, sørlige deler av flya, hvor det til dels er store sammenhengende våtmarker dominert av hengegras. Dette graset er på sine steder 10—20 cm høyt og høyere og vokser i tette bestander. Normalt skulle dette være fine beiteområder. Likevel ser det ikke ut som om det foregår videre beiting der. Vi kjenner ikke til hvilken beiteverdi hengegras har.

3. *Reinrosevegetasjon* (Dryas-hei)

Sørskråningen av flya mot Liefdefjorden er dekket av spredt reinrosevegetasjon. Denne vegetasjonstypen (Rønning 1965) forekommer på rabber i klimatisk og geologisk sett gode områder. De artene som vokser der er ofte små og tørre, og det ser normalt ikke ut som om reinrosetuene beites.

4. *Rabbevegetasjon med polarvier* (Salix polaris)

Inne på flya mangler stort sett reinrose, i stedet vokser det polarvier på rabbene. Det er usikkert i hvilken grad polarvieren beites. Hjeljord (1975) peker på at beitemerker på *Salix polaris* er vanskelig å observere slik at polarvierens betydning som beite trolig er underestimert. I vomprøver fant han mye polarvier.

På — eller i nærheten av rabbene finner en også de største lavforekomstene. Lavvegetasjonen på flya er ikke særlig rik. Arter av slekta *Stereocaulon* (saltlav) finnes her og der i relativt store mengder. I ett tilfelle ble rein iakttatt beitende på *Stereocaulon*-tuer. På steiner og blokker vokser mange lavarter. Særlig arter av slekta *Umbilicaria* (navlelav) kan visstnok bli beitet, men vi observerte ikke slik beiting. Det finnes også rapporter om beiting av «svart skorpelav» på stein (Lønø 1959, Heintz 1964). Denne svarte skorpelaven er trolig *Parmelia*-arter, men forholdet bør undersøkes nærmere. Laven *Cetraria delisei* er sjelden på flya, i områder uten rein finnes den ofte i betydelige mengder (f.eks. Brøggerhalvøya, Mitrahalvøya). Dette kan tyde på at laven på flya er utsatt for et sterkt beitepress. Hvis så er tilfelle vil det ha negativ virkning på kvaliteten av vinterbeitet.

5. *Snøleievegetasjon og snøleiepreget vegetasjon*

Store deler av flya har en vegetasjon karakteristisk for områder hvor snøen ligger lenge og vekstperioden for plantene av den grunn blir kort. Vanlige karplanter i slik snøleievegetasjon var aksgroende fjellrapp (*Poa alpina vivipara*), fjellsyre (*Oxyria digyna*), knoppsildre (*Saxifraga cernua*), sprikesnøgras (*Phippsia concinna*) og polararve (*Cerastium regelii*). Noe sjeldnere var snøgras (*Phippsia algida*), snøarve (*Cerastium arcticum*) og rødsildre (*Saxifraga oppositifolia*), og relativt sjelden fantes sæterrapp (*Poa alpigena*), tuesildre (*Saxifraga caespitosa*), skjørbuksurt (*Cochlearia officinalis*) og polarsoleie (*Ranunculus sulphureus*). Av de nevnte artene er det bare to som antas å bety noe for reinens sommerbeite, nemlig fjellrapp og fjellsyre. De andre er enten for små, for sjeldne, eller på annen måte uegnet som næring for reinen. Flere ganger så vi rein som beitet, og ved kontroll viste det seg at den hadde beitet en eller begge av artene fjellrapp og fjellsyre.

Undersøkelser av faunaen

Av arthropoder (leddyr) som har betydning for omsetningen av organisk materiale har vi fra Reinsdyrflya følgende data. Prøve tatt 2. august 1974 fra *Dryas*-vegetasjon nær Worsleyhamna. Metodikk: Tullgren funnel (Wallwork 1970). Terminologi: Gisin (1960).

	Antall pr. m²	
Collembola (Spretthaler)		
Folsomia quadrioculata	24 480	
F. bisetosa	8 960	
Willemia anophtalma	1 120	
Onichiurus arcticus	240	
Anurida pygmea	160	
Sum *Collembola*		34 960
Acarina (Midd)		
Oribatei	2 520	
Meso- og a-stigmata	1 720	
Sum *Acarina*		4 240
Sum microarthropoder		39 200

Dette er et øyeblikksbilde av tettheten for microarthropoder. Tallene tyder ikke på at den jordlevende evertebratfauna på Reinsdyrflya er uvanlig liten, til tross for områdets ekstreme beliggenhet. Prøver fra *Dryas*-vegetasjon ved Ny-Ålesund samme sommer ga i gjennomsnitt 19 500 collemboler pr. m^2. Maksimum der var ca. 46 400 collemboler pr. m^2. Prøvene ble begge steder tatt i dybdesjiktet 0—3 cm.

Konklusjoner

Resultatene fra undersøkelsene av mikroarthropoder indikerer at produksjon og omsetningsforhold i de *Dryas*-dominerte områdene av flya ikke skiller seg vesentlig fra andre lignende områder på Svalbard. Den karrige vegetasjon på de sentrale deler av flya (vegetasjonstype 5) tyder imidlertid på at det her rår andre forhold for primærproduksjonen. Hvor mye av denne produksjonen reinen er i stand til å nyttiggjøre seg, er ennå et åpent spørsmål.

Reinen og kortnebbgåsa (*Anser fabalis brachyrhynchus*) preger ikke områdene bare ved sitt nærvær, like tydelig er akkumuleringen av dyras ekskrementer. Dette er forhold vi mener er av betydning for forståelsen av disse områdenes biologiske funksjon. Svalbard mangler store deler av den tempererte verdens evertebratfauna (virvelløse dyr).

Dette gir seg to påfallende utslag:

For det første mangler alle gjødselbiller. Dette fører til at ekskrementer blir liggende der de faller. Der tørker de, og mange næringsstoffer føres ikke tilbake til jorda før ekskrementene etter en tid gror ned av mose eller annen vegetasjon.

For det andre mangler jordbunnens makrofauna, f.eks. store oligochaeter (fåbørstemark), diplopoder (tusenbein), isopoder (skrukketroll) og gastropoder (snegler). Dette fører til at det stedlige strøfall nedbrytes sakte, det tørker og akkumuleres som en kake over de minerogene avsetningene. Dette skyldes at ingen vertikal transport av organisk materiale via makrofaunaen kan skje. Slik hemmes en virkelig jordsmonndannelse, og tilbakeføringen av det organiske materialet blir sterkt forsinket.

Det er uriktig å dra vidtrekkende konklusjoner om reinbeitet på flya etter et kort sommerbesøk. Med forbehold kan vi antyde at de karplantene reinen foretrekker om sommeren ennå ikke er utsatt for overbeiting. Dette kan bekrefte at det er vinterbeitet som først vil bli ødelagt ved for stor reinbestand på flya.

For å få et sikrere inntrykk av beitesituasjonen, burde det foretas systematiske undersøkelser over lengre tid. En del av de spørsmål en da måtte prøve å få svar på, kan samles i følgende punkter:

a. Hvor mye organisk materiale produseres i ulike plantesamfunn?
b. Hvilken potensiell næringsverdi har dette plantematerialet for reinen til ulike årstider?
c. Hvilke planter spiser reinen til ulike årstider, og hvor mye?

d. Hvordan greier reinen i praksis å nyttiggjøre seg det tilgjengelige plantematerialet?
e. Hvor mange rein finnes i et gitt område til ulike årstider, hvor stor er kalveproduksjonen og hvor stor er den naturlige dødelighet i populasjonen?
f. I hvilken grad er primærproduksjonen en begrensende faktor for reinpopulasjonen til ulike årstider?
g. Hva skjer med den del av primærproduksjonen som ikke nyttiggjøres ved beiting: akkumulering, dekomposisjon?

Litteratur

GISIN, R. H., 1960: *Collembolenfauna Europas.* 1—312. Geneve.

HEINTZ, A., 1964: Om rein og isbjørn på Svalbard. *Norsk Polarinstitutt Medd.* Nr. 92. 1—20. Oslo.

HJELJORD, O., 1975: Studies of the Svalbard reindeer. *Norsk Polarinstitutt Årbok* 1973. 113—123. Oslo.

LØNØ, O., 1959: Reinen på Svalbard. *Norsk Polarinstitutt Medd.* Nr. 83. 1—31. Oslo.

ORVIN, A. K., 1969: Outline of the geological history of Spitsbergen. *Skr. om Svalbard og Ishavet* Nr. 78. 1—57. Oslo.

RØNNING, O. I., 1964: Svalbards flora. *Norsk Polarinstitutt Polarhåndbok* Nr. 1. 1—123. Oslo.

— 1965: Studies in Dryadion of Svalbard. *Norsk Polarinstitutt Skrifter* Nr. 134. 1—52. Oslo.

— 1972: The distribution of the Vascular Cryptograms and Monocotyledons in Svalbard. *Det Kgl. Norske Videnskabers Selskab Skrifter* Nr. 24. 1—63. Trondheim.

SUMMERHAYES, V. S. & C. S. ELTON, 1928: Further contribution to the ecology of Spitsbergen. *J. Ecology* **16**. 193—268. London.

URSING, B., 1962: *Svenska växter, Kryptogamer.* 1—530. Stockholm.

WALLWORK, J. A., 1970: *Ecology of soil animals.* 1—283. London.

The muskox population (*Ovibos moschatus*) in Svalbard

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Abstract

Today the muskoxen in Svalbard have their distribution on Nordenskiöld Land, the peninsula between Isfjorden and Van Mijenfjorden. They are the descendants of the 17 muskoxen (11 calves and 6 yearlings) from East Greenland released on 24 September 1929 at Moskushamn, Adventfjorden.

In 1932 the first calves were born. The muskoxen increased in number until World War II, decreased during the war because of illegal hunting and many abandoned dogs, and then increased again. The muskox population possibly counted about 50 animals in 1959 when 36 were observed during a survey. In 1974 they amounted to only about 30, when I observed 29 muskoxen – 7 ♂♂, 21 ♀♀, and one calf.

The stagnation and even the decline in the muskox population may be due to competition for food. Climatic conditions may also have detrimental effects on the population. During the summers 1973 and 1974, 5577 reindeer were observed on the peninsula. In 1925 when the reindeer became protected in Svalbard, they were almost exterminated on Nordenskiöld Land.

Introduction

On 24 September 1929, 6 yearlings and 11 calves of muskoxen, *Ovibos moschatus wardi* LYDEKKER 1900, from East Greenland were released at Moskushamn in Adventfjorden, Svalbard (HOEL 1929, 1930). Two of the men taking care of the animals during the transportation from Norway to Svalbard

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Table 1

Muskox age and sex composition in Svalbard in the summers of 1973 and 1974. The figures in parentheses are 1973 observations. In 1973 only the area north of the watershed on Nordenskiöld Land was surveyed.

Locality	Herd size	Calf	1 year ♂♂	1 year ♀♀	2 years ♂♂	2 years ♀♀	3 years ♂♂	3 years ♀♀	4 years or older ♂♂	4 years or older ♀♀
Fivelflyane, Adventdalen	2 (5)					(1)			1(1)	1 (3)
Fivelflyane, Adventdalen	2*								1	
Indre Hiorthhamn, Adventdalen	5							1	2	2
The plateau NE of Bjørndalen	1									1
Fuglefjella's NW-side	3 (7)	(1)		1	(1)			(1)	(1)	2 (3)
Fuglefjella's NW-side	1									1
Grumantdalen	4 (1)	1							(1)	3
Fardalen	3* (5)	(1)	(1)	1					(1)	1 (2)
Colesdalen/Fardalen	(3)							(1)	(1)	(1)
Colesdalen/Ringdalen	(1)									(1)
Reindalen/Gramdalen	1									1
Reindalen/Tverrdalen	3								1	2
Reindalen/Gangdalen	1								1	
Reindalen/Semmeldalen	2									2
Reindalen/Semmeldalen	3								1	2
Total	29 (22)	1(2)	(1)	2	(1)	(1)		1(2)	7(5)	18(10)

* One of the animals observed before.

state that the 6 yearlings were 3♂♂ and 3♀♀. As for the calves there is a discrepancy, as one says there were 6♂♂ and 6♀♀ of which 1♂ died on the ship, while the other says 7♂♂ and 5♀♀ of which 1♀ died (note and letter from 1932 in the files of Norsk Polarinstitutt). The latter figures are possibly correct since this man also took part in the catching and transportation to Norway of the 6 yearlings and 4 calves that had been bought from two Norwegian sealing expeditions. The other 8 calves were captured by participants of a Norwegian scientific expedition (ORVIN 1930).

The muskoxen were followed with great interest by people in Longyearbyen during the first years after the introduction, and several reports were sent to Dr. ADOLF HOEL (files of Norsk Polarinstitutt). Later information about the animals is sparse. In the summer of 1959 ODD LØNØ lead a count of the muskoxen along the north side of Van Mijenfjorden and Bellsund, west of Grønfjorden, and in Adventdalen (LØNØ 1959b, 1960a, b). During the study of reindeer on Nordenskiöld Land in July and August 1973 and 1974 (ALENDAL and BYRKJEDAL 1976), I also investigated distribution, total number, sex and age composition of muskoxen in this area (Table 1).

Study area

All observations of muskoxen in Svalbard are from Nordenskiöld Land (and Sabine Land), the peninsula between Isfjorden and Van Mijenfjorden. The only exception is the observation of a bull on 8 August 1966 at Gipshuken north of Sassenfjorden (EHRENROTH and LOHM 1967). Descriptions of this area are found in ALENDAL and BYRKJEDAL (1976).

Methods

The survey was made on foot north of the watershed on Nordenskiöld Land from Sassendalen to Grønfjordbreen in July and August 1973. On 15 July 1974 the same area was surveyed from a light airplane. Earlier in July 1974 the area from Adventdalen-Helvetiadalen to Colesdalen, the most important distribution area of muskoxen north of the watershed, had been investigated on foot. The area south of the watershed west of 17°30′E and west of Fridtjovhamna-Grønfjorden was investigated on foot in August 1974.

The animals were age determined up to 3 years old from body size and horn development. Age determination of animals 4 years old is so uncertain that such individuals must be included in a group of older animals. The sex of yearlings was determined when they urinated (which they often do after getting up from a resting period or when being frightened), while animals of 2 years and older were sex determined from the form of the horns. To avoid double registration I made a simple sketch of the horns of almost all the animals in the summer of 1974. When a muskox population consists of few animals, it is relatively easy to recognize most of them by the form of the horns and their furrows (especially in the broad base).

Table 2

Synopsis of muskoxen observed in Svalbard, 1929–1974.

Year	Date	Total number obs.	Calf	Locality	Reference
1929	24/9	17	11	Moskushamn, set free	Hoel (1929, 1930)
1930	/3	7		Moskushamn	A. Hoel****
1930	/3	6		Adventdalen	A. Hoel****
1931	10/5	16		Adventdalen	A. Hoel****
1932	/10	18	4(3)	Adventdalen	A. Hoel**** (Anon. 1935)
1932	/10	1		Sassendalen	A. Hoel****
1933	/6	9	3(5)	Revneset	A. Hoel**** (Anon. 1935)
1935/36		30*			A. Hoel****
1937	6/6	5		Moskushamn	Munthe-Kaas Lund (1947)
1946	8/7	1		Moskushamn	Munthe-Kaas Lund (1947)
1947	/7	9	3	Fardalen	Munthe-Kaas Lund (1947)
1948	/5	34*	4	Fardalen-Skiferdalen	Lønø (1960a)
1955	2/10	15		Adventdalen	F. Bonde and R. Myrland***
1956	22/7	1+13	2	Adventdalen	M. Stokke, O. Breivik and P. Malmedal***
1957	8/7	15		De Geerdalen	N. Jones and R. Gillmor***
1958	16/6	14	4	Adventdalen	T. Jakobsen***
1959	Summer	36**	2	Nordenskiöld Land	Lønø (1960a, 1960b)
1960	16/7	14		Adventdalen	H. Barth and P. Høser***
1961	16/7	12		Helvetiadalen	Portmann and D. Huseby***
1962	12/7	7		Camp Millar, Bellsund	Heintz (1963)

1962	15/8	13	3	Adventdalen	Heintz (1963)
1963	3/8	15	2	Kreklingpasset	Heintz (1965)
1963	3/8	1		Helvetiadalen	Heintz (1965)
1964	25/6	1+13		Adventdalen	Heintz and Norderhaug (1966a)
1965	/7	12	2	Moskushamn	Heintz and Norderhaug (1966b)
1966	10/7	2		Grumantdalen	Ehrenroth and Lohm (1967)
1966	24/7	16	4	Adventdalen	Ehrenroth and Lohm (1967)
1966	8/8	1		At Gipshuken	Ehrenroth and Lohm (1967)
1967	7/3	10–12		Adventdalen	S. Vik***
1968	28–30/7	13**	4	Reindalen	Norderhaug (1970)
1969	25/8	14	4	Adventdalen	Voisin (1970)
1970	15/7	9		Adventdalen	Norderhaug (1972)
1971	19/8	13	3	Adventdalen	Norderhaug (1973)
1972	6/4	17		Fuglefjella's NW-side	Larsen (1974)
1973	Aug.	22**	2	North part of Nordenskiöld Land	Author's observations
1974	Summer	29**	1	Nordenskiöld Land	Author's observations

* See text for comments.
** Several herds.
*** In the hut name book of the hut at Indre Hiorthhamn, Adventdalen.
****In the files of Norsk Polarinstitutt, Oslo.

Table 3

Recorded mortality of the muskoxen in Svalbard, 1929–1974.

Sex M	Sex F	Sex U	Date of death	Age	Found dead	Reason of death	Locality	References
		1	1933	Yearl.		Fall from cliff	Adventdalen	Lønø (1960a, b)
		19	1942–45			Shot	Nordenskiöld Land	Lønø (1960a, b)
		1	1943	Ad.		Killed by dogs(?)	Lundströmdalen	Lønø (1960a, b)
		1	1943	Ad.		Killed by dogs(?)	Semmeldalen	Lønø (1960a, b)
		1					Died in a zoo, Russia	Lønø (1960a, b)
		1		Calf			Found floating at sea	Lønø (1960a, b)
		1	/5–57?	Calf			Nordenskiöld Land	Lønø (1960a, b)
		1	17–19/5–59	Calf	19/5–59	Slid from a plateau and abandoned alive	Adventdalen	Lønø (1960a, b)
		1			14/7–59		Reindalen at Gramdalen	Lønø (1959b)
		1					(Stuffed, Barentsburg)	E. Wrånes (pers. comm.)
		1	1962		30/5–62		Indre Hiorthhamn, Adventdalen	T. Knutsen**
		1	1963	Yearl.	13/4–63	Starved to death(?)	Gangdalen	Heintz (1965)
		2	1963	Yearl.	/4–63	Starved to death(?)	Transport Gangdalen-Longyearbyen	Heintz (1965)
		1			2/8–63		Indre Hiorthhamn-Koslådalen, Adventdalen	J. F. Voisin**
	1		1963–64				Vårsolhytta-Camp Bell	Heintz and Norderhaug (1966a)
		1		Yearl.	30/5–65		Indre Hiorthhamn, Adventdalen	B. Isaksen**
		1	1966	Calf			Hiorthhamnfjellet	B. Henningsen (in. lit.)

	1*			Ad.	/8–67		At Løwø-hytta, Adventdalen	B. HENNINGSEN (in. lit.)
1			/5 or 6–68			Shot	Longyearbyen	B. HENNINGSEN (in. lit.)
		1	1969	Calf/yearl.			Bjørndalen	B. HENNINGSEN (in. lit.)
		2	1969	Calf/yearl.		Abandoned by their mothers	Bjørndalen and Adventdalen. Died in captivity in Longyearbyen	B. HENNINGSEN (in. lit.)
	1		Bef. 1970	Ad.	26/7–74		Reindalen south of Langnosa	Author's observation
	1		Ca. 1971	Ad.	10/8–74		Reindalen south of Langnosa	Author's observation
	1		Ca. 1971	Ad.	7/8–73		East of Fivelflyane, Adventdalen	Author's observation
		1	Ca. 1971	Yearl.	27/8–73		Ringdalen/Colesdalen	Author's observation
1*	1*	2	Ca. 1971			Fall from cliff?	Grumantdalen	B. HENNINGSEN (in. lit.)
		1	/5–71	Calf			Fuglefjella's NW-side	B. HENNINGSEN (in. lit.)
1			/2–72	Ad.		Overdosis of drug	Transport Longyearbyen-Sassendalen	B. HENNINGSEN (in. lit.)
		1	/4–72			Fall in riverbed	Longyearbyen	B. HENNINGSEN (in. lit.)
	1		Ca. 1972	Ad.	25/7–74		Reindalen east of Tverrdalselva	Author's observation
1			1973	2 yrs	2/9–73	Fall from cliff	Grumantdalen	Author's observation
1			1973	Ad.	16/8–73	Fall from cliff?	On the seashore, Bjørndalen	Author's observation
1			/7–73	Ad.	17/8–73		Grumantdalen	Author's observation
1			1974	Calf	16/7–74	Fall from cliff	Fuglefjella's NW-side	Author's observation
1*			/3–75	Ad.		Fall from cliff	Fuglefjella's NW-side	B. HENNINGSEN (in. lit.)

* Seen and sex determined by the author.

** In the diary of the hut in Indre Hiorthhamn, Adventdalen.

Results

DISTRIBUTION AND POPULATION SIZE

Years 1929–72

During the first years after introduction, the muskoxen mostly lived in small herds in the area north of Adventfjorden and in Adventdalen. In 1932 when the oldest cows were 4 years old, the first calves were born (Table 2). In the winter 1935/36 a herd of 30 muskoxen was reported seen, and it was assumed that the total population then consisted of about 40 animals (A. Hoel in the files of Norsk Polarinstitutt; Lønø 1960a, b). This figure is probably not correct. According to Tables 2 and 3 the population consisted of maximum 24 animals in the autumn of 1933, since 7 or 8 calves were born during the first two years of calving. Considering the low number of females among the introduced animals and the low calving frequency of muskox cows, it is not likely that a minimum of 16 calves were born in the following two years. One may also expect that more than one animal died during these years. The total number of muskoxen was perhaps at least 30 animals that winter, and it is doubtful that all these were gathered in one herd, although the observation was made in the winter when the herds are largest.

In the hut name book at Moskushamn (synonyms are Hiorthhamn and Ytre Hiorthhamn) no one reports to have seen many muskoxen in the period 1934–47. The maximum are 5 animals near the hut on 6 June 1937 (Lund 1947). During World War II the population probably became much reduced as it is reasonable to assume that more than 2 muskoxen were killed by dogs and more than 19 shot by the Norwegian garrison in Svalbard (Lønø 1960a, b). A muskox reported shot by a German officer is probably confused with a bull shot in Dovrefjell, Norway, in the summer of 1941.

Information about muskoxen in Svalbard collected in 1947 by Lund (1947) shows that few animals were seen after the war. In late July/early August that year, Lund looked for muskoxen from Adventdalen to Colesdalen via Endalen-Fardalen, but saw none. Also Lønø (1960a) writes that only a few animals were seen after the war, but goes on to say that 34 muskoxen were reported seen in Skiferdalen-Fardalen in May 1948. However, this figure is probably too high. If that many muskoxen were gathered in Skiferdalen-Fardalen, the total number of muskoxen in Svalbard must have been larger. In the summer of 1959 the total population was assumed to consist of about 50 animals after 36 muskoxen had been counted within an area comprising three-quarters of the distribution area (Lønø 1960a, b).

Table 2 gives a review of animals observed after the introduction and each year since 1955. Most of the observations are from Adventdalen, one of the most important areas for the muskoxen. The figures for 1955–71, although they do not represent absolute counts, show that the number of muskoxen in this area has been rather stable during these years.

Years 1973–74

Fig. 1 shows places on Nordenskiöld Land where I saw muskoxen or wool, tracks, and excrements left by them. The distribution area may be divided into four parts: the area north of Adventfjorden and Adventdalen with branch valleys (area A_1); Bjørndalen-Fuglefjella-Grumantdalen-Colesdalen-Fardalen-Bødalen-Ringdalen (area A_2); the area south of the watershed (area B); and the coastal area west of Fridtjovhamna-Grønfjorden (area C). Muskoxen may roam from one to the other of these four areas, but because of the topography they do so only occasionally. The most used passage must be between areas A_2 and B via Ringdalen-Tufsdalen and via Skiferdalen where it is relatively easy to wander and where there is even some vegetation on the passage between the valleys.

North of the watershed on Nordenskiöld Land I observed 22 muskoxen in August 1973 and 19 muskoxen in July 1974 (Table 1). While investigating this area from a plane on 15 July 1974, I saw 13 of the 19 muskoxen I had seen earlier in July. This was partly because strong winds and great flocks of seabirds made it impossible to fly near Fuglefjella or into Grumantdalen to make a thorough survey there. Of these, 5 and 8 muskoxen lived in Adventdalen the summers of 1973 and 1974, respectively. S. R. THORBJØRNSEN (pers. comm.) says that only 5 muskoxen lived in Adventdalen-Mälardalen-Hanaskogdalen in May 1974. This is fewer animals than have lived in area A_1 for several years. In area A_2 I saw 17 and 11 muskoxen in 1973 and 1974, respectively, of which 8 lived in Fuglefjella-Grumantdalen both summers. On the NW side of

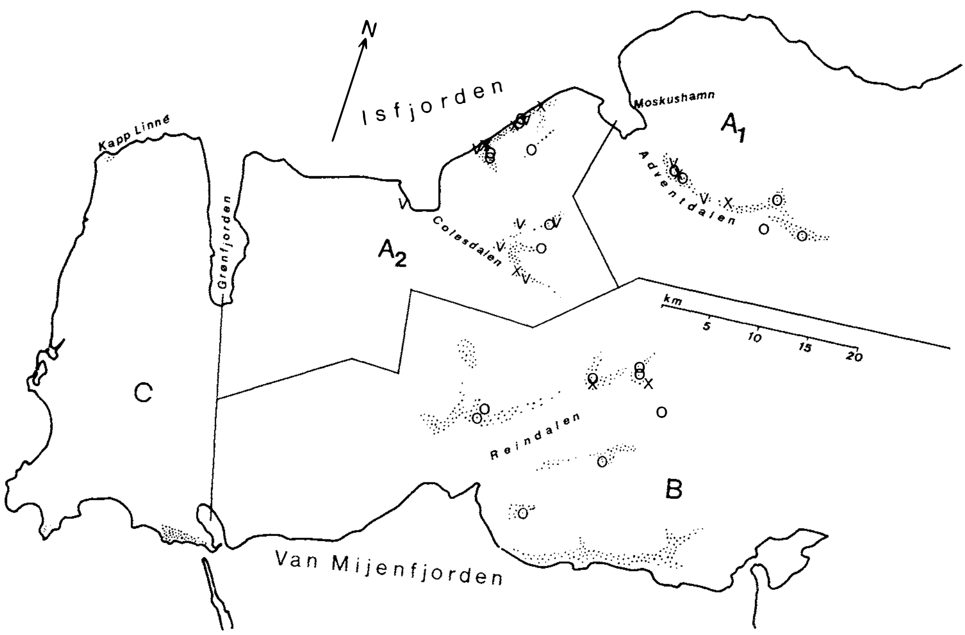

Fig. 1. V *and* O*: position of muskoxen observed on Nordenskiöld Land in the summers of 1973 and 1974, respectively.* X*: carcasses and skeletons.* Dotted areas*: wool, tracks, and excrements.*

Fuglefjella S. R. THORBJØRNSEN saw a herd of 11 muskoxen from the air on 28 April 1974.

South of the watershed (Area B) I observed 10 muskoxen in August 1974, while LØNØ (1959b) saw 16 in July 1959. In Area C, tracks, wool, and excrements showed that muskoxen had lived between Akselsundet and Camp Bell both earlier in 1974 and in previous years. Excrements from some thousands of seabirds in Ingeborgfjellet have caused a very luxuriant vegetation to grow here, especially grass. In July 1959, LØNØ (op. cit.) saw 3 muskoxen here. A bull that lived at Kapp Linné (Isfjord Radio) in July 1974 was not seen there in August. This bull was possibly not one of the 29 muskoxen I saw.

The areas investigated in the summer of 1974 comprise the whole distribution area of muskoxen in Svalbard. The muskoxen are easily discovered at great distances as their colour contrasts markedly with the vegetation in the relatively surveyable valleys. It is reasonable to conclude, therefore, that the total population of muskoxen in Svalbard in the summer of 1974 was of about 30 animals (maximum 35 animals).

HERD SIZE AND COMPOSITION

Sex and age composition in the muskox herds in the summers of 1973 and 1974 are shown in Fig. 2. The histogram comprises 68 animals because some animals are included more than once both summers as a result of exchange of animals between herds. These are: a solitary cow which joined a cow with a yearling; a cow which was together with a bull joined a herd of five, while the bull joined another bull; two cows together with a bull were later seen without the bull and some days later the cows had joined a herd of five. As shown in Fig. 2, the herds were small; the average herd size was 3.9 and 2.6 for the two summers.

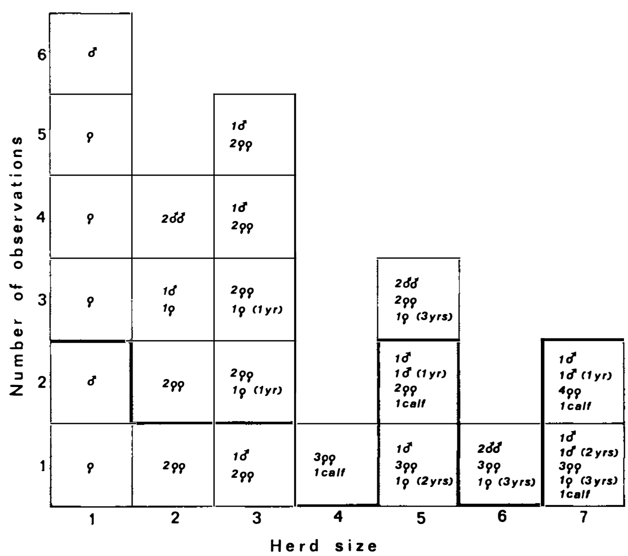

Fig. 2. *Herd size frequency of the muskox population on Nordenskiöld Land in August 1973 (below the broad line) and in July and August 1974.*

There was no bull in five of the ten herds consisting of 2–4 animals. Of solitary muskoxen I saw one bull and one cow in 1973, and one bull and three cows in 1974.

CALF PRODUCTION

Out of 22 and 29 muskoxen observed in the summers of 1973 and 1974 there were two and one calves, respectively (Table 1), giving calf percentages of 9.1 and 3.4. Minimum figures for fecundity for cows 3 years old and older, were 16.7 and 10.5 per cent, respectively, as I also found a dead male calf in July 1974. In this calculation I find it correct not to include 2 years old cows, since wild cows only exceptionally calve at this age, and then probably as a result of good supply of natural food (ALENDAL 1971, 1973). Very often wild muskoxen are more than 3 years old when producing their first calves.

It may be mentioned that TENER (1965) and FREEMAN (1971) have excluded solitary bulls or those in pairs when calculating calf percentages; FREEMAN, for instance, writes: " – these figures exclude solitary or paired animals, which are invariably males – " (see Fig. 2 of this paper).

MORTALITY

Table 3 shows that 57 muskoxen lost their lives during the 45 years gone since the introduction. The mortality figure is probably at least 120 if we assume that averagely at least 3 calves have been born every year since 1932.

Hunger, especially during their first year of life and in connection with high age, has probably caused the death of some muskoxen.

Many muskoxen have lost their lives falling from cliffs or down the steep slope on the NW side of Fuglefjella. Thousands of seabirds breed on the steep slopes of Grumantdalen and on the NW side of Fuglefjella, especially the Little Auk (*Plotus alle*), Brünnich's Guillemot (*Uria lomvia*), and Kittiwake (*Rissa tridactyla*). Excrements from the birds have made this area one of the most luxuriant on Nordenskiöld Land. Muskoxen have here their favourite haunts, grazing especially on *Alopecurus alpinus*. However, the stratum on the steep slope on Fuglefjella's NW-side is very unstable, and there are often small landslides in the summer. Muskoxen when grazing here, especially on the sprouting vegetation during the melting of ice and snow, may release a landslide or lose their foothold and rush down the steep slope ending in the sea or on a narrow seashore. On this shore I found some old bones from muskoxen, and farther up on the slope a dead calf that had fallen from a cliff, probably in June 1974.

In the summer of 1974 I saw neither the male yearling which I saw in Fardalen in 1973 nor the 2 years old bull which I saw in Fuglefjella that year. Neither did I see a cow I saw in Colesdalen, at Kapp Laila, and in Fardalen in 1973. Perhaps one or more of them had lost their lives on the steep slope of Fuglefjella in 1973 or 1974.

Although a few wanderings occur from one to the other of the main distribution areas on Nordenskiöld Land, it is of interest that young cows, subadults, yearlings, and calves lived in the area Fuglefjella-Grumantdalen and Fardalen in 1973 as well as in 1974, while the muskoxen that lived in Adventdalen and south of the watershed in 1974 were adults, most of them being old animals according to horn development and hair colour, especially on their heads.

Discussion

Table 2 gives a synopsis of (maximum) observed muskoxen on Svalbard over a period of some years since the introduction. Some animals denoted as calves might have been yearlings, while herds not specified might have contained calves. During the surveys in 1959, 1973, and 1974 the calves represented 5.6 (LØNØ 1960a, b), 9.1, and 3.4 per cent, respectively, of the observed animals. From the available information, little can be said about the reproduction, but on the average it has possibly been low; for instance one expected more than 2 calves of 36 observed muskoxen in 1959, when there was probably no interspecific competition for food.

The calf percentage in Svalbard has probably oscillated dependent on climate and availability of food, although not as much as several authors have shown for the muskoxen in East Greenland. During the years 1947–50 JOHNSEN (1953) observed 42 calves (16.7 per cent) out of 252 muskoxen in Peary Land, while after the unfavourable winter 1953/54 VIBE (1954) found no calf and only 5 yearlings out of 350 muskoxen between Andrée Land and Carlsbergfjorden. More exceptional is a calf percentage of about 20 which has occurred several times on Nunivak Island (SPENCER and LENSINK 1970) and in Dovrefjell, South Norway (ALENDAL 1973).

Table 1 shows a sex ratio distorted in favour of females in Svalbard: 7♂♂ and 21♀♀ when not including the calf born in 1974. This may be due to a higher mortality of males because solitary bulls wander more about on the steep mountain slopes, but also solitary bulls might have escaped the author's discovery. The ancestors of the muskoxen on Nunivak Island, Alaska, were also introduced from East Greenland. There the male: female ratio was 56:44 out of 673 animals early in April 1968 (SPENCER and LENSINK 1970). In Northeast Greenland about two-thirds were bulls in the summer of 1954 (VIBE 1954).

A total of 4 solitary cows were seen in Svalbard in the two summers. In East Greenland solitary animals are always bulls (PEDERSEN 1936, JOHNSEN 1953), and this is the rule for muskoxen in Arctic Canada (TENER 1965) too. In Dovrefjell I have exceptionally seen solitary cows.

Table 3 shows that on the average 2.3 muskoxen have lost their lives during the last 10 years, but the correct figure is no doubt higher, as JENS ANGARD (pers. comm.) has observed dead animals not included in the table. I was also told in Longyearbyen that 3 muskoxen had fallen down the steep slope on the NW side of Fuglefjella in the first part of 1973 and a bull in the winter of 1973/74, but we saw none on the seashore the two summers (these are not included in Table 3). A carcass of a bull found buried in the pebbles on the seashore in Bjørndalen had probably been carried by the sea to this place from Fuglefjella in the spring of 1973.

Although the distribution area is on 78°N, temperatures above 0°C may occur every month of the winter. Subsequent frost with icing and hard snow makes it still more difficult for the muskoxen to find food. In Svalbard 3 yearlings probably died from starvation in mid-April 1963 (HEINTZ 1965). In East Greenland frost after periods of mild weather in the winter has caused the death of large numbers of muskoxen (VIBE 1954, 1958, 1967). Moreover, the hair of newly born calves is short. If this pelage becomes soaked during mild and rainy weather, subsequent wind chill or frost may cause their death, as has been shown to happen to calves of barren-ground caribou (HART et al. 1961).

My observations in Dovrefjell, Norway, 1967–73, and in Svalbard in the summers of 1973 and 1974 showed that muskoxen require more special plant communities and grazing plants than the reindeer do. In the summer the muskoxen prefer bright green plant communities consisting mainly of special species of sprouting and growing grasses with elements of sedges and herbs, often found along rivers and brooks or along dried up brooklets or on hillsides which have been irrigated by water from melting snow.

Grasses well grazed by muskoxen in Svalbard are *Alopecurus alpinus* and *Poa alpigena*, but they also graze on other species of *Poa*, on *Festuca*, and on sedges and herbs as *Oxyria digyna*. The arctic willow, *Salix arctica*, which is considered an important and preferred browsing plant for muskoxen in East Greenland (PEDERSEN 1936, JOHNSEN 1953), does not exist in Svalbard. Lichens are so scarce on Nordenskiöld Land that they are almost negligible as food for the reindeer.

In Dovrefjell there is no competition for food between reindeer and muskoxen in the summer and almost none in the winter, whereas in Svalbard the reindeer forage in the favourite plant communities of muskoxen in the summer. One exception in Svalbard is Grumantdalen and Fuglefjella's NW-side where we observed only 4 and 2 reindeer, respectively, in the summer of 1973. Furthermore, my investigations seem to indicate that the reindeer bite off the forage nearer to the ground than the muskoxen do.

Before the intense reindeer hunting started at the end of the 19th century, many thousand reindeer probably lived in the area between Isfjorden, Van Mijenfjorden, and Agardhbukta at Storfjorden (WOLLEBÆK 1926, LØNØ 1959a), but in the summer of 1925 only 16 reindeer were seen (HOEL 1926). Therefore the forage was possibly relatively abundant in 1929 when the muskoxen were released, resulting in a relatively rapid increase in the muskox population. Yet, the population presumably consisted of not more than about 50 animals in 1941. After the reindeer became protected in 1925, they increased to about 400–500 animals on Nordenskiöld Land and Sabine Land in 1940 (LØNØ 1959a). Abandoned dogs and illegal hunting during World War II resulted again in a low number of reindeer, but also reduced the number of muskoxen.

In the summer of 1959 the muskox population had increased to about 50 animals (LØNØ 1960a, b). This summer LØNØ (1959b) recorded only 90 reindeer south of the watershed from Kjellströmdalen to Bellsund. In the summers of 1973 and 1974 we observed a total of 5577 reindeer between Isfjorden and Van Mijenfjorden (ALENDAL and BYRKJEDAL 1976). This indicates a very rapid growth of the reindeer population since 1959. The muskox population, however, has decreased slightly during the same period.

The muskox in Svalbard is probably the losing part in the competition with the reindeer for food, particularly in the winter, although I have no data to support this theory. The winter lasts for about eight months in Svalbard. Because of competition and climatic factors, Nordenskiöld Land is probably a suboptimal or even marginal area for a viable muskox population.

For comparison it is of interest that in 1920 and 1928 a total of 604 reindeer (595 were females) and in 1925 10 woodland caribou bulls were brought to Nunivak Island in the Bering Sea. In the summer of 1938 they had increased to about 12000 animals, but to protect muskoxen on the island, PALMER (1938: 11–12) recommended no more than 10000 reindeer. In 1944 the reindeer population was estimated to number 30000 (PALMER and ROUSE 1945).

During 1935 and 1936 a herd of 31 muskoxen (13 were females) were established on the island. The population numbered 49 in 1947 (SPENCER and LENSINK 1970). This slow increase might be ascribed to animals lost in the sea ice or may be a result of low reproduction because of competition from the high number of reindeer, in the same way as the stable population or slight decline in the number of muskoxen in Svalbard today is possibly caused by the large reindeer population.

Overpopulation and severe winters, caused the reindeer population on Nunivak Island to decline rapidly during the late forties, and by 1951 did not exceed 5000 animals (SPENCER and LENSINK op. cit.), which must have been propitious for the muskoxen on the island. SPENCER and LENSINK state that at present (1968) there is little competition for food between muskoxen and reindeer, numbering about 750 and 10000 animals, respectively, because, in the critical winter period, the muskoxen are almost exclusively coastal in distribution whereas the reindeer forage primarily in interior areas. However, their conclusion is that an unchecked growth of either species would no doubt increase the likelihood for competition. After having examined winter feeding areas of muskoxen on this island, LENT and KNUTSON (1971) write: "Reindeer will forage through snowcover having twice the depth and three times the integrated ram hardness value of any snowcover encountered at muskox feeding sites."

The participants of the German Arctic expedition of 1869–70 saw both reindeer and muskoxen in East Greenland (KOLDEWEY 1873 and 1874). The dying out of the reindeer in East Greenland around 1900, mainly because of unfavourable climate (VIBE 1967), must have been favourable for the muskoxen. The high number of muskoxen and high hunting pressure on this mammal during the nineteen-twenties and thirties could hardly have occurred if there had been competition from reindeer.

Human activities on Nordenskiöld Land will most likely increase in the future. Disturbance by people may result in extra hunger and even death of muskoxen. If animals become frightened by airplanes, helicopters, or snow-scooters, especially if they are frightened into running, their basal metabolism will increase manifold (see KLEIBER 1961), meaning lost energy, which might be disastrous to an emaciated animal in a period of scarcely any food.

When muskoxen are approached by people they cease grazing which again means lost energy. Disturbance by humans on the day of birth or the following day may result in abandonment of the calf (LENT 1970, ALENDAL 1974).

Since another introduction of muskoxen to Svalbard hardly will come into question, their future in Svalbard is dependent on the recruitment of the already established population. Few calves being born as a result of poor conditions for the cows, severe winters with competition for food or loss of animals in steep mountains where even herds may be lost, may at its worst decimate the muskox population so much that it will hardly survive.

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References

ALENDAL, E., 1971: Tidlig og god formering hos moskusfe på Dovrefjell. *Fauna* **24**. 96–100.

— 1973: *Moskusfeet på Dovrefjell; populasjonsdynamikk, sosiale forhold og næringsøkologi.* Unpubl. Thesis. Univ. Bergen. 212 pp.

— 1974: Myskoxens historia i Sverige. *Fauna och flora* **69**. 41–46.

ALENDAL, E. and I. BYRKJEDAL, 1976: Population size and reproduction of the reindeer (*Rangifer tarandus platyrhynchus*) on Nordenskiöld Land, Svalbard. *Norsk Polarinstitutt Årbok* 1974.

ANONYMOUS 1935: Svalbard. *Naturfredning i Norge. Årsberetning* 1934. 6–7.

EHRENROTH, B. and U. LOHM, 1967: Faunistiska och floristiska iakttagelser vid mellersta Västspetsbergen sommaren 1966. *Fauna och flora* **62**. 263–278.

FREEMAN, M. M. R., 1971: Population characteristics of musk-oxen in the Jones Sound region of the Northwest Territories. *J. Wildl. Mgmt.* **35**. 103–108.

HART, J. A., O. HEROUX, W. H. COTTLE, and C. A. MILLS, 1961: The influence of climate on metabolic and thermal responses of infant caribou. *Can. J. Zool.* **39**. 845–856.

HEINTZ, N., 1963: Iakttagelser over dyrelivet på Svalbard sommeren 1962. *Norsk Polarinstitutt Årbok* 1962. 80–92.

— 1965: Iakttagelser over dyrelivet på Svalbard i 1963. *Norsk Polarinstitutt Årbok* 1963. 157–168.

HEINTZ, N. and M. NORDERHAUG, 1966a: Iakttagelser over dyrelivet på Svalbard i 1964. *Norsk Polarinst. Årbok* 1964. 119–129.

— 1966b: Iakttagelser over dyrelivet på Svalbard. *Norsk Polarinstitutt Årbok* 1965. 103–118.

HOEL, A., 1926: Forslag til Kongelige forskrifter vedrørende fredning, jakt, fangst og fiske på Svalbard i henhold til Lov om Svalbard av 17. juli 1925. *Naturfredning i Norge. Årsberetning* 1926. 8–24.

— 1929: Moskusokser til Svalbard. *Norsk Jæger og Fisker-for. Tidsskr.* **59**. 326–328.

— 1930: Overføring av moskusokser til Svalbard. *Norge. Tidsskrift om vårt land.* **6**(1). 15–18.

JOHNSEN, P., 1953: Birds and mammals of Peary Land in North Greenland, including notes from Northeast Greenland. *Medd. Grønl.* **128**(6). 1–140.

KLEIBER, M., 1967: *Der Energiehaushalt von Mensch und Haustier. "The fire of life"*. Hamburg und Berlin (Paul Parey). 358 pp.

KOLDEWEY, K., 1873 and 1874: *Die zweite deutsche Nordpolarfahrt in den Jahren 1869 und 1870 – –* Leipzig (Brockhaus). 1873, I:lxix+700 pp. 1874, II:ix+963 pp.

LARSEN, T., 1974: Iakttagelser over dyrelivet på Svalbard i 1972. *Norsk Polarinstitutt Årbok* 1972. 147–151.

LENT, P. C., 1970: Muskox maternal behavior: a preliminary description. *Am. Zool.* **10**. p. 481.

LENT, P. C. and D. KNUTSON, 1971: Muskox and snow cover on Nunivak Island, Alaska. 50–62. IN: HAUGEN, A. O. (ed.) *Snow and ice in relation to wildlife and recreation. Symposium.* Iowa St. Univ.

LUND, H. MUNTHE-KAAS, 1947: *Opplysninger om moskusfeet på Spitsbergen samlet sommeren 1947.* Typewritten report. Files of Norsk Polarinstitutt. 3 pp.

LØNØ, O., 1959a: Reinen på Svalbard. *Norsk Polarinstitutt Medd.* Nr. 83. 31 pp. (Særtrykk av *Fauna* **12** (2) 1959).

— 1959b: *Telling av moskusdyr og rein på Svalbard 1959.* Typewritten report. Files of Norsk Polarinstitutt. 4 pp.

— 1960a: Moskusoksene, en ny dyreart for Svalbard. *Polarboken* 1959–60. 123–130.

— 1960b: Transplantation of the muskox in Europe and North-America. *Norsk Polarinstitutt Medd.* No. 84. 1–25.

NORDERHAUG, M., 1970: Iakttagelser over dyrelivet på Svalbard 1968. *Norsk Polarinstitutt Årbok* 1968. 101–106.

— 1972: Iakttagelser over dyrelivet på Svalbard 1970. *Norsk Polarinstitutt Årbok* 1970. 264–270.

— 1973: Iakttagelser over dyrelivet på Svalbard 1971. *Norsk Polarinstitutt Årbok* 1971. 87–92.

ORVIN, A., 1930: Ekspedisjonen til Østgrønland med "Veslekari" sommeren 1929. *Norges Svalbard- og Ishavs-unders. Medd.* nr. 11. 89–146. (Særtrykk av *Norsk Geogr. Tidsskr.* **3** 1930).

PALMER, L. J., 1938: *Management of muskoxen and reindeer on Nunivak Island, Alaska.* Unpubl. Rept. Bur. Sport Fisheries and Wildl., Juneau. 25 pp.

PALMER, L. J. and C. H. ROUSE, 1945: Study of Alaska tundra with reference to its reactions to reindeer and other grazing. *U.S. Fish and Wildl. Serv. Research Rept.* No. 10. 48 pp.

PEDERSEN, A., 1936: Der Grönländische Moschusochse, *Ovibos moschatus wardi* Lydekker. *Medd. Grønl.* **93**(7). 1–82.

SPENCER, D. L. and C. J. LENSINK, 1970: The muskox of Nunivak Island, Alaska. *J. Wildl. Mgmt.* **34**. 1–15.

TENER, J. S., 1965: Muskoxen in Canada. *Can. Wildl. Serv. Monograph* 2. Ottawa (Queen's Printer). 166 pp.

VIBE, C., 1954: Problemerne omkring Grønlands moskusokser. *Grønland* No. 2. 401–414.

— 1958: The musk ox in East Greenland. *Mammalia* **22**. 168–174.

— 1967: Arctic animals in relation to climatic fluctuations. *Medd. Grønl.* **170**(5). 1–227.

VOISIN, J-F., 1970: Some notes about birds and mammals in Svalbard, summer 1969. *Norsk Polarinstitutt Årbok* 1969. 107–115.

WOLLEBÆK, A., 1926: The Spitsbergen reindeer (*Rangifer tarandus spetsbergensis*). *Resultater av de norske statsunderstøttede Spitsbergenekspedisjoner.* **1**(4). 1–71.

Tagesperiodik von Kieselalgen und Grünalgen in einem Gewässer Spitsbergens

VON AGNES MÜLLER-HAECKEL[1] und JOHN O. SOLEM[2]

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Summary

Investigations on the drift rate of uni-cellular algae in Storvatnbekken, Ny-Ålesund, Spitsbergen (79°N, 12°E) were carried out in July 1974. *Achnanthes minutissima* (Diatomeae) was fully synchronized, while *Synedra minuscula* and *Diatoma vulgare* (Diatomeae) were weakly synchronized to the 24-hr period. The green algae *Monoraphidium dybowskii* showed aperiodicity at the latitude 79°N while this species at the Polar Circle areas (66—67°N) has been found to have greatest drift densities at nighttime. However, on cloudy days and nights at the Polar Circle — in time periods with relatively small amplitudes in light intensities — *M. dybowskii* also performed aperiodicity while the Diatomeae-species were still synchronized.

On the dates at which investigations were carried out at 79°N, in July 1974, the sky was cloudy at daytime, but bright at nighttime, and therefore small diel amplitudes in light intensities occurred. The light intensities at midnight at Spitsbergen is about ten times higher than those at the Polar Circle. This may be the reason for the weak synchronization of some of the Diatomeae at 79°N.

When *A. minutissima* in spite of that, was clearly synchronized, this is probably due to the fact that this species has a highly variable sensitivity to light. Among the Diatomeae in the drift at 79°N, *A. minutissima* predominated, which may indicate that this species is the one that best can utilize the Polar light. The partly clear and partly weak synchronization of the Diatomeae and the arhythmicity of the green algae demonstrated specific activity patterns for the species. Species differences in sensitivity to Zeitgeber(s) may be of importance to adaption to different geographical areas.

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Zusammenfassung

Die Drift einzelliger Fliesswasseralgen im Storvatnbekken auf Spitsbergen (79°N) im Juli 1974 war im tagesperiodischen Verhalten uneinheitlich. Während die in ihrer Drift tagaktiven Diatomeen teilweise klar synchronisiert (*Achnanthes minutissima*), teilweise schwach synchronisiert (*Synedra minuscula*, *Diatoma vulgare*) waren, erwies sich die nachtaktive Grünalge *Monoraphidium dybowskii* in ihrer Drift arhythmisch. In Polarkreisnähe hat sich gezeigt, dass Bewölkung mit herabgesetzter täglicher Lichtamplitude im Gefolge bei *Monoraphidium dybowskii* Arhythmik, bei Diatomeen klare Synchronisation hervorruft. Das wolkenreiche Wetter in Spitsbergen an den Untersuchungstagen im Juli 1974 erklärt das Verhalten von *Monoraphidium* und *Achnanthes*. Schwache Synchronisation bei Diatomeen zeigte sich in Polarkreisnähe bei klarem Wetter mit hohen mitternächtlichen Lichtintensitäten. Diese liegen in Spitsbergen mehr als eine Zehnerpotenz höher als am Polarkreis. Das mag der Grund für schwache Synchronisation einiger Diatomeen sein. Dass *Achnanthes minutissima* trotzdem klar synchronisiert ist, mag auf der relativ hohen Variabilität der Empfindlichkeit dieser Art gegenüber Licht beruhen. Dies macht zugleich verständlich, dass die Art in der Lage ist, das Dauerlicht des Polarsommers am besten auszunutzen.

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Ergebnisse

Eine der zentralen Fragen tagesperiodischen Verhaltens von Organismen ist: Wie reagiert eine Pflanze, ein Tier oder der Mensch, wenn der durch den Umlauf der Erde um die Sonne bedingte Wechsel von Tag und Nacht ausfällt? In der arktischen und subarktischen Region trifft dies um Mittsommer ein. Erste grundlegende Untersuchungen führten LEWIS & LOBBAN (1957) an Menschen auf Spitsbergen (79°N) und SWADE & PITTENDRIGH (1967) an Kleinsäugern in Point Barrow in Alaska (71°N) durch, REMMERT (1965), KURECK (1966) und SYRJEMÄKI (1969) untersuchten tagesperiodische Äusserungen an Insekten auf Spitsbergen. Aus südlicheren Bereichen der subarktischen Region liegen zahlreiche Untersuchungen an verschiedenen Organismengruppen vor (PEIPONEN 1962; MÜLLER 1968, 1973; ERKINARO 1969; MÜLLER-HAECKEL 1973). Die Resultate über das Verhalten von Organismen zur Mittsommerzeit in der Arktis und Subarktis sind unterschiedlich: Der an den Licht-Dunkelwechsel in der 24-Stundenperiode gebundene Aktivitäts-Ruhewechsel kann im «Dauerlicht» des Polarsommers erhalten bleiben (REMMERT, KURECK, SYRJEMÄKI, MÜLLER), er kann auch verloren gehen (LEWIS & LOBBAN, SWADE & PITTENDRIGH, PEIPONEN, MÜLLER, ERKINARO, SYRJEMÄKI, MÜLLER-HAECKEL). Im letzteren Falle wechseln die Organismen Aktivität und Ruhe arhythmisch oder mit ihrer endogenen, circadianen Periode (MÜLLER 1968; ERKINARO 1969).

Es hat sich gezeigt, dass die tagesperiodische Drift benthischer, einzelliger Fliesswasseralgen in der Nähe des Polarkreises (66°42'N) nicht in jedem

Sommer desynchronisiert oder arhythmisch verläuft, sondern nur unter bestimmten, wetterabhängigen lichtklimatischen Bedingungen (MÜLLER-HAECKEL 1973). Wir waren deshalb daran interessiert, das Mittsommerverhalten von Algen auf höheren nördlichen Breiten studieren zu können.

Während des Monats Juli 1974 wurden im Storvatnbekken nahe Ny-Ålesund auf Spitsbergen (79°N, 12°E) drei Serien von Wasserproben in Zweistunden-Intervallen über je 24-Stunden eingeholt. Die Proben wurden an einem Platz des Baches entnommen, wo das Wasser relativ rasch, in etwa 10 cm tiefer Schicht über das Bachbett von 1 bis 1,5 m Breite floss. Die Wasserproben wurden unmittelbar nach der Entnahme mit konzentrierter Jod-Jodkaliumlösung fixiert. Art und Anzahl der Driftalgen wurden unter dem Planktonmikroskop bestimmt.

Die nachfolgende Algenliste gibt einen Überblick über die in der Drift gefundenen Arten. Sie ist vermutlich nicht vollständig, enthält aber die im Storvatnbekken im Juli häufig vorkommenden Arten. Die meisten gehören zur Gruppe der echten Benthonten, die am Substrat festgeheftet leben, aber in tagesperiodischer Ordnung einen Teil der Zellen in die Drift entlassen (BLUM 1954; MÜLLER-HAECKEL 1966, 1967, 1975). Die Hauptarten sind in nordskandinavischen Waldbächen verbreitet (SKUJA 1964; QUENNERSTEDT 1965). Dominierend trat in der Drift des Storvatnbekken *Achnanthes minutissima* auf. Mit Abstand folgen *Synedra minuscula*, *Diatoma vulgare*, *Ceratoneis arcus* und *Synedra tenera*. Unter den Grünalgen ist nur *Monoraphidium dybowskii* regelmässig in den Driftproben vertreten. Während *Achnanthes minutissima* eine klare tagesperiodische Verteilung der Drift mit Maxima am Tage erkennen lässt (Abb. 1), ist das Bild bei den anderen Arten weniger einheitlich und deutlich (Abb. 2). Man kann nicht sagen, dass die Drift dieser Arten desynchronisiert sei, aber doch dass sie schwach synchronisiert ist, besonders bei *Diatoma vulgare*. Die in der Drift nachtaktive Grünalge *Monoraphidium dybowskii* (MÜLLER-HAECKEL 1969, 1973) zeigt sich im Storvatnbekken im Juli 1974 arhytmisch (Abb. 3). Nach den Wetterverhältnissen an den Untersuchungstagen, mit bedecktem Himmel und dadurch bedingten stark herabgesetzten, täglichen Lichtamplituden war das Ergebnis zu erwarten. Wir haben früher gefunden, dass *Monoraphidium* am Polarkreis um Mittsommer bei wolkenreichem Wetter einen arhythmischen Driftverlauf hat (Reduktion der Lichtamplitude). Die in ihrer Drift tagaktiven Kieselalgen (Diatomeae) dagegen erwiesen sich am Polarkreis bei klarem Wetter (hohe mitternächtliche Lichtintensität) schwach synchronisiert. Wenn schwache Synchronisation bei einigen Diatomeenarten auf Spitsbergen auch bei wolkigem Wetter auftritt, so vermutlich deshalb, weil dort die mitternächtlichen Lichtintensitäten wesentlich höher liegen als am Polarkreis (6000—10 000 lux). Auch dürfte die längere Einwirkungsdauer eines schwachen «Zeitgebers» in Spitsbergen eine Rolle spielen. Das geringe Material lässt keine weitgehenderen Schlüsse zu, doch passen sich die Ergebnisse gut in die Erkenntnisse, die am Polarkreis gewonnen wurden, ein.

Der hohe Anteil von *Achnanthes minutissima* an der Drift in Spitsbergen (Abb. 1), fällt auf, wenn man ihn mit dem Anteil vergleicht, den die Art auf süd-

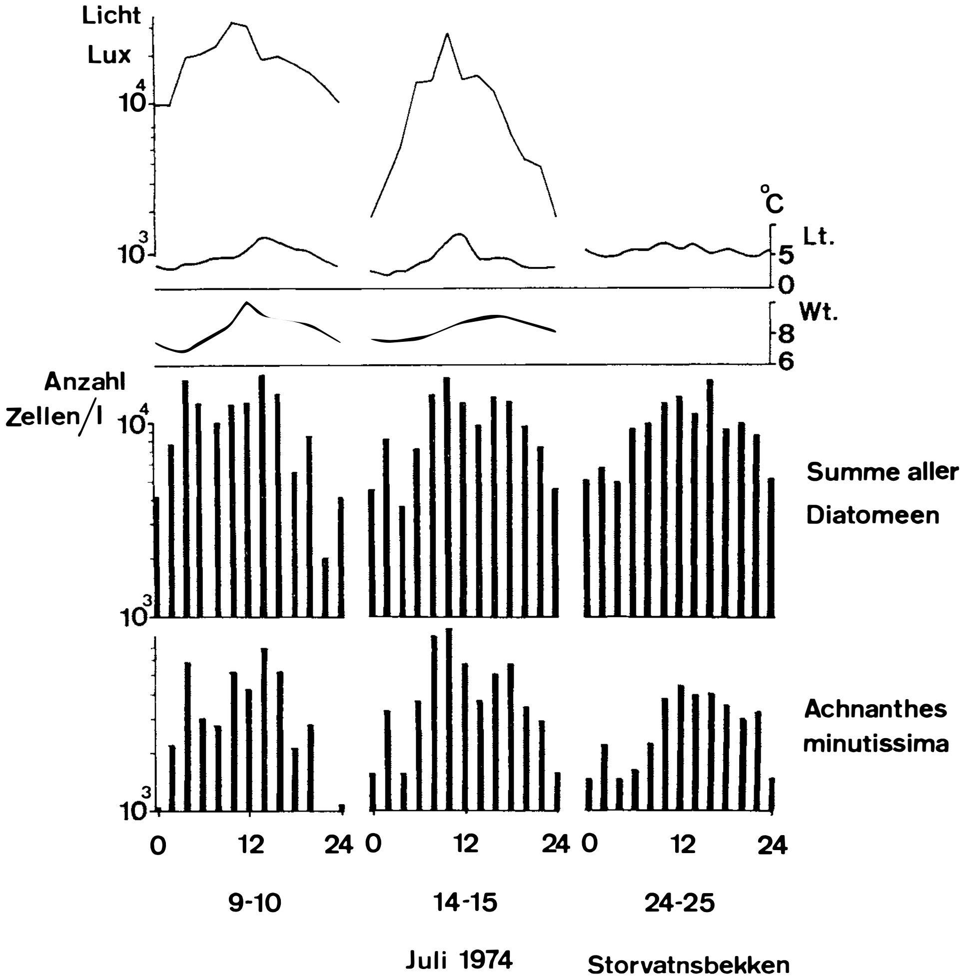

Abb. 1. *Tagesverlauf der Drift aller Diatomeen und Achnanthes minutissima im Storvatnbekken bei Ny-Ålesund auf Spitsbergen. Drei Tagesperioden im Juli 1974. Von oben nach unten: Verlauf der Lichtintensität, Luft- und Wassertemperatur (soweit gemessen).*
Ordinate: Zellen pro Liter, Licht in lux, Temperatur in °C. Abszisse: Zeit in Stunden.

licheren Breitengraden an der Drift hat (Abb. 4 und Tab. 1). *Achnanthes minutissima* ist weit verbreitet und wird als tolerant gegenüber pH-Werten, Licht und Strömungsgeschwindigkeiten beschrieben (SCHEELE 1952; KLASVIK 1974), wobei sie eher strömungsliebend zu sein scheint, da sie in den oberen, schnell fliessenden Abschnitten von Gebirgsbächen häufig ist (SCHEELE op. cit., BACKHAUS 1969). In ihrem jahresperiodischen Verhalten wird die Art oft als Sommerform charakterisiert (BUTCHER 1940, SCHEELE op.cit., MÜLLER-HAECKEL 1970, JURIS 1973). Eine Diatomeenart, die ihre Hauptwachstumszeit im Sommer hat, ist sicher besser an die extrem kurze Vegetationsperiode hoher nördlicher Breiten angepasst als Arten mit ausgesprochenem Früjahrsmaximum: *Ceratoneis arcus* oder Arten mit Herbst- und Früjahrsmaxima: *Synedra*-arten. Die der Art *Achnanthes minutissima* nachgesagte Toleranz gegenüber Licht, d.h. ihre hohe Variabilität in der Empfindlichkeit, bewirkt möglicherweise, dass die

Lichtvariationen des arktischen Sommertages auf Spitsbergen zur Synchronisation ausreichen, und dass die Art andererseits die grossen Lichtmengen (Lichtintensität und Lichtdauer) des arktischen Sommers ausnutzen kann. Wenn *Achnanthes* auf südlicheren Breitengraden gegenüber anderen Arten zurücktritt, so vermutlich u.a. deshalb, weil Grünalgen in diesen Gewässern im Sommer dominieren (BACKLUND 1973). Ihnen gegenüber reicht dieKonkurrenzkraft von *Achnanthes minutissima* nicht aus. Die Frühjahrsform *Ceratoneis arcus*, die in südlicheren Bereichen im Mai/Juni ihr Haupt-Jahresmaximum hat (MÜLLER-HAECKEL 1967) kann sich auf Spitsbergen erst Anfang Juli und relativ schwach entwickeln (Tab. 1). In der zweiten und dritten Probenserie tritt die Art nur noch sporadisch auf. Ähnliches gilt für *Synedra tenera*. Auch *Diatoma vulgare* zeigt auf Spitsbergen einen starken Abfall in der Drift von der ersten zur dritten Probenserie (Abb. 2).

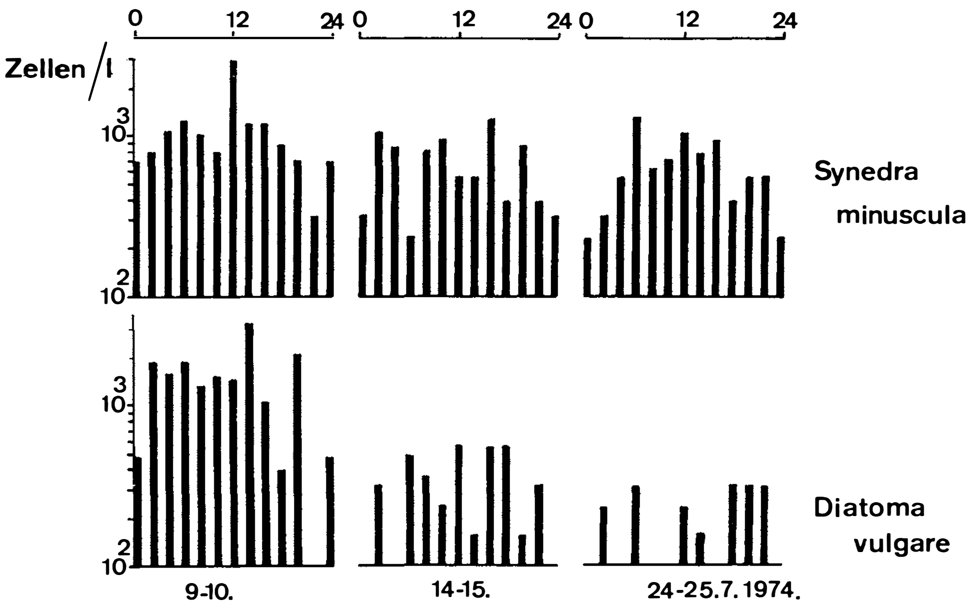

Abb. 2. *Tagesverlauf der Drift von Synedra minuscula und Diatoma vulgare im Storvatnbekken bei Ny-Ålesund auf Spitsbergen an drei Tagesperioden im Juli 1974. Ordinate: Zellen/l, Abszisse: Zeit in Stunden.*

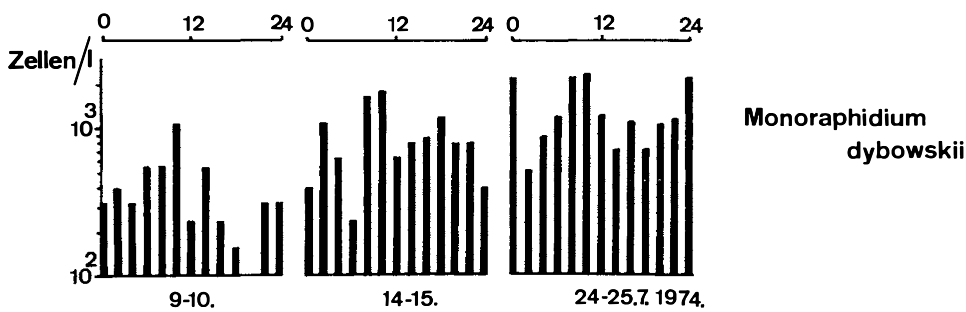

Abb. 3. *Tagesverlauf der Drift von Monoraphidum dybowskii im Storvatnbekken bei Ny-Ålesund auf Spitsbergen an drei Tagesperioden im Juli 1974. Ordinate Zellen/l, Abszisse: Zeit in Stunden.*

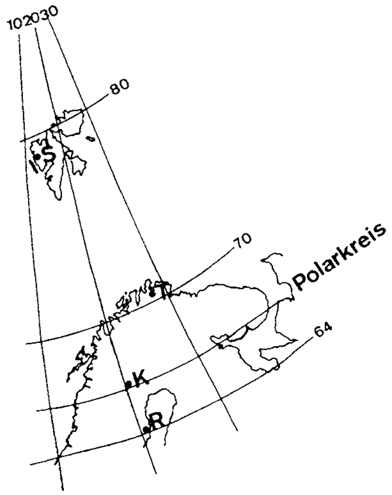

Abb. 4. *Kartenskizze über einen Teil der Nordkalotte mit den vier zum Vergleich herangezogenen Untersuchungesplätzen in vier Bächen auf verschiedenen Breitengraden.* (Siehe Tabelle 1).

Tabelle 1

Prozentanteil einzelner Arten an der Gesamt-Diatomeendrift. (*Mittelwerte aus Zweistunden-Intervall-Serien von ein bis drei 24-Stundenperioden im Juli 1974*)

Gewässer	Breitengrad	Achnanthes minutissima	Synedra minuscula	Ceratoneis arcus	Synedra tenera	Diatoma vulgare
Storvatnbekken .	79°N	33	8	3*	2*	6**
Tsharasjokk	69°N	50	5	1	—	—
Kaltisjokk	66°N	20	33	6***	—	—
Rickleån........	64°N	10	20	2***	33	14

* nur in der ersten Probenserie (9./10.7.1974) regelmässig vorhanden.
** 9./10.7.74: 12%; 14.15.7.74: 3%; 24./25.7.74: 2 %.
*** Juniwerte: Kaltisjokk 20%; Rickleån 15%.

Algenarten in der Drift des Storvatnbekkens bei Ny-Ålesund (*Spitsbergen*)

Diatomeae: *Achnanthes minutissima* Kütz., *Synedra minuscula* Grun., *Synedra tenera* W. Schmith, *Diatoma vulgare* Bory, *Ceratoneis arcus* Kütz., *Tabellaria flocculosa* Kütz., *Gomphonema* sp., *Navicula viridula* Kütz., *Navicula* sp. *Caloneis* sp., *Didymosphaenia geminata.* M. Schmidt (leere Schalen).

Chlorophytae: *Monoraphidium dybowskii* (Wolosc.), *Ankistrodesmus falcatus* Ralfs *Pediastrum boryanum* Menegh., *Dictyosphaerium pulchellum* Wood, *Closterium* sp. *Cosmarium* sp.

Literatur

BACKHAUS, D., 1969: Ökologische Untersuchungen an den Aufwuchsalgen der obersten Donau und ihrer Quellflüsse. *Arch. Hydrobiol. Suppl.* **36.** 1–26.

BACKLUND, S., 1973: Något om mikroalgers drift. *Zool. Revy* **35.** 115–118.

BLUM, J., 1954: Evidence for a diurnal pulse in stream phytoplancton. *Science* **119.** 732–734.

— 1956: The ecology of river algae. *Bot. Rev.* **22.** 291–341.

BUTCHER, R. W., 1940: Studies in the ecology of rivers. IV. *J. Ecol.* **28.** 210–233.

ERKINARO, E., 1969: Der Verlauf desynchronisierter circadianer Periodik einer Waldmaus (Apodemus flavicollis) in Nordfinnland. *Z. vergl. Physiol.* **64.** 407–410.

JURIS, S., 1973: Quantitative Studien der Algenkomponente des Periphytons des Tschechoslowakischen Teiles der Donau. *Acta Rev. Nat. Mus. Nat. Slov. Bratislava* **19.** 1–56.

LEWIS, P. R. & M. C. LOBBAN, 1957: Dissociation of diurnal rhythms in human subjects living on abnormal time routines. *Quart. J. Exptl. Physiol.* **42.** 371–386.

KLASVIK, B., 1974: Computerized analysis of stream algae. *Växtekologiska Studier (Uppsala)* **5.** 1–100.

KURECK, A., 1966: Schlüpfrhythmus von *Diamesa arctica* (Diptera: Chironomidae) auf Spitzbergen. *Oikos* **17.** 276–277.

MÜLLER, K., 1968: Freilaufende circadiane Periodik von Ellritzen am Polarkreis. *Naturwissenschaften* **55.** 140.

— 1973: Circadian rhythms of locomotor activity in aquatic organisms in the subarctic summers. *Aquiolo, Zer. Sool.* **14.** 1–18.

MÜLLER-HAECKEL, A., 1966: Diantomeendrift in Fliessgewässern. *Hydrobiologia* **28.** 73–87.

— 1967: Tages-und Jahresperiodizität von *Ceratoneis arcus* Kütz (Diatomeae). *Oikos* **18.** 351–356.

— 1969: Tagesperiodik von Algen in subarktischen Gewässern. *Umschau* **69.** 521.

— 1970: Tages- und Jahresperiodik einzelliger Algen in fliessenden Gewässern. *Österreichs Fischerei* **23.** 97–101.

— 1971: Bewegungsverhalten einzelliger Fliesswasseralgen. *Natur und Museum.* **101.** 167–172.

— 1973: Different patterns of synchronization in diurnal and nocturnal drifting algae in the subarctic summer. *Aquilo, Ser. Zool.* **14.** 19–22.

PEIPONEN, V. A., 1962: Zur Aktivität der Graurötelmaus, Clethrionomys rufocanus im Dauerlicht des arktischen Sommers. *Arch. Soc. Vanamo* **17.** 171–178.

Quennerstedt, N., 1965: The major rivers of Northern Sweden. *Acta Phytograph. Suec.* **50.** 198–204.

REMMERT, H., 1965: Über den Tagesrhythmus arktischer Tiere. *Z. Morpho. Økol. Tiere* **55.** 142–160.

SCHEELE, M., 1952: Systematisch-ökologische Untersuchungen über die Diatomeenflora der Fulda. *Arch. Hydrobiol.* **46.** 305–423.

SKUJA, H., 1964: Grundzüge der Algenflora und Algenvegetation der Fjeldgegenden um Abisko in Schwedisch-Lappland. *Nova Acta Soc. Sci. Upsal. Ser. 4,* Nr. 18. 1–465.

SWADE, R. H. & C. S. Pittendrigh, 1967: Circadian locomotor rhythms of rodents in the arctic. *Amer. Naturalist* **101.** 431–466.

SYRJEMÄKI, J., 1969: Diel Patterns of swarming and other activities of two arctic Dipterans (Chironomidae and Trichoceridae) on Spitsbergen. *Oikos* **19.** 250–258.

Glaciological work in 1974

(Гляциологические работы в 1974 г.)

By OLAV LIESTØL

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Abstract

In 1974 mass balance measurements were made on four glaciers in Norway. All showed a positive balance. In Spitsbergen measurements were made on three glaciers, Austre Brøggerbreen, Midre Lovénbreen, and Finsterwalderbreen. All showed a negative balance. Comparisons were also made between mass balance measurements and volume changes measured on maps. The agreement was reasonable.

Length fluctuations of twelve glaciers were measured; five were advancing, six retreating, and one stationary.

Аннотация

Сотрудниками Норвежского Полярного Института (Norsk Polarinstitutt) в 1974 г. были измерены оказавшийся положительным вещественный баланс четырех ледников в Норвегии (Storbreen, Hardangerjøkulen, Supphellebreen, Blomsterskardbreen) и оказавшийся отрицательным вещественный баланс трех ледников на Шпицбергене (Austre Brøggerbreen, Midre Lovénbreen, Finsterwalderbreen). С положительным результатом сравнены измерения вещественного баланса с измеренными на картах изменениями объема.

Были измерены колебания длины языков двенадцати ледников, из которых наступали пять, отступали шесть, а стационарным оказался один.

Storbreen in Jotunheimen

As in the two previous years precipitation came with a larger part than normal from the west. Larger than normal were also the snowfalls during the

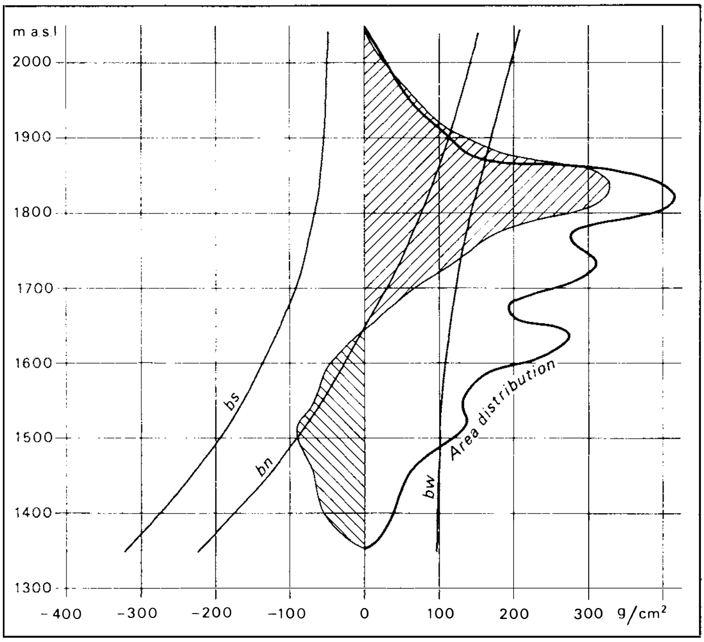


Fig. 1. *Variations in mass balance of Storbreen 1973–74 in relation to height above sea level.*
Вариации вещественного баланса ледника Storbreen в 1973/74 г.
в зависимости от высоты над уровнем моря.

ablation period. This also slowed down the ablation as the albedo in periods was much higher than normal. Particularly a heavy snowfall in August prevailed for a long time even on the tongue and lasted out the whole ablation period in the highest parts of the glacier.

Although the summer temperature was above average, the high accumulation and the mentioned summer snowfalls caused a positive balance (Fig. 1 and Table 3).

Hardangerjøkulen

The mass balance of Rembesdalsskåki, a western outlet glacier from Hardangerjøkulen, was carried out on a reduced scale for the balance year 1973–74. Only two stakes survived the winter and some of the new stakes replacing the lost ones were broken down during the summer. The calculated values for the balance are not as accurate as in previous years, therefore. As on Storbreen summer snowfalls slowed down the ablation. In the highest parts the balance was even the same in the middle of August as in the beginning of June.

The result was a calculated positive balance of 46 g/cm². The uncertainty is higher than in previous years and is estimated to ±20 g/cm² (Fig. 2 and Table 3).

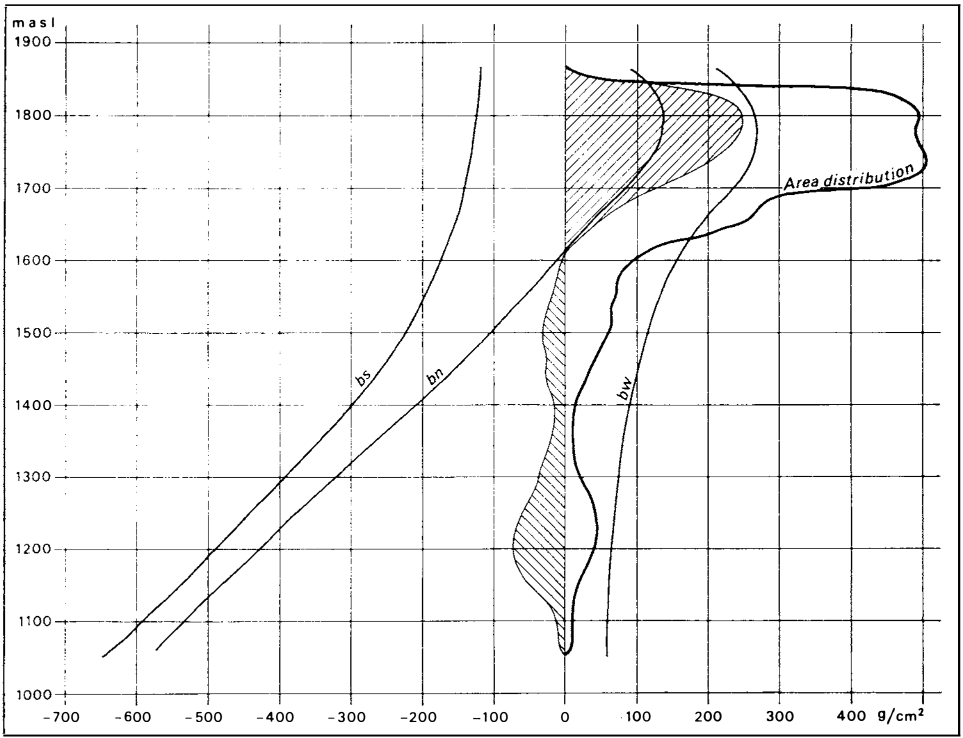


Fig. 2. *Variations in mass balance of Hardangerjøkulen (Rembesdalsskåki) 1973–74 in relation to height above sea level.*

Вариации вещественного баланса ледника Hardangerjøkulen (Rembesdalsskåki) в 1973/74 г. в зависимости от высоты над уровнем моря.

Supphellebreen, Jostedalsbreen

Supphellebreen, an outlet glacier from the southwestern part of Jostedalsbreen, has previously been studied in detail by OLAV ORHEIM in 1963 to 1968. The mass balance measurement was renewed on a reduced scale in 1972–73 and continued in 1973–74. The net balance was approximately 80 g/cm².

Blomsterskardbreen, Folgefonni

This outlet glacier drains southwards from the centre of Folgefonni and has one of the largest balance figures in Norway. After a detailed study by ARVE TVEDE in 1969–71, the mass balance measurements have been continued based on three stakes near the firn line. As mentioned in the last report, the even and simple accumulation pattern registered in earlier years gives a reliable basis for calculation of the mass balance. As no accumulation measurement has been made, only net balance figures are available.

The calculation showed a positive balance as in previous years and the net balance was 53 g/cm².

Glaciers in Spitsbergen

In Spitsbergen mass balance studies were carried out on Midre Lovénbreen, Austre Brøggerbreen, and Finsterwalderbreen.

Also this year detailed attention was given to the superimposed ice on Brøggerbreen. In the autumn when the weather changed between snow, rain, and cold, superimposed ice formed on the cold glacier surface. As snow was left in the upper part of the glacier the whole summer of 1973, superimposed ice formed continuously on the underlying ice from the time when melting started until late in the autumn. Part of this ice, that which formed after the budget year of 1973–74 started, is added to this year's accumulation. The ablation in the summer of 1974 was extremely high – the highest measured since the measurements started in 1966. No snow was left and most of the

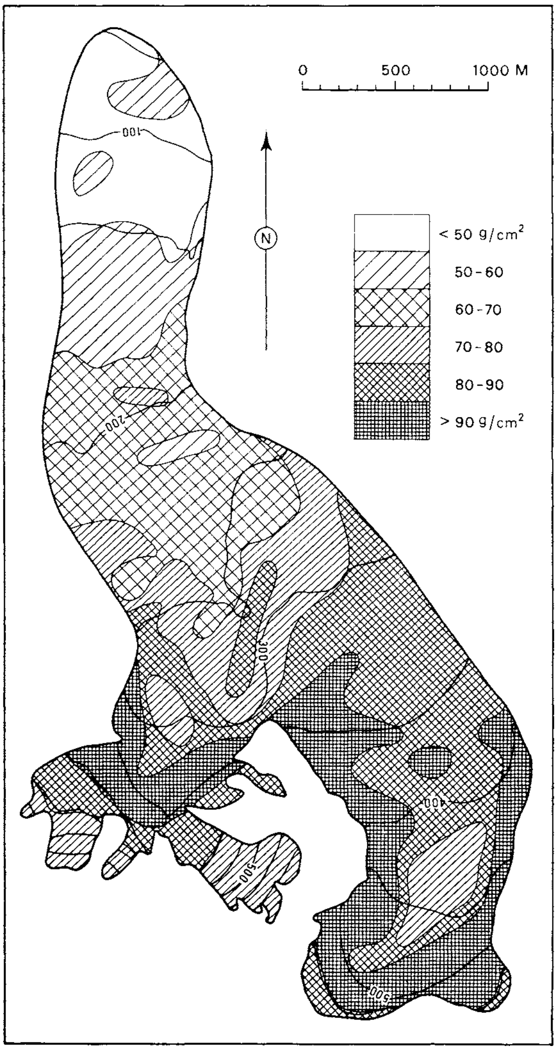


Fig. 3a. *Distribution of snow accumulation of Austre Brøggerbreen 1973–74.*
Распределение снегонакопления ледника Austre Brøggerbreen в 1973/74 г.

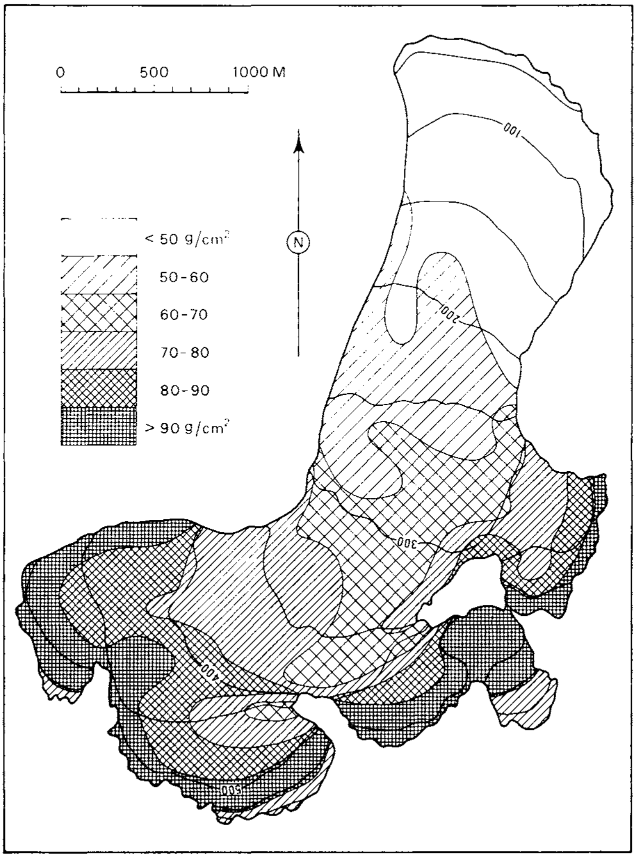


Fig. 3b. *Distribution of snow accumulation of Midre Lovénbreen 1973–74.* Распределение снегонакопления ледника Midre Lovénbreen в 1973/74 г.

superimposed ice formed during the spring and early summer disappeared. Blue ice could be seen right to the cirque bottom of the glacier.

The mass balance measurement showed a large deficit in the net balance and as with the ablation, it was the largest since the measurement started in 1966. It was also the 8th of a continuous number of negative balance years. As stated in previous reports, it is difficult to say whether this fact is due to higher ablation or lower accumulation. The ablation is dependent upon different meteorological factors of which radiation and convection are the most important ones. As there is good correlation between these two factors and the summer temperature, the summer temperature should again give a good correlation with the ablation. In contrast to the mean winter temperatures which have shown large variations, the summer temperatures have been nearly constant during the 60 years of observations at Isfjord Radio. In the last 8 years when mass balance studies have been carried out, the summer temperatures are slightly below the 60 years average. The winter precipitation figures for the same 8 years are above normal. Both these facts should indicate an increase in the glacier mass. There could be different reasons or explanations for this discrepancy. The meteorological station at Isfjord Radio is

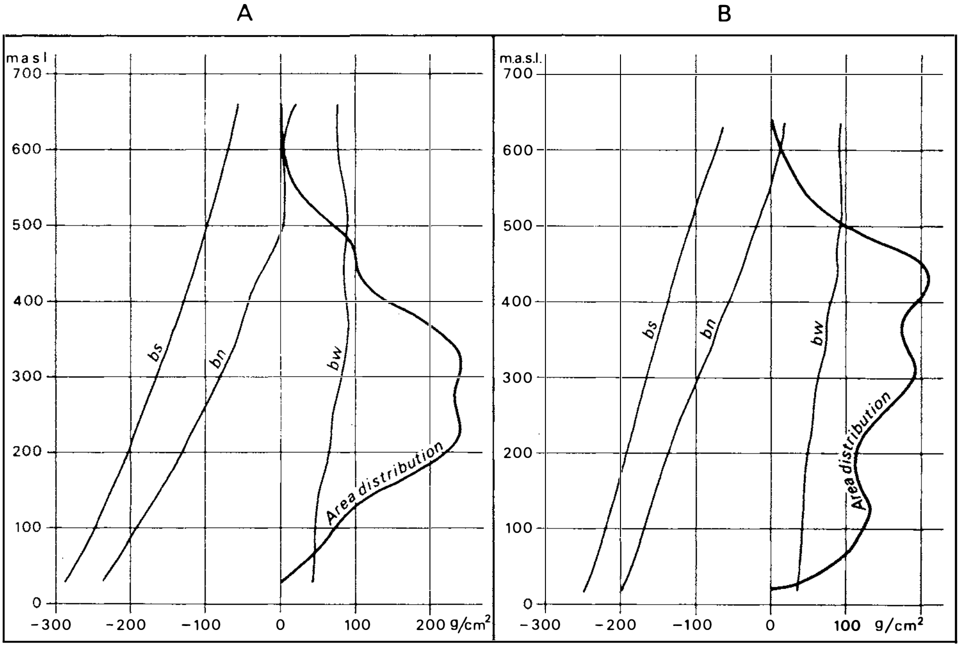


Fig. 4. *Variations in mass balance in relation to height above sea level of Austre Brøggerbreen (A) and Midre Lovénbreen (B) 1973–74.*

Вариации вещественного баланса в зависимости от высоты над уровнем моря ледников Austre Brøggerbreen (A) и Midre Lovénbreen (B) в 1973/74 г.

Table 1

Mass balance figures in g/cm² for Austre Brøggerbreen and Midre Lovénbreen 1967–74

Year	Austre Brøggerbreen			Midre Lovénbreen		
	$\bar{c}$	$\bar{a}$	$\bar{b}$	$\bar{c}$	$\bar{a}$	$\bar{b}$
1967	77	142	÷65			
1968	57	67	÷10	48	51	÷ 3
1969	40	133	÷93	41	125	÷84
1970	37	91	÷54	36	89	÷53
1971	65	123	÷58	70	116	÷46
1972	95	126	÷31	98	120	÷22
1973	74	82	÷ 8	82	84	÷ 2
1974	75	167	÷92	70	159	÷89

possibly not representative for the glaciers, but both this station and the glacier are located near to the west coast and only about 100 km apart. The temperature should, therefore, give a reasonable good correlation. The measurement of precipitation is often unreliable in Arctic regions and the correlations even over short distances are not good. There is reason to believe, therefore, that a low winter precipitation is responsible for all these years of negative mass balance. Photographs and maps show continuous retreat both on Brøggerbreen and Lovénbreen in the last 70 years.

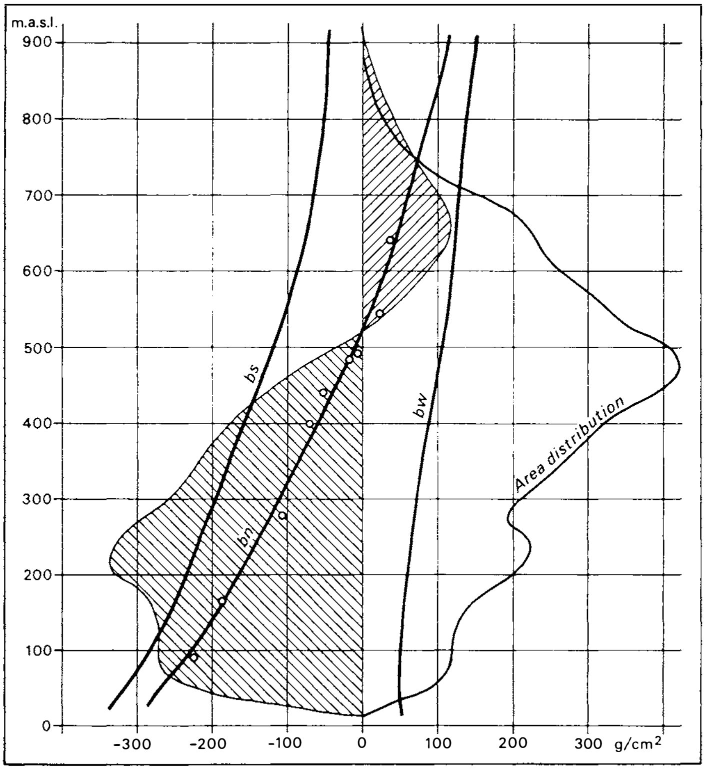


Fig. 5. *Variations in mass balance of Finsterwalderbreen 1973–74 in relation to height above sea level.*
Вариации вещественного баланса ледника Finsterwalderbreen в 1973/74 г.
в зависимости от высоты над уровнем моря.

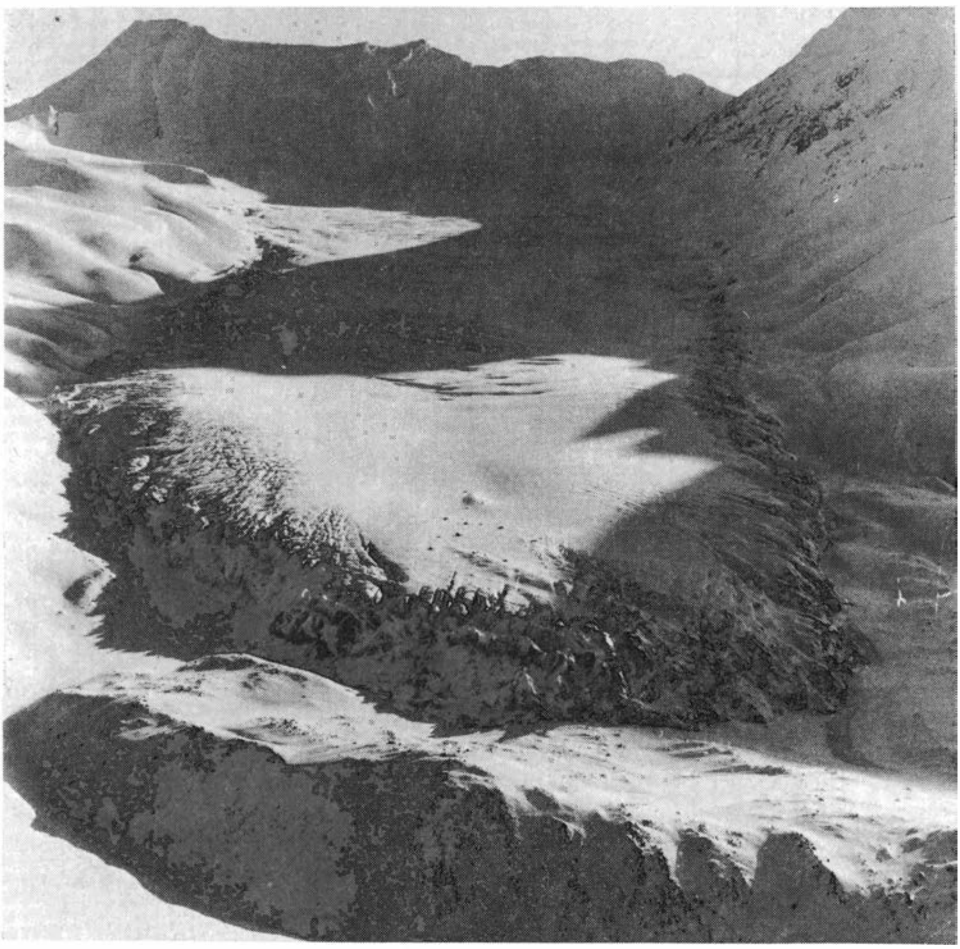
In 1962 the East German Expedition to Spitsbergen made a photogrammetric map of Midre Lovénbreen in the scale of 1:10,000. Later Norsk Polarinstitutt constructed maps in the scale of 1:20,000 based on air photographs taken in 1966 and 1969. Brøggerbreen was mapped in 1966 and the position of the stakes on both glaciers surveyed.

The shrinkage is largest in the lower part and decreases with height. This is due to the small downward mass transport. Measurements for this transport were carried out during the German expedition 1962–63 and 1964–65. The calculation was based on gravity measurements of the ice depth and velocity measurements. The transport in two profiles at c. 170 and 260 m a.s.l. was compared with the volume lost by ablation below the profiles. The same calculation was made for the period 1969–74 using the same profiles together with the mass balance figures for the area below the profiles. The velocity was not measured in the profile in 1969–74, but interpolated between nearby stakes. The reduced ice depth made the profile area smaller and also reduced the velocity. The transported ice volume through the profiles then of course was also smaller.

Table 2

		Upper profile	Lower profile
Volume transported in $10^6 m^3$/year	1962–63	0.31	0.18
	1964–65	0.38	0.20
	1969–74	c. 0.25	0.10
Ablation below profile $10^6 m^3$/year	1962–64		2
	1969–74	3.2	2.4

As will be seen from the Table 2, the ablation loss is more than a magnitude larger than the downward transport. The lowering of the ice surface on the tongue is therefore nearly proportional to the net balance figure. In fact there is good agreement between the net balance figures registered and the volume



Fjg. 6. *Air photo of Hessbreen after the surge.*
Воздушная фотография ледника Hessbreen после подвижки.
Photo: J. Angard

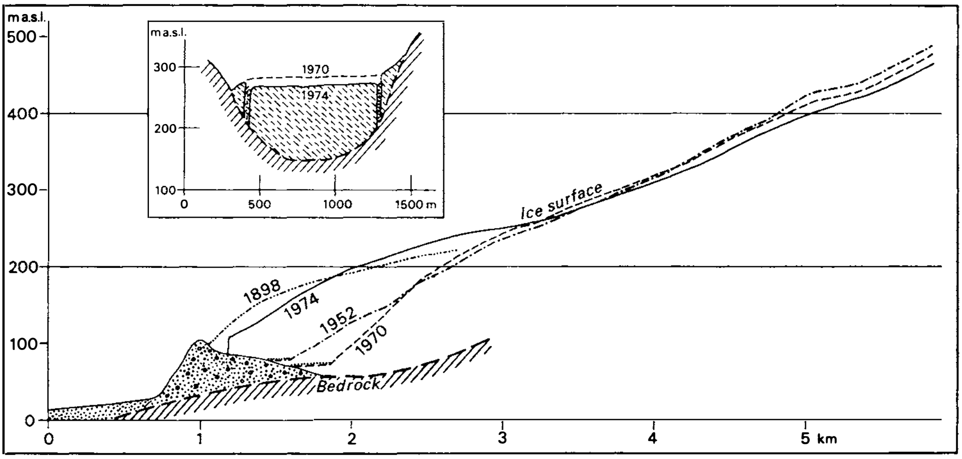


Fig. 7. *Vertical profile along the center line of Hessbreen in different years.*
Вертикальный профиль по центральной линии ледника Hessbreen в разные годы.

measured trigonometrically. An exception is the front part of the tongue where the volumes measured on maps are larger than the net balance computed. No stake covers this snout area and the net balance curve has been extrapolated. Obviously the curve has to be changed according to this fact in future calculations.

The same calculations have been made for Brøggerbreen. The result was almost the same but the difference in net ablation between the upper and lower part is not so pronounced.

This year mass balance was also carried out on Finsterwalderbreen, a glacier south of Van Keulenfjorden. The glacier was visited by airplane in the end of May. Most of the stakes were found and snow depth and density were measured. By a revisit in the end of August all the stakes except one were found and measured.

Like the glaciers near Ny-Ålesund, this glacier too had a negative balance, —51 g/cm². The equilibrium line was at 520 m a.s.l. on Finsterwalderbreen. This is a little below the line of Austre Brøggerbreen and Midre Lovénbreen, where the height was 550 m.a.s.l. But in contrast to these glaciers Finsterwalderbreen has a large net accumulation area above the line (Fig. 5).

Hessbreen

It was observed at a visit to Van Keulenfjorden in May 1974 that the glacier Hessbreen had made a large advance. The glacier had totally changed its appearance since it was last visited two years earlier. From having a smooth, even surface it was now strongly crevassed in the upper part and the tongue had steep, rugged sides (Fig. 6).

The glacier has been in continuous retreat since 1898 when it was first surveyed. On HAMBERG's photographs from 1898 the front is standing against the outermost moraines indicating a surge some years earlier. The auothor has

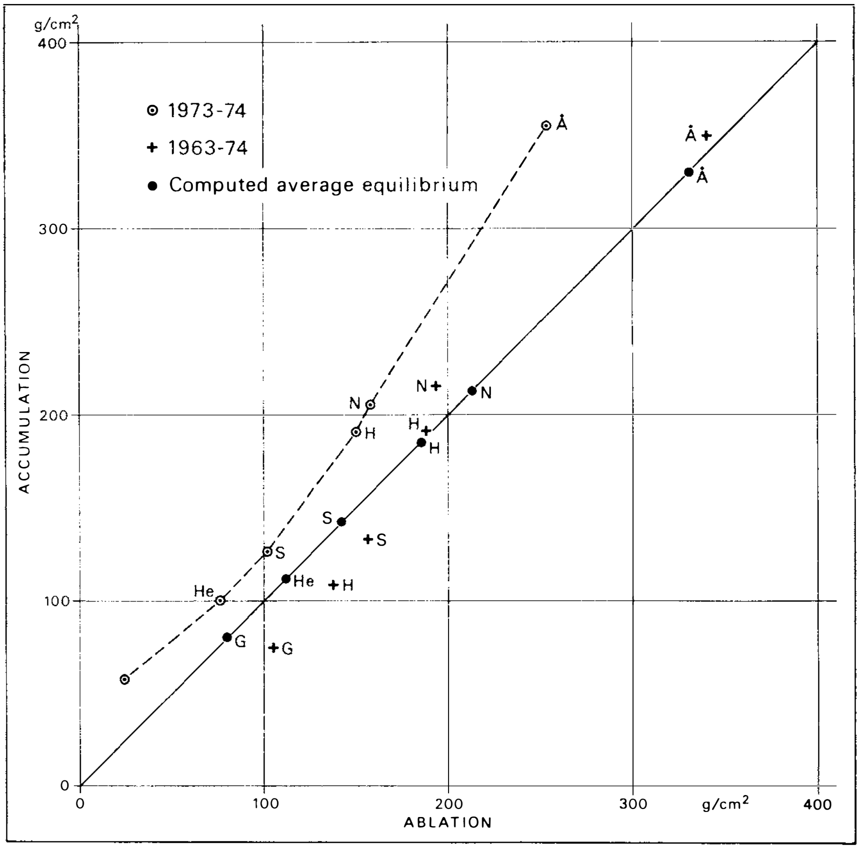


Fig. 8. *Relation between accumulation and ablation compared to the mean of the previous twelve years, and also to that of a year with a computed balance budget and a "normal" mass exchange.*

G = Gråsubreen. H = Hardangerjøkulen. He = Hellstugubreen.

N = Nigardsbreen. S = Storbreen. Å = Ålfotbreen.

Взаимоотнощения между аккумуляцией и абляцией в сравнении с средними значениями предыдущих двенадцати лет, так же как с значениями года с подсчитанным балансированным бюджетом и «нормальным» вещественным обменом.

later surveyed the glacier in 1950, —52, —60, —70, and —74. Photogrammetric maps were also made in 1920, 1936, and 1970. Fig. 7 shows a vertical profile along the center line of the glacier. The surveys before 1952 are not accurate enough to be used. From 1952 to 1960 and from 1960 to 1970 the thickness decreased in the firn area above 300 m a.s.l. and increased in the area between 300 and 170 m a.s.l. Further towards the snout there was a gradually increasing shrinkage. This is because the velocity and the transport from the firn area to the snout are decreasing. The lowest 200 metres were almost stagnant with a velocity less than 0.5 m a year at a stake at about 100 m elevation.

Water are draining from the glacier through the whole winter indicating that part of the glacier base is at melting point. On the other hand temperature measurements on the lower part of the tongue show a negative temperature of —4.2 at 10 m depth. The tongue may therefore be frozen to bedrock. This may also explain the stagnant lower part and a damming effect on the mass transport. The gradient of the surface and thereby the shear stress at the base may after some time reach a value large enough to start a surge. This means that such a surge starts at the tongue and not in the accumulation area.

The lower part of the glacier seems to move like a solid block. Boulders and surface moraines had their orientation undisturbed after the surge. Part of a terminal moraine from a small corrie glacier on the west side was cut off and moved almost undisturbed about 600 m. All the differential movement occurred in a small zone at the edge of the glacier. Here the glacier ice was crushed to a mixture of small and large blocks of ice with material like coarse snow in between. A rim of ice was left undisturbed between this zone and the valley side when the glacier body surged.

Other investigations

The Norwegian Water Resources and Electricity Board carried out measurements on seven glaciers in Norway of which three, Engabreen, Trollbergdalsbreen, and Høgtuvbreen, are situated in northern Norway. The measurements and the investigations dealt with in this paper are presented in Table 3.

The mass balance figures for southern Norway are also presented graphically in Fig. 8.

Table 3

Mass balance measurements of different glaciers in Norway and Spitsbergen 1973–74

Name of glacier	Area km²	Winter balance g/cm²	Summer balance g/cm²	Net balance g/cm²
South Norway				
Ålfotbreen	4.79	357	254	103
Blomsterskardbreen	45.72			051
Folgefonni	9.55	214	155	059
Hardangerjøkulen	17.30	191	150	041
Supphellebreen	11.98			080
Nigardsbreen	47.21	206	158	048
Storbreen	5.35	126	102	024
Hellstugubreen	3.29	100	076	024
Gråsubreen	2.52	058	024	034
North Norway				
Høgstuvbreen	2.60	346	368	—022
Engabreen	38.02	339	262	077
Trollbergdalsbreen	1.82	257	297	—040
Spitsbergen				
Austre Brøggerbreen	6.10	75	167	— 92
Midre Lovénbreen	5.76	70	159	— 89
Finsterwalderbreen	33.90	92	143	— 51

Measurements of the fluctuation of glacier tongues were carried out on 11 glaciers, and the results are presented in Table 4. Fig. 9 shows the variations of Briksdalsbreen from 1901 when the measurements of the fluctuations started.

Table 4

Fluctuations in m of some glacier tongues

Jotunheimen		*Folgefonni*	
Storbreen	— 5	Buarbreen	0
Styggedalsbreen	+ 5	Bondhusbreen	+3
Jostedalsbreen		*Møre*	
Briksdalsbreen	+10	Trollkyrkjebreen	—1
Fåbergstølbreen	—22	Finnebreen	0
Stegaholtbreen	—12	*Svartisen*	
Tunsbergdalsbreen	— 4	Engabreen	—4
Austerdalsbreen	+10		

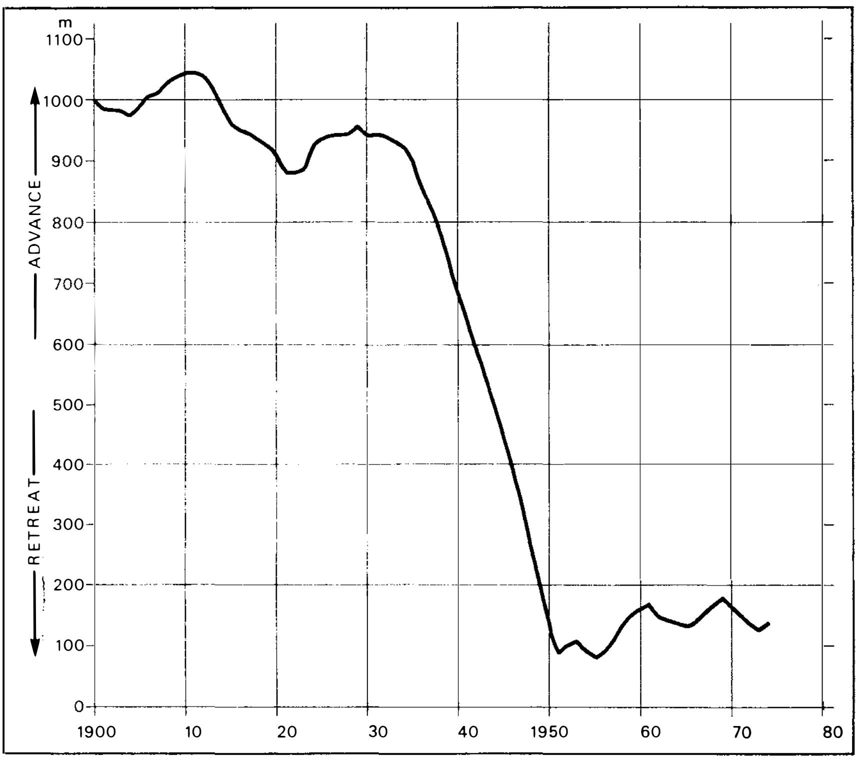


Fig. 9. *Fluctuations in the length of the tongue of Briksdalsbreen.*
Колебания длины языка ледника Briksdalsbreen.

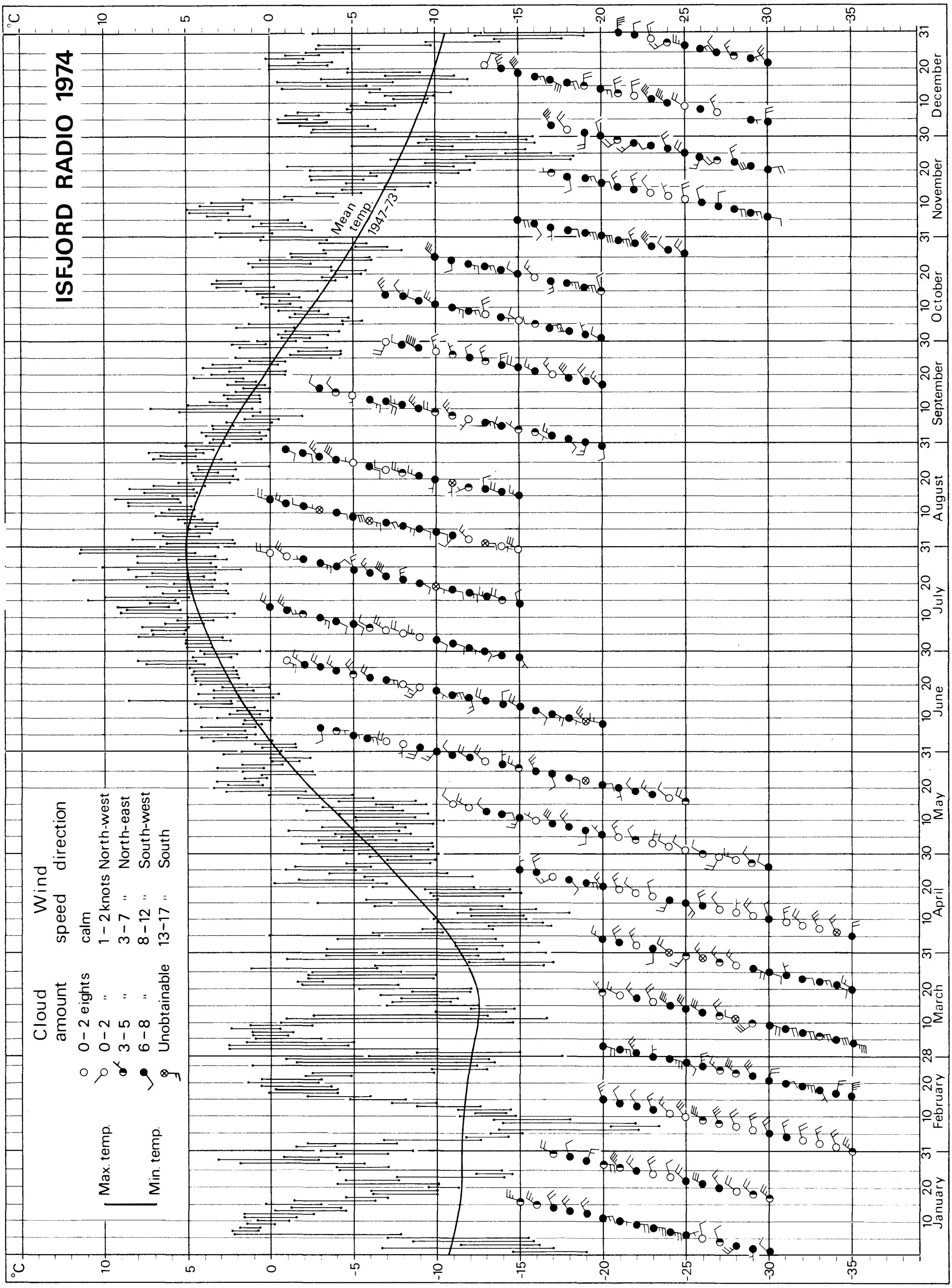
The weather in Svalbard in 1974

By Vidar Hisdal

The diagram presents some important meteorological elements observed at Isfjord Radio during 1974: the daily maximum and minimum temperatures, the cloud amount, and the direction and speed of the wind. The cloud and wind observations entered are those taken at 12 GMT. The figure also shows the average annual temperature variation for the period 1947–73. The symbols used are explained by examples in the diagram.

The table contains the monthly mean temperatures for Isfjord Radio, Hopen, and Bjørnøya for 1974 as well as their deviations from the means based on the period 1947–73. The term "normal" used below refers to this latter period.

The typical circulation pattern for the last days of the preceding year, distinguished by a cold Arctic air flow to the east of a high pressure area over Greenland, continued during the first few days of January. About the 5th of the month the situation changed. Deep depressions approached from the southwest, leading to a strong transport of mild air from lower latitudes, and temperatures considerably above the normal for the season. Except for a somewhat cooler period from about the 17th to the 25th of the month, this weather type remained until 3 February, when a high pressure ridge from the Polar Basin towards Greenland started to dominate the air circulation, resulting in a marked temperature fall. The lowest temperature of the year at Isfjord Radio, —23.4 °C, occurred during this period, on 7 February. From the middle of the month, however, low pressure centres again started to pass over or near Svalbard. This cyclonic weather type, with overcast skies, frequent precipitation, often strong winds, and above normal temperatures, prevailed throughout March and during the first days of April. It may be mentioned, as a characteristic of this very mild winter weather, that at Isfjord Radio the months of January, February, and March had ten, five, and nine days, respectively, with temperatures exceeding 0 °C. The second week of April had northeasterly currents of Arctic air, and comparatively low temperatures, while during the last half of the month some rather weak depressions passed, interrupted by high pressure ridges and cooler spells. These high pressure ridges became a more outstanding feature of the pressure pattern during the last days of April and the first part of May. The weather was mostly cool,


ISFJORD RADIO 1974
Mean temp. 1947–73
Max. temp.
Min. temp.
Cloud amount
0–2 eights
0–2 "
3–5 "
6–8 "
Unobtainable
Wind speed direction
calm
1–2 knots North-west
3–7 " North-east
8–12 " South-west
13–17 " South
°C
10
5
0
-5
-10
-15
-20
-25
-30
-35
January
February
March
April
May
June
July
August
September
October
November
December

with weak to moderate winds. From about 18 May and during the larger part of June the situation was again characterized by greater cyclonic activity, and the temperature was most of the time above the long-term average.

The end of June and the beginning of July were dominated by high pressure areas centred over or near the Svalbard region. The winds were light and variable, and the temperatures kept about or above the normal. On 11 July a depression entered from the south, followed by several others during the succeeding days, and the temperature continued to stay about or above the normal. The annual temperature maximum at Isfjord Radio, 11.8 °C, was observed on 21 July. In connection with a high pressure ridge stretching eastward from Greenland, the last two to three days in July and the first couple of days in August formed, except for cases with local fog, a consecutive clear-weather period. The middle of August as well as the end of this month were dominated by cyclonic passages and advection of mild air. The first eight days of September and, also, the period from the 24th to the 27th of the month had comparatively clear, cool weather, while during the rest of September several well-developed cyclones passed over or just south of Svalbard, and were associated with a transport northwards of mild, maritime air. This alternation between a cool, anticyclonic and a milder, cyclonic weather type was still more marked in October. The most pronounced mild spell occurred about the middle of the month. Also, the first eleven days of November formed a remarkably mild period, with strong southerly air streams in the front of extensive low pressure systems, and daily temperature maxima ranging from 0° to 5 °C. The last part of November was colder. This applies especially to the last week of the month, which had a predominant flow of Arctic air from the Polar Basin. The major part of December had temperatures considerably above normal. Thus, three days at Isfjord Radio had maximum temperatures equal to or higher than 0 °C. As would be expected, this temperature regime was connected with a very intense and persistent cyclonic activity. During the last few days of the month Arctic air again invaded the archipelago, leading to a marked temperature fall.

The year as a whole, and especially the winter months, were unusually mild, the annual temperature mean for the three stations in the table being from 2° to 3° C higher than the corresponding long-term average. The monthly means for March are the highest ever recorded since the observations started at the three stations. In this connection it may be noted that the means for March are appreciably higher than the more "normal" means for April. As indicated by the above description, the reason for these mild weather conditions was a very intense cyclonic activity over the North Atlantic, particularly during the months of January to March, as well as December, resulting in strong advection of mild air over this whole northern region. At the west-coast of Spitsbergen, March had the highest monthly amount of precipitation, 76 mm at Isfjord Radio, or 15 per cent of the annual total at this station. Due to the mild weather, a not inconsiderable part of the winter precipitation fell in the form of sleet, rain or drizzle.

Monthly mean temperatures for 1974 (T) and their deviations (d) from the means of the period 1947–73

		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Isfjord Radio	T	–5.4	–8.9	–6.7	–9.5	–3.4	2.4	5.6	4.9	1.3	–1.8	–5.2	–5.5
	d	6.0	2.8	5.8	–0.3	0.0	0.8	1.0	0.7	0.3	1.4	1.8	4.1
Hopen	T	–5.7	–7.3	–4.6	–10.9	–4.5	0.2	1.8	2.7	1.9	–0.5	–3.9	–4.8
	d	7.4	5.3	9.3	–0.2	0.2	0.5	–0.2	0.5	1.2	2.5	3.4	5.8
Bjørnøya	T	–2.4	–3.4	0.2	–2.8	–0.5	3.3	4.6	4.9	4.0	1.4	–1.5	–2.6
	d	5.2	3.8	8.1	2.6	1.0	1.4	0.3	0.6	1.2	1.6	1.5	3.1

Sea ice conditions in 1974

BY TORGNY E. VINJE

A survey of the sea ice distribution at the end of each month is shown in Figs. 1–12. The main source of data is the American satellite pictures, supplemented by observations from aircraft, Arctic weather stations, and ships. The observations were plotted at Meteorologisk Institutt, Oslo. By comparison of the kind of satellite pictures used here with surface observations, it was found that a concentration less than 3/8 is not always registered in the satellite pictures.

The ice conditions north of Iceland were close to normal also in 1974 after a gradual improvement since the extraordinarily bad ice year in 1968. The eastward extension of Vesterisen (Fig. 3) was relatively small, particularly in February-March, and the annual reoccurring features of Odden and Nordbukta (Fig. 3) were very little developed with only an indication at the end of March. This was in great contrast to what was observed for instance in 1970 and 1973 (see VINJE Norsk Polarinstitutt Årbok 1970 and 1973).

Along the west coast of Spitsbergen the ice conditions were relatively close to normal during the first months of the year. The ice disappeared from this area in the beginning of May and stayed away for the rest of the year, which indicates far better ice conditions than normal. For July and August this was also the case around the rest of the archipelago.

The ice conditions in Østisen (Fig. 3) were close to normal except for the last three months of the year when the ice edge was found at more northerly positions than usual. Nordostodden was fairly pronounced at the end of March.

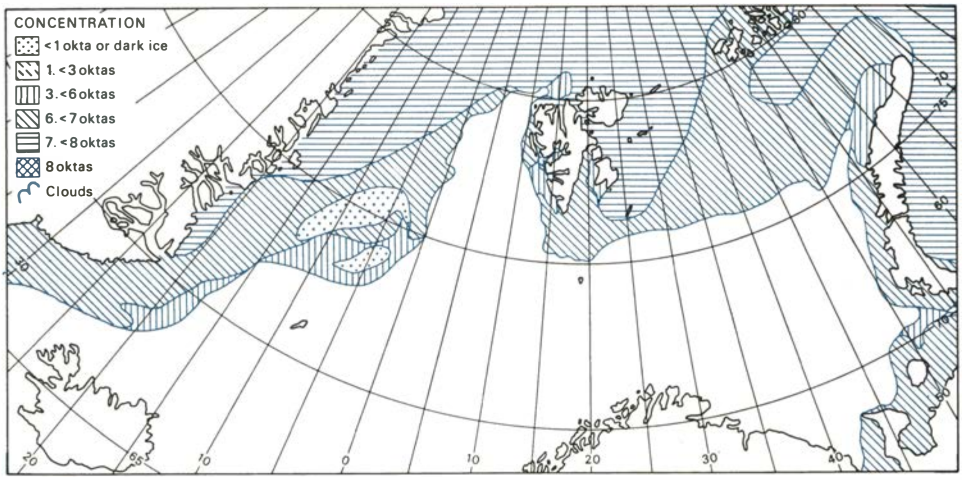


Fig. 1. *Sea ice distribution at the end of January.*

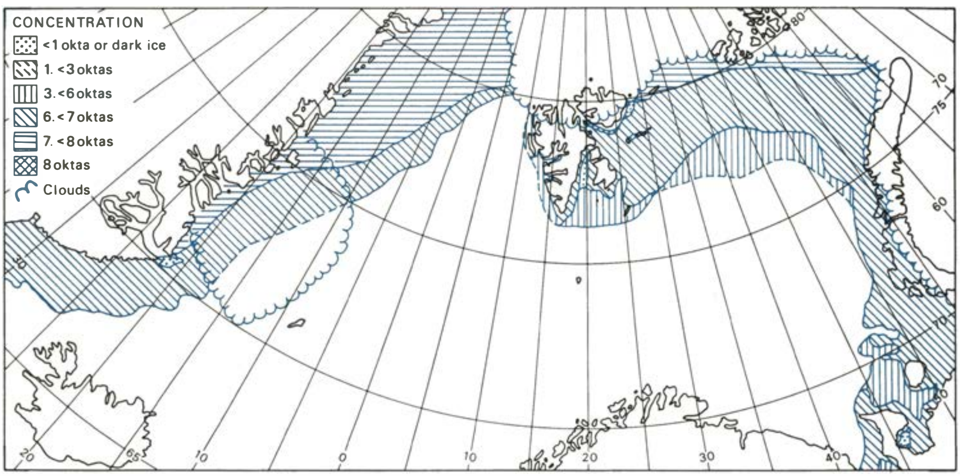


Fig. 2. *Sea ice distribution at the end of February.*

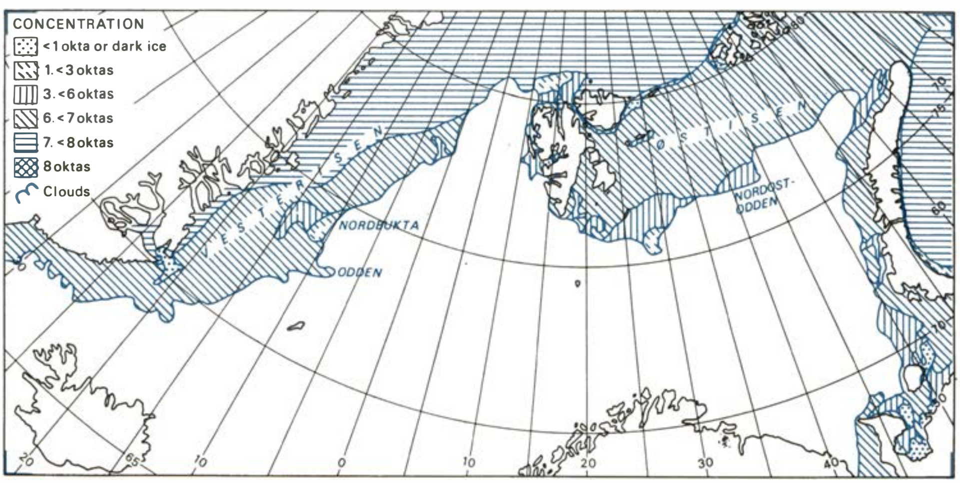


Fig. 3. *Sea ice distribution at the end of March.*

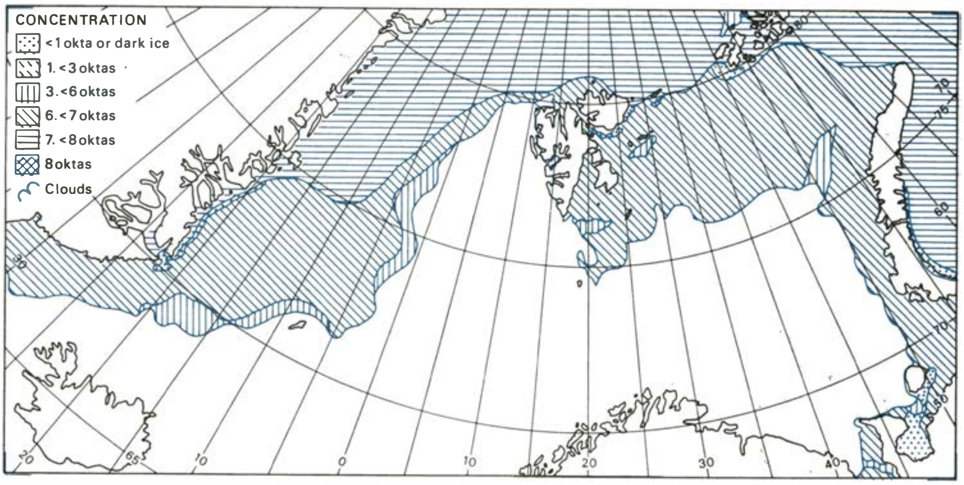


Fig. 4. *Sea ice distribution at the end of April.*

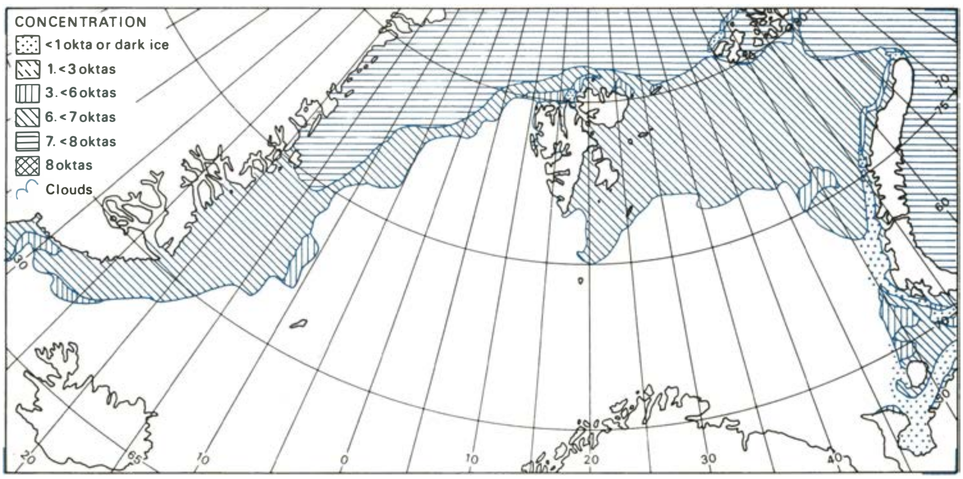


Fig. 5. *Sea ice distribution at the end of May.*

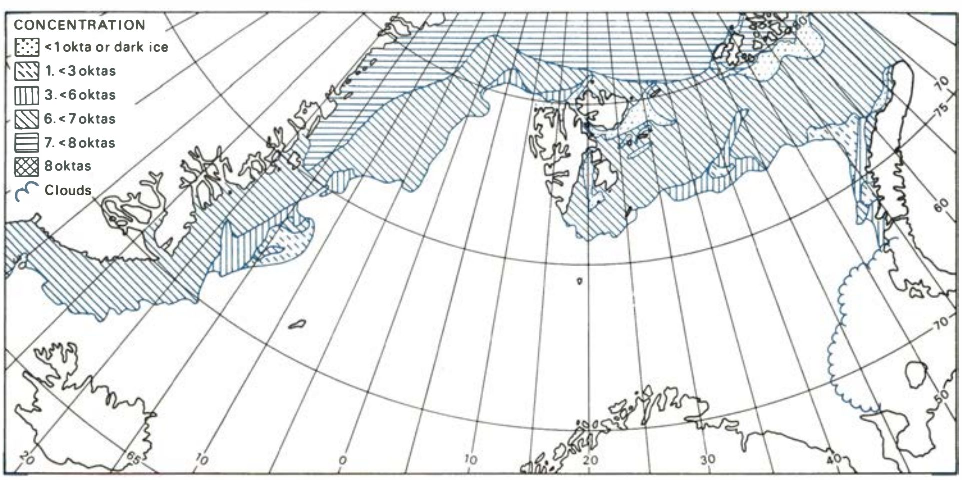


Fig. 6. *Sea ice distribution at the end of June.*

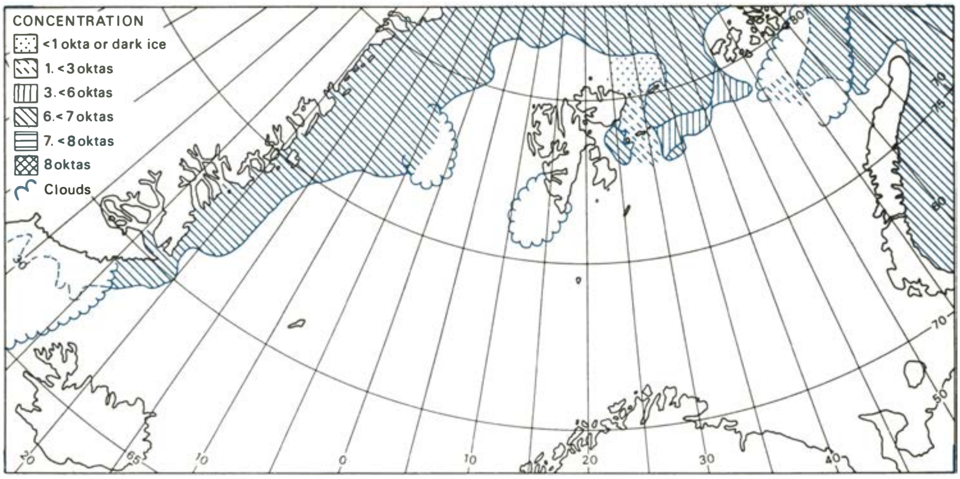


Fig. 7. *Sea ice distribution at the end of July.*

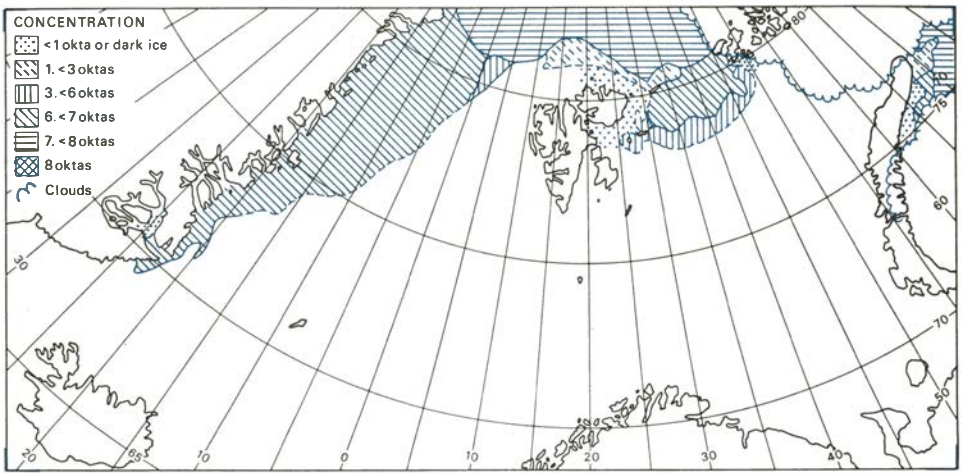


Fig. 8. *Sea ice distribution at the end of August.*

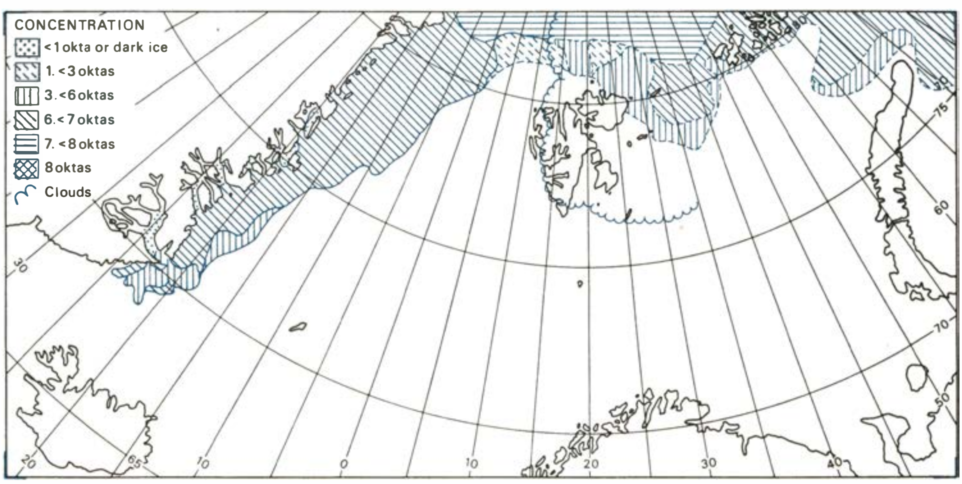


Fig. 9. *Sea ice distribution at the end of September.*

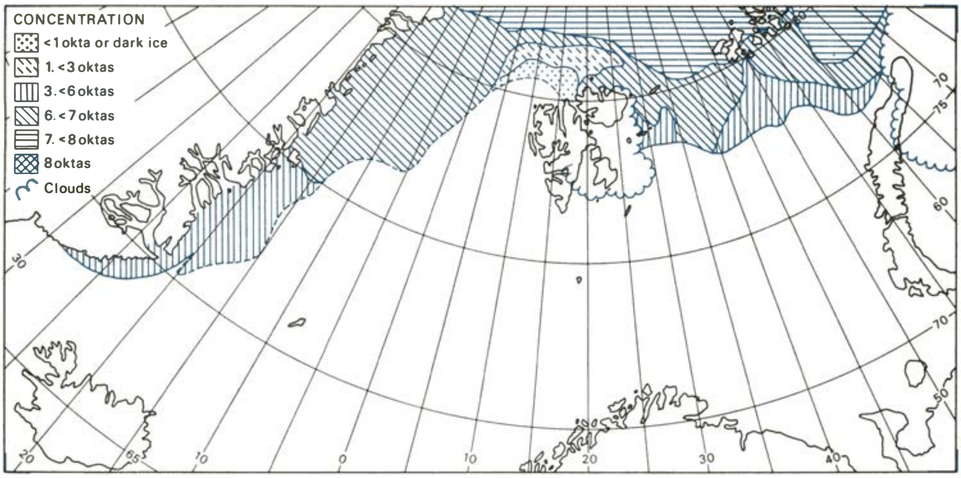


Fig. 10. *Sea ice distribution at the end of October.*

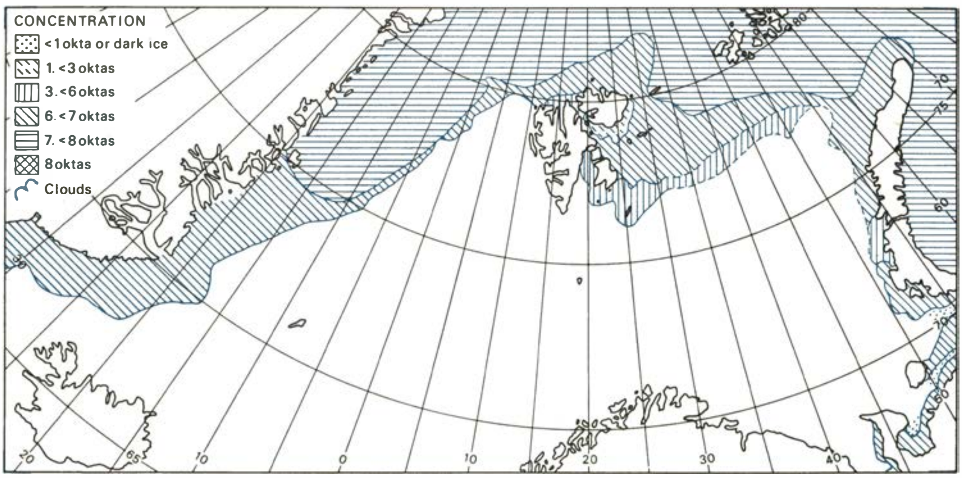


Fig. 11. *Sea ice distribution at the end of November.*

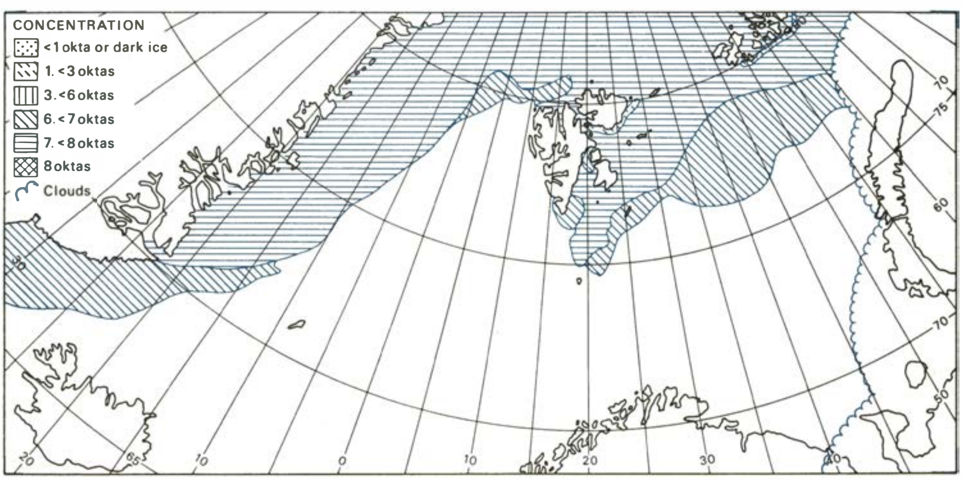


Fig. 12. *Sea ice distribution at the end of December.*

Radiation conditions in Spitsbergen in 1974

By Torgny E. Vinje

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Introduction

The most extensive and northern area of open water in the Arctic in the winter is generally found west of Spitsbergen in the Svalbard archipelago. Outside a cold coast-current the remnants of the Gulf stream passes northwards before it submerges beneath the lighter water just north of the islands. Because the net-radiation of this relatively large area of open water at these latitudes must play an important role in the heat budget, radiation measurements have been started at a permanently operated research station in Ny-Ålesund (78° 50′N, 11°30′E).

Instruments

The following instruments are mounted in Ny-Ålesund either on the roof of the research station or on the tundra nearby.

Instruments	Registration of radiation from	Where mounted
Eppley pyranometer	Sun and sky	On the roof
Kipp pyranometer (sun screened)	Sky	On the roof
Schulze radiometer (sun screened)	Sky and atmosphere	On the roof
Kipp albedometer	Sun, sky, and ground	On the tundra
Schulze radiometer (new type)	Sun, sky, atmosphere, and ground	On the tundra

The instruments are inspected regularly by the station personnel. The short wave calibrations are made every summer with the aid of an Ångstrøm compensating pyrheliometer and the long wave calibrations are made with a hemispherical black-body radiator. The sensitivity of the Eppley pyranometer, (model PSP), is found to be independent of the altitude of the sun. This is also assumed by the manufacturer. Our calibrations also show accordance with the accompanying calibration certificate. The instrument is used as reference when calibrating the other pyranometers. For the Schulze radiometer (old type on the roof) the long wave calibration factor is found to be 0.0237 ly $min^{-1} mV^{-1}$ from 15 measurements with a standard deviation of 0.0006 ly $min^{-1} mV^{-1}$. The short wave factor is found to be 2.4% less.

A double-walled tin filled with water was used for the measurements which were performed with an instrument temperature of between 5 and 10 degrees Centigrade, and a water temperature of between 25 and 35 degrees Centigrade. It is believed that the long-wave calibration factor is not dependent upon the instrument temperature. This is indicated from earlier measurements within a temperature range of +20 to —45 degrees Centigrade (VINJE, 1964).

The Ångström pyrheliometer (No. 160) has been compared at the Radiation Observatory at the University of Bergen where also a long-wave calibration of the Schulze radiometer, old type, has been made with the aid of an ice dome. Our own long-wave calibrations are within the error margin of 10% which is given for the measurement made in Bergen.

There are two parallel registrations to secure continuity. The main one is made in a digital form on a Kennedy incremental tape recorder via a Dynamco data logger where the logging speed is set to one scan every second minute. The other registration is made on a Honeywell compensating point printer.

The formation of hoarfrost on the radiation instruments in Ny-Ålesund occurs very seldom. This is probably due to the fact that some of the instruments are mounted on a roof, i.e. well above the surface and that the other instruments on the tundra are placed in a slightly sloping terrain exposed to catabatic flow which keeps the temperature above the saturating level. Snowfalls at temperatures around zero degrees Centigrade have a serious effect on the registrations on instruments not continuously ventilated, i.e. the pyranometers and the albedometer. (A continuous ventilating system for these instruments is now being tested.) However, registrations from the downward facing cell of the albedometer can under such conditions be used for a correction, as the albedo changes very little.

Results

The registrations of the different radiation fluxes at Ny-Ålesund have been added up for every hour. In the present context we are interested in the monthly sums for some of the radiation components only. These are given in Table 1 together with the albedo of the tundra.

The annual sum of the global radiation is seen to be about 57,000 ly. This is slightly higher than the maximum value registered at Isfjord Radio between 1951 and 1960 according to SPINNANGR (1968). The annual sums at this place vary between about 56,700 and 50,600 ly with an average of 53,423 ly $year^{-1}$.

Table 1

Monthly sums, ly month^{-1}, of radiation components at Ny-Ålesund in 1974. G: global radiation, a: albedo, A: long-wave radiation from the atmosphere, and B: total radiation balance of the surface.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
G		30	1521	8142	12881	12740	11808	7011	2560	286			56979
a		.83	.850	.813	.775	.400	.129	.140	.386	.583			
A	15665	13080	17090	14925	18184	19790	20973	20579	17831	17954	16107	16083	208261
B	−1578	−1695	−705	−248	1845	7111	8213	3496	−639	−1264	−1624	−1895	11017

The atmospheric long-wave counter-radiation as well as the global radiation measured at Ny-Ålesund are considered to be fairly representative for the surrounding area so that we can calculate the heat balance of the open water west of Spitsbergen. If the albedo of the water surface is assumed to be around 0.1 (BÜTTNER, 1929), and the radiative temperature of the surface to be zero degrees Centigrade, we get the result shown in Fig. 1. The same figure also gives the daily average of global radiation and the radiation balance of the tundra.

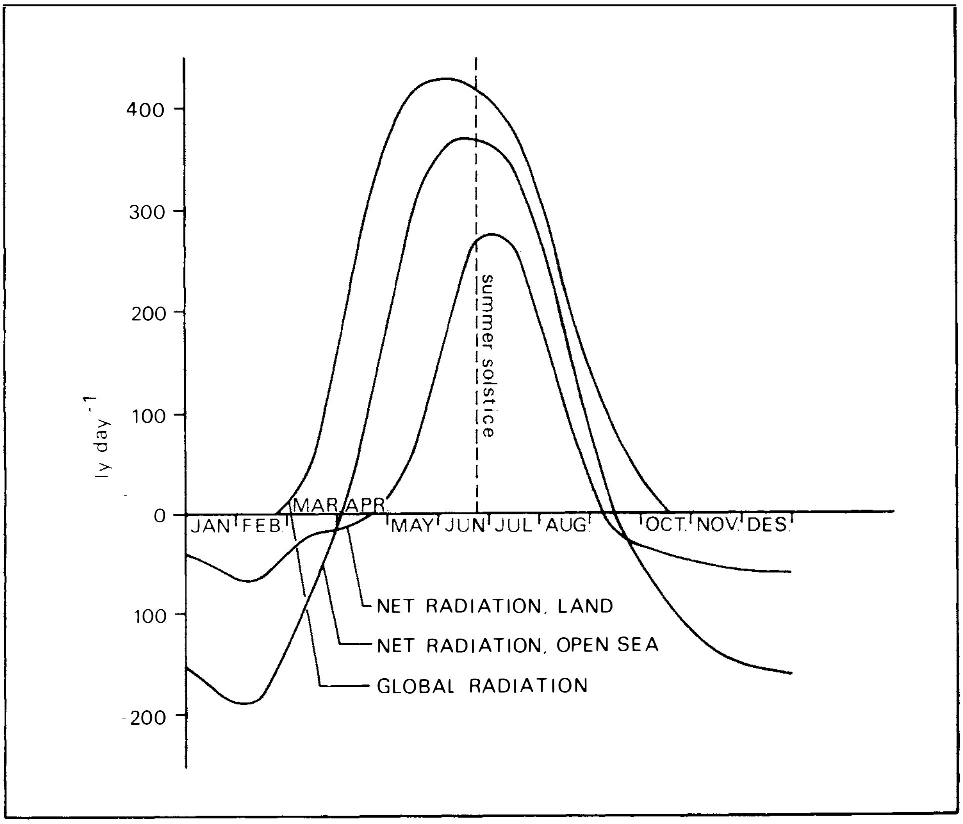

Fig. 1. *Daily averages of global radiation and net radiation at Ny-Ålesund. Calculated net radiation for open water with assumed albedo of 0.1 and surface temperature of zero degree centigrade.*

The marked skew distribution of the global radiation with respect to the summer solstice, corresponds with the observed increase in the percentage of cloud cover from the spring towards summer and autumn (see STEFFENSEN (1969)). A supplementary effect for a skew distribution is of course the disappearance in June of the snow from relatively large areas at the measuring site. When the snow vanishes, the global radiation is relatively reduced because of the reduction of the multiple reflection between the surface and the clouds.

The maximum of the radiation balance of the tundra occurs after the summer solstice when the albedo has been reduced drastically and the cloud cover has increased markedly, while the calculated radiation balance of the open sea shows a more even distribution with respect to the summer solstice. As we have kept the long-wave radiation from the water surface constant in the calculations, this indicates that the reduction in the global radiation to a certain extent is compensated by a higher long-wave radiation from the atmosphere due to increasing cloud amount.

For the period when the sun is below the horizon there is a very high difference between the long-wave radiation loss over land and over open sea. According to Fig. 1 the loss over the sea is, on an average, three times greater than over land during the polar night. The extremely high losses from the open water are found when there is a northerly wind with clear air. Thus during February 6 and 7 the daily sum of the atmospheric long-wave radiation was at its minimum, 314 ly day^{-1}. The average net radiation over land was —136 ly day^{-1} and the calculated value for the open water becomes —347 ly day^{-1}. The relative magnitude of the two latter values is, however, for this extreme occasion less than for average conditions with a quotient of 2.6 against 3.0. This is probably due to the relatively greater increase of the radiation loss over land than over sea as the cloud cover decreases. The maximum contrast in the radiation balance between snow covered ice and open sea in the winter will probably occur when there is overcast or fog together with a low temperature.

The minimum atmospheric counter radiation was seen to be 314 ly day^{-1}. This value can be compared with the observations during clear sky conditions at e.g. the station "North Pole 6" drifting between 78 and 80 degrees N. From the tabulated data (DRIACOG (1961)) the monthly average for clear sky conditions is calculated to be between 285 and 360 ly day^{-1}.

The turbulent transfer of heat over open water at high latitudes can be of extraordinary great magnitude. Based on calculations of VOWINCKEL and ORVIG (1973) this flux, on an average for the polar night, amounts to about 1200 ly per day in the Beaufort Sea. This calculated heat exchange is, according to the authors, significantly higher than other published results, and we may possibly consider them as maximum values. One should also expect that values observed in the marginal zones of the Arctic will be markedly less than those observed in the central area. Compared with our calculated net radiation loss from the open sea which averages about 160 ly per day for the polar night, one may say that the net radiation of the open sea west of Svalbard on an average constitutes at least 10–15 % of the dominant turbulent flux of heat during the winter.

References

BÜTTNER, K., 1929: *Met. Z.* **46**.

DRIACOG, V. M. (ed.), 1961: *Observations from the floating scientific stations "North Pole 6" and "North Pole 7" 1957/58.* Arctic and Antarctic Research Institute, Leningrad.

SPINNANGR, G., 1968: Global Radiation and Duration of Sunshine in Northern Norway and Spitsbergen. *Met. Ann.* **5** (3).

STEFFENSEN, E., 1969: The Climate and its Recent Variations at the Norwegian Arctic Stations. *Met. Ann.* **5** (8).

VINJE, T. E., 1964: On the radiation balance and micro-meteorological conditions at Norway Station, Antarctica. Den norske Antarktiseksp. 1956–60. Sc. Res. No. 6. *Norsk Polarinstitutt Skrifter* Nr. 131. Oslo.

VOWINCKEL, E. and S. ORVIG, 1973: Synoptic Energy Budget from the Beaufort Sea. *WMO Technical Note* No. 129. Energy Fluxes over Polar Surfaces. Proc. of the IAMAP/IAPSO/SCAR/WMO Symposium Moscow, 3–5 August 1971. Geneva.

Observations of animal life in Svalbard in 1974

(Наблюдения над фауной Свальбарда в 1974 г.)

By Thor Larsen

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Abstract

Observations on birds and mammals in Svalbard were collected from 21 expeditions and persons during 1974. Accurate counts exist on the reindeer (*Rangifer tarandus platyrhynchus*) and muskox (*Ovibos moschatus*) populations in Nordenskiöld Land, and some quantitative information on a few bird species. Walrus (*Odobenus rosmarus*) was again observed on Moffen, and in some other areas. The spotted flycatcher (*Muscicapa striata*) was observed for the first time in Svalbard, on Kvalpynten 15 August.

Аннотация

Результаты наблюдений над птицами и млекопитающими на Свальбарде получены от 21 наблюдателя (т.е. экспедиций и лиц) в 1974 г. Количественные данные имеются по популяциям северных оленей (*Rangifer tarandus platyrhynchus*) и овцебыков (*Ovibos moschatus*) на Земле Норденшельда (*Nordenskiöld Land*), и частично также по нескольким птичьим видам. Моржи (*Odobenus rosmarus*) опять были отмечены на о-ве Moffen и в некоторых другим областях. Серая мухоловка (*Muscicapa striata*) была впервые обнаружена на Свальбарде, на мысе Kvalpynten 15 августа.

Introduction

Norsk Polarinstitutt's questionnaire on the fauna of Svalbard has been distributed to most Norwegian and foreign expeditions visiting the archipelago in 1974. Observations were made in most parts of the archipelago. In some cases, quantitative data and population estimates have been obtained. I am grateful to the following persons and groups who have contributed with data and in-

Fig. 1. *First observation in Svalbard of spotted flycatcher* (Muscicapa striata) *was made on Kvalpynten 15/8–74.*
Первое обнаружение серой мухоловки (Muscicapa striata) на Свальбарде было сделано на мысе Kvalpynten 15/VIII–74.
Photo: J. THOMASSEN

formation: E. ALENDAL and P. H. PETERSEN (EA/PHP) from Nordenskiöld Land, K. BIRKENMAJER (KB) from Torell Land and Hornsund, J. T. BJØRKE (JTB) from Verlegenhuken, D. BJØRKEDAL (DB) from Mistakodden, Bjørnøya Radio (Bj.rad) from Bjørnøya, A. M. van DIJK and T. M. van SPANJE (AMD/TMS) from Nordenskiöld Land, Isfjorden, Brøggerhalvøya and west coast of Wijdefjorden, T. FJELD (TF) from Hinlopenstretet, Wahlenbergfjorden and Mistakodden, W. B. HARLAND (WBH) from Nathorst Land and the Ny-Ålesund area, Hopen Radio (Hop.rad) from Hopen, K. HUSEBY and I. KRISTENSEN (KH/IK) from Revnosa-Agardhpynten, F. KRÜLL (FK) from Adventdalen, Longyearbyen Jeger- og Fiskerforening (LJF) from Lomfjorden — Sorgfjorden, O. SALVIGSEN (OS) from van Keulenfjorden, Recherchefjorden and Dunderdalen, E. SENDSTAD (ES) from Liefdefjorden, Woodfjorden, and Reinsdyrflya, SEVMORGEO, Leningrad (SEV) from northwest Spitsbergen, H. STAALAND (HS) from the Ny-Ålesund area, J. THOMASSEN and K. KASTNES (JT/KK) from the west coast of Spitsbergen to Ny-Ålesund and Kvalpynten, T. WINSNES (TW) from Adventdalen, Hinlopenstretet and Palanderbukta, J. ÅKERMAN (JÅ) from Hornsund, Kapp Linné and the Ny-Ålesund area and K. AASGAARD (KAA) from the Ny-Ålesund area. The author with assistant R. AABAKKEN (NPB) made observations on Moffen, in Ny-Ålesund, in Liefdefjorden, Sorgfjorden, Hinlopenstretet, Kongsøya and the north coast of Nordaustlandet.

The majority of the observations were made between June and August. Observations from Bjørnøya and Hopen are from 1973 and 1974.

Mammals

Svalbard reindeer (*Rangifer tarandus platyrhynchus*): 76 adults were observed in Palanderdalen on 7 August. 9 adults and 2 calves were seen on Giæverneset the same day. 9 adults and 3 calves were seen in Zeipelfjella on 4 August (TW). Several antlers and old skull fragments were found on Kongsøya in August, indicating that there must have been at least two animals on the island, probably less than 20 years ago (NPB). Extensive counts were made on the southern half of Nordenskiöld Land and west of Grønfjorden/Fridtjovhamna in July and August. 3042 observations were made, including 240 calves. The total reindeer population in Nordenskiöld Land was estimated to about 6000 animals in 1973/74 (ALENDAL and BYRKJEDAL 1975).

Muskox (*Ovibos moschatos*): The total muskox population in Nordenskiöld Land was estimated to about 30, and maximum 35 animals, in 1974 (ALENDAL 1975). Old bones from a muskox carcass was found south of Agardhfjellet in August (KH/IK).

Microtus sp: Unidentified specimens were observed in Fuglefjella on 9 July. The animals were blue-grey and had a short tail (EA/PHP).

Polar bear (*Ursus maritimus*): One adult was seen in Brepollen 22 June (KB). A female with two cubs was seen in Bolterdalen 13 July and on Elveneset 15 July (EA/PHP). One adult was seen on Gråhuken in July (SEV). A female with two cubs was seen on Verlegenhuken 1 August (JTB). One adult bear was seen on Lågøya 30 August (NPB). Bears were also observed on Hopen during the winter 1973/74, on Bjørnøya, and in the drift ice in Hinlopenstretet and Erik Eriksenstretet, as well as on Kongsøya the summer of 1974. The observations will be specially treated in another publication.

Harp seal (*Pagophilus groenlandicus*): One adult was seen in Sassenfjorden 31 August (TMD/TMS).

Hooded seal (*Cystophora cristata*): Two young animals were observed at Brøggerhalvøya 17 July (TMD/TMS).

Walrus (*Odobenus rosmarus*): One adult was seen off Adventpynten in late June (EA/PHP). Several observations were made on Moffen. On 31 July, 41 adults were counted, of which there were probably 18 males and 23 females. A few walrus were spotted off Verlegenhuken in July (WBH) and 15 adult animals were seen in the sea in Hinlopenstretet off Wahlenbergfjorden 31 July (TW). The north coast of Nordaustlandet between Storøya and Lågøya was

Table 1
Observations of white whale (Delphinapterus leucas) *in Svalbard in 1974*
Наблюдения белух (*Delphinapterus leucae*) на Свальбарде в 1974 г.

Locality/date Местность/дата	Number Число	Observer/remarks Наблюдатель/примечания
Adriabukta, 22/6	50 ad+	K. Birkenmajer
,, 3/8	10 ad	,,
,, 5/8	2 ad, 3 juv.	,,
,, 15/8	20 ad, 10 juv.	,,
Kørberbreen, 20/8	20 ad, 10 juv.	,,
Van Keulenfj., 1/7	12 ad	W. B. Harland
Van Mijenfj., 9/7	20 ad	,,
Mosselbukta, Aug.	—	,, (Observed)
Sorgfjorden, Aug.	—	,, ,,
Van Keulenfj., 8/8	15 ad	O. Salvigsen
Recherchefj., 22/8	20 ad	,,
Recherchefj., east, 22/8	4 ad	,,
Revnosa, 13/8	8 ad	K. Huseby/I. Kristensen
Kongsfjorden, 14/7	—	T. M. van Dijk/T. M. van Spanje ("A flock")
Grønfjorden, 7/9	25 ad, 3 juv.	,,
Austfjorden, July	20 ad	SEVMORGEO

extensively surveyed for walrus by use of helicopter, 29 and 30 August, but no animals were seen. (NPB).

White whale (*Delphinapterus leucas*): See Table 1.

Greenland right whale (*Balaena mysticetus*): Parts of skin and blubber, two whalebones and a few bones from a stranded specimen were found on Mistakodden in August (DB). One baleen measured 3.40 metres, indicating that it must have been a big male.

Birds

Black-throated diver (*Gavia arctica*): Two adults were observed at Mistakodden 14 August. The observation is uncertain (TF).

Great northern diver (*Gavia immer*): Four observations of adult birds were made along the west coast of Nordenskiöld Land, and one adult was seen in Wijdefjorden in July/August (TMD/TMS).

Mallard (*Anas platyrhynchos*): One adult was seen on Isfjordflya 29 June (TMD/TMS).

Teal (*Anas crecca*): Two pairs were seen at Ny-Ålesund 30 June (WBH).

Pintail (*Anas acuta*): Two adult birds were seen in Gipsdalen 3 August (TMD/TMS). One adult female was seen at Kvalpynten in late August (JT/KK).

Table 2

Observations of large flocks of eiders (Somateria mollissima) *in Svalbard in the summer of 1974. Flocks of less than 50 birds are not listed.*

Наблюдения крупных стай гаг (*Somateria mollissima*) на Свальбарде летом 1974 г. Не включены в список стаи, насчитывающие меньше 50 особей.

Locality/date Местность/дата	Number Число	Observer/remarks Наблюдатель примечания
Coast of Nordenskiöld Land south and west (Barryneset-Kapp Linné) July/August	1800	E. ALENDAL/P. H. PETERSEN. About 1000 obs. between Akselsd. and Lågbukta.
Eolusneset, 1/8	approx. 60 ad	NPB
Kongsøya, August	100 ad÷	,, (estimated)
Nordaustlandet, north coastline, Glenhalvøya, Platenhalvøya, Sjuøyane, northern Laponiahalvøya, 30/8	approx. 400 ad	,, (counted)
Lågøya, 30/8	500 ad+	,, (counted)
Kapp Wijk, August	«Some hundred»	SEVMORGEO
Vestfjorden, July	,,	,,
Austfjorden, July	,,	,,
Revnosa, 14/8	100 ad	K. HUSEBY/I. KRISTENSEN
Agardhbukta, August	110 ad	,,

Tufted duck (*Aythya fuligula*): A 1972 observation of this species should be mentioned. One adult bird was seen in Ny-Ålesund that year (ANDERSON et al. 1974).

Long-tailed duck (*Clangula hyemalis*): 20 adults were seen at Bjørnøya Radio 21 May (Bj.rad). 50 adults were seen at Ny-Ålesund 30 July (NPB). 20 adults were observed at Kapp Laila but the date is not given (JÅ). At Kvalpynten, an estimated 20 different birds were counted in August (JT/KK).

Steller's eider (*Polysticta stelleri*): One adult bird was seen on Gravsjøen 28 June (TMD/TMS).

Eider (*Somateria mollisima*): See Table 2.

King eider (*Somateria spectabilis*): 16 adults and 12 young were seen at Kapp Linné between 28 June and 15 July (JÅ). About 25 adults were seen at Sarstangen 5 August, and the bird was common among the eiders at Kvalpynten in August (JT/KK). More than 200 birds were counted along the coast of Nordenskiöld Land in September (TMD/TMS).

Pink-footed goose (*Anser fabalis brachyrhynchus*): See Table 3.

Brent goose (*Branta bernicla hrota*): See Table 4.

Barnacle goose (*Branta leucopsis*): See Table 5.

Spitsbergen ptarmigan (*Lagopus mutus hyperboreus*): See Table 6.

Table 3

Observations of pink-footed goose (Anser fabalis brachyrhynchus) *in Svalbard in 1974*

Наблюдения короткоклювых гуменников (*Anser fabalis brachyrhynchus*) на Свальбарде в 1974 г.

Locality/date Местность/дата	Number Число	Observer/remarks Наблюдатель/примечания
Braastadskaret, 24–27/5	50+90+40	Hopen Radio
Fuglebergsletta, 14–30/6	18 ad	J. Åkerman
Linnédalen, 12/7	6 ad	,,
Ossian Sarsfj., 19/7	12 ad	K. Aasgaard
Kongsvegen, 20/7	13 ad	H. Staaland
Worsleyhamna, 2/8	33 ad	E. Sendstad
Reinsdyrflya, 18–20/8	98 ad	,,
Kilneset, 2/8	43 ad	,,
Kapp Kjeldsen, 23/8	60 ad	,,
Sørdalsbukta, 26/8	159 ad	,, (five flocks)
Roosneset, 5/8	100 ad	,, (two flocks)
Kvalpynten, 17/8	23 ad	J. Thomassen/K. Kastnes
Southern half of Nordenskiöld Land and west of Grønfjorden/ Fridtjovhamna, July and August	378 ad and young	E. Alendal/P. H. Petersen (most geese in flocks between 25 and 50).
Worsleyhamna—Sørbukta, 31/7	approx. 450 ad	NPB (counts from helicopter, 9 large flocks)
Eolusneset, 1/8	62 ad	,, (counts)
Kongsøya, August	2 ad 1 young	,,
Ny-Ålesund, 29/6	20 ad	W. B. Harland
Van Keulenfj., 6/7	20 ad	,,
Van Keulenfj., north side July/ Aug.	60 ad	,, (moulting)
Dugurdneset, 9/8	30 ad	,,
Van Keulenfj., 11/8	60 ad	,,
Frysjadalen, 17/8	30 ad	,,
Davisdalen, 19/8	40 ad	,,
Ekmanfjorden, September	15 ad	SEVMORGEO

Oystercatcher (*Haematopus ostralegus*): One adult was seen in Herwighamna 13 May, 2 at Bjørnøya Radio 14 May, and 3 at Nordkapp, Bjørnøya 21 May (Bj.rad).

Lapwing (*Vanellus vanellus*): One adult was seen at Bjørnøya Radio 8 May, and another on 26 May (Bj.rad).

Ringed plover (*Charadrius hiaticula*): One adult was seen at Festningen 10 July (JÅ), two were seen at Brandallaguna 14 July (HS), two pairs at Ny-Ålesund in early July (WBH), two adults and two young at Ny-Ålesund 30 July, and two adults defending territories on Eolusneset 1 August (NPB). In the Adventfjorden area, 11 adults and 2 young were observed in July, and in van Mijenfjorden/Nordenskiöld Land, 5 adults were seen in August (EA/PHP).

Table 4
Observations of brent goose (Branta bernicla hrota) *in Svalbard in 1974*
Наблюдения черных казарок (*Branta bernicla hrota*) на Свальбарде в 1974 г.

Locality/date Местность	Number Число	Observer/remarks Наблюдатель/примечания
Kapp Mineral, 2/7	4 ad	J. Åkerman
Kvalpynten, 8–9/8	9 ad	J. Thomassen/K. Kastnes
Slettvika, 7/8	4 ad	E. Alendal/P. H. Petersen
Eungane, 21/8	3 ad	,,
Lågnesrabbane, 22/8	2 ad	,,
Finsterwalderbreen, 17/8	15 ad[1]	O. Salvigsen
Davisdalen, 16/8	13 ad[1]	,,
Dunderdalen, 12/8	20–25 ad[1]	,,

[1] May have been pink-footed goose.

Golden plover (*Pluvialis apricaria*): One adult was seen on Nordkapp, Bjørnøya 22 May (Bj.rad). 10 observations were made in Littledalen and Reindalen in early August. One pair was probably breeding (EA/PHP).

Dotterel (*Eudromias morinellus*): Four adults and one young were seen in the Longyearbyen area 28 July (TW).

Turnstone (*Arenaria interpres*): Four pairs were observed at Ny-Ålesund in early July (WBH). Later in the month, at least one pair had three young (NPB). 12 adults and one young were seen at Kapp Linné 9 July (JÅ). Three adults were seen in Ebeltofthamna 7 August (HS).

Bar-tailed godwit (*Limosa lapponica*): 55 adults were seen at Sassenelva 31 July (TMD/TMS). One adult was seen at Sundodden 19 August (EA/PHP).

Redshank (*Tringa totanus*): One adult was seen on Kvadehuksletta 16 July (TMD/TMS).

Knot (*Calidris canutus*): Four adults were seen on Kvadehuksletta 16 July (TMD/TMS).

Little stint (*Calidris minuta*): Two adults were seen in Gipsvika 3 August (TMD/TMS).

Dunlin (*Calidris alpina*): Two adults were seen on Fivelflyane 21 July (EA/PHP). 3 adults were seen in Ny-Ålesund 30 July (NPB), two in Ebeltofthamna 7 August (HS), and one off Revnosa 16 August (KH/IK).

Sanderling (*Crocethia alba*): Five adult birds and one nest were found on Kvadehuken 16 July (TMD/TMS). Three adults were seen in Ekrollhamna 17 August (JT/KK).

Table 5

Observations of barnacle goose (Branta leucopsis) *in Svalbard in 1974*

Наблюдения белощеких (*Branta levcopsis*) на Свальбарде в 1974 г.

Locality/date Местность/дата	Number Число	Observer/remarks Наблюдатель/примечания
Hopen Radio, 17/4	2 ad	Hopen Radio
Tobiesenelva, 19/5	20 ad	Bjørnøya radio
Griegfjellet, 10/7	2 ad	J. ÅKERMAN
Nottinghambukta, 2/7	30 ad, 40 young	K. BIRKENMAJER
Hyttevika, 3/8	25 ad, 20 young	,,
Gnålodden, 29/7	40 ad	,,
Rålstranda, mid September	approx. 150 ad	,,
Hessbreen, 23/8	approx. 65 ad	O. SALVIGSEN[1]
Gravsjøen, July	approx. 40 ad	T. M. VAN DIJK/T. M. VAN SPANJE (21 nests, mean clutch size 3.9)
Orustdalen-Reindalen, August	approx. 700 ad, 20 young	E. ALENDAL/P. H. PETERSEN (in flocks of various sizes)
Kapp Martin, 1/8	20 ad, 30 young	J. THOMASSEN/K. KASTNES
Kvalpynten, August	—	J. THOMASSEN/K. KASTNES (observed daily, 18/8, 19 ad)
Nyströmøya, 7/8	1 ad	T. FJELD
Bourbonhamna, 8/8	30 ad	W. B. HARLAND (feeding)
Kjellströmdalen, 14/8	20 ad	,, (on a lake)

[1] O. SALVIGSEN made observations of 220 unidentified geese in Recherchefjorden in late August, and of 180 in Dunderdalen in mid August.

Table 6

Observations of Spitsbergen ptarmigan (Lagopus mutus hyperboreus) *in Svalbard in 1973 and 1974*

Наблюдения шпицбергенских тундряных куропаток (*Lagopus mutus hyperboreus*) на Свальбарде в 1973–1974 гг.

Locality/date Местность/дата	Number Число	Observer/remarks Наблюдатель/примечания
Lomfjorden, 13/4–73	approx. 100 ad	Longyearb. Jeger- og Fisker-forening
Davisdalen, 11/7	Nest w. 10 eggs	W. B. HARLAND
Davisdalen, 13/7	Female w. 12 chicks	,,
Davisdalen, 14/7	Female w. 8 chicks	,,
Zeipelfjellet, 4/8	Female w. 6 chicks	T. WINSNES
Longyearbyen, 25/7	2 females w. 11 chicks	,,
Kapp Linné, 4/7	Female w. 6 chicks	J. ÅKERMAN
Bockfjorden, 10/8	Female w. 7 chicks	E. SENDSTAD
Kongressfjellet, September	4 females w. 23 chicks	SEVMORGEO
Vestfjorden, August and September	10 ad, 60 chicks	,,

Table 7

Observations of colonies of ivory gull (Pagophila eburnea) *in Svalbard in 1974*

Наблюдения колоний белых чаек (*Pagophila eburnea*) на Свальбарде в 1974 г.

Locality/date Местность/дата	Number Число	Observer/remarks Наблюдатель/примечания
NW Bendefjellet, 30/7	30 ad, 28 nests	K. Birkenmajer
Polakkfjellet, 2/8	5–6 ad w. nests	,, (found in 1962)
Låghumpane, 1/8	32 ad, probably 20 nests or more	NPB
Retziusfjellet, mid August	approx. 33 nests in 3 breeding localities	,, (one chick in most nests, various ages)
N. Agardhfjellet, mid August	38 ad w. nests	K. Huseby/I. Kristensen

Red-necked phalarope (*Phalaropus lobatus*): Three adults were seen at Kapp Linné 4 July, and one in Longyearbyen 15 July (JÅ). One adult male was seen at Adventpynten 8 July (EA/PHP).

Pomarine skua (*Stercorarius pomarinus*): The bird was relatively common in the drift ice in Erik Eriksenstretet in late July. 19 adults were observed in a flock of kittiwakes (*Rissa tridactyla*) at Kapp Åkerhielm 20 August (NPB).

Great skua (*Catharacta skua*): One adult was seen off Nordkapp, Bjørnøya, 15 April, and another at Miseryfjellet 23 May (Bj.rad). One adult was seen in Forlandssundet 6 July (WBH), and one at Nordneset 23 August (NPB).

Ivory gull (*Pagophila eburnea*): See Table 7.

Great black-backed gull (*Larus marinus*): One adult was observed at Nordkapp, Bjørnøya, 12 April, two at Bjørnøya Radio 27 April and two at Austervåg 2 May (Bj.rad). One adult was observed at Ytterdalselva 30 August (EA/PHP) and one pair was found breeding at the entrance of van Keulenfjorden (WBH).

Black-headed gull (*Larus ridibundus*): Three adults were seen at Bjørnøya Radio 20 May (Bj.rad). Probably one single bird was independently observed at Ny-Ålesund 14 July (TMD/TMS) and at Brandalpynten the same day (HS).

Sabine's gull (*Xema sabini*): Two adults were observed at Kapp Koburg 9 August (NPB).

Arctic tern (*Sterna macrura*): This species was less abundant in the eastern areas. But on 23 August, a flock of more than 60 adults were seen on Kongsøya, probably on migration (NPB).

Snowy owl (*Nyctea scandiaca*): One adult was probably seen at Hopen Radio 13 February (Hop.rad). One adult was seen at Nordkapp, Bjørnøya 12 March (Bj.rad), one in Adventdalen 8 August (FK), one adult male on Kongsøya 18 August (NPB), and one adult female on Årdalstangen 12 and 18 August (JT/KK).

Swallow (*Hirundo rustica*): One adult was seen at Bjørnøya Radio 14 May (Bj.rad).

Raven (*Corvus corax*): One adult was seen at Hopen Radio in August 1973 and another on 2 March 1974 (Hop.rad).

Hooded crow (*Corvus cornix*): One adult was seen several times at Hopen Radio between 22 January and 10 February (Hop.rad).

Fieldfare (*Turdus pilaris*): One specimen was found dead near Kapp Wijk (TMD/TMS).

Redwing (*Turdus iliacus*): Two adults were observed at Bjørnøya Radio 12 April. One adult was observed on 14 April, 26 May and 2 June (Bj.rad). One dead specimen was found at Stormyrvatna 3 August (EA/PHP).

Blackbird (*Turdus merula*): One adult was observed at Bjørnøya Radio between late March and mid April (Bj.rad).

Wheatear (*Oenanthe oenanthe*): Two adults with four young were seen at Isfjord Radio in the first half of July (JÅ). One adult was observed in Adventdalen 7 July and one in Colesdalen 14 July. One adult and two young were seen at Langnosa 10 August, and two adults were seen in Reindalen 11 August (EA/PHP).

Whinchat (*Saxicola rubetra*): One adult was seen at Ny-Ålesund 13 September (TMD/TMS).

Spotted flycatcher (*Muscicapa striata*): One adult was captured and banded at Kvalpynten 15 August (JT/KK). This is the first observation of the species in Svalbard (Fig. 1).

Meadow pipit (*Anthus pratensis*): One adult was seen in Colesbukta 5 September (TMD/TMS).

Starling (*Sturnus vulgaris*): 10 adult birds were seen at Bjørnøya Radio in mid November 1973 (Bj.rad).

Redpoll (*Carduelis flammea*): One adult was seen in Skansbukta 11 August (TMD/TMS). Another possible observation was made in Harlowfjellet 21 August (WBH).

Lapland bunting (*Calcarius lapponicus*): One adult female followed the boat between Bjørnøya and the mainland 4 September (NPB).

House sparrow (*Passer domesticus*): One adult male was observed from and on the boat at Bjørnøya 13 June (JÅ).

References

ALENDAL, A., 1976: The muskox population in Svalbard. *Norsk Polarinstitutt Årbok* 1974.

ALENDAL, A. and I. BYRKJEDAL, 1976: Population size and the reproduction of the reindeer on Nordenskiöld Land, Svalbard. *Norsk Polarinstitutt Årbok* 1974.

ANDERSON, A., L. CAMPBELL, W. MURRAY, D. P. STONE, and R. L. SWANN, 1974: Spitsbergen 1972 – ornithological work of the Aberdeen University expedition. *Scottish Birds* **8** (2), 53–62.

Norsk Polarinstitutts virksomhet i 1974

AV KAARE Z. LUNDQUIST[1]

Organisasjon og administrasjon

PERSONALE

Norsk Polarinstitutt hadde 34 faste stillinger i 1974, det samme som foregående år. DAVID WORSLEY fratrådte sin stilling som geolog II den 19.5. REIDAR MANDT ble ansatt som karttegner II fra 14.1. Karttegner II MAGNE GALÅEN er etter søknad innvilget ett års invalidepensjon med virkning fra 1.3.

Med virkning fra 1.1. 1974 ble stillingene som glasiolog, geolog I og II, operasjonssjef, meteorolog, geofysiker II og biolog (i alt 11 stillinger) omgjort til forskerstillinger, fordelt med 3 stillinger som forsker I, 4 stillinger som forsker II og 4 stillinger som forsker III.

Den faste staben:

Direktør:	GJELSVIK, TORE, dr. philos.
Underdirektør:	LUNDQUIST, KAARE Z., o/kapt.
Kontorsjef:	LUND, REIDAR, cand. jur.
Forsker I:	
Glasiolog	LIESTØL, OLAV, cand. real.
Geolog, opr.sjonssjef:	SIGGERUD, THOR, cand. real.
Geolog	WINSNES, TORE, cand. real.
Forsker II:	
Meteorolog	HISDAL, VIDAR, cand. real.
Geolog	MAJOR, HARALD, cand. real.
Geolog	OHTA, YOSHIHIDE, Ph. D.
Glasiolog	ORHEIM, OLAV, Ph. D.
Havisforsker	VINJE, TORGNY E., cand. real.
Forsker III:	
Geolog	HJELLE, AUDUN, cand. real.
Biolog	LARSEN, THOR, cand. real.
Geolog	SALVIGSEN, OTTO, cand. real.
Geolog	WORSLEY, DAVID, Ph. D. Til 19/5. Stillingen ledig ut året.

[1] Rapportene fra de forskjellige fagområder er utarbeidet ved de respektive avdelingsledere.

Førstehydrograf:	HORNBÆK, HELGE, høyere skipsførereksamen.
Hydrograf I:	CHRISTIANSEN, JOHAN H., kapt.lt.
Førstetopograf:	HELLE, SIGURD G., cand.mag.
Topograf i særkl.:	BJØRKE, JAN TERJE, jordskiftekandidat.
	SUNDSBY, JOHN, cand. real.
Geodet I:	STEINE, OLA, jordskiftekandidat.
Konsulent I:	HAGEVOLD, PETER, cand. mag.
Inspektør:	ARNESEN, BJØRN E.
Karttegner II:	GALÅEN, MAGNE, Invalidepensjon fra 1.3.
	MANDT, REIDAR, fra 14.1.
Bibliotekar:	LUND, REIDUNN
Ingeniør:	NETELAND, EINAR
Materialforvalter:	BRATLIEN, KÅRE M.
Regnskapsfører:	ANDERSEN, EVA
Kontorfullm. i særkl.:	ØVERLAND, SIGNE
Laborant i særklasse:	VABRÅTEN, KNUT J.
Kontorfullmektig II:	EDVARDSEN, GUDRUN
	DANIELSEN, KIRSTEN
Kontorassistent I:	JOHANSEN, PER H.

Midlertidig engasjerte:

BREKKE, ANNEMOR,	redaksjonssekretær
EDWARDS, MARC B., Ph. D.	(Lønnet av NTNF på Barentshavprosjektet)
HUSETH, ROLF EGIL,	assistent
KNUDSEN, ELSA,	kontorassistent
KRISTIANSEN, IVAR RENDAL,	cand.mag.
LIEN, MAI-BRITT,	tegner II. Fra 11.11.

Stipend og forskningsbidrag er ytt til:

Cand.mag. BJØRN WOLD, stipend til dekning av reise- og oppholdsutgifter i Ny-Ålesund i forbindelse med feltarbeider til hovedfagsoppgave i glasiologi.

Cand.mag. KARI PEDERSEN, stipend til dekning av utgifter i forbindelse med feltarbeider på Briksdalsbreen til hovedfagsoppgave i glasiologi.

Dr.philos. HANS STAALAND, stipend for spesielle undersøkelser av alkekonger ved fysiologiske målinger på Svalbard.

Amanuensis THOR KVINGE, reisebidrag for deltakelse i Polar Ocean Conference, Montreal.

Naturverninspektør MAGNAR NORDERHAUG, bidrag til dekning av utgifter til to reiser til Stockholm i forbindelse med bearbeidelse av miljøgiftanalyser på biologisk Svalbard-materiale.

Cand.real. OLAV HJELJORD, stipend til analyser av prøver i forbindelse med bearbeidelse av materiale om Svalbardreinens økologi.

Det Kgl. Norske Videnskabers Selskab, Museet, stipend til dekning av reiseutgifter for to mann i forbindelse med botaniske undersøkelser på Svalbard.

Forskningsstipendiat NILS A. ØRITSLAND, reisestipend til dekning av reiseutgifter tur/retur Fort Churchill, Canada, i forbindelse med et prosjekt for isbjørnundersøkelser.

Cand.mag. BJØRN OLAV ROSSELAND, stipend til dekning av utgifter i forbindelse med fysiologiske undersøkelser på Svalbardrøye.

Cand.real. NILS GULLESTAD, stipend til dekning av utgifter vedrørende aldersbestemmelse for polarrev fra Svalbard.

Oppnevnelser og tillitsverv:

GJELSVIK (1) kallet til medlem av Det Norske Videnskaps-akademi i Oslo, (2) oppnevnt til medlem av Styringsgruppen for Man and Biosphere (MAB)-prosjektet, (3) valgt til president for Scientific Committee on Antarctic Research (SCAR) for perioden 1974—78.

OHTA oppnevnt som medredaktør av tidsskriftet *Pacific Geology*, Tokai Univ. Press., Tokio.

VINJE oppnevnt som medlen av Den norske nasjonalkomité for Global Atmospheric Research Programme (GARP).

REGNSKAP for 1974

Kap. 950. Poster:		*Bevilget*		*Medgått*
1. Lønninger	kr.	2.710.000	kr.	2.812.300
9. Deltaking i Antarktisekspedisjon	-	100.000	-	84.100
10. Kjøp av utstyr	-	35.000	-	34.500
15. Vedlikehold	-	3.000	-	2.700
20. Ekspedisjoner til Svalbard og Jan Mayen	-	2.265.000	-	2.371.300
21. Forskningsstasjonen på Svalbard	-	1.000.000	-	905.100
29. Andre driftsutgifter	-	1.079.000	-	1.151.600
70. Stipend	-	45.000	-	45.000
	kr.	7.237.000	kr.	7.406.600
Kap. 31. Fyr og radiofyr på Svalbard	kr.	38.000	kr.	41.000
Kap. 3950. Inntekter:		*Budsjettert:*		*Regnskap:*
1. Salgsinntekter	kr.	70.000	kr.	85.700
2. Refusjon fra Svalbardbudsjettet	-	550.000	-	550.000
3. Andre inntekter	-	10.000	-	0
	kr.	630.000	kr.	635.700
Kap. 4909. Tilfeldige inntekter	kr.	0	kr.	790

Kap. 950.

Post 20. Ekspedisjoner til Svalbard og Jan Mayen. — Finansdepartementet samtykket i at denne post ble overskredet med inntil kr. 410.000,—. Samlet bevilgning blir da kr. 2.675.000,—. Mindreforbruket skyldes vesentlig at toktet med hydrograferingsfartøyet «Olaf Scheel» ble avbrutt på grunn av havari.

Post 21. Forskningsstasjonen på Svalbard. — Mindreforbruket, kr. 94.900, — skyldes vesentlig at det heller ikke i år har vært ansatt forsker som stasjonsbestyrer (i stedet for vit.ass.), samt en restriktiv holdning til andre utgifter i påvente av en omorganisering i driften av stedet Ny-Ålesund.

Feltarbeid

NORGE

Glasiologi

De rutinemessige målinger av breenes massebalanse på Storbreen og Hardangerjøkulen ble utført av LIESTØL med assistanse av hovedfagsstudenter. På Supphellebreen og Blomsterskardsbreen ble forenklede balansemålinger foretatt av henholdsvis ORHEIM og ARVE TVEDE. På samme måte som året før viste alle et overskudd vesentlig på grunn av stor vinternedbør.

Målinger av bretungenes lengdevariasjoner ble foretatt på 12 steder: 2 ved Folgefonni, 2 i Jotunheimen, 5 ved Jostedalsbreen, 2 på Møre og 1 ved Svartisen. 4 viste fremgang, 3 stillstand og 5 tilbakegang. Mest bemerkelsesverdig var fremgangen på Styggedalsbreen og Austerdalsbreen som har vært i kontinuerlig tilbakegang de siste 50 år.

SVALBARD

Norsk Polarinstitutts sommerekspedisjon til Svalbard og Jan Mayen ble organisert og ledet av operasjonssjef SIGGERUD og omfattet, foruten besetningene på fartøyer og helikoptre, 39 personer, herav 4 på Jan Mayen og 2 i Norge. Økningen i antall deltakere fra 33 i fjor skyldes den nedkuttede ekspedisjonstiden, og at noen var med på ganske korte prosjekter. Av deltakerne var 15 instituttets faste medarbeidere, 4 engasjerte fagmedarbeidere, 16 var assistenter og 4 var mannskap på hydrograferingsbåten «Svalis».

To biologer fra Universitetet i Bergen fikk assistanse av ekspedisjonen og arbeidet i området sør for Isfjorden.

En gruppe botanikere fra Universitetet i Trondheim fikk støtte ved feltarbeid på Reinsdyrflya.

Hovedvekten av arbeidet på Svalbard ble lagt i de østlige og sydøstlige deler med hydrografering, topografiske målinger og geologiske arbeider. Hydrografisk aktivitet var det også i Isfjorden, geofysiske arbeider i Ny-Ålesund og kvartær-geologiske undersøkelser i Van Keulenfjordområdet. Ekspedisjonens planlagte program ble gjennomført, bortsett fra avbrekket for sjøkartleggingen ved M/S «Olaf Scheel»'s grunnstøting. Se for øvrig rapporter fra de enkelte faggruppene.

Ekspedisjonsfartøyet M/S «Polarstar» med kaptein JOHAN HOLSTAD og 11 manns besetning ble overtatt i Bodø 25/7. Ekspedisjonsutstyret ble losset og deltakerne gikk fra borde i Bodø 5/9.

M/S «Olaf Scheel» med kaptein I. ANGELSHAUG som skipssjef og 7 manns besetning, var leid av Statens Skjermbildefotografering. Fartøyet ble ved Framnæs mek. verksted i Sandefjord ombygget og spesialinnredet for kartleggingsformål på Svalbard, og overtatt av toktlederen hydrograf CHRISTIANSEN i Bodø 25/7. På grunn av grunnstøting ble fartøyet tilbakelevert allerede 13/8.

Til transporter fra M/S «Polarstar» og ut i felten var 2 Bell 47 J helikoptre med 2 flyvere og 1 mekaniker leiet fra Helikopter Service A/S. Fartøyet satte først ut geologpartiet SALVIGSEN i Van Keulenfjorden og hentet helikoptrene som var kommet med kullbåt til Longyearbyen. Deretter gikk «Polarstar» rundt nordsiden og begynte arbeidet for topografene nordligst i Hinlopenstretet. Geologene ble etterhvert satt ut og senere forflyttet, vesentlig på Nordaustland-siden.

Et biologparti ble satt ut på Kong Karls Land. Etter avslutning av topografarbeidet og henting av biologpartiet ble øst- og nordkysten av Nordaustlandet rekognosert for å registrere dyrelivet, spesielt eventuelle hvalross. Via Ny-Ålesund gikk fartøyet til Longyearbyen, hvor helikoptrene ble landsatt for hjemsendelse med kullbåt. På nedtur ble geologparti SALVIGSEN hentet i Van Keulenfjorden. Under hele ekspedisjonen ble det gjort biologiske registreringer fra ekspedisjonsfartøyet, delvis også ved bruk av helikoptre og småbåt.

Sommerens dramatiske begivenhet var «Olaf Scheel»'s grunnstøting 12/8 som førte til en ukes avbrekk for arbeidet på «Polarstar». Imidlertid fikk topografene benyttet noe av tiden til å fullføre den gjenværende rest av måleprogrammet på Edgeøya.

Værforholdene var den første del av sommeren helt ualminnelig gode og muliggjorde store landmålingsarbeider. Tåkeperioder var det som vanlig i siste del av sommeren og kraftig vind hindret da også delvis arbeidet.

Issituasjonen var god med lite eller ingen is størstedelen av sommeren. Bare ved landsetting på Kong Karls Land var det virkelige ishindringer som ble overkommet ved hjelp av helikoptrene.

Hydrografi

I feltsesongen (15/7—15/9) utførte HORNBÆK, assistert av SIVERT UTHEIM og BJØRN FJELD samt engasjert hydrograf KJELL-OLAV PETTERSEN, assistert av ERLING BROCH SVENSSON og INGE FJELD, lodding i Billefjorden og rundt Gåsøyane med hydrograferingsbåten «Svalis».

Hydrograferingstoktet i år med M/S «Olaf Scheel» ble ledet av CHRISTIANSEN. NETELAND hadde tilsyn med vedlikehold og drift av HI-FIX-systemet og annet elektronisk utstyr.

Som assistenter hadde man IVAR RENDAL KRISTENSEN og KJELL HUSEBY på Agardhpynten og JØRN THOMASSEN og KNUT KASTNES på Edgeøya til å passe HI-FIX slavestasjonene.

Etter ønske fra fiskeriorganisasjonene ble det lagt ut 4 stk. merkebøyer på Forlandsrevet for å lette navigasjonen for reketrålerne som trafikerer farvannet. Båkene på Sarstangen og Murraypynten ble gjenoppbygget og malt med fluoriserende maling. Disse arbeider samt ettersyn av radio og lysfyrene gikk uten vanskeligheter, og var fullført 5/8. Sysselmannsfartøyets besetning ble instruert om opptaking og utlegging av merkebøyene.

Da isforholdene i Storfjorden var meget gunstige, ble det besluttet å starte opploddingen i nordre del av fjorden og arbeide seg sydover. HI-FIX slavestasjonene, som ble etablert på Edgeøya nord for Kvalpynten og på Agardhpynten, var på luften om ettermiddagen 9/8. Opploddingen ble påbegynt og fortsatte uten avbrudd til fartøyet grunnstøtte 0810, 12/8 rett vest av Mistakodden. Toktet ble avbrutt 13/8 og CHRISTIANSEN og NETELAND returnerte til Norge med første hurtigrute etter at utstyr etc. var tatt ombord i M/S «Polarstar».

I alt rakk man å lodde ca 500 n mil med loddelinjer med en linjeavstand på 20 lanes.

Geodesi — topografi

De geodetiske og topografiske feltarbeidene ble utført av BJØRKE, DAG BJØRKEDAL (engasjert for sesongen), STEINE (leder) og SUNDSBY med TORSTEIN FJELD, TOR JACOBSEN, IVAR LUND-MATHIESEN og OLVE WENDELBO som assi-

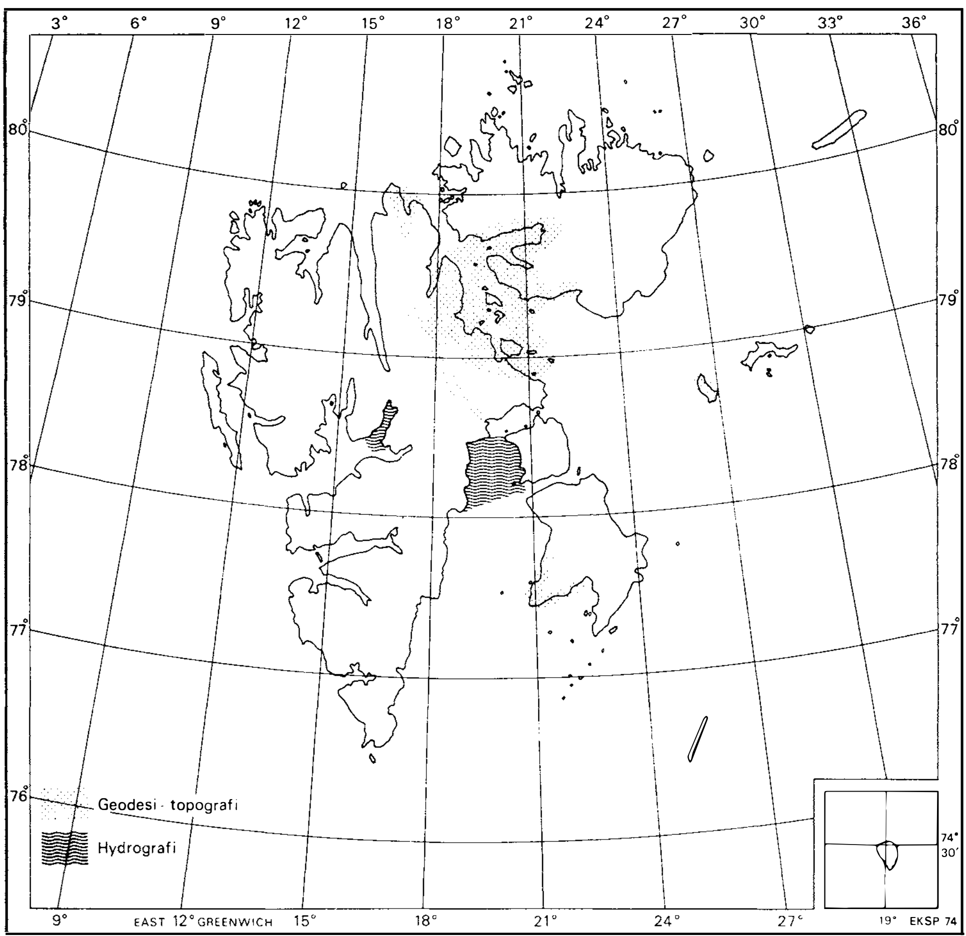

Fig. 1. *Geodetiske, topografiske og hydrografiske arbeidsområder i 1974.*

stenter. Alle reiste til og fra Svalbard med ekspedisjonsbåten M/S «Polarstar» som også var base for landmålerpartiene. De to helikoptrene ombord ble brukt som fremkomstmiddel.

Oppgaven var å utvide triangelnettet og å måle passpunkt på begge sider av Hinlopenstretet og på øyene der for kartlegging i målestokk 1:100 000. — I tillegg til arbeidet i det nevnte området ble det anledning til å utføre noen supplerende målinger på sørvestsiden av Edgeøya mens M/S «Polarstar» assisterte M/S «Olaf Scheel». Ca. 100 punkter ble innmålt.

Geologi

I det geologiske feltarbeidet deltok 4 partier.

WINSNES med assistent STEIN NYBAKKEN, og EDWARDS med assistent TRYGVE HANSEN arbeidet dels med base i ekspedisjonsfartøyet, dels med leire på land på sørlige del av Nordaustlandet og øyer i Hinlopenstretet. I forbindelse med avbrekket ved forliset til M/S «Olaf Scheel» ble også Agardhfjellet besøkt. Arbeidet var dels kartlegging, dels opptagning av stratigrafiske profiler med prøveinnsamling i forbindelse med Barentshavprosjektet.

GJELSVIK med assistent NYBAKKEN arbeidet ut fra Forskningsstasjonen i Ny-Ålesund og på Prins Karls Forland i tiden 4/7—20/7.

SALVIGSEN med assistentene SVEIN STURØD og HALLGEIR MATRE arbeidet med kvartærgeologiske studier og kartlegging i Van Keulenfjorden 29/7—2/9.

Geofysikk

Massebalansemålingene på breene ved Ny-Ålesund ble fortsatt på samme måte som året før. I mai og juni foretok LIESTØL med assistanse av BJØRN WOLD målinger på Finsterwalderbreen og Hessbreen. Hessbreen hadde i løpet av vinteren foretatt et kraftig fremstøt og ble derfor ofret spesiell oppmerksomhet. BJØRN WOLD og KJELL REPP (hovedfagsstudenter) fortsatte sine undersøkelser av Brøggerbreen og utførte meget av det praktiske arbeid.

HISDAL oppholdt seg ved Forskningsstasjonen i Ny-Ålesund i tiden 5/7—9/8, og foretok en rekke målinger av intensitetsfordelingen av direkte og diffust spredt solstråling. Spesielt ble innflytelsen på måleresultatene av den diffuse himmelstrålings polarisasjon nærmere undersøkt. Han stod videre for flyttingen av den meteorologiske stasjon fra den tidligere ESRO-stasjon ned til sentrum av bebyggelsen i Ny-Ålesund.

VINJE oppholdt seg samme sted fra 20/7 til 16/8. Han overhalte strålingsinstrumentene og foretok kalibreringer i kort- og langbølgeområdet. Ventileringsstrømmen fra viftene ble fordelt til flere instrumenter for å holde disse fri for rim og snø. Datologgeren har i år gått noenlunde kontinuerlig, registreringene kompletteres med data fra en skriver som går parallelt.

Biologi

LARSEN med assistent ROAR AABAKKEN arbeidet med faunistisk kartlegging og isbjørnundersøkelser på Kong Karls Land 3—28 august. Arbeidet ble særlig konsentrert om feltobservasjoner av bjørn for studier av døgnrytme og sosial

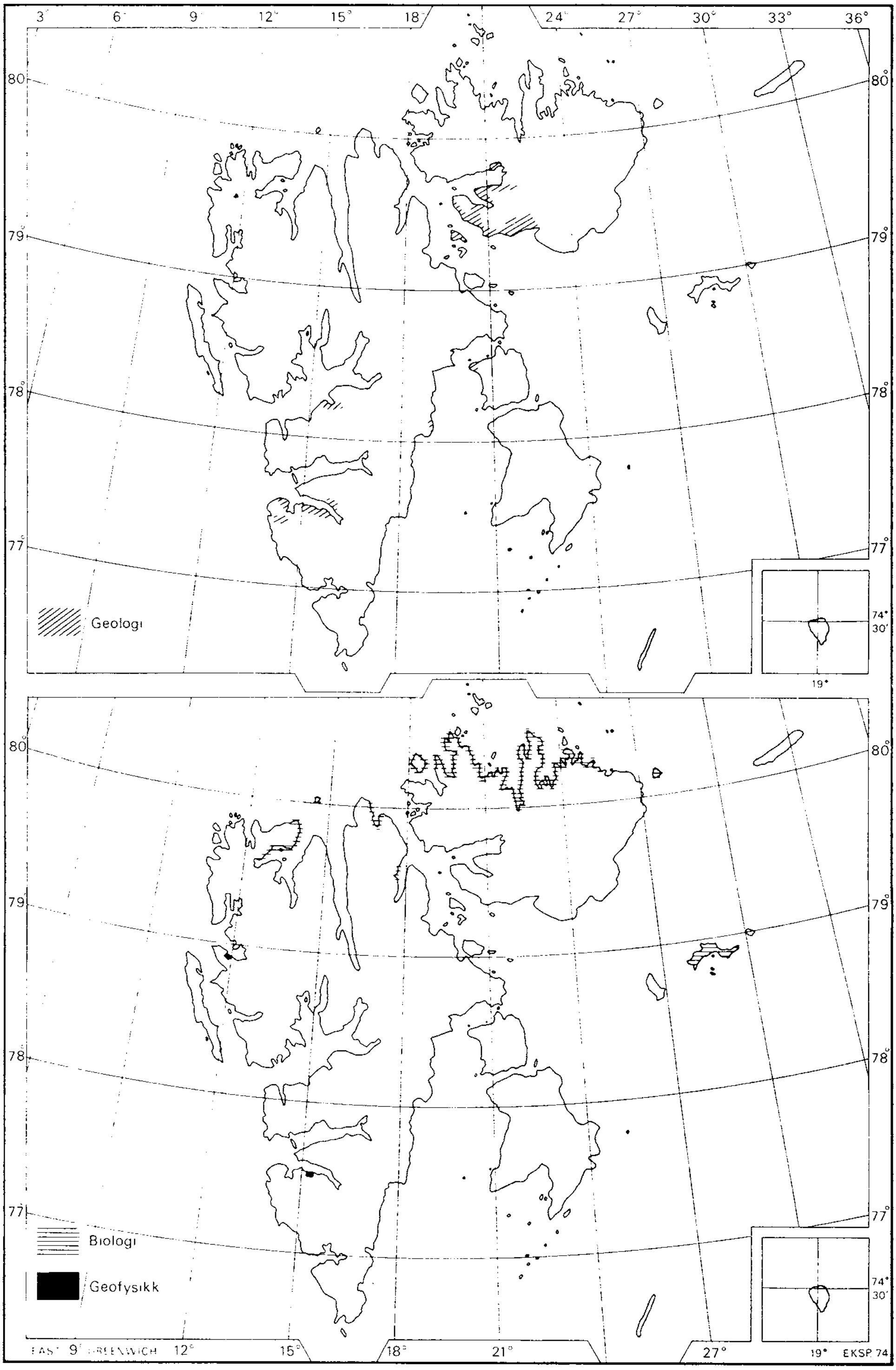

Fig. 2. *Geologiske, biologiske og geofysiske arbeidsområder i 1974.*

adferd. 7 bjørn ble fanget og merket. Det ble samlet inn ekskrementprøver og kranier av selvdøde bjørn for senere bearbeidelse. Partiet fikk også anledning til å gjøre faunistiske registreringer langs deler av Liefdefjorden, Moffen og langs Nordaustlandets nordkyst. Faunistiske observasjoner ble samlet inn fra en rekke hold: fra Norsk Polarinstitutts øvrige feltpartier, fra diverse ekspedisjoner som hadde mottatt støtte fra Norsk Polarinstitutt, fra værstasjonene Bjørnøya og Hopen og fra flere utenlandske ekspedisjoner.

Fyr og radiofyr

Ettersyn av fyr og radiofyr ble foretatt i tiden 29/7—3/8 av NETELAND, assistert av ekspedisjonsdeltakere og besetningsmedlemmer på M/S «Olaf Scheel». Fyrene på Fuglehuken, Blåhuken og Rudmosepynten ble bygget om fra gass til elektrisk drift. De tre fyrene som ble bygget om i 1973 ble kontrollert, og det viste seg at de hadde fungert tilfredsstillende.

Planene om å montere en vindgenerator ved et av radiofyrene for lading av akkumulatorbatteriene, ble utsatt inntil videre. Generatoren, som er montert på prøve i Ny-Ålesund, bør utprøves ytterligere før den monteres ved radiofyr, der den vil være uten regelmessig tilsyn.

JAN MAYEN

Ved imøtekommenhet fra Forsvarets fellessambands side, særlig i forbindelse med transportspørsmålet, ble det mulig å foreta glasiologiske og geologiske undersøkelser på Midt- og Sør-Jan Mayen.

ORHEIM, assistert av KNUT LIESTØL, utførte i tiden 15/6—22/6 massebalansemålinger på Sørbreen.

Den islandske geolog PÁLL IMSLAND assistert av WERNER KARLSSON arbeidet i tiden 25/7—23/8 med kartlegging av lavastrømmene og innsamling av prøver.

ANTARKTIS

Tre norske grupper foretok feltarbeid i Antarktis i 1974, alle med logistisk støtte fra National Science Foundation.

I januar var ORHEIM, med amerikansk assistent, på Deception Island og Livingston Island og innsamlet snøprøver for isotopstudier og foretok massebalansemålinger.

Glasiologene LIESTØL og ORHEIM deltok i november ved et kjerneboringsprosjekt på Amundsen-Scott Sydpolstasjonen, hvor et 100 m dypt hull ble boret under stasjonen.

På den norske Antarktis-ekspedisjon november 1974 til februar 1975 deltok HJELLE, OHTA, WINSNES og KJELL REPP. Det geologiske feltarbeide ble utført i den sydlige del av Ellsworth-fjellene, mellom 79° og 80°S og 80° og 85°V. Arbeidet bestod i stratigrafiske tektoniske undersøkelser av lagrekkene i to snitt gjennom fjellkjeden, undersøkelser anbefalt av SCAR og av betydning for den generelle forståelse av Antarktis' geologiske oppbygging.

Arbeid ved avdelingene

(Se også under publikasjoner)

Hydrografi

HORNBÆK beregnet middelvannstand for Ny-Ålesund på grunnlag av tidevannsregistreringer. Han foretok redaksjonelle arbeider på sjøkartene 505, 509 og 522 i forbindelse med trykking av nye opplag og forberedte nye utgaver av sjøkartene 502 og 503.

CHRISTIANSEN overførte lodderesultatene fra 1972 i området Hopen—Kong Karls Land til loddeoriginal. Resultatene ble senere bearbeidet og redigert for sjøkart 505. I forbindelse med ombyggingen av M/S «Olaf Scheel» hadde han sammen med overingeniør SØNDENÅ planlegging og tilsyn med de arbeider og montasjer som ble rekvirert av Norsk Polarinstitutt.

Geodesi—topografi

En del beregninger av sommerens målinger, i kombinasjon med eldre målinger på Svalbard, ble utført. I serien Svalbard 1:100 000 ble kartbladene C8 Billefjorden og D9 Agardhfjellet konstruert. Det ble også arbeidet med C11 Kvalvågen og ny utgave av C9 Adventdalen i samme serien. Rosenbergdalen på Edgeøya (Svalbard) ble konstruert i målestokk 1:10 000 med 10 m's koter. For geologisk avdeling ble konstruert tre pingoer i Chamberlindalen og to pingoer i Dunderdalen på Spitsbergen (Svalbard) i målestokk 1:2 000 med 2 m's koter. Kartbladene N5 Forposten og N6 Sarkofagen i serien Dronning Maud Land 1:250 000 er ferdige til trykking.

Geologi

EDWARDS (under Barentshavsprosjektet) utarbeidet flere artikler til fagtidsskrifter. Etter sommerens Svalbardekspedisjon bearbeidet han bergartsprøver samlet under ekspedisjonen. Han samlet også opplysninger om lagrekkene på Svalbard ved besøk til England og holdt flere foredrag, som senere vil bli publisert.

HJELLE samarbeidet med F. R. ROOTS, Canada om en beskrivelse av bergartsprøver fra Maudheimekspedisjonen. Han gjorde også forberedende studier i forbindelse med Antarktisekspedisjonen 1974/75.

MAJOR foretok kullpetrografiske studier av kull fra Longyear gruve og fra Svea. I januar—februar foretok han befaring av diverse gruver på Svalbard. Han arbeidet også med Statens utmål på Svalbard ved deltakelse i utmålsforretninger og nye utmålsbegjæringer.

OHTA utførte kjemiske og elektronmikroskopiske spesialanalyser av bergarter fra Smeerenburgfjorden og St. Jonsfjorden og utarbeidet manuskript over undersøkelser av feltspat.

SALVIGSEN skaffet seg en oversikt over Svalbards kvartærgeologi ved litteraturstudier og studier av flybilder. Etter sommerens ekspedisjon er feltobservasjoner under bearbeidelse.

WINSNES har vesentlig vært beskjeftiget med administrative oppgaver vedrørende den geologiske avdeling og forberedelser til Antarktisekspedisjonen.

I forbindelse med utmålsbegjæring over funnpunkter i Agardhområdet deltok han i bergmesterens kontroll av funnpunktene.

Alle geologene har ved siden av sitt ordinære arbeid også besvart forespørsler og vært saksbehandlere vedrørende geologien på Svalbard og i Antarktis.

Geofysikk

HISDAL fullførte en undersøkelse av fordelingen av skymengden og solskinnets varighet ved de norske ishavsstasjonene, og utarbeidet en oversikt over værforholdene på Svalbard i 1973. Regnearbeidet i forbindelse med strålingsobservasjonene fra Ny-Ålesund ble fortsatt, og en avsluttende analyse av de målte spektralfordelinger påbegynt.

LIESTØL bearbeidet glasiologisk, meteorologisk og annet feltmateriale fra Svalbard og Norge. Han var også veileder for 3 hovedfagsstudenter, holdt en forelesningssserie i glasiologi ved Universitetet i Oslo og var sensor i hovedfag limnologi og fysisk geografi.

ORHEIM bearbeidet glasiologisk feltmateriale fra Antarktis, Jan Mayen, og Norge. Arbeider om globale massebalansevariasjoner og om Syd-Shetlandsøyenes breer er ferdig. Videre utarbeidet han program for måling av masse- og varmetransport på undersiden av en isshelf. ERTS-1 satellittbilder fra Dronning Maud Land ble vurdert, og et program for studier av bilder fra ERTS-2-satellitten innsendt til og akseptert av NASA. Han var også veileder for en hovedfagsstudent.

VINJE utarbeidet isoversikt for den nordlige atlantiske sektor og beregnet driftshastigheter ut fra satellittbilder, og isbilder fra ERTS-1-satellitten ble analysert. Et program for studier av bilder fra ERTS-2-satellitten over Svalbardområdet ble innsendt til og akseptert av NASA. Bearbeidelsen av målingene tatt på Camp Norway II i forbindelse med studiet av friksjon og varmeutveksling mellom luft og snø ble avsluttet. Videre arbeidet han med utredninger angående havis m.m. i to komiteer.

Biologi

LARSEN bearbeidet faunistisk observasjonsmateriale, registreringer av isbjørnhi på Kong Karls Land og innsamlet feltmateriale fra 1974 for publisering. Tidligere års observasjoner er ført over til det nye kortsystemet. Fangstjournaler og kraniometriske data ble bearbeidet. Våren 1974 bisto han Grønlands Zoogeografiske Undersøgelse med planleggingen av den andre feltsesong i isbjørnprosjektet på Nordøst-Grønland. Cand.real. KARL HAGELUND bisto med bearbeidelse av faunaregistreringen.

Biblioteket

I 1974 ble det registrert 204 titler, herav bl.a. 31 innkjøpte bøker, 95 av gammel bestand, 64 sætrykk og småskrifter, 57 fra bytteforbindelser og 17 som gaver. Hertil kom tilgang fra ca. 200 publikasjonsserier fra bytteforbindelser og abonnementer.

Særtrykksamlingen er nå på 5 970 nummer. En ny bytteforbindelse er opprettet. Tilvekstliste er under utarbeidelse.

Registrerte utlån var i alt 540, derav 411 til instituttets personale, 95 til personer utenfra og 34 til andre biblioteker. Registrerte lån fra andre biblioteker var 39.

Konsulent- og informasjonsvirksomhet

I likhet med tidligere år har instituttet vært konsultert om polarspørsmål av norske myndigheter og av personer og institusjoner i inn- og utland.

Instituttet oversendte i januar departementet en utredning, som var utarbeidet under medvirkning av Fagkollegiet, om instituttets beliggenhet på lengre sikt. Utredningen har vært til behandling i Nasjonalkomitéen for Polarforskning, i Det Interdepartementale Polarutvalg, og i Polarrådet.

GJELSVIK deltok i januar og februar i forberedelsene til forhandlingene med en sovjetrussisk delegasjon om norsk-russisk vitenskapelig samarbeid og ble oppnevnt som formann i den norske forhandlingsdelegasjon. I mars deltok han i flere møter i UD i anledning statsminister Bratteli's besøk i Moskva.

Foruten LUNDQUIST har forskerne, innen sine respektive fagområder, besvart henvendelser fra massemedier vedrørende instituttets arbeidsoppgaver og virksomhet i polarstrøkene.

Forskningsstasjonen på Svalbard

Fra 1.1., 1974 gikk driften av Forskningsstasjonen i Ny-Ålesund inn som en del av Norsk Polarinstitutts normale virksomhet ved at stasjonens budsjett ble overført til instituttets vanlige driftsbudsjett Kap. 950, post 21.

I løpet av året skjedde det store forandringer i Ny-Ålesund idet ESRO-stasjonen ble nedlagt. Det så lenge ut til at det kunne bli praktisk umulig å fortsette driften av Forskningsstasjonen. Men 31.5., 1974 ble det oppnådd enighet med Kings Bay Kull Comp. A/S som grunneier at Forskningsstasjonens leierforhold kunne fortsette for sesongen 1974—75 på midlertidig basis. KBKC driver kraftstasjon, vannanlegg etc. og NP betaler en fast avgift på kr. 500 000 for disse ytelser.

Vinteren 1974/75 er det derfor en leirbesetning på 5 mann fra KBKC i Ny-Ålesund ved siden av de to engasjerte medarbeiderne ved NP's forskningsstasjon.

Virksomheten har fortsatt som tidligere, hovedsakelig med registrering av data for forskjellige vitenskapelige interesser som har prosjekter gående i Ny-Ålesund. Dataene sendes til Norge for bearbeidelse ved de institusjoner som er ansvarlig for det vitenskapelige program.

I 1974 hadde stasjonen en rekke offisielle besøk av bl.a. justisminister INGER LOUISE VALLE og ministerråd OLAV BUCHER-JOHANNESSEN med følge.

En rekke forskere, T. GJELSVIK, V. HISDAL og T. VINJE fra Norsk Polarinstitutt, L. H. JENNEBORG fra Gøteborg Universitet, K. AASGAARD fra Universitetet i Oslo og H. STAALAND fra Norges Landbrukshøgskole, arbeidet ved stasjonen i løpet av våren og sommeren. O. LIESTØL sammen med assistent B.

WOLD og to russiske glasiologer var ved stasjonen i mai —juni, og en gruppe på åtte mann under ledelse av O. I. RØNNING fra Universitetet i Trondheim benyttet stasjonen om sommeren. En del folk fra Universitetet i Tromsø oppholdt seg i sommermånedene ved stasjonen for å kontrollere anleggene og foreta nyinstallasjoner

Følgende virksomhet av noe omfang kan nevnes:

1. *Fotometer:*
   Oppdragsgiver: Nordlysobservatoriet, Tromsø. 4 kanaler senit fotometer med digital/analog utlesning i drift fra 10.11.,1973 til 1.2., 1974.
2. *Magnetometer:*
   Oppdragsgiver: Nordlysobservatoriet, Tromsø. Registreringene har gått som normalt hele perioden.
3. *Riometre:*
   Oppdragsgiver: Nordlysobservatoriet, Tromsø. Tre på 20, 27 og 30 Mhz i drift. Utstyret har etter nedleggelsen av ESRO-sambandet fungert tilfredsstillende.
4. *All-sky-camera:*
   Oppdragsgiver: Nordlysobservatoriet, Tromsø. Modifisert kamera tatt i bruk 10.11.,1973. Problem med ny, automatisk tidsmarkering som periodevis ødela registreringene. I drift til 15.3., 1974.
5. *Seismisk stasjon:*
   Oppdragsgiver: Jordskjelvstasjonen, Univ. i Bergen. Har gått som normalt, bortsett fra fire uker sommeren 1974, da det var en teknisk feil.
6. *Luftforurensingsmålinger:*
   Oppdragsgiver: Norsk Institutt for Luftforskning. Utstyr for måling av partikler i luft satt i gang 4.11., 1973. Prøvetagningen har blitt forstyrret av lokale forurensingskilder. Sektorsampler for eliminering av lokale kilder ventes ferdigmontert innen utgangen av 1974.
7. *Oseanografi:*
   Oppdragsgiver: Havforskningsinstituttet, Bergen. Tre målinger er tatt i stasjon A og fire i stasjon B i perioden 14.6. til 2.9., 1974. Det er vanskelig å få tatt prøvene. Slik værforholdene har vært ble utsetning av båten problematisk. I mørketiden er det ikke forsvarlig å ta prøvene.
8. *Meteorologi:*
   Oppdragsgiver: Meteorologisk Institutt, Oslo. Siden 15.9., 1974 er meteorologiske observasjoner blitt tatt tre ganger daglig, kl. 0630, 1230 og 1830.
9. *Strålingsmålinger:*
   Oppdragsgiver: Norsk Polarinstitutt. De fem viktigste strålingskomponenter for klimatiske undersøkelser har vært registrert hele året.
10. *Tidevannsmåler:*
    Oppdragsgiver: Norsk Polarinstitutt. Har gått normalt i perioden. Urverket reparert i november 1974.

11. *Glasiologi:*
    Oppdragsgiver: Norsk Polarinstitutt. Avlesning på akkumulasjonsstaker.
12. *Biologi:*
    Oppdragsgiver: Norsk Polarinstitutt. Registrering av generelle biologiske observasjoner, hele året.

Bemanningen i 1974 har vært:

FRED KLOKKERVOLD	14.12., 1973–15. 3., 1974
JENS ANGARD	21. 2., 1974–31.12., 1974
KJELL REPP	19.10., 1973–13. 9., 1974
DAG BJØRKEDAL	13. 9., 1974–31.12., 1974.

Reiser, møter og kursvirksomhet

GJELSVIK deltok i august i møte i Rovaniemi, Finland, for direktører ved de nordiske geologiske institusjoner. I september deltok han i det XIII møte i SCAR, som ble holdt i Jackson Hole, Wyoming. Under oppholdet i USA drøftet han den amerikanske hjelp til norsk feltvirksomhet i Antarktis med representanter for National Science Foundation, Office of Polar Programs.

I Norge har man deltatt i en rekke møter i Det interdepartementale Polarutvalg samt i to møter i Polarrådet, henholdsvis i Bergen og Tromsø. I Den Norske Nasjonalkomité for Polarforskning har det vært et møte i tillegg til et forberedende møte for forhandlingene med sovjetrusserne i februar.

BJØRKE deltok i mars i «Kartdagene 1974», som ble arrangert i Bergen av Norges Karttekniske Forbund.

BRATLIEN besøkte i mars Grønlands Geologiske Undersøgelse, København, for å studere danskenes logistiske opplegg for Grønlandsekspedisjonene.

EDWARDS besøkte i oktober Universitetet i Cambridge for å foreta bibliotekstudier i stratigrafi. I desember deltok han samme sted i en konferanse om sedimentologi.

HELLE, STEINE og SUNDSBY deltok i mai i Det 7. nordiske geodetmøte i København.

HISDAL deltok i juni i Det 9. nordiske meteorologmøte i Bergen.

HORNBÆK og NETELAND gjennomgikk i desember et kurs i Rotterdam for brukere av Motorola elektroniske posisjonssystem MRS-III.

LARSEN deltok i april i World Wildlife Fund International Congress i Morges, Sveits. I juni deltok han i First International Theriological Congress i Moskva og i desember i IUCN Polar Bear Specialist Group's møte i Morges, Sveits. Videre besøkte han i november Århus Universitet, for faglige drøftelser med representanter for Genetisk Institutt.

LIESTØL ledet sammen med ORHEIM et symposium, som ble arrangert i Fjærland i august for medlemmer av den nordiske seksjon i International Glaciological Society. I tilknytning til symposiet ble det foretatt ekskursjoner til Nigardsbreen, Austerdalsbreen og Supphellebreen.

LUND deltok i januar i kurs i personaladministrasjon, del II, som ble arrangert av Forbruker- og administrasjonsdepartementet på Klækken Turisthotell.

LUNDQUIST deltok i november som medlem av den norske delegasjon til Moskva i forhandlingene med Sovjet om grensespørsmål i Barentshavet. Han møtte i Polarutvalget noen ganger som varamann for GJELSVIK.

OHTA gjennomgikk i februar et kurs i mikroskopstudier av gloucofan-skifer ved Universitetet i Stockholm.

ORHEIM besøkte i februar (på tilbakereise fra Antarktisekspedisjon) polare institusjoner i Buenos Aires, Rio de Janeiro, Ohio og Washington. I mars deltok han i et møte i Bern om europeiske Antarktisprogrammer og i mai i SCOR/SCAR Polar Oceans Conference i Montreal. Sammen med LIESTØL ledet han et symposium, som ble arrangert i Fjærland for medlemmer av den nordiske seksjon i International Glaciological Society. Videre deltok han i september som norsk representant for Arbeidsgruppen i logistikk i XIII SCAR møte i Jackson Hole, Wyoming. Han møtte som norsk representant i SCAR's arbeidsgruppe for glasiologi, som avholdt møte i Cambridge i september, og deltok også i International Glaciological Society's symposium on Remote Sensing, avholdt i Cambridge i september..

SIGGERUD deltok i juli i NATO Advanced Study Institute, Reykjavik, om «Geodynamics of Iceland and the North Atlantic Area». I november deltok han i et seminar om «olje i Nord», arrangert av NIF i Harstad.

VINJE deltok i IAMAP/IAPSO First Special Assemblies og i møte i SCAR Working Group on Meteorology, begge avholdt i Melbourne i januar. I juni deltok han i Det 9. nordiske meteorologmøte i Bergen. Videre deltok han i Nordisk havisforskermøte i Stockholm og i oktober i Second Informal Planning Meeting on POLEX i Oslo.

WINSNES deltok i mars i en konferanse om Barentshavet i Statens oljedirektorat.

Forelesnings- og foredragsvirksomhet

Instituttets medarbeidere har i 1974 holdt følgende foredrag:

GJELSVIK: «Blant oljeletere, forskere og eskimoer i det kanadiske øyriket». Det Norske Geografiske Selskab, Oslo, i mars.
— «Resources of Minerals and Hydrocarbons in the Arctic—Outlook for the future». *Det vestlige Arktis og Svalbard.* Norske Sivilingeniørers Forening, Oslo, i mars.
— «Om den senere tids utvikling og forskning på Svalbard». Norsk-Svenska Föreningen, Stockholm, i mai.
— «Om Svalbards geologi». Texas University, Austin, i september.

EDWARDS: «Sedimental Problems on Svalbard». Oxford University, i desember.

LARSEN: «Utilization of marine and terrestrial mammals in Svalbard» og «Results of polar bear research in Scandinavian countries and in North America». Begge foredrag holdt på First International Theriological Congress, Moskva, i juni.
— «De økologiske isbjørnundersøkelsene på Svalbard». Arktisk Forening, Tromsø, i november.

LUNDQUIST: «Kartlegging av norske arktiske og antarktiske områder. Blir de norske interesser varetatt». Kartografisk Forening, Oslo, i oktober.
— Orienterte om instituttets syn på isbjørnundersøkelsene i tilknytning til LARSEN's foredrag i Arktisk Forening, Tromsø, i november.

ORHEIM: «Global Glacier mass balance during the past 300 years». Polar Oceans Conference, Montreal, i mai.
— «Bremålinger på Jan Mayen» og «Massebalansen for Antarktis». Begge foredrag holdt på symposiet i Fjærland for den nordiske seksjon av International Glaciological Society, i august.

SIGGERUD: «Svalbard». Geografisk Forening, Universitetet i Oslo, i februar.
— «History and Surveillance of Volcanic Activity of Jan Mayen Island». Nato Advanced Study Institute, Reykjavik, i juli.

VINJE: «Om formen på temperatur og vindprofiler nær en snøflate». Det 9. nordiske meteorologmøte, Bergen, i juni.

Publikasjoner

Skrifter:

Nr. 158 — A. HJELLE and Y. OHTA: Contribution to the geology of north western Spitsbergen.
Nr. 159 — JU. JA. LIVSIC: Palaeogene deposits and the platform structure of Svalbard.
Nr. 160 — R. A. FORTEY: The Ordovician Trilobites of Spitsbergen. I. Olenidae.
Nr. 161 — W. B. HARLAND, J. L. CUTBILL, P. F. FRIEND, D. J. GOBBETT, D. W. HOLLIDAY, P. I. MATON, J. R. PARKER, and R. H. WALLIS: The Billefjorden Fault Zone, Spitsbergen — the long history of a major tectonic lineament.

Meddelelser:

Nr. 103 — ODD LØNØ: Norske fangstmenns overvintringer — Del II — Jan Mayen.

Årbok 1972:

HJELLE, AUDUN: Some observations on the geology of H. U. Sverdrupfjella, Dronning Maud Land. 7—22.

GJELSVIK, TORE: A new occurrence of Devonian rocks in Spitsbergen. 23—28.

NAVRESTAD, T. and A. SØRNES: The seismicity around Jan Mayen. 29—40.

AUSTEGARD, ATLE: Some earthquakes near Jan Mayen. 41—46.

GULLIKSEN, BJØRN: Bunnfaunaundersøkelsene på Bouwensonbåen og Eggvingrunnen i 1972. 47—54.

BAAGØE, JETTE and KLAUS VESTERGAARD. An annotated list of the vascular plants collected by the Danish Jan Mayen Expedition 1972. 55—62.

FLEETWOOD, ÅKE, BIRGER PEJLER, ULRICH EINSLE, and ROLF ARNEMO. Stratigraphical and biological investigations of some Bjørnøya lakes. 63—72.

LARSEN, THOR: Polar bear den surveys in Svalbard in 1972. 73—82.

GOSSOW, HARTMUT and SVEIN THORBJØRNSEN: Air and ground survey of reindeer in Nordenskiöld Land and Sabine Land, Spitsbergen. 83—88.

NORDERHAUG, MAGNAR: Undersøkelser av ringgjess på Tusenøyane. 89—98.
— Studier av sjøfuglkoloniene på Fuglehuken, Prins Karls Forland nasjonalpark. 99—106.

LEHMANN, U.: Bericht über die Spitsbergen-Expedition des Geologisch-Paläontologischen Institutes der Universität Hamburg. 107—110.

WORSLEY, PETER: On the significance of the age of a buried tree stump by Engabreen, Svartisen. 111—118.

LAUMANN, T.: Måling av det frie vanninnhold i snø ved hjelp av den dielektriske metode. 119—124.

LIESTØL, OLAV: Glaciological work in 1972. 125–136.
HISDAL, VIDAR: The weather in Svalbard in 1972. 137–140.
VINJE, TORGNY E.: Sea ice and drift speed observations in 1972. 141–146.
LARSEN, THOR: Iakttagelser over dyrelivet på Svalbard i 1972. 147–152.
GJELSVIK, TORE: Norsk Polarinstitutts virksomhet i 1972. 153–168.
– The activities of Norsk Polarinstitutt in 1972. 169–173.
– Main field work of scientific and economic interest carried out in Svalbard in 1972. 174–175.
KILIAAN, H. P. L.: The possible use of tools by polar bears to obtain their food. 177–178.
LIESTØL, OLAV: Avalanche plunge-pool effect. 179–181.
GULLESTAD, NILS: Enkelte observasjoner av polarrev i Ny-Ålesund vinteren 1970–71. 182–183.

Sjøkart:
505 Norge–Svalbard, 1:750 000, nordre blad (ny utgave).
509 Fra Storfjordrenna til Forlandsrevet med Isfjorden, 1:350 000 (ny utgave).
522 Fra Forlandsrevet til Femtebreen, 1:100 000. (Nytt kart erstatter tidligere 508 Kongsfjorden og Krossfjorden).

Landkart:
Rosenbergdalen (Edgeøya, Svalbard, 1:10 000, lyskopi).

Annen publisering:
Instituttets medarbeidere har utenom instituttets serier publisert:
VIDAR HISDAL: A mathematical method for representing frequency distributions of cloud amount and related elements. *Arch.Met.Geoph.Biokl.*, Ser. B, **22** (3), Wien 1974.
THOR LARSEN og MAGNAR NORDERHAUG: Hvalrossen kommer tilbake til Svalbardområdet. *Norsk Natur* **2**, 1974.
– Isbjørnen – et eksempel på forvaltningen av en truet dyreart. *Norsk Natur* **4**, 1974.
THOR LARSEN har vært medforfatter i et skandinavisk undervisningsprogram (elevhefte, lærerveiledning og audiovisuelle hjelpemidler) i økologi. Han har også vært medforfatter i NKI – Statens Miljøleksikon (I trykk).
OLAV LIESTØL (sammen med SIGURD MESSEL, ARVE M. TVEDE og GUNNAR ØSTREM): Glasiologiske undersøkelser i Norge 1973. Rapport 1–74 fra NVE.
OLAV ORHEIM: Glaciological studies in the South Shetland Islands. *Ant. Journ. of the U.S.* **9** (4).

The activities of Norsk Polarinstitutt in 1974

Extract of the annual report

BY KAARE Z. LUNDQUIST

Norsk Polarinstitutt had 34 permanent positions in 1974. In addition six employees were engaged on limited-term contracts.

Field work

NORWAY

Glaciology

The studies were led by O. LIESTØL, who conducted routine glacier mass balance measurements at Storbreen and Hardangerjøkulen. O. ORHEIM and A. TVEDE conducted simplified mass balance measurements at respectively Supphellebreen and Blomsterskardbreen. Like in the previous year the glaciers showed positive balance, mainly because of large winter precipitation.

Frontal position variations were measured at 12 glaciers, two off Folgefonni, two in Jotunheimen, five at Jostedalsbreen, two in Møre, and one at Svartisen. Four were advancing, three stationary, and five retreating. It is remarkable that both Styggedalsbreen and Austerdalsbreen are now advancing after continuous retreat during the last 50 years.

SVALBARD

The summer expedition was organized and led by T. SIGGERUD. Altogether 39 persons participated. Herein are included four people at Jan Mayen and two in Norway.

The expedition conducted hydrographic, topographic, and geologic work, mostly in eastern and southeastern parts of Svalbard. In addition were conducted hydrographic survey in Isfjorden, geophysic investigations in Ny-Ålesund, and quaternary geologic studies in the Van Keulenfjorden area. The planned programme was carried out, with the exception of the break in the hydrographic survey caused by the wrecking of M/S "Olaf Scheel".

Two biologists from the University of Bergen were assisted by the expedition and worked in the area south of Isfjorden.

A group of botanists from the University of Trondheim were assisted in field work at Reinsdyrflya.

The main part of the expedition sailed from Bodø on M/S "Polarstar" with Captain J. HOLSTAD and a crew of 11 on 25 July. The expedition disembarked in Bodø on 5 September.

Two Bell 47 J helicopters with crew were rented from Helikopter Service A/S for transport between M/S "Polarstar" and the field localities.

M/S "Olaf Scheel" with Captain I. ANGELSHAUG and a crew of 7 was rented from Statens Skjermbildefotografering. The vessel was rebuilt at Framnæs Shipyard and specially equipped for survey around Svalbard. The vessel sailed from Bodø on 25 July, with J. H. CHRISTIANSEN as leader. Because of the wrecking the vessel returned on 13 August.

M/S "Polarstar" first put ashore geologist O. SALVIGSEN in Van Keulenfjorden and fetched the helicopters that were transported by cargo ship to Longyearbyen. It then continued north of Svalbard and a topographic survey was conducted in the northern part of Hinlopenstretet. The geologists were placed in field locations mostly at Nordaustlandet. One biologic party was placed at Kong Karls Land. After the topographic work was completed, the biologists flew around the north and east coasts of Nordaustlandet to register the animal life, particularly the walrus. M/S "Polarstar" returned via Ny-Ålesund to Longyearbyen, where the helicopters were put ashore for return to Norway by cargo ship. On the return voyage to Norway, geologist SALVIGSEN was picked up at Van Keulenfjorden. Biologic observations, partly by use of helicopters and small boats, were conducted during the whole expedition.

The dramatic event of the summer was when "Olaf Scheel" struck bottom on 11 August, which caused a one-week break in the work aboard "Polarstar". During this period the topographers were able to complete a measuring programme at Edgeøya.

The weather conditions were exceptionally good and permitted much surveying. Some fog and strong winds hindered the work at times during the last part of the season.

The ice situation was good, with little ice during most of the summer. Only around Kong Karls Land did ice hinder boat operations.

Hydrography

H. HORNBÆK, assisted by S. UTHEIM and B. FJELD, and K. PETTERSEN, assisted by E. B. SVENSSON and I. FJELD, used the sounding boat "Svalis" from 15 July to 15 September in Billefjorden and around Gåsøyane.

The other hydrographic survey with M/S "Olaf Scheel" was led by J. H. CHRISTIANSEN. E. NETELAND looked after the HI-FIX-system and other electronic equipment.

HI-FIX slave stations on Agardhpynten and Edgeøya were operated by two assistants at each place.

Four navigational buoys were placed on Forlandsrevet. The yearly inspection and maintenance of lighthouses and other navigational aids was completed by 5 August.

Due to the favourable ice conditions it was decided to start sounding north in Storfjorden and work southwards. Sounding started on 9 August and continued without break until 12 August when the vessel went aground straight west of Mistakodden. Equipment etc. was transferred to M/S "Polarstar" and CHRISTIANSEN and NETELAND returned to Norway by coastal steamer. Altogether 500 miles were sounded.

Geodesy-topography

The field work was done by J. BJØRKE, D. BJØRKEDAL, O. STEINE (leader) and J. SUNDSBY, with four assistants. All travelled to and from Svalbard on M/S "Polarstar" which also served as their base, with the helicopters used for transportation. The main work was to extend the triangulation network and measure ground control points for mapping at the scale of 1:100,000 in the area of Hinlopenstretet and nearby islands. Some supplementary measurements were also done in the southwest of Edgeøya.

Geology

Four geologic parties worked in Svalbard. T. S. WINSNES, M. B. EDWARDS, and assistants worked partly from M/S "Polarstar" and partly from camps in the southern part of Nordaustlandet and on islands in Hinlopenstretet. They also visited Agardhfjellet. The work was mostly mapping and measuring stratigraphic sections in connection with the Barents Sea Project.

T. GJELSVIK and assistant worked around Ny-Ålesund and at Prins Karls Forland.

O. SALVIGSEN and assistants conducted quaternary geologic studies in the Van Keulenfjorden area.

Geophysics

Measurements of mass balance of glaciers around Ny-Ålesund continued as in previous years. O. LIESTØL assisted by B. WOLD visited Finsterwalderbreen and Hessbreen in May/June. The latter glacier had advanced strongly during the winter and was therefore especially investigated. B. WOLD and K. REPP continued their studies of Brøggerbreen.

V. HISDAL worked at The Research Station in Ny-Ålesund from 5 July to 9 August measuring intensity distributions of direct and diffuse sun radiation. The effect of polarization of the diffuse radiation was especially studied. He supervised the move of the meteorologic station to a new location.

T. VINJE also worked in Ny-Ålesund, from 20 July to 16 August. He calibrated the radiation instruments both in the short- and long-wave region. The ventilation of various instruments was improved. The data logger has worked nearly continuously during the year.

Biology

T. LARSEN and assistant conducted faunistic mapping and polar bear research at Kong Karls Land in August. Seven bears were caught and tagged, and samples of excrements and crania of bears dead from natural causes were collected for later studies. Observations were made of diurnal rhythm and social behaviour. Faunistic observations were also obtained from various other parts of Svalbard.

JAN MAYEN

O. ORHEIM and assistant conducted mass balance studies at Sørbreen, Jan Mayen, in June and he gave instructions for further observations.

P. IMSLAND and assistant carried out geologic mapping of the lava fields in July/August.

ANTARCTICA

Three Norwegian groups conducted field work in Antarctica, with logistic support from the National Science Foundation.

O. ORHEIM with assistant from the U.S. did glaciologic research at Deception and Livingston Islands in January. LIESTØL and ORHEIM participated in November in core drilling to 100 m depth at Amundsen-Scott South Pole Station.

The geologists A. HJELLE, Y. OHTA, T. S. WINSNES and K. REPP worked in the southern part of the Ellsworth Mountains from November 1974 to January 1975, conducting mostly stratigraphic/tectonic studies.

Preparation of data

Hydrography

H. HORNBÆK computed mean sea level for Ny-Ålesund from tidal records. Editing work was done on charts 505, 509 and 522. Preparations were made for reprinting charts 502 and 503.

J. H. CHRISTIANSEN worked on the 1972 soundings in connection with chart 505. He oversaw together with engineer T. SØNDENAA the work of rebuilding M/S "Olaf Scheel".

Geodesy-topography

Adjustments of the geodetic net in Svalbard have continued. Maps C8 Billefjorden and D9 Agardhfjellet have been constructed. Work was also done on C11 Kvalvågen and a new edition of C9 Adventdalen. Rosenbergdalen on Edgeøya was constructed to the scale of 1:10,000, and maps of 5 pingoes at a scale of 1:2,000 and 2 m contour intervals were constructed for the geologists.

Maps N5 Forposten and N6 Sarkofagen in the series Dronning Maud Land 1:250,000 are ready for printing.

Geology

M. B. EDWARDS prepared several articles, and continued studies of various rocks collected during the expedition. He also visited England and obtained data on the Svalbard stratigraphy, and he held several lectures.

A. HJELLE cooperated with Dr. E. F. ROOTS on analysis of samples and observations from the Norwegian-British-Swedish Maudheim Expedition 1949–52. He also conducted preparatory studies for the 1974/75 Antarctic expedition.

H. MAJOR continued coal petrographic studies of samples from mines in Longyearbyen and Svea. He visited various mines in Svalbard in January/February, and was involved in claim surveys.

Y. OHTA studied samples from around Smeerenburgfjorden and St. Jonsfjorden, and prepared a paper on studies of feltspar.

O. SALVIGSEN reviewed the literature of quaternary geologic work in Svalbard, and worked on data from the summer's field work.

T. S. WINSNES adminstered the geologic work at the institute and made preparations for the Antarctic expedition. He participated in a claim survey in the Agardh area.

Geophysics

V. HISDAL completed a study on distribution of cloud amount and duration of sunshine for Norwegian Arctic stations, and prepared a description of the weather in Svalbard in 1973. Calculations of the radiation observations from Ny-Ålesund were continued, and a final analysis of the measured spectral distribution was initiated.

O. LIESTØL prepared glaciologic, meteorologic and other field data from Svalbard and Norway. He was also adviser for three graduate students and held a lecture series in glaciology at the University of Oslo.

O. ORHEIM analyzed glaciologic data from Antarctica, Jan Mayen, and Norway. Manuscripts were prepared on global mass balance variations and on the glaciers of the South Shetland Islands. He developed a project for measuring mass and heat transport at the underside of an ice shelf. ERTS-1 (LANDSAT-1) satellite images from Dronning Maud Land were evaluated, and a proposal for studies of images from LANDSAT-2 was sent to and accepted by NASA. He was adviser for one graduate student.

T. VINJE prepared sea ice charts for the Atlantic sector and computed drift velocities using satellite images. Images from LANDSAT-1 were analyzed. A proposal for studies of LANDSAT-2 images of the area was sent to and accepted by NASA. Analysis of measurements from Camp Norway II (Antarctica) in connection with studies of friction and heat exchange between air and snow was completed. He also prepared reviews of sea ice problems and future research.

Biology

T. LARSEN prepared for publication faunal observations, data and registrations of polar bear dens at Kong Karls Land. Past year's data have been transferred to the new registration form for faunal observations. Hunting journals and crania data were analyzed. In spring 1974 he assisted Grønlands Zoogeografiske Undersøgelse with the planning and conducting of the second field season of a polar bear project on North-east Greenland. K. HAGELUND helped with the analysis of the faunal registrations.

The Research Station at Ny-Ålesund

There were great changes at Ny-Ålesund during the year as the ESRO station was closed down. In May agreement was reached that Kings Bay Kull Comp. A/S would supply the logistic needs for the research station for 1974/75 for a payment of kr. 500,000. – from Norsk Polarinstitutt. During the 1974/75 winter, five support personnel from Kings Bay Kull Comp. A/S worked in Ny-Ålesund in addition to the two scientists/technicians.

The work has continued as in previous years, mostly registering data for later analysis in Norway. The main aspects of the work in 1974 have been:

Aurora measurements with a 4-channel photometer.
Registration of earth magnetism.
HF absorbtion measurements by rhiometers.
Night sky photography by "all-sky-camera".
Seismic registrations.
Air pollution measurements.
Oceanographic observations.
Meteorological radiaton measurements.
Tidal registrations.
Measurements of mass balances of glaciers.
Biologic observations were made throughout the year.
Synoptic weather observations (Norwegian met. inst.).

15 scientists, plus assistants, have used the station for testing and control of instruments or as a base for field work. The visits, mostly during the summer, varied in length from seven days to six weeks.

Main field work of scientific and economic interest carried out in Svalbard in 1974

By KAARE Z. LUNDQUIST

Nationality	Institution or company (residence) Name of expedition	Name(s) of leader(s) Number of participants	Area of investigation Period	Work
Norwegian	Norsk Polarinstitutt	THOR SIGGERUD 34 (+ transport crew, 2 ships, 1 boat, 2 helicopters)	Ny Friesland, Olav V Land, Nordaustlandet, Kong Karls Land, Gåsøyane, Storfjord area, Forlandsundet, Ny-Ålesund July–September	Hydrography, topography, geology, geophysics, and biology. See pp. 224–229
	Norsk Polar Navigasjon A/S	15	Kvadehuken and Sarstangen 10 March–June and 13 July–22 December	Test drilling for oil
	University of Trondheim	OLAF I. RØNNING 7	Kongsfjorden, Woodfjorden, Liefdefjorden, Bockfjorden July–August	Botanical and zoological investigations
American	AMAX International Coal Exploration	12	Van Mijenfjorden 16 July–August/September	Coal investigations
British	Cambridge Spitsbergen Expedition 1974	W. B. HARLAND 18	Prins Karls Forland, Van Keulenfjorden, Ny Friesland July–August	Geology
Dutch	Zoologische Museum, Amsterdam	T. M. VAN SPANJE 3	Isfjorden, Van Mijenfjorden, Ny-Ålesund 20 June–14 September	Ornithology, botany
	Not known	WIM MONNA 2	Longyearbyen and Ny-Ålesund areas July	Ornithology, botany

Nationality	Institution or company (residence) Name of expedition	Name(s) of leader(s) Number of participants	Area of investigation Period	Work
German	Friedrich-Alexander Universität, Erlangen	HERMANN REMMERT 4	Area around Longyeardalen July–August	Zoology
	Not known	H. ULLRICH 2	Areas around Longyearbyen and Ny-Ålesund	Biology
Polish	Wroclaw University Svalbard Expedition 1974	STANISLAV BARANOWSKI 18	Hornsund area 15 June–20 September	Glaciology, geology, etc.
Soviet	Sevmorgeo	O. V. SEMEVSKIJ 15 (+ transport crew)	Isfjorden, Raudfjorden, Hopen 2 July–24 September	Geology
	Arktikugol	GUSEV & KUZNETZKOV abt. 100 with ice breaker "Krassin" as base	Colesbukta From May/June, 1974	Oil drilling
	Institute of Geography, Moscow	L. TROITSKI 3	Adventdalen and Endalen May–October	Glaciology
	Institute of Geography, Moscow	EVGENY SINGER 5	Longyeardalen and Endalen May–October	Glaciology
Swedish	Uppsala Universitet	STIG LARSSON 2	4–20 July	Physical geography
	Marinbotaniska Institutionen, Gøteborg	LARS-HARRY JENNEBORG 2	Areas around Ny-Ålesund, Prins Karls Forland 27 June–10 August	Marine biology

Notiser

Bremålinger på Jan Mayen

(Glaciological studies at Jan Mayen)

Abstract. — The mass balance of Sørbreen (Figs. 1 and 2) has been measured from 1972 to the present. Figs. 3 and 4 show the variation with elevation of summer balance (b_s), winter balance (b_w), and net balance (b_n), for the years 1972/73 and 1973/74. The curves are mostly based on annual measurements in spring and autumn of between 10 and 20 stakes. The upper part of the curves are the least reliable, because the balances vary much here due to very uneven surface topography. The unusual shapes of the lower parts of the summer and net balance curves are real, and are probably mostly caused by persistent mist over the lower part of the glacier. Wind transport of winter snow from upper to lower part of the glacier may also be a contributing factor; deflation is an important phenomenon on the Jan Mayen glaciers.

Breene på Jan Mayen var forholdsvis lite undersøkt inntil 1959, da University of London satte i gang systematiske undersøkelser, først og fremst av Sørbreen. Disse undersøkelsene ble fortsatt i 1961 og 1963, men dessverre ble ikke det

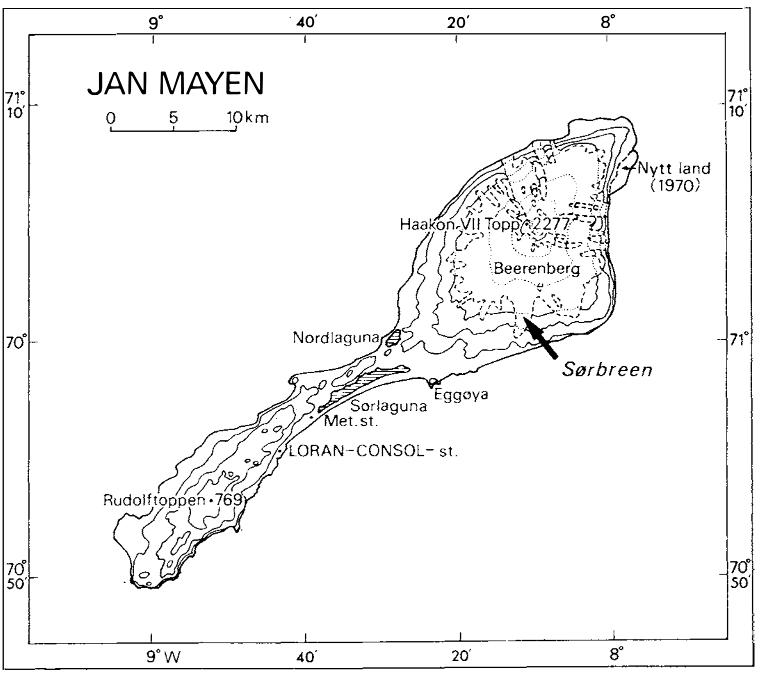

Fig. 1. *Kart over Jan Mayen med angivelse av Sørbreen.* Index map of Jan Mayen with position of Sørbreen.

Fig 2. *Sørbreen over 600 m, fotografert 24. august 1973. Merk den uregelmessige topografien.* Sørbreen above 600 m elevation, photographed 24 August 1973. Note the uneven topography.

Photo: O. ORHEIM

glasiologiske resultatet så stort som man kunne håpet, da lederen for programmet omkom sammen med fire andre i 1961 ved en drukningsulykke.

Vårt dårlige kjennskap til breene på øya gjorde det naturlig å inkludere bremålinger i programmet for Norsk Polarinstitutts ekspedisjon dit i 1972. Målingene ble konsentrert om Sørbreen (Figs. 1 og 2), som er den lettest tilgjengelige og mest beskrevne bre på Jan Mayen. Hovedformålet var å forstå samspillet mellom dagens klima og breens tilstand, og å få utredet hvordan klima og brevariasjoner har vært i fortiden. Med dette for øyet er breen bl. a. blitt fotografert og fronten oppmålt. Forskjellige kvartærgeologiske undersøkelser er blitt gjennomført, spesielt i 1975 i samarbeid med amanuensis JAN MANGERUD fra Universitetet i Bergen.

Hovedvekten av målingene har imidlertid vært knyttet til massebalansestudier, for å se om breen vokser eller minker. Disse har nå vært foretatt i fire år, dels av meg selv hver sommer og dels av personale fra den faste stasjonen. Målingene har for det meste vært basert på mellom 10 og 20 staker, som de fleste år er blitt målt hver vår/forsommer og om høsten.

Figs. 3 og 4 viser resultatet av disse målingene for balanseårene 1972/73 og 1973/74. Bare nedre halvdel av breen, opptil 1100 m høyde, er dekket med målinger. Det er derfor ikke mulig å bestemme breens totalbalanse, selv om arealet over denne høyde er en forholdsvis liten del av breens totalareal. Mest bemerkelsesverdig ved massebalansekurvene er forholdene over breens nedre del, hvor ablasjonen ikke avtar med høyden slik tilfellet vanligvis er. Forklaringen er antagelig at tåke jevnlig dekker nedre del av breen, mens det er klarvær og større mengde stråling høyere på breen. Også av betydning er vindtransport av vintersnøen nedover breen. Spesielt synes dette å ha vært viktig vinteren 1972/73. De sterke vindene fra Beerenberg gjør at vindtransporten av snø er av større betydning for breene på Jan Mayen enn det er vanlig i Norge og på Svalbard; i enkelte perioder om vinteren kan breene

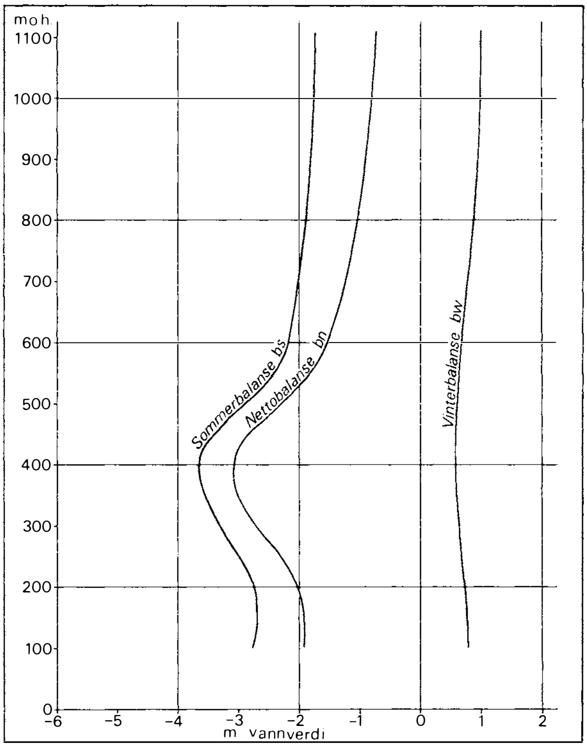

Fig. 3. *Sørbreens massebalanse, 1972/73.* Mass balance variations in m water, for Sørbreen, for the balance year 1972/73. Elevations are in m above sea level.

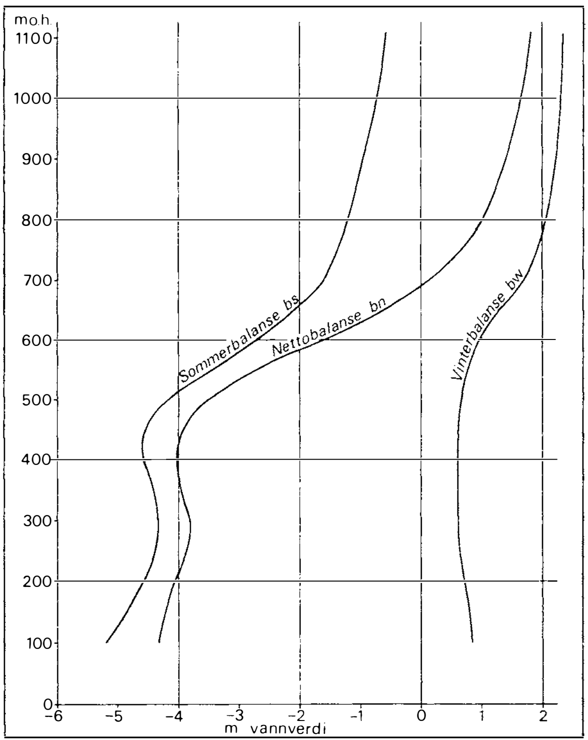

Fig. 4. *Sørbreens massebalanse, 1973/74.* Mass balance variations in m water, for Sørbreen, for the balance year 1973/74.

blåses omtrent frie for snø. På Sørbreen gjør dessuten et lokalt fenomen seg gjeldende: breen er meget sterkt kupert (Fig. 2), og vindtransporten gjør at snømengdene varierer sterkt over korte avstander, med opptil 2–3 m fra kul til dump. Disse store variasjonene gjør at massebalansekurvene vist i Figs. 3 og 4 må ansees som noe usikre, spesielt for øvre del. Mye mer omfattende snøsonderinger enn hittil gjennomført må til før akkumulasjonen og massebalansen kan bestemmes nøyaktig for breens øvre deler.

Bremålingene på Jan Mayen i disse fire årene har foregått med forholdsvis liten innsats i felten. Meningen har ikke vært å gjennomføre fullstendige målinger av breen, men å innskaffe nok grunnleggende data til å kunne formulere et større program som kunne passe for et par hovedfagsoppgaver i glasiologi og kvartærgeologi. Innledningsfasen er nå snart over og hvis mulig vil mer omfattende undersøkelser bli igangsatt i 1976. Følgende er blant de problemer som en hovedfagsstudie i glasiologi burde vurdere:

a) Hvorfor rykket mange breer på Jan Mayen fram i 1950-årene, på en tid da breene i omliggende områder trakk seg tilbake?
b) Hva er Sørbreens totalbalanse, og hvilke faktorer er viktigst for varmebalansen?
c) Er Sørbreen representativ for breene på Jan Mayen? Hvordan er varme- og masse-balansen f. eks. på en bre på vestsiden av øya?
d) Er Sørbreens kuperte overflate knyttet til spesielt aktiv erosjon? Hvor stor er erosjonen, og hvor mye materiale transporteres ut med breelvene?
e) I samarbeid med de kvartærgeologiske studier bør det utredes om klimautviklingen på øya kan utledes fra eldre brevariasjoner.

I alt ti mann fra stasjonen har ved forskjellige anledninger vært med på bremålingene, foruten tre som har vært med fra Norge. Uten hjelpen fra disse og en rekke andre ved stasjonen hadde det ikke vært mulig å gjennomføre målingene. De forskjellige stasjonssjefer har alle stillet seg svært positive til prosjektet. Jeg vil rette en spesiell takk til Forsvarets Fellessamband, som har hjulpet meg med reiser til og fra øya, og som ellers har støttet arbeidet ved å la meg få benytte stasjonens tjenester.

Olav Orheim

Growth faults in Upper Triassic Kapp Toscana Group, Kvalpynten, Edgeøya, Svalbard; a preliminary report[1]

The coastal cliffs at Kvalpynten (Fig. 1) are composed of Middle and Upper Triassic sandstones and shales of the Kapp Toscana Group (FLOOD et al. 1971). The strata in the lower part of the cliffs, up to about 150 m above sea-level, are distinctly tilted gently towards the north. The immediately overlying beds are horizontal (Fig. 2).

FALCON (1928) suggested that the structure indicated an unconformity in this part of the succession, while BUCHAN et al. (1965) interpreted the structure

[1] Publication No. 73 of the Continental Shelf Division of the Royal Norwegian Council for Scientific and Industrial Research (NTNFK).

Fig. 1. *Location of growth fault exposures.*

as large-scale cross-stratification, based on an appraisal of photographs in FALCON. Neither KLUBOV (1970) nor FLOOD et al. (1971) noted the structure, although they had worked in the area.

In order to further study this structure, close-up photographs of the largely inaccessible cliffs were taken during a helicopter fly-by in the course of the 1974 Svalbard Expedition. Study of these photographs reveals that the structure closely resembles growth faults as depicted in Tertiary deltaic sediments (CURTIS 1970; WEBER 1971; BRUCE 1973). Growth faults are faults along which movement occurs contemporaneously with sedimentation (HARDIN and HARDIN 1961). In particular, lateral thickness changes of a given layer, the abrupt termination of individual sandstone units, and the local tilting of the strata (Fig. 3) all indicate growth faulting. They are believed to be caused, at least partly, by abnormally high fluid pore pressures in impermeable shale masses (BRUCE 1973).

The identification of growth faults in the Kapp Toscana Group, around the boundary between the Tschermakfjellet and De Geerdalen Formations has

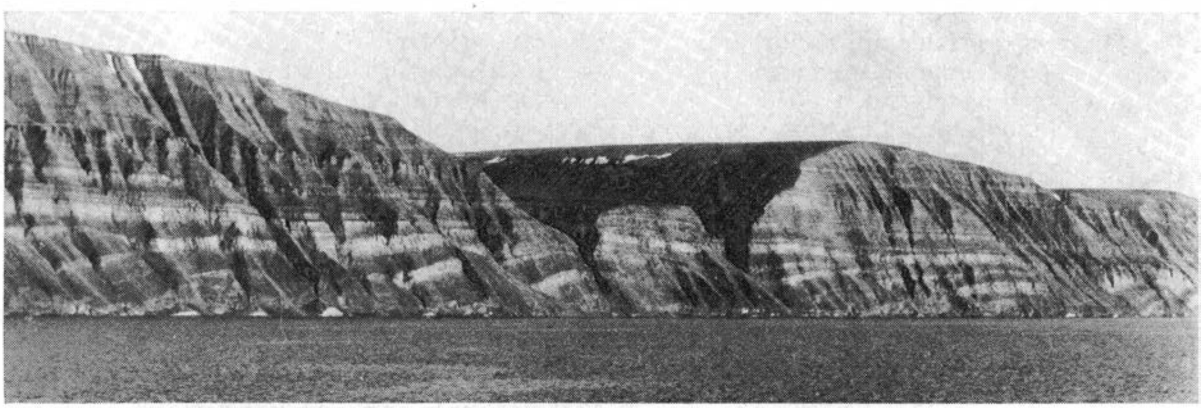

Fig. 2. *View of cliffs at Kvalpynten, showing northward dipping strata overlain by horizontal strata.*

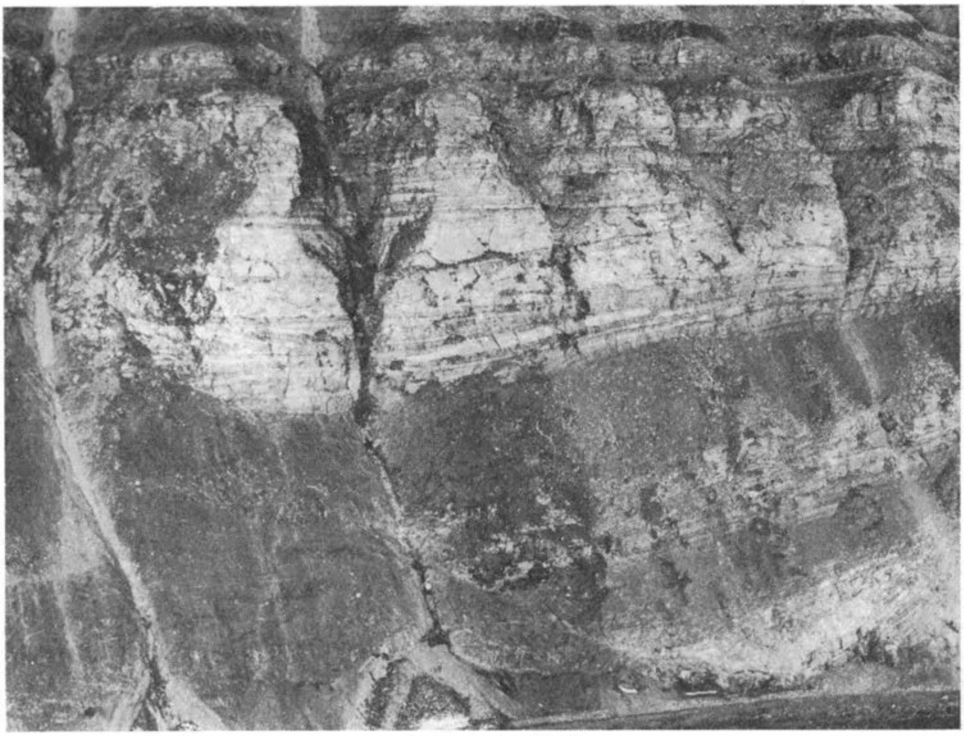

Fig. 3. *Photograph, taken from helicopter, of north dipping strata adjacent to one of the growth faults. Sandstones and shales are arranged in coarsening upward sequences.*

several consequences. The stratigraphic interval affected by growth faulting probably corresponds to the "Blue and Purple Shales" of FALCON (1928) and the "Passage Beds" of KLUBOV (1970). This interval reflects increasing influence of deltaic sedimentation, especially in the form of alternating sandstone and shale units arranged in coarsening upward sequences. The tilting of strata, and their lateral dying out is neither a tectonic nor an environmental feature, but is due to simultaneous faulting and flexing of the strata during sedimentation. Deformation caused in association with growth faulting may be confused with tectonic faults, channels or cut-outs, slumps, large-scale cross-stratification, or tilting associated with uplift and erosion. The presence of extensive folds and faults in correlative strata at Mistakodden, Barentsøya, about 110 km to the north (Fig. 1), suggests that growth faulting was a widespread phenomenon at this time in Svalbard. Problematic field and/or borehole relationships along this stratigraphic horizon should be considered in this light, before invoking another simpler explanation.

Finally, it should be mentioned that growth faulting is a critical feature in the local development of oil and gas occurrences (e.g. BUSCH 1975).

A detailed account of the structure is being presented elsewhere (EDWARDS 1976).

References

BRUCE, C. H., 1973: Pressured shale and related sediment deformation: mechanism for development of regional contemporaneous faults. *Amer. Assoc. Petrol. Geol. Bull.* **57**, 878–886.

BUCHAN, S. H., A. CHALLINOR, W. B. HARLAND, and J. R. PARKER, 1965: The Triassic stratigraphy of Svalbard. *Norsk Polarinstitutt Skrifter.* Nr. 135. 92 pp.
BUSCH, D. A., 1975: Influence of growth faulting on sedimentation and prospect evaluation. *Amer. Assoc. Petrol. Geol. Bull.* **59**, 217–230.
CURTIS, D. M., 1970: Miocene deltaic sedimentation, Louisiana Gulf Coast. IN: *Deltaic Sedimentation Modern and Ancient* (ed. J. P. MORGAN). *Soc. Econ. Pal. Min. Spec. Pub.* No. 15, 293–308.
EDWARDS, Marc B., 1976: Growth faults in Upper Triassic deltaic sediments, Svalbard. *Amer. Assoc. Petrol. Geol. Bull.* **60** (3).
FALCON, N. L., 1928: Geology, Appendix III in Watkins, H. G., "The Cambridge Expedition to Edge Island." *Geogr. J.* **72**, 134–139.
FLOOD, B., J. NAGY, and T. S. WINSNES, 1971: The Triassic succession of Barentsøya, Edgeøya, and Hopen (Svalbard). *Norsk Polarinst. Medd.* Nr. 100, 20 pp.
HARDIN, F. R. and G. C. HARDIN Jr., 1961: Contemporaneous normal faults of Gulf Coast and their relation to flexures. *Amer. Assoc. Petrol. Geol. Bull.* **45**, 238–248.
KLUBOV, V. A., 1970: A geological sketch of Edgeøya. IN *Geology of Spitsbergen, 1965.* pp. 76–88. National Lending Library for Science and Technology.
WEBER, K. J., 1971: Sedimentological aspects of oil fields in the Niger Delta. *Geol. Mijnb.* **50**, 559–576.

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A Rb-Sr age for granite-gneiss clasts from the late Precambrian Sveanor Formation, Central Nordaustlandet[1]

Abstract. — Red granite-gneiss clasts occurring in a tillite unit of the late Precambrian Sveanor Formation yield a Rb-Sr whole-rock three point isochron age of 1275±45 m.y. with an initial $^{87}Sr/^{86}Sr$ ratio of .72172±.00056. The high initial $^{87}Sr/^{86}Sr$ ratio implies derivation of the granite-gneisses from still older crustal rocks.

Introduction. — Granites, gneisses and migmatites have long been known from the northern part of Nordaustlandet (SANDFORD 1926). These rocks have been considered, in part, as Precambrian basement to Hecla Hoek (Precambrian to Ordovician) sedimentary rocks (SANDFORD 1926, 1956), and alternatively as synorogenic and post-orogenic rocks intruded into the Hecla Hoek during the Caledonian orogeny (WINSNES 1965). Published structural, petrographical, and geochronological data have been insufficient to establish the relative importance of Caledonian and pre-Caledonian intrusive activity in this area (FLOOD et al. 1969). Radiometric age data supporting both hypotheses have been reported (e.g. GAYER et al. 1966) and alternative hypotheses have been proposed to account for pre-Caledonian ages (HAMILTON and SANDFORD 1964; FLOOD et al. 1969).

The presence of clasts of intrusive igneous rocks in late Precambrian tillites of Svalbard provides evidence for the existence of pre-Caledonian intrusives in this region (WINSNES 1965). At Aldousbreen, Wahlenbergfjorden, Nordaust-

[1] Contribution No. 74 of the Continental Shelf Division of the Royal Norwegian Council for Scientific and Industrial Research (NTNFK).

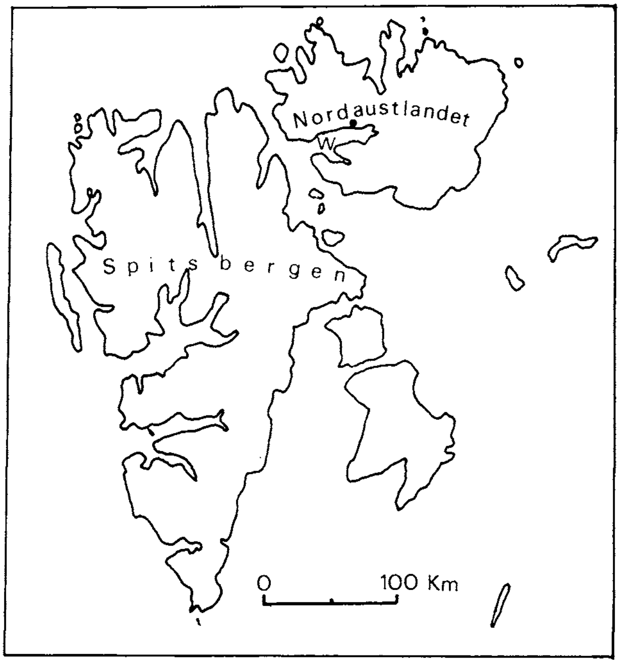

Fig. 1. *Location map.*

landet, the late Precambrian Sveanor Formation contains a few large red granite-gneiss boulders up to 1 m in diameter, in a massive tillite unit. This tillite unit has been interpreted as a subglacial till deposit (ground moraine) (EDWARDS, this vol.), and the large size of these boulders suggests that transport did not exceed a few tens of kilometers. In hand specimen, these large clasts closely resemble the Rijpfjorden post-orogenic granite (AUDUN HJELLE pers. comm.).

Six samples of the red granite-gneiss collected for Rb-Sr whole-rock geochronological studies were taken from the single massive tillite unit about 30–40 m above the base of the Sveanor Formation.

Analytical methods. — Rb and Sr concentrations and Rb/Sr ratios of the samples have been determined by x-ray fluorescence spectrometry on pressed powder pellets, using G2 as a standard. Sr samples for isotopic analyses were prepared by conventional ion exchange techniques. Isotopic analyses of Sr samples were performed on a VG Micromass 30 solid source mass spectrometer at the Mineralogisk-Geologisk Museum, Oslo. A value of 0.71037±

Table 1

Rb–Sr whole-rock isotope analyses of the red granite-gneiss clasts.

Sample	Rb (P.P.M.)	Sr (P.P.M.)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
MBE 1	68	249	0.795±.018	.73579±9
MBE 2	62	263	0.687±.018	.73410±8
MBE 3	55	273	0.579±.011	.72132±6
MBE 4	76	140	1.593±.035	.77568±9
MBE 5	117	156	2.178±.046	.76064±6
MBE 6	32	158	0.588±.011	.72611±6

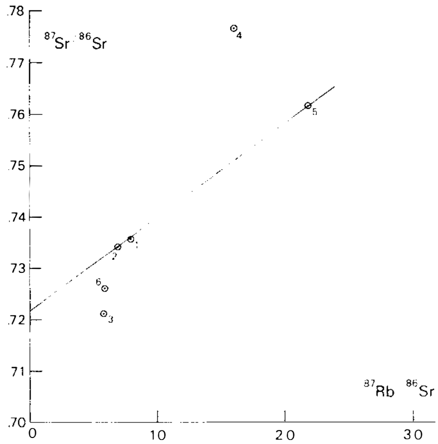

Fig. 2. *Rb-Sr whole-rock isotopic data on the six red granite-gneiss clasts. The isochron through points 1, 2 and 5 yields an age of 1275±45 m.y. and an initial $^{87}Sr/^{86}Sr$ ratio of .72172±.00056 (2 sigma errors). Data on samples 3, 4 and 5 have been ignored in the calculation of the age.*

.00005 (2 sigma) is obtained for the $^{87}Sr/^{86}Sr$ ratio of NBS 987 Sr isotope standard.

Analytical results for the six samples of granite-gneiss are given in Table 1. Isochron fitting is by the method of York (1969), using the decay constant for ^{87}Rb, $\lambda = 1.39 \times 10^{-11}$ yr.$^{-1}$.

Results. — In Fig. 2, the six Rb–Sr whole-rock isotopic analyses are plotted in a correlation diagram of $^{87}Sr/^{86}Sr$ against $^{87}Rb/^{86}Sr$. The data points for samples 1, 2, and 5 define an isochron, but samples 3, 4 and 6 do not appear to be related to other samples on any meaningful linear array. (The apparent steep correlation lines through data points 2, 6 and 3 and through data points 4, 1 and 6 would yield spurious high ages and implausibly low initial $^{87}Sr/^{86}Sr$ ratios.) The isochron defined by data points 1, 2 and 5 is a perfect fit with M.S.W.D. of 0.99. The isochron yields a date of 1275±45 m.y. and an initial $^{87}Sr/^{86}Sr$ ratio of 0.72172±.00056 (2 sigma errors).

If it is assumed that the granitic rocks 1, 2 and 5 are cogenetic, from the same intrusion, then the date may be interpreted as the age of crystallization of the rocks as granites. The high initial $^{87}Sr/^{86}Sr$ ratio suggests that those granites were derived by remelting of still older continental crustal material.

On petrographic grounds samples 1, 2 and 5 could well be related: samples 1 and 2 almost certainly are from the same intrusion. However, these three samples have no obvious distinction from the samples which fail to plot on the isochron. It is possible that samples 3, 4 and 6 have been affected by weathering and/or leaching processes and thus have not preserved closed Rb–Sr whole-rock systems from the time of igneous crystallization. Alternatively the terrane eroded by the late Precambrian ice sheets which deposited the tillites may have had a long and varied igneous and metamorphic history, so that several separate intrusive complexes may be represented by the six granite-gneiss clasts here analysed. The 1275±45 m.y. date may tentatively be regarded as the age of intrusion of a granite constituting part of the local basement. Further geological studies may relate this event to the timing of Hecla Hoek sedimentation.

Acknowledgements. — The sample material was collected during the 1974 Norsk Polarinstitutt Svalbard Expedition. Cand. real. THORE S. WINSNES introduced EDWARDS to the locality at Aldousbreen, and MR. TRYGVE HANSEN assisted in the field. We thank TORIL ENGER for skilled technical assistance with the analytical work, which was carried out in the G. Unger Vetlesen Laboratory for Geochronology at the Geologisk Museum, Oslo. TAYLOR gratefully acknowledges the award of a post-doctoral fellowship by the Royal Society (London).

References

EDWARDS, MARC B., 1976 (this vol.): Sedimentology of Late Precambrian Sveanor and Kapp Sparre Formations at Aldousbreen, Wahlenbergfjorden, Nordaustlandet. *Norsk Polarinstitutt Årbok* 1974, pp. 51–61.

FLOOD, B., D. G. GEE, A. HJELLE, T. SIGGERUD, and T. S. WINSNES, 1969: The geology of Nordaustlandet, northern and central parts. *Norsk Polarinstitutt Skrifter* No. 146.

GAYER, R. A. et al., 1966: Radiometric age determinations on rocks from Spitsbergen. *Norsk Polarinstitutt Skrifter* No. 140.

HAMILTON, E. I. and K. S. SANDFORD, 1964: Rubidium-strontium ages from North-East Land (Spitsbergen). *Nature* **201**. 1208–9.

SANDFORD, K. S., 1926: The geology of North-East Land (Spitsbergen). *Quart. J. Geol. Soc. London* **15**. 461–493.

— 1956: The stratigraphy and structure of the Hecla Hoek Formation and its relationship to a subjacent metamorphic complex in North-East Land (Spitsbergen). *Quart. J. Geol. Soc. London* **112**. pp. 339–362.

WINSNES, T. S., 1965: The Precambrian of Spitsbergen and Bjørnøya. **In**: The Geologic Systems. *The Precambrian* **2** (Edt. K. RANKAMA), Interscience Publishers (John Wiley & Sons). London.

YORK, D., 1969: Least squares fitting of a straight line with correlated errors. *Earth and Planetary Sci. Letters* **5**. 320.

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Cretaceous Palynomorphs from Spitsbergenbanken, NW Barents Shelf[1]

Abstract. — Cretaceous palynomorphs have been found in a black shale pebble recovered during grab sampling in the NW part of the Barents Shelf. The proposed age is consistent with the findings of recent faunal and lithological studies on associated grab material.

During the summer of 1971 NTNF's Continental Shelf Division, in cooperation with Norsk Polarinstitutt, carried out extensive bottom sampling (grab and short core) of the Barents Shelf between Bjørnøya (Bear Island), Hopen, and Sørkapp (Fig. 1). Bottom sediments consist of gravel, sand, silt, and clay. The coarse fraction is dominated by sedimentary rock types.

In a detailed paleontological study of the sample material, NAGY (1973) reported bivalves, ammonites, and belemnites of Upper Jurassic to Lower

[1] Contribution No. 63 in NTNF's Continental Shelf Project.

Fig. 1. *Map showing location of station 25, 100m depth contour shown.*

Cretaceous age, and considered the material "more or less in situ". EDWARDS (1975), in a detailed sedimentological analysis, reported Triassic to Lower Cretaceous sedimentary rocks, and on independent sedimentological and stratigraphic evidence concluded that much of the bottom sediment of the Barents Shelf was transported only for short distances.

Thirty samples were investigated palynologically, yielding one workable assemblage from Station 25 (Fig. 1). The assemblage occurs in a pebble of dark grey fissile silty shale, which is the dominant rock type at this station. The bottom sediments at this station occur at a water depth of 100 m and consist of silt containing small pebbles and granules. EDWARDS (1975) suggested that stations with homogeneous gravel lithologies represent local material, transported for only relatively short distances. As most of the pebble material at Station 25 is dark shale, a local derivation for this shale is also likely.

Part of the assemblage is illustrated in Fig. 3. The assemblage is dominated by microplankton, but spores and bisaccate pollen are also present. The palynomorph assemblage is assigned a Cretaceous age. Characteristic Cretaceous palynomorphs include *Hystrichosphaeridium tubiferum* var. *brevispinum* DAVEY & WILLIAMS 1966, *Oligosphaeridium complex* (WHITE) DAVEY & WILLIAMS 1966 and *Cicatricosisporites australiensis* (COOKSON) POTONIÉ 1956. *Hystrichosphaeridium petilum* GITMEZ 1970 is previously recorded only in the Upper Jurassic of England (GITMEZ 1970). A number of reworked palynomorphs were also recorded.

Assemblages comparable to the present one have not to date been reported from the Mesozoic rocks of Svalbard. At Sørkapp, a section through the Janusfjellet Subgroup (Agardhfjellet and Rurikfjellet Formations) (Fig. 2) proved completely barren of palynomorphs, consistently yielding a rich black organic debris of high thermal metamorphic grade. At Agardhfjellet, well preserved Upper Jurassic to Lower Cretaceous microplankton assemblages were recovered (BJÆRKE, EDWARDS, and THUSU, this vol.) but are not comparable to the assemblage reported here. At this locality the presence of Upper Jurassic—Lower Cretaceous microplankton such as *Sirmiodinium grossi* (ALBERTI) WARREN

LOWER CRETACEOUS		CAROLINEFJELLET FM.
		HELVETIAFJELLET FM.
	JANUSFJELLET SUBGR.	RURIKFJELLET FM.
JURASSIC		AGARDHFJELLET FM.
		WILHELMØYA FM.
TRIASSIC		KAPP TOSCANA FM.
		SASSENDALEN GROUP

Fig. 2. *Lithostratigraphic units in the Mesozoic of Spitsbergen.*

1973, *Imbatodinium villosum* VOZZHENNIKOVA 1967, and *Gonyaulacysta cladophora* (DEFLANDRE) DODEKOVA 1967, impart an older aspect to this assemblage which is absent in the present material.

The works of EDWARDS and NAGY (op. cit.) suggest that the Rurikfjellet and Carolinefjellet Formations occur on Spitsbergenbanken. Our material may come from one of these units. Further onshore palynological coverage is needed to elucidate the age and correlation of the present assemblage.

Acknowledgements. — This paper is a part of the Barents Shelf Project, involving the cooperation of several Norwegian research institutions. Sampling was carried out by the Continental Shelf Division and Norsk Polarinstitutt.

Fig. 3. *Illustrations of palynomorphs.*

a) Gonyaulacysta *sp. Sample BAR 25, slide single I,* × *500*
b) Hystrichosphaeridium tubiferum *var. brevispinum* DAVEY and WILLIAMS *1966. Sample BAR 25, slide 2, coord. 37.3–104.8,* ×500
c) Hystrichosphaeridium petilum GITMEZ *1970. Sample BAR 25, slide 3, coord. 38.9–97.7,* ×500
d) Oligosphaeridium complex (WHITE) DAVEY and WILLIAMS *1966. Sample BAR 25, slide single I,* ×500
e) Lycopodiumsporites austroclavatidites (COOKSON) POTONIÉ *1956. Sample BAR 25, slide 1, coord. 30.9–100.1,* ×800
f) Cicatricosisporites australiensis (COOKSON) POTONIÉ *1956. Sample BAR 25, slide 4, coord. 28.1–113.4,* ×1000
(*Coordinates refer to the Leitz Orthoplan microscope No. 859913, belonging to NTNF's Continental Shelf Division.*)

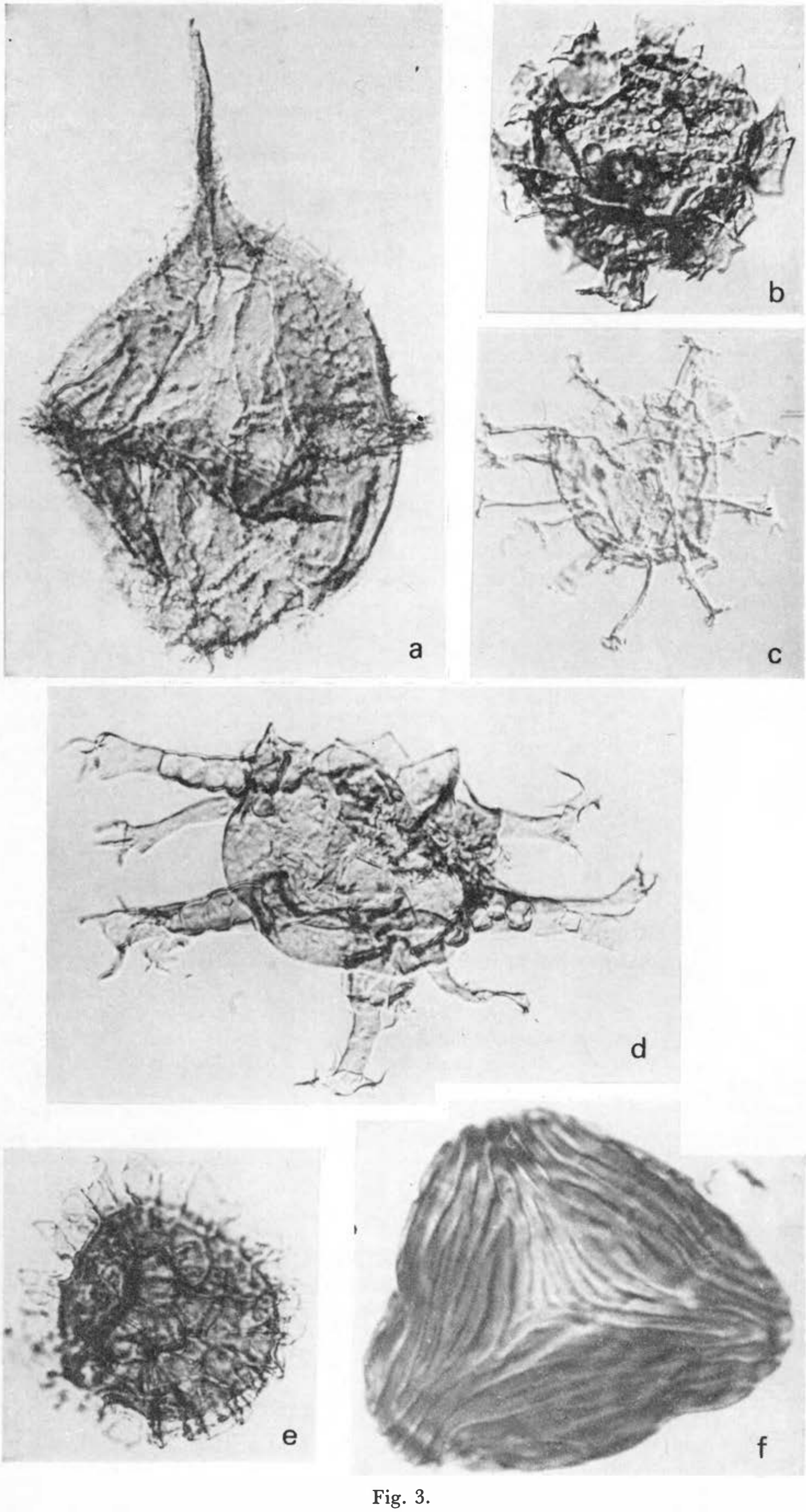

Fig. 3.

The authors are thankful to Dr. S. B. MANUM who initiated this palynological investigation at the Institutt for Geologi, Universitetet i Oslo. The final manuscript was improved by Dr. MARC B. EDWARDS.

References

DIBNER, V. D., V. A. BASOV, A. A. GERKE, M. F. SOLOVJEVA, G. P. SOSIPATROVA, and N. J. SHLUGINA, 1970: The age of the Pre-Quaternary deposits on the bottom of the Barents Sea. *Oceanology* **10** (4). pp. 520–529.

EDWARDS, M. B., 1975: Gravel Fraction on the Spitsbergen Bank, NW Barents Shelf. *Norges Geol. Unders.* **316**. pp. 205–217.

FLOOD, B., J. NAGY, and T. S. WINSNES, 1971: Geological map, Svalbard, 1:500 000, Sheet 1G, Spitsbergen, southern part. *Norsk Polarinstitutt Skrifter* Nr. 154 A. Oslo.

GITMEZ, G. U., 1970: Dinoflagellate cysts and acritarchs from the basal Kimmeridgian (Upper Jurassic) of England, Scotland, and France. *Bull. Br. Mus. Nat. Hist.* (*Geol.*) **18**. pp. 231–331.

KLENOVA, M. V., 1960: Geology of the Barents Sea. *Moscov. Izd. Akad. Nauk.*, SSSR.

NAGY, J., 1973: Fossilførende blokker av mesozoisk alder fra Svalbardbanken (Fossil bearing rock fragments of Mesozoic age from Svalbardbanken). (In Norwegian with English summary). *Publ. 42, NTNF Continental Shelf Division.* Oslo.

PARKER, J. R., 1967: The Jurassic and Cretaceous sequence in Spitsbergen. *Geol. Mag.* **104** (5). pp. 487–505.

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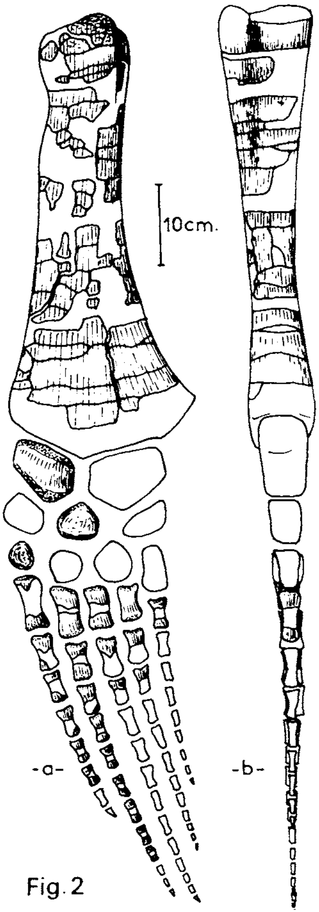
Un nouveau gisement à Plésiosaures dans le Jurassique du Spitsbergen (Archipel du Svalbard)

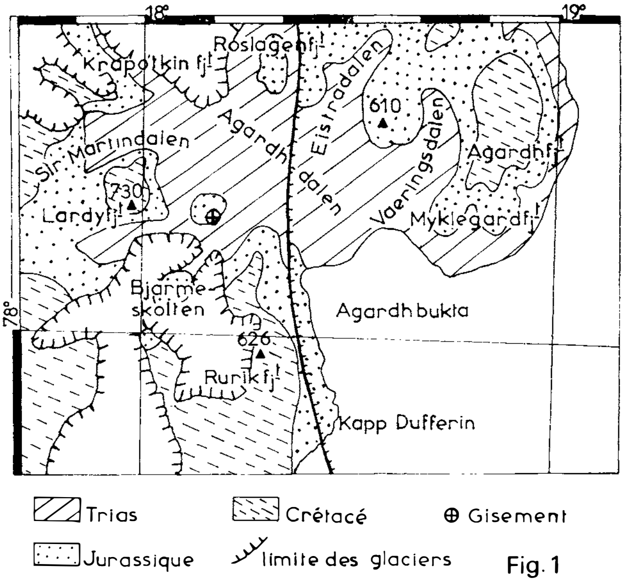
Résumé: D'importants restes d'un grand Plésiosauridé rapportés au genre *Tricleidus* ont été découverts dans le Jurassique supérieur de Agardhbukta, sur la côte orientale du Spitsbergen. La même localité présente également de niveaux toarciens où ont été récoltés de nombreux restes de Poissons, notament *Leptolepis nathorsti.*

Abstract: Remains of some large plesiosaurids determined as belonging to the genus *Tricleidus* has been discovered in the Upper Jurassic of Agardhbukta, on the East coast of Spitsbergen. At the same locality, Toarcian layers are exposed and contain numerous remains of fishes, e.g. *Leptolepis nathorsti.*

Historique

Des restes de Plésiosauridés ont été découverts à plusieurs reprises dans le Jurassique du Spitsbergen. Dès 1914, WIMAN décrit une vertèbre de Plésiosaure provenant de Kapp Delta, mais ce n'est qu'en 1925, puis en 1931 que l'on en découvrit des restes plus importants, notamment la partie postérieure d'un squelette en connexion. C'est cette pièce qui fut décrite en 1962 par PERSSON sous le nom de *Tricleidus svalbardensis.* Enfin, dans sa révision des Reptiles





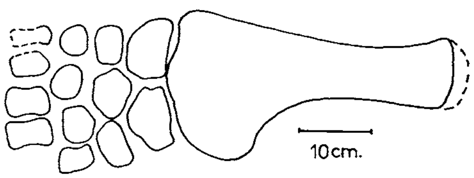


Fig. 3

Fig. 1. *La région de Agardhbukta, sur lac ôte orientale du Spitsbergen, avec les grandes lignes de sa géologie et l'emplacement du gisement à Plésiosauridés* (●).

Fig. 2. *Membre postérieur gauche de ?* Tricleidus svalbardensis *provenant des schistes à Buchia du Lardyfjellet. Tous les contacts entre les fragments du fémur sont assurés, les parties reconstituées ne sont que superficielles. L'ordre des phalanges est en grande partie hypothétique. a, vue supérieure (dorsale) ; b, vue interne.*

Fig. 3. *Membre postérieur gauche du type de* Tricleidus svalbardensis *de l'Oxfordien de Deltaneset (d'après* PERSSON 1963, Fig. 1).

fossiles de Norvège et du Spitsbergen (1964), N. HEINTZ rapporte la découverte en 1961, par WINSNES, de quelques vertèbres de Plésiosauridé au débouché de la Kjellstrømdalen dans l'Agardhbukta. C'est précisément dans ce même secteur que nous avons découvert, au cours de la mission française de 1969, les restes de Plésiosauridé décrits ici.

Localisation du gisement

Toutes les pièces que nous avons découvertes étaient exposées à même le sol sur le versant Sud-Est du premier monticule à l'Est du Lardyfjellet, au Sud de l'Agardhdalen (voir carte). Il existe en cet endroit une petite butte témoin de Jurassique surmontant les grès du Trias et comprenant des niveaux schisteux allant du Toarcien à l'Oxfordien. Ce gisement est donc situé juste en face de celui découvert par WINSNES.

La base des séries jurassiques que l'on y recontre repose sur un conglomérat rougeâtre qui fait rapidement suite à des grès fins puis à une alternance de schistes bitumeux et de minces bancs de calcaire phosphaté dans lequel nous avons trouvé des Bélemnites et des Ammonites caractérisant le Toarcien ainsi que de nombreux restes d'un petit Téléostéen primitif, *Leptolepis nathorsti*. Au-dessus du Toarcien fossilifère, la série des schistes continue mais on y rencontre guére qu'un petit bivalve, *Buchia* sp. C'est dans cette dernière séquence que nous avons découvert deux membres incomplets et quelques vertèbres d'un grand Plésiosauridé. Ces schistes à *Buchia* (*Aucella* schistes des auteurs classiques) représentent le Jurassique ainsi que le Cretacé inférieur jusqu'au Valanginien. Toutefois, selon la carte accompagnant le mémoire d'ORVIN (1940), le Lardyfjellet est entièrement dans le Jurassique et le gisement, situé à une centaine de mètres seulement au-dessus des grès triasiques, semble indiquer un âge approximativement callovo-oxfordien.

Description

La pièce principale du matériel du Lardyfjellet est un membre postérieur gauche (?) d'un grand Plésiosauridé. Lors de sa découverte, le fémur, bien que complétement fragmenté par le gel, était encore en place tandis que les autres os avaient déjà roulé sur la pente. Seuls le tibia, l'intermédiaire et quelques phalanges plus ou moins complètes ont pu être retrouvées. Non loin du fémur gauche gisait l'épiphyse proximale du droit ainsi qu'un fragment d'os plat interprété comme une partie de la ceinture pelvienne. Enfin, tout au long de la pente on pouvait récolter des vertèbres caudales généralement fragmentées par le gel. Il est très vraisemblable que le reste du squelette se trouve toujours engagé dans la roche avec, peut-être, le crâne. L'extraction en serait assez aisée car la pente est faible et le sédiment schisteux.

La comparaison de ces pièces avec la partie postérieure du squelette de *Tricleidus svalbardensis* de l'Oxfordien de Deltaneset (Fig. 3) révèle une très grande similitude dans la forme et les dimensions. La longueur du fémur du Lardyfjellet est de 50 cm environ et celle du fémur du type de *T. svalbardensis* de 42 cm. Le tibia du premier mesure 9 cm de largeur tandis que celui du second 8,4 mm. De même, on peut constater que le bord interne du fémur du Lardyfjellet présente, comme celui de *T. svalbardensis*, un large processus distal qui, selon PERSSON, serait assez caractéristique de cette forme. Sur le fémur le plus complet, comme sur l'épiphyse du second, la face interne de la partie proximale est légèrement concave.

Conclusion

En l'absence d'un bassin complet, il nous est impossible d'affirmer que les pièces décrites ici appartiennent à l'espèce *Tricleidus svalbardensis*, mais cette attribution est probable. Le Jurassique supérieur du Spitsbergen apparaît donc comme assez riche en gisements à Plésiosauridés. Ces grands Reptiles marins devaient se risquer dans des eaux peu profondes à l'occasion de petites transgressions temporaires ou de grandes marées et se trouvaient envasés ensuite dans les argiles à *Buchias* où leur squelette était la plupart du temps conservé en connection.

Bibliographie

FREBOLD, H., 1930: Verbreitung und Ausbildung des Mesozoikums in Spitsbergen. *Skrifter om Svalbard og Ishavet* Nr. 31, Oslo.

HEINTZ, N., 1964: Mesozoiske Øglefunn fra Norge og Svalbard. *Norsk Polarinstitutt Meddelelser* Nr. 91.

ORVIN, A. K., 1940: Outline of the geological history of Spitsbergen. *Skr. om Svalbard og Ishavet* Nr. 78, Oslo.

PERSSON, P. O., 1962: Plesiosaurians from Spitsbergen. *Norsk Polarinstitutt Årbok* 1961, Oslo.

WIMAN, C., 1914: Ein Plesiosaurierwirbel aus dem jüngeren Mesozoikum Spitzbergens. *Bull. Geol. Inst. University of Upsala* XII. Uppsala.

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Counts of sea-birds between Norway and Spitsbergen in the summer 1973

In July and September 1973, counts of birds were made from M/S "Norvarg" on two journeys between Norway and Spitsbergen.

Method. — Observations were carried out from the bridge, 5 meters above the sea. It was possible to cover an approximately 180° view in a forward direction. All birds that could be seen with binoculars (8×30 and 7×50) in this section were counted, the recording unit being number of birds seen during successive 15-minute periods. In this paper, however, a unit of one hour is used. Due to the limited outlook backwards from the bridge, it was difficult to keep watch of birds trailing the ship. These birds were not included in the count, but flocks following other ships were recorded. Birds flying and birds resting on the sea were not counted separately. When possible, we attempted to distinguish between adult and immature Gulls, and between light and dark phases of Skuas.

All distances are given in nautical miles (1 naut. mile = 1852 m).

The transects. — The first transect was made 19–20 July, starting as the ship passed the northern point of Fugløy, Troms, at 1210 hrs., Norwegian time, and ending 20 nautical miles west of Sørkapp, Spitsbergen, at 1710 hrs. Due to the midnight sun, observations could be carried out day and night. The weather was good, with long, sunny periods during the first half of the transect. During the second half, the sky was overcast most of the time, but the visibility was good. Rain and drizzle with poor visibility occurred in three short periods. The sea was calm, and at times completely smooth, enabling us to discover birds resting on the surface at quite a distance. In addition to the authors, AAGE TØRRIS EKKER took part in the observations.

The second transect started at Sørkapp, on 4 September at 0800 hrs., and ended the next day east of Andenes Lighthouse, Andøya, Troms, at 1800 hrs. The weather was much the same as on the July-transect, with sunny periods and relatively smooth sea. A short period of fog occurred. On this trip the

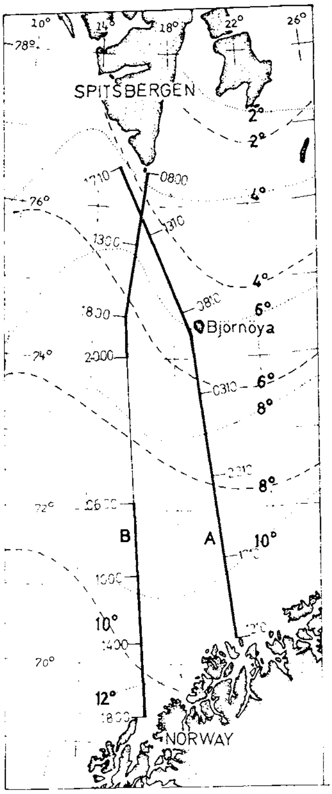

Fig. 1. *Figure showing the transects. A = 19–20 July. B = 4–5 September. Hours (Norwegian time) are given along each route. Isotherms from Det Norske Meteorologiske Institutt (Iskart: 17.–19.7, 1973, 21.7, 1973, 3.9, 1973 and 6.9, 1973): - - - - - - - - -: 19.–21.7, 1973; ....: 3.–6.9, 1973.*

light did not allow us to make observations during night, hence there is a break between 2000 hrs. and 0600 hrs. Observers were E. ALENDAL, I. BYRKJEDAL, and AA. T. EKKER. On both transects the ship made a steady speed of 12½ knots. The routes are shown on Fig. 1.

Results. — The results for the most abundant species are presented in Fig. 2 and Fig. 3.

July transect. — As expected, density was high near breeding colonies. The size of the sea-bird colonies on Fugløy was estimated in 1963 by LÜTKEN (1965).

The occurrence of the various species outside Fugløy corresponded roughly to the proportions between their breeding colonies on the island as estimated by LÜTKEN. Puffin (*Fratercula arctica*) and Razorbill (*Alca torda*) showed density-peaks between 6 and 9 nautical miles, and between 3 and 6 miles north of the island, respectively, while no marked concentration of Guillemot (*Uria* spp.) was seen before we reached Bjørnøya. The first Kittiwake (*Rissa tridactyla*) was seen as far as 38 naut. miles N of Fugløy, not appearing regularly before we had reached 100 miles off the coast. The only Black Guillemots (*Cepphus grylle*) were seen four miles north of Fugløy (3 individuals).

As we passed Bjørnøya (nearest distance being 7 naut. miles) great numbers of Guillemots (*Uria* spp.) were seen. In most instances it was impossible to distinguish between Guillemots (*U. aalge*) and Brünnich's Guillemots (*U. lomvia*). These two species are therefore treated together in this material. An

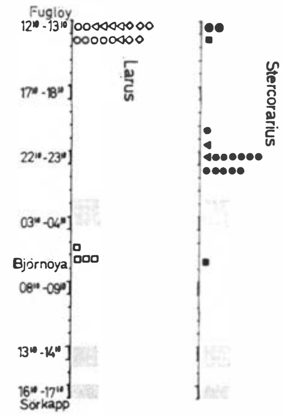

Fig. 2B. *Skuas* (Stercorarius) *and Gulls* (Larus) *on the July transect. Only one dark phased Arctic Skua* (S. parasiticus) *was seen (between 2210 and 2310 hrs.). All Gulls were adults.*
Stercorarius skua ■ S. pomarinus ▼
S. parasiticus ● Larus marinus ○
L. fuscus ▽ L. argentatus ◊
L. hyperboreus □ reduced visibility ▩

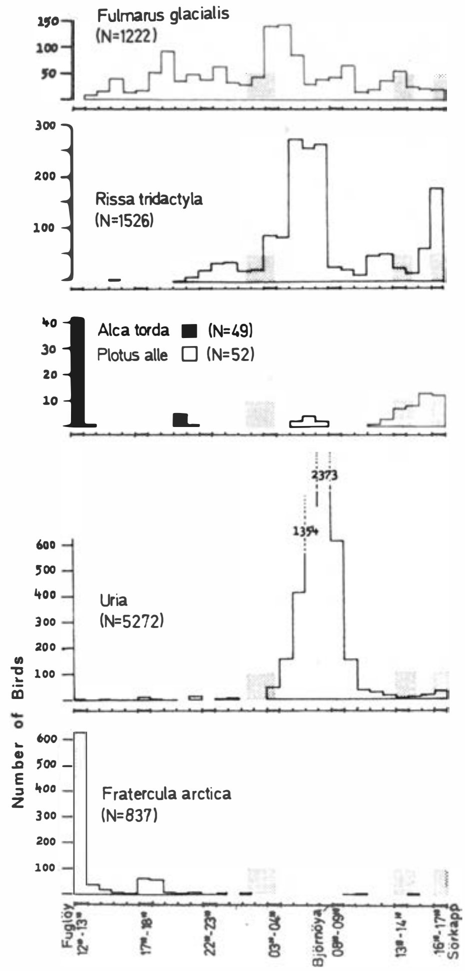

Fig. 2A. *Number of birds seen per hour on the July transect. Shaded areas denote periods of reduced visibility.*

increase in density occurred also for Kittiwakes and Fulmars, while Puffins and Black Guillemots were not recorded, and only a few Little Auks (*Plotus alle*) were seen.

According to LØVENSKIOLD (1964), all these species breed commonly on Bjørnøya: Fulmars, Kittiwakes, and Brünnich's Guillemots breeding in "enormous numbers", especially on the S–SE side of the island. The Little Auk breeds mainly on the N and E side, and the Puffin is breeding frequently all around the island.

At the end of the transect an increase in abundance of Kittiwakes was evident, although observations were terminated as far as 20 naut. miles from the coast of Spitsbergen.

September transect. — By this time all but the Fulmars have left the breeding colonies. Little Auks and Guillemots (*Uria* spp.) showed density-peaks at quite a distance from the coast of Spitsbergen.

The affinity of Fulmars to fisheries was demonstrated on at least two occasions: A "swarm" of 2000 Fulmars was seen in the wake of a trawler 6 miles

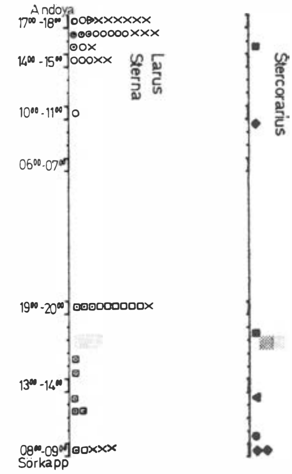

Fig. 3B. *Skuas, Gulls, and Terns* (Sterna sp.) *on the September transect. Legend as in* Fig. 2B, *butin addition:*
Stercorarius sp. ◆ Larus sp. △
Sterna sp. × *Juvenile* Larus: *Small dot inside the symbol.*

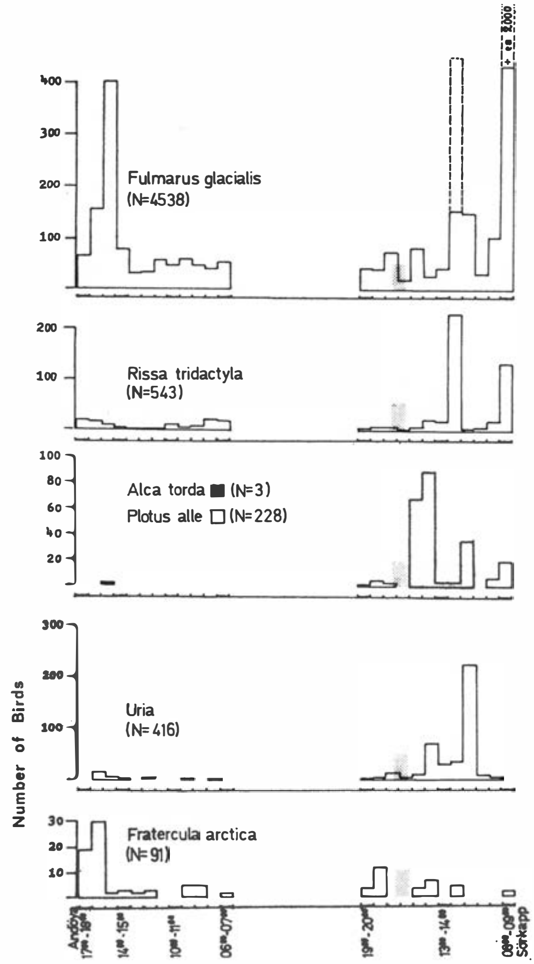

Fig. 3A. *Number of birds seen per hour on the September transect. Broken lines indicate concentrations around trawlers.*

S of Sørkapp, and a flock of 300 by another trawler about 60 miles S of Sørkapp. On the same place, the Kittiwake increased in number, but did not concentrate in a flock as did the Fulmar. The increased density of Fulmars near the Norwegian coast may also have been caused by fishing activities, although birds were not seen gathered around vessels.

On both transects the Fulmar was the most evenly distributed species, occurring mostly as single birds or a few individuals together. The Kittiwakes were fairly abundant, too. The figures for these two species may be somewhat higher than the actual density, since they are likely to be attracted to a ship, although they do not necessarily follow it. The adult/juvenile ratios for Kittiwake were 152:14 in July, and 36:158 in September.

The Alcids may have had a greater pelagic abundance than is indicated in this material. Most of them (except *Uria* spp. near Bjørnøya) were seen on the sea surface, and were hard to detect if the sea was not entirely smooth.

Species not shown on the graphs in Fig. 2 and Fig 3 (excluding a few *Alcidae* indet., scattered along both transects):

	July	September
Phalacrocorax sp.	1 (19.7., 1240 hrs.)	
Sula bassana		2 (5.9., 1730 hrs.)
Clangula hyemalis		1 (5.9., 0945 hrs.)
Cepphus grylle	3 (19.7., 1225 hrs.)	2 (4.9., 0830 hrs.)
		1 (4.9., 1330 hrs.)
Calidris maritima		2 (4.9., 0830 hrs.)
Limicolae indet.	2 (20.7., 0810 hrs.)	

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References

LÜTKEN, E., 1965: Ynglefuglene på Nord-Fugløy, Nord-Norge, deres udbredelse og antal. *Dansk Orn. Foren. Tidsskr.* **58**. 166–192.

LØVENSKIOLD, H. L., 1964: Avifauna Svalbardensis. *Norsk Polarinstitutt Skrifter* Nr. 129. Oslo.

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