DET KONGELIGE DEPARTEMENT
FOR HANDEL, SJØFART, INDUSTRI, HÅNDVERK OG FISKERI

NORGES SVALBARD- OG ISHAVS-UNDERSØKELSER
LEDER: ADOLF HOEL

SKRIFTER OM SVALBARD OG ISHAVET

Nr. 15

GUNNAR HORN AND ANDERS K. ORVIN:

GEOLOGY OF BEAR ISLAND

WITH SPECIAL REFERENCE TO THE COAL DEPOSITS,
AND WITH AN ACCOUNT OF THE
HISTORY OF THE ISLAND

OSLO
I KOMMISJON HOS JACOB DYBWAD
1928

Results of the Norwegian expeditions to Svalbard 1906—1926 published in other series. (See Nr. 1 of this series.)

The results of the Prince of Monaco's expeditions (Mission Isachsen) in 1906 and 1907 were published under the title of 'Exploration du Nord-Ouest du Spitsberg entreprise sous les auspices de S. A. S. le Prince de Monaco par la Mission Isachsen', in Résultats des Campagnes scientifiques, Albert Ier, Prince de Monaco, Fasc. XL—XLIV. Monaco.

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The following topographical maps have been published separately:

Bjørnøya (Bear Island). Oslo 1925. Scale 1 : 25 000. Kr. 10,00.

Bjørnøya (Bear Island). Oslo 1925. Scale 1 : 10 000. (In six sheets.) Kr. 30,00.

A preliminary edition of topographical maps on the scale of 1 : 50 000 covering the regions around Ice Fjord and Bell Sound, together with the map of Bear Island, scale 1 : 25 000, is published in:

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GUNNAR HORN AND ANDERS K. ORVIN

WITH 9 PLATES AND 70 TEXT FIGURES

The mineral resources of Svalbard consist chiefly of extensive coal deposits. Coal has been shipped from Spitsbergen since 1907, and the yearly export now amounts to about 300,000 tons. Within the borders of Norway proper there exist no coal deposits of commercial value, and the coal fields of Svalbard are therefore of great importance to the country. In this publication series there has already been published a general description of Svalbard coal (HOEL, ADOLF, The Coal Deposits and Coal Mining of Svalbard. Oslo 1925). The present publication on the geology of Bear Island is the first of a series of monographs of the various coal-fields.

In 1919 the Norwegian Government became financially interested in the *Bjørnøen A. S.*, a Stavanger company operating a coal-mine on Bear Island, through advances against coal deliveries given in order to help the company to finish its development work. In 1922 it was decided by the Department of Trade and Industry, by authority of the Storting the same year, that an accurate topographical and geological survey, with special regard to the coal deposits and their workability, should be carried out. The Norwegian Svalbard Expeditions were entrusted with the planning and execution of this work. The plans were examined by the Government Coal Committee, whose members were: B. STUEVOLD-HANSEN, Chairman, A. K. HILLESTAD, Hj. BATT, and LUDV. FOLTMAR, Secretary, and were finally approved of by the said Department.

In the summers of 1922 and 1923 the island was topographically mapped on the scale of 1 : 10 000. Special large-scale maps of certain more important parts of the island, such as the mining areas, were also prepared. In 1922 Prof. W. WERENSKIOLD did geological reconnaissance work. In 1924 a few small remaining areas were mapped by the topographers, and the survey was finished.

A topographical map on the scale of 1 : 10 000 (in six sheets), and a general map on the scale of 1 : 25 000 were published in 1925.

The geological work was done in 1924 and 1925 by the authors of this paper assisted by H. MARSTRANDER.

Hitherto there has existed no general summary of the history of Bear Island, and, as it is closely connected with the coal deposits and the development of the mining industry, a brief account of its discovery and history is attached to this paper.

The paper also contains a fairly complete list of publications dealing with the history and the geology of the island.

Oslo, May 15, 1928. ADOLF HOEL

Contents.

Illustrations.

Preface.

The geological field work, the results of which are presented here, was done during a total of five months and a half in 1924 and 1925.

Besides the mapping and measuring of sections, twenty-four test-pits were dug in order to uncover the seams and get reliable sections. Further, four boreholes having an aggregate length of 760 metres were drilled to establish the sequence and to find any new seams that might occur.

The drilling was done with outfit from *Norsk Diamantborings A/S*, Oslo, and in 1924 Mr. H. MERCKOLL, the present mining inspector of Svalbard, was in charge of the drilling operations.

Mr. H. MARSTRANDER, Mining Engineer, who took part in the geological field work, was especially engaged in the uncovering of the coal-seams, and also measured several detailed sections. Thus the greater part of the section along the east coast is due to him.

To Mr. ADOLF HOEL, the leader of the Norwegian Svalbard Expeditions, we are greatly indebted for valuable help and many useful suggestions.

Throughout the survey, Mr. ODD ROALKVAM, Managing Director of Bjørnøen A. S., Mr. F. THETING, Mine Manager, Mr. H. SYVERTSEN, and the other members of the staff, extended to us their most hearty co-operation in this work and many personal courtesies, for which we are most grateful.

The chief results of the survey bearing upon the occurrence of coal and its workability were published in due course in the parliamentary papers of the Norwegian Storting, but the preparation of this final paper has been long delayed owing to other pressing work.

Oslo, May 15, 1928.

GUNNAR HORN and ANDERS K. ORVIN.

Introductory.

Bear Island (Norw. *Bjørnøya*) is situated between Norway and Spitsbergen, and is the southernmost island of Svalbard, which is the denomination given to the Norwegian possessions in the Arctic Ocean, between 74° and 81° N. Lat. and 10° and 35° Long. E. of Gr.

The isle extends from 74°20.5′ to 74°31.3′ N. Lat. and from 18°46′ to 19°17′ Long. E., and is of triangular shape with one side running about east-and-west and pointing southwards. The greatest length is 20 kilometres from north to south, and the greatest width is 15.5 kilometres from west to east. The total area is 178.07 sq. kilometres (68.75 sq. miles), of which 0.26 sq. kilometre is islets and skerries. The distance from North Norway is 240, and from Sørkapp (South Cape) on Spitsbergen 120 nautical miles. Bear Island is situated on the continental shelf which extends from Norway to Spitsbergen; west of the island this shelf falls abruptly towards the great depths of the Greenland Sea. Were the sea bottom raised 500 metres, the isle would become joined to Norway and Spitsbergen.

At Tunheim, in the northeast, there are a mining camp, a meteorological station, and a powerful wireless installation for communicating with Norway. — Only the staff of this station remain on the island all the year round. Huts are found in a number of places. Bear Island is reached by steamer from Norway in 1—1½ days, but, no regular steamship service exists.

In the summer the isle is most of the time enveloped in fog, the weather being on the whole dull and dreary. The climate is mild considering the high latitude, the average temperature of the year being —3.8 C[1]. The summer temperature is about the same as in Spitsbergen, but the winter is much milder than there. In latitude 74°30′ N. the midnight sun lasts from Apr. 30 to Aug. 13 (106 days), and the sun is continually below the horizon from Nov. 7 to Feb. 4 (90 days).

The flora and fauna are very poor; of mammals there are only a few arctic foxes, and when the drift-ice surrounds the island the polar bear makes its appearance, to disappear, however, with the ice. The cliffs are the resort of countless numbers of sea-fowls, particularly auks, and the southern mountains of Bear Island have unquestionably the distinction of being the largest fowling cliffs in the northern hemisphere.

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1 The monthly averages from 1912—26 are: Jan. —9.4, Febr. —11.2, March —11.0, Apr. —7.6, May —2.3, June 1.7, July 4.2, Aug. 3.6, Sept. 1.9, Oct. —1.7, Nov. —6.3, Dec. —7.5.

As regards ice, it has not during late years been any serious obstacle to traffic. Ice is brought to the sea around the island by a west-going current, and from February to May drift ice is of frequent occurrence; this ice may be met with in the summer, but, as a rule, the island is ice-free during the summer, autumn, and early winter. The occurrence of ice is, however, subject to great variations, and ships have reached the island in every month of the year. Fig. 1 shows the position of Bear Island and ice limits in the month of August.

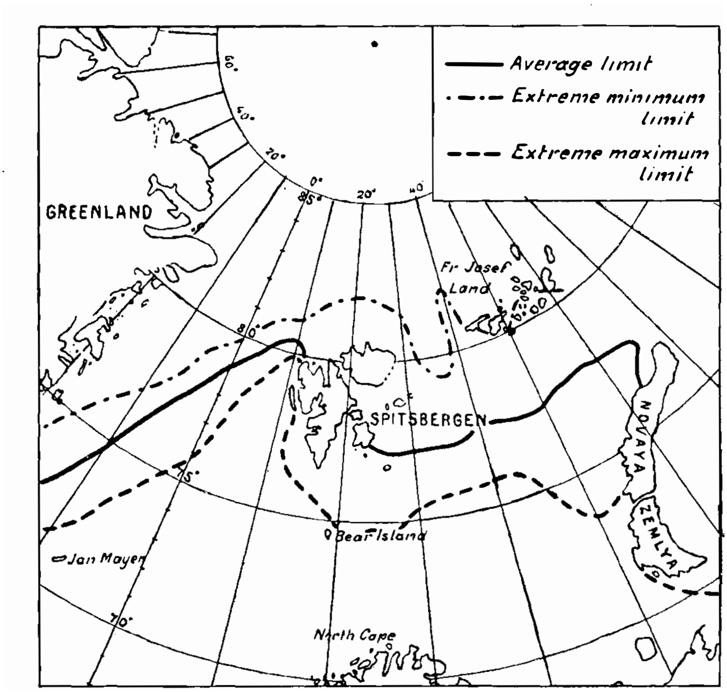


Fig. 1. Map showing ice limits in the month of August.
Average of 20 years' observations. After Speerschneider (1917).

Geography.

Topography.

Bear Island falls naturally into a southern mountainous, and a northern level part, everywhere terminating seawards in steep cliffs.

Turning first to the mountains, we have on the east coast the Miseryfjell (Mount Misery), a very characteristic plateau mountain with three summits, Urd, Verdande, and Skuld, reaching altitudes of 536, 462, and 454 metres respectively, the first-named being the highest mountain on the island. Miseryfjell is separated from the southern mountains by a stretch of undulating lowland drained by Russeelva (Russian River) (pl. VII, B), on the south side of which Antarcticfjellet rises to an altitude of 360 metres above sea-level. The broad valley of Ymesdalen (pl. VI, A) separates this mountain from Alfredfjellet, 420 metres high, south of which come Hambergfjellet and Fuglefjellet with altitudes of 440 and 411 metres respectively. All these mountains are more or less of the plateau type, and they terminate in precipitous, almost vertical cliffs at the coast. The cliffs of Hamberg- and Fuglefjellet are particularly imposing, the height of the former is in one place 441 metres, rising sheer out of the sea. The photographs[1] will serve better than many words to give a clear impression of the aspect of these cliffs. Oswaldfjellet is situated northwest of Alfredfjellet, with Ellasjøen (Ella Lake) between, and consists of rounded hills, nowhere reaching an altitude of more than 165 metres (pl. VII, A).

These mountains present an exceedingly barren and desolate aspect, devoid of vegetation except on some of the hill tops, e. g. of Fuglefjellet, where there is an abundance of mosses. The cliffs, however, are teeming with life: there millions of sea-fowls, chiefly Brünnich's guillemot (*Uria lomvia*), are nesting. On the little flat rock of Alkeholmen, the auks sit so closely packed that the rock-surface is hidden from view.

The northern part of the island, about 110 sq. kilometres,

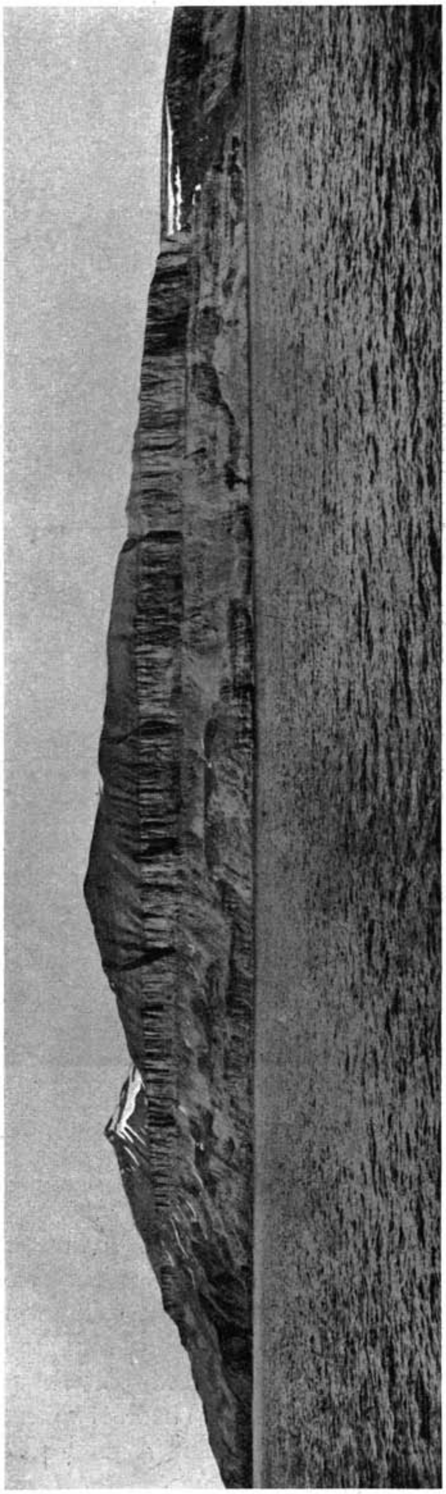


Fig. 2. Miseryfjell seen from the southwest.
A. Koller phot. 11/7 1924.

[1] Most of these were taken by the topographers of the expedition in the course of the stereo-photogrammetric survey of the island.

is a plain 30—40 metres above sea-level also terminating seawards in a cliff 20—30 metres high. This cliff is mainly vertical, making access from the sea impossible, except in a few places where rivers come down. The surface of this plain is slightly undulating, and is strewn with lakes and ponds (pl. IV, A and B). In Bear Island there are about 700 lakes having a total area of 18.8 sq. kilometres. i. e. 10.6 per cent. of the entire area, and by far the greater number of these lakes are situated in the northern half of the island. The lakes are often elongated in a north-and-south direction, or roughly parallel to the strike of the rocks, the water having gathered in depressions formed by the sea, and later by the ice, in the softer parts of the series or along faults.

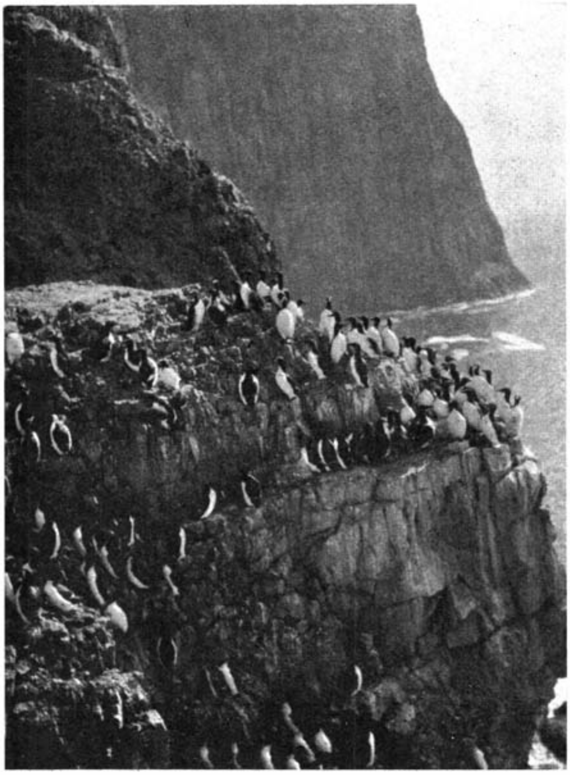


Fig. 3. Auks in Hambergfjellet.
A. K. Orvin phot. 26/7 1924.

Valleys and Rivers.

Valleys of any importance occur only in the southern mountainous region. Ymesdalen is the most prominent one, and Russeelva has its source in this valley, the watershed being situated on the very edge of the sea cliff, which is here 324 metres high (fig. 4). From the head to Gåsvatna (Goose L.) the valley is typically U-shaped. The length is about 5 kilometres, and the width from 0.5 to 1 kilometre. The present shape of the valley is due to glacial abrasion. The greater part of the drainage area of this valley has been removed by marine denudation, and the time is not far off when the sea will have excavated to such an extent that the valley will be open towards the south. In the ridge from Fuglefjellet (Bird Mtn.) to Antarcticfjellet we have undoubtedly a part of the watershed between the northern and southern parts of ancient Bear Island. The little valley, Revdalen, running south-southeast between Fuglefjellet and Antarcticfjellet and terminating abruptly at the sea cliff, here forming a waterfall, the Spitrefoss, about 120 metres high, must be regarded as the upper part of a larger valley once running southwards towards the ancient coast farther south. The fine slope leading down to Kapp Kolthoff, and the cape itself, are nothing but a remaining part of the right side of this valley. NANSEN (1920) suggests that the cape is part of the "strandflat" (marine denudation plain), but this is consequently not the case.

The rivers of the northern plain do not form pronounced valleys. The head of Engelskelva (English River), the most important river next to Russeelva, is found on the slopes north of Miseryfjell. The river forms a number of pools, partly very shallow owing to silting up (e. g. Storlona).

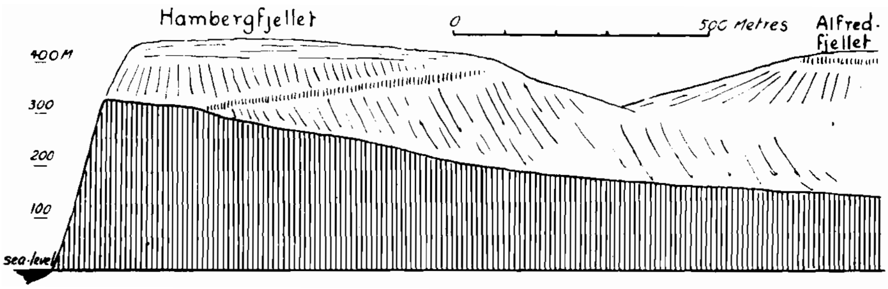


Fig. 4. Section of Ymesdalen from south to north.
Showing watershed situated on the edge of the sea cliff.

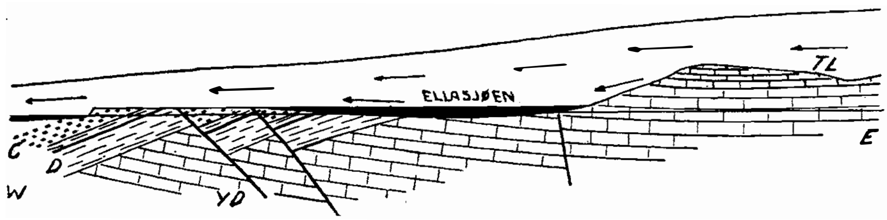


Fig. 5. Section of Ellasjøen.
The section shows how this lake is held in a rock basin formed by the ice. The arrows indicate the direction of the ice. *YD* Younger Dolomite, *TL* Tetradium Limestone, *D* Devonian, *C* Culm.

Hauselva and Lakselva come from the lakes of the same names, and, after joining, the river enters Nordhamna (North Haven). In the regions with Carboniferous limestone, subterranean rivers occur. Thus a river called Jordbruelva, west of Djupvatnet, has a subterranean run of about 300 metres.

Lakes.

As already mentioned the island has about 700 lakes and ponds, most of them being very small and shallow. Ellasjøen, north of Alfredfjellet, is, however, quite deep, in most places about 30 metres and locally deeper, up to 43 metres. The area is 0.73 sq. kilometres, and the height above sea-level is 20.8 metres. NATHORST (1899 b) thinks that the lake owes its origin to dislocations, but this can hardly be the case, as only one fault crosses the lake. A much more reasonable explanation is that the lake basin has been excavated by the ice, which has moved here from east to west. The Devonian shales have been less resistant to the action of the ice than the Culm sandstone in the west, which has acted as a barrier (fig. 5).

In Ellasjøen a salmon-like fish, the char (*Salmo alpinus*), is quite common and stays there all the year, as a waterfall prevents the fish from entering the lake from the sea. The lakes situated on the northern plain are all shallow, and the largest contain fish. Many of them are situated in hollows formed in the less resistant beds, and run more or less parallel to the strike. This is the case with Spelvatnet, Stevatnet, Hausvatnet, and the lakes south of the last-named to Røyevatnet, and also with a number of lakes farther west. The largest lake is Laksvatnet (Salmon Lake), situated on horizontal beds of Upper Carboniferous limestone. It has rather an irregular outline. The depth is only 2—3 metres.

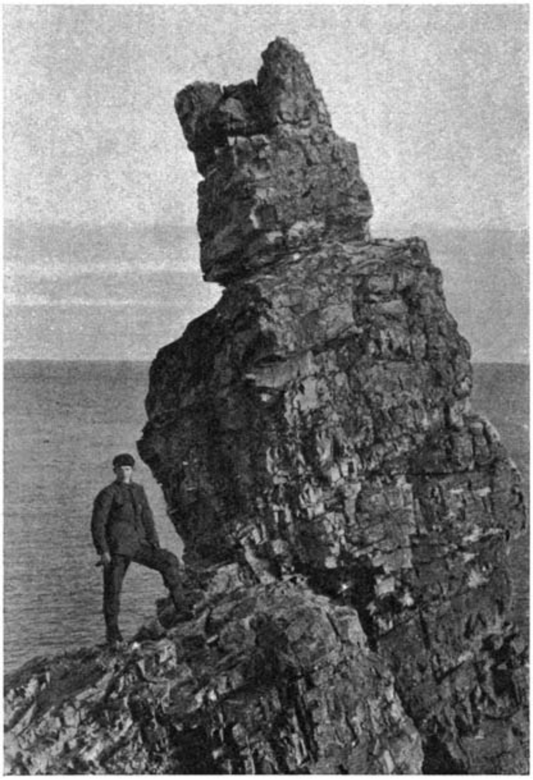


Fig. 6. Fugleodden at Tunheim.
A stack of Devonian sandstone not yet separated from the coast.
B. Luncke phot. 29/8 1924.

Coast.

The coast-line is very little indented, and the island is therefore poorly supplied with sheltered places. Sørhamna (South Haven) is a cove with a good anchorage, but open to southern winds. All around the island are many open bays, but generally the cliff is very steep, making it impossible to land. The most sheltered places with a fairly good landing are: Båtvika in the southwest, cove on Kapp Dunér in the west, Nordhamna and Herwigshamna in the north, Austervåg — with coal-loading plant — in the northeast, and Russehamna, Norskehamna, and Kvalrosshamna in the southeast.

The island is nearly everywhere limited by a steep cliff which is frequently overhanging. No sheltering island wall surrounds Bear Island,

and the sea acts with its full force upon the land, the different rocks offering varying resistance to the action of surf and swell. The cliff is naturally the result of sea abrasion, and is maintained by cutting at the base. At about high-tide level there is often an undercut, and from time to time blocks are dislodged from the overhanging rock by frost or other agents of disintegration.

In several places projections of rocks or stacks of about the same height as the cliff have been separated from the land by the attack of

Fig. 7. Engelske Staur on the northeast coast.
Projection of rock or stack, 29 metres high, separated from the sea cliff by the attack of the waves.
P. Berge phot. 1924.

the waves. The most prominent one is the Engelske Staur (English Stack) on the northeast coast, rising out of the sea about 200 metres from the shore (fig. 7). Another fine example is Måkestauren (Gull Stack) north of Kapp Forsberg (fig. 28). On the north coast Taggen, off Kapp Heinsius, is very conspicuous (fig. 8). All these stacks rise from the wave-cut bench from which they will ultimately be razed. On the west coast the cliff consists of limestones, and the dissolving action of the water has produced channels and holes, which in some places reach the surface some distance inland.

In the south the destructive action of the sea is seen on the most stupendous scale. The cliff is made up of roughly horizontal beds of dolomite. In Sørhamna a series of slates reaches the sea, and the harbour has been formed, thanks to the lesser resistance offered by these rocks. The same thing applies more or less to Kvalrossbukta and Røedvika. In the dolomite cliffs hollows and channels are also quite common. The most imposing one is Perleporten (Pearl Gate), which is a passage 170 metres long through Kapp Kolthoff (fig. 10). The tunnel is quite wide, with walls smoothed by the sea. The current is strong here, and it is a thrilling experience to shoot the rapids of the tunnel in a small motor-boat. The well-known Borgmesterporten (Burgomaster Gate) in Russehamna was first described by DUNÉR and NORDENSKIÖLD (1867). NATHORST walked on the roof of it in 1870, but when ANDERSSON visited the island in 1899 the roof had fallen in. A channel through Meholmen on the east side of Sørhamna has also been called the Burgomaster Gate. Stappen, a stack 186 metres high, off the south promontory, has also fine channels (fig. 14). Projections of rock on the south coast are: Sylen, a needle rock 80 metres high (fig. 11) Håsteinen, Keilhaus Øy, and Alkeholmen, the last two being flat on the top. Måkeholmen (Gull Island), on the east side of Sørhamna, is the only islet of any size. It forms a plateau 40—50 metres above the sea, and terminates in very steep cliffs.

Fig. 8. Taggen.
Isolated rock, 23 metres high, off Kapp Heinsius on the north coast.
G. Horn phot. 16/9 1925.

Landslips.

Bear Island furnishes a number of excellent examples of landslips on a big scale. On the seaward side of Miseryfjell, below Urd, huge masses of Spirifer limestone together with the overlying Triassic shales have slid forward into the sea (fig. 17). It is easily seen how the harder limestone has been broken and crushed as it moved. Scratches resembling glacial striæ have been formed during this process. Farther north a big section of coal-bearing Devonian beds has slid down, and the coal-seams still retain their relative position.

The most magnificent examples of landslips are to be seen in Ymesdalen. On the west side of the valley huge sections of Upper Carboniferous limestones have slid down, and now occupy a position about half-way up the slope (fig. 12). ANDERSSON (1900 b) considers it

Fig. 9. Old graves in Nordhamna.
Originally the graves were a little distance from the edge of the cliff. This is, however, gradually being worn back by the sea, and now a coffin can be seen jutting out. — G. Horn phot. 16/8 1924.

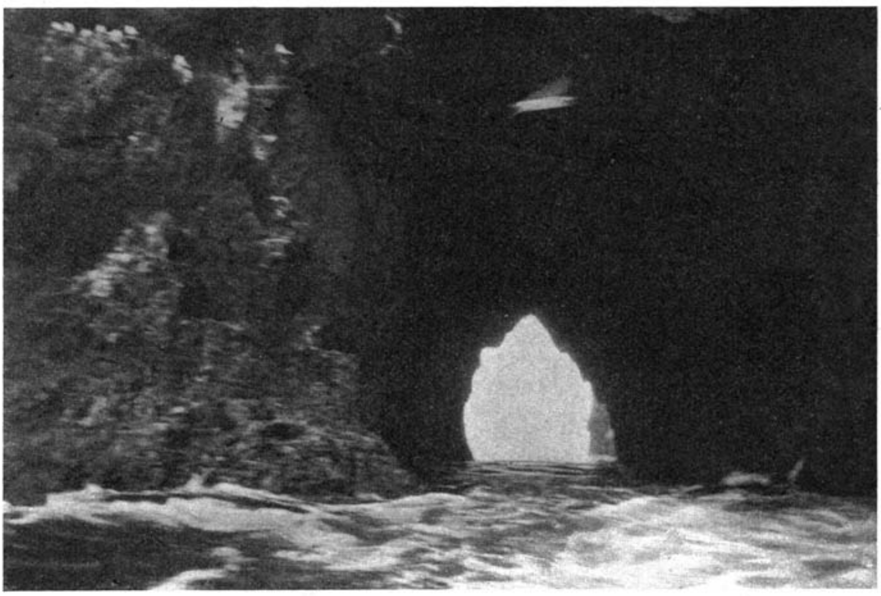


Fig. 10. Perleporten, Kapp Kolthoff.
Showing northern entrance of this wave-cut channel, about 170 metres long, through Kapp Kolthoff. G. Horn phot. 3/8 1925.

to be due to a fault, but this cannot be the case as no fault is traceable either south or north of the Carboniferous rocks. The dip of the beds in the sections that have slid is towards the slope. The total length of the landslip is about 700 metres. As regards the age of this landslip it has the appearance of being very old. When Ymesdalen was glacier-filled the water may have dissolved much of the dolomite rock below the Carboniferous, and when the ice disappeared it had not sufficient support and came down. The Devonian area of ANDERSSON in the bottom of the valley is not Devonian at all, but Upper Carboniferous sandstone, having slid down into the valley from its original position on top of the mountains.

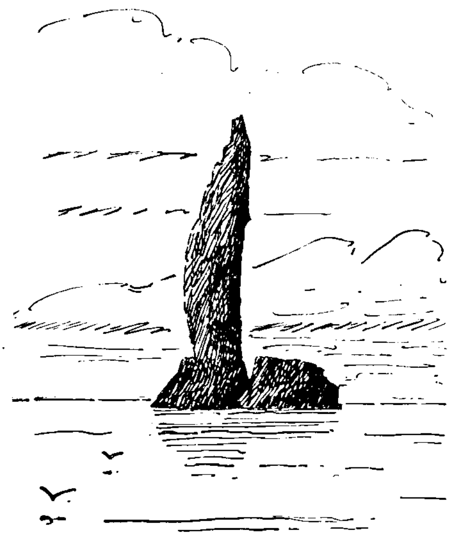


Fig. 11. Sylen (The Awl).
Isolated rock of dolomite, 80.6 metres high, off the south-west coast. Drawn after phot. by G. Horn 3/8 1925.

At the foot of the steep mountain sides are deposits of talus, often arranged in cones. In the winter fragments of rock slide down on the snow surface, and after the snow has melted away a curving ridge of rock fragments may remain, convex away from the source of the slide. The thawed part of the ground has also on a sloping surface a tendency to move, sliding downwards on the frozen part (solifluction, ANDERSSON (1906)). Good examples are seen on the north side of Miseryfjell.

Alluvial cones are not frequent. The northern part is too flat for their formation, and, in the south, sand and shingle are carried directly into the sea.

No glaciers exist on Bear Island, but it may happen that accumulations of snow do not melt away in the summer.

Surface.

The greater part of Bear Island is covered with fragments of the bed-rock or is quite bare. In Devonian and Culm country the surface is covered with angular blocks of sandstone, making walking here exceedingly fatiguing and slow (pl. IV, B). The Carboniferous limestones and calcareous sandstones, however, give rise to an even, smooth surface (pl. V, A), and here something approaching soil has been formed.

Fig. 12. Old landslips on the west side of Ymesdalen.
G. Horn phot. 20/8 1925.

Fig. 13. Ptarmigan on the rocky northern slope of Miseryfjell.
A. K. Orvin phot. 27/9 1924.

Soil.

BJØRLYKKE (1927) has examined 3 soilprofiles taken on the island by one of the writers. The weathering has produced a soil consisting mostly of crumbled rocks. BJØRLYKKE found however some humus, and the upper strata show some elutriation of soluble salts, as does the soil in humid districts. He considers the soil of Bear Island to represent a transition type between the sterile soil of Spitsbergen and that of the humid regions of North Norway.

Moraine and wash material are as a rule absent. In a few places, however, heap-shaped accumulations of blocks of sandstone or limestone are found, which must have been carried thither by the ice (fig. 42 and 43).

Not infrequently are found blocks of sandstone exhibiting peculiar sections (Dreikanter), due to the abrading action of the sand grains carried along by the wind.

Frozen Ground.

Beneath a thin surface layer the ground on Bear Island is in a permanently frozen state. The boreholes should furnish valuable information about this, but owing to lack of suitable instruments we were not able to obtain accurate measurements of the temperature of the ground in the boreholes. However, in borehole No. 9 at Vestre Flyvatn, rough measurements were made at 25-metre intervals to a depth of 75 metres. As the hole was full of water, and we only had an ordinary thermometer at our disposal, the results cannot be claimed to be of any great value. At a depth of 50—75 metres the temperature is apparently about 0° C. In 1924 the water in borehole No. 6 became frozen to a depth of 65—68 metres. On Bear Island the ground thus appears to be permanently frozen to a depth of 60—70 metres. About 0.75 metre of the surface becomes thawed in the summer.

The action of the freezing of the water on outcropping strata is interesting. The more porous layers become saturated with water, and when it freezes the beds are forced apart, getting a steeper dip than before. Dip observations near the surface may thus be wrong, the correct dip being obtainable several metres down.

Stratigraphy.

Hecla Hoek.

A. E. NORDENSKIÖLD visited the island in 1864 (DUNÉR and NORDENSKIÖLD (1867)), and was the first to correlate the dolomites, limestones, etc., of its southern part with the rocks at Hecla Mount on Spitsbergen; no fossils were then found, and the rocks were considered contemporaneous solely on petrological grounds. During the expedition of NATHORST in 1898, of which J. G. ANDERSSON was a member, and on the expedition of the latter the year after (ANDERSSON (1900 b)), the Hecla Hoek was studied more thoroughly. In 1898 fossils were found in a dark limestone: mostly badly preserved cephalopods, but also corals, viz., a Tetradium, the latter fixing the age as being Upper Ordovician according to LINDSTRÖM (1899). ANDERSSON divided the formation into three members: oldest, dark limestone with Tetradium, followed by dolomite with quartzitic sandstone on top, and red and green slate. The dolomite, which unquestionably also underlies the Tetradium Limestone, he did not incorporate in his sequence. He considered the area with slates in Sørhamna to be a down-faulted one, and the dynamic metamorphism to which the Hecla Hoek strata has been subjected to indicate their having been involved in the Scandinavian-Caledonian mountain folding. HOLTEDAHL (1920 b) investigated the Hecla Hoek in 1918 and arrived at a sequence different from that of ANDERSSON. He found a new fossiliferous zone in the dolomites below the Tetradium Limestone. With some alterations of the thicknesses we have adopted the succession of HOLTEDAHL, which is as follows, in descending order:

	Min. thickness in metres
Tetradium Limestone series	240
Younger Dolomite series, with fossiliferous zone in lower part	400
Slate-quartzite series	175
Older Dolomite series. In lower part with oolites, oolitoids, and stromatolites; in upper part strongly arenaceous	400
	1215 metres.

The Older Dolomite series occupies the area between Sørhamna and Miseryfjell. The dip is to the northeast (35°—40°). At Sørhamna the dip is steeper, and in Måkeholmen even vertical. Along a line from Sørhamna towards the northwest the older dolomite, as pointed out by HOLTEDAHL, has been pushed over the slate-quartzite and younger dolomite. The slates have thereby become folded and contorted, whereas the superincumbent dolomites, being more rigid, have resisted the pressure better, and only the part just above the slate series has become folded. The thrust plane is clearly seen in Kvalrossbukta and Sørhamna. The western boundary of the older dolomite is everywhere a faulted one. Towards the east this series is conformably overlain by the Slate-quartzite series. The older dolomite is traversed by a number of reversed faults striking approximately northwest. The beds thus become repeated, and HOLTEDAHL has observed a bed with stromatolites to occur twice (1920 b). Veins with barytes, galena, and blende are fairly common in this series. The dolomites are in the upper part very sandy. A sample taken south of Miseryfjell looks in hand specimen like an arenaceous limestone. Under the microscope it shows a fine-grained ground mass of dolomite with a considerable amount of partly rounded quartz grains (0.2—0.5 mm). The rock is here also oolitic, but not so much as lower down in the series. Pyrites is present, and also traces of microcline. These sandy strata form a transition to the overlying Slate-quartzite series. Fossils have not been found in the Older Dolomite series, but HOLTEDAHL considers it to be contemporaneous with the Porsanger Dolomite of Finnmark in North Norway, and to fall within the time division Ozarkian of the Americans (Upper Cambrian or Basal Ordovician).

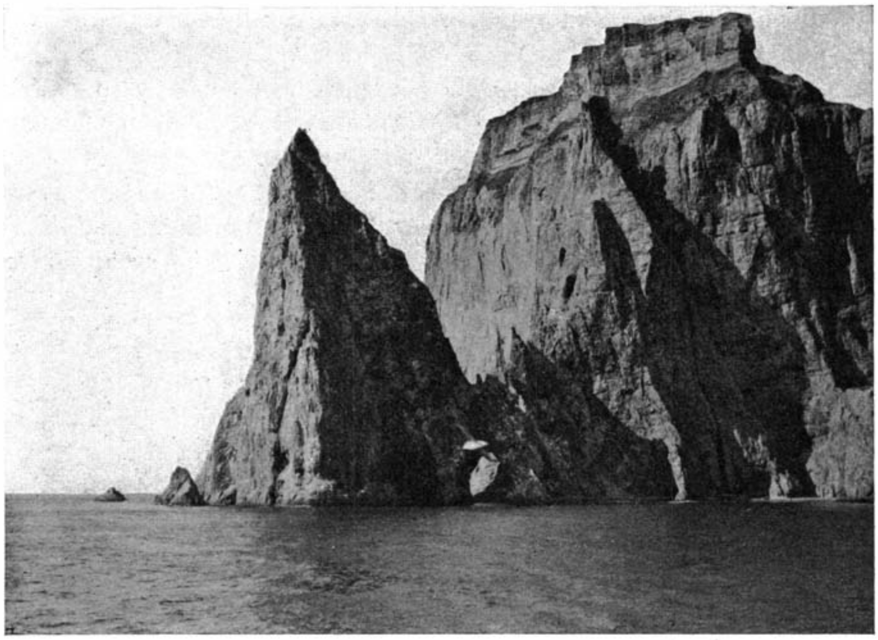


Fig. 14. Southern promontory of Bear Island.
Stappen, 186 metres high, to the left. To the right Fuglefjellet. The cliff is about 350 metres high. Flat-lying beds of Hecla Hoek dolomite with Spirifer Limestone capping Fuglefjellet. — P. Berge phot. 11/9 1924.

The Slate-quartzite series consists of red and green slates with well developed cleavage, and beds of quartzitic sandstone. It is exposed (I) on the shore at the south corner of Miseryfjell where the series rests conformably on the former series, and is unconformably overlain by the Devonian (fig. 17), (2) between Sørhamna and Kvalrossbukta, strongly folded between the two main lines of fracture (fig. 15), and (3) at the junction of Ørvella and Russeelva, where it is just visible surrounded by the overlying younger dolomite. The slate here is undoubtedly continuous with the slate south of Krillvatnet, the roof of dolomite being thin and much puckered. In Sørhamna the dip of the foliation is 30°—60° SE to SSE, and does not coincide with the bedding, which has a steeper dip. One gets the impression that the beds have been thrown into sharp folds, uniformly cut by the planes of foliation. In thin section the slate proves to be exceedingly fine-grained, making it impossible to identify the minerals. However, a few angular quartz grains are seen.

With regard to the quartzite a sample from a locality north of Sørhamna was examined. In thin section angular quartz grains (0.1—0.2 mm) are seen cemented by a black mass of magnetite with cores of pyrites. Accessory minerals: tourmaline, zircon, and rutile. The rock is very slightly pressed. Quartzitic sandstone, from south of Miseryfjell has in hand specimen the appearance of a white fine-grained sandstone. Thin section: Subangular grains of quartz (0.1—0.3 mm), partly close inter-

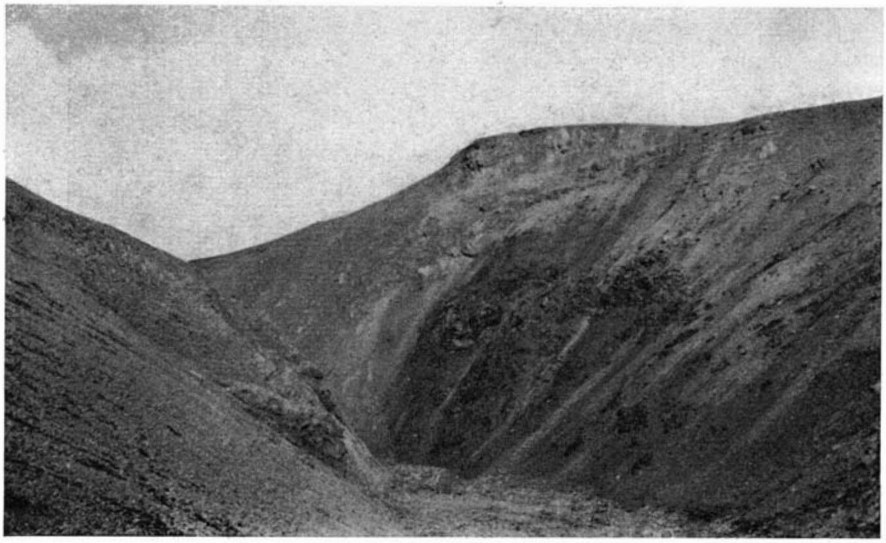


Fig. 15. The gap of Kvalrosselva, near Sørhamna.
Sharply inflected fold of slate overlain by the Younger Dolomite. — G. Horn phot. 20/8 1928.

locking of the grains. Accessory minerals: feldspar, pyrites, apatite, zircon, and sericitic mica. As seen from fig. 16 it is not a quartzite, but a very slightly pressed sandstone. We have, however, used the determination Slate-quartzite series because this series on Spitsbergen is really quartzitic.

The Younger Dolomite series consists of a monotonous sequence of grey dolomite with yellowish weathering. It is found over a large area in the southern part of the island, and forms the abrupt sea cliffs of Antarcticfjellet, Fuglefjellet, and Hambergfjellet. The visible thickness is about 400 metres, but, as there is nowhere a continuous section to the underlying slate series, the total thickness is not known. As is evident from the map, the beds lie more or less horizontal with gentle undulations. Locally, dips of 30° are observed. Near the big overthrusts steep dips and contortions are seen. In the upper part of the dolomite, beds of dark limestone occur, heralding in the deposition of the main limestone. The dolomite is a very uniform rock of a grey colour and yellowish weathering. The grains vary in size; in one sample they were up to 0.5 mm, in another up to 0.1 mm. The dolomite is not sandy, excepting a very few thin horizons. HOLTEDAHL ((1920 b), p. 125) found fossils in this series at Kapp Kolthoff, 250 metres below the Tetradium Limestone, and also in a locality 4 kilometres farther NNE Amongst the genera found, *Calathium*, *Archaeoscyphia*, and *Piloceras* are important for dating the horizon, which is thus of low Ordo-

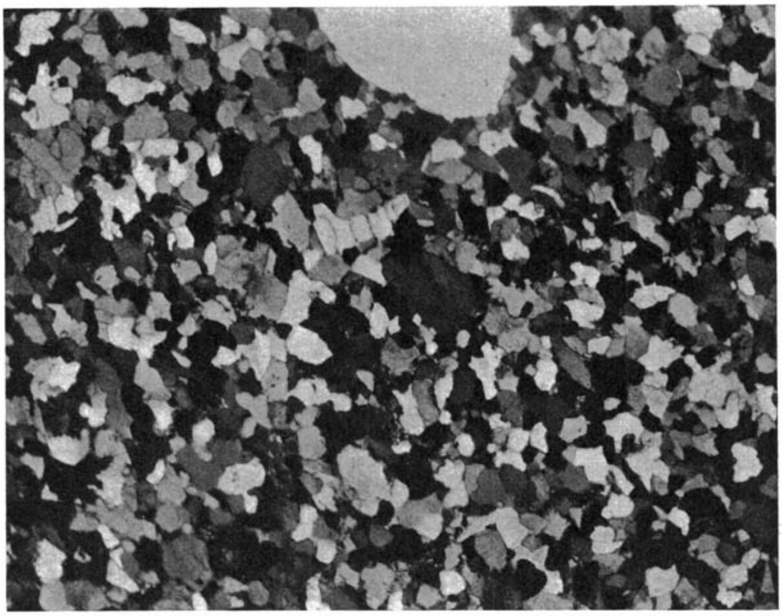


Fig. 16. Sandstone, Hecla Hoek, south of Miseryfjell.
As will be seen from the photograph the sandstone is very slightly pressed, and is not quartzitic. — × 25. — O. Andersen phot. 1928.

vician age, or Canadian according to American classification (op. cit. pp. 130—131).

The Tetradium Limestone series is the youngest of the Hecla Hoek members, and occupies the central part of the Hecla Hoek area. Antarcticfjellet, Ymesdalen, and the northern spur of Alfredfjellet are built up of this limestone. The rock forms rugged, barren hills almost black in colour. The limestone follows the younger dolomites conformably, and has an undulating dip. A secondary cleavage imparted by a pressure from the northeast makes the series appear to have a dip in this direction. The thickness is min. 240 metres.

The limestone is dark grey to black, with white calcite on minute cracks and fissures. On the northeastern slopes of Antarcticfjellet, near the big fault, lenses and veins with semi-transparent calcite are fairly common. On the north side of Svartkulpen, east of Ellasjøen, is a vein with barytes.

The limestone is very fine-grained with a diameter of the grains from 0.005 to 0.01 mm. In the big veins the crystals may attain a diameter of up to 10 cm.

The grains of the limestone show the effect of pressure and are closely interlocked.

Fossils are quite common in a zone about 120 metres above the base of the series (HOLTEDAHL (1920 b)).

The fossils known from the Tetradium Limestone are (op. cit., p. 133): *Tetradium* cf. *syringoporoides* ULRICH, *Bryozoa*, several species, *Crinoid stems*, *Rafinesquina* sp., *Maclurites* sp., *Orthoceras* (*Kionoceras* ?) sp., *Endoceras* (*Vaginoceras* ?) sp., *Endoceras* ? sp., *Actinoceras Bigsbyi* BRONN (= *A. tenuifilum* HALL ?), *Gonioceras* (*occidentale* HALL ?) sp., *Gonioceras Nathorsti* n. sp., and HOLTEDAHL states that these fossils fix the age as being Middle Ordovician ("Black River", U. S. A.).

Devonian.

When KEILHAU visited the island in 1827, he noticed the coal-bearing strata to lie below the fossiliferous limestone which by v. BUCH (1848) was found to be of Carboniferous age. Despite the very clear statement in the paper by v. BUCH, NORDENSKIÖLD (DUNÉR and NORDENSKIÖLD (1867)) suggested a correlation with the coal-bearing strata of Spitsbergen, which had been found to be of Tertiary age. However, in 1868 NORDENSKIÖLD collected a great material of plant fossils from the coal-bearing formation, and the fossils were determined by HEER (1871), who found that they represented a particular stage of the Lower Carboniferous (effecting a transition to the Upper Devonian). He suggested the term "Ursa-Stufe" for the Bear Island stage. The Carboniferous plants brought home from Spitsbergen by NATHORST and WILANDER in 1870 were also referred to this "Ursa-Stufe". NATHORST (1894) revised this determination, as he found that the Bear Island flora was older, being distinctly Upper Devonian. This view was supported by the material collected on the expeditions in 1898 and 1899 (NATHORST (1900 a and 1902)). The "Ursa-Stufe" includes the whole sandstone series up to the Middle Carboniferous; and to 1916, when Culm fossils were found in a drill core, the whole series was considered to be Upper Devonian. The finding of these fossils definitely proved that the upper part of the sandstone series is of Culm age. The Devonian and Culm deposits form, however, a distinct arenaceous unit quite different from the underlying Hecla Hoek and the overlying Middle Carboniferous, and we have therefore retained the name "Ursa", using it as the formational name of the entire sandstone series.

The Devonian consists of sandstones, conglomerates, shales, and transitions between these and a number of coal-seams, as a rule with stony bands. The coal-seams fall naturally into two groups, one in the upper part of the formation, the Tunheim Series, and one in the lower part, the Misery Series. The sandstones often show false bedding; small unconformities and other evidence of irregular deposition are also often seen. It was evidently a continental deposit formed by lakes and rivers.

The general lithological development of the Devonian will be seen from the sections of the boreholes (pl. III) and the coastal section (pl. IX).

The beds rest with a pronounced unconformity on the abraded Hecla Hoek surface. At the south corner of Miseryfjell this unconformity is well exposed (fig. 17). The Hecla Hoek rocks dip 15°—25° NE and the Devonian about 6° NE. On the east coast the dip is 2°—10° E, whereas at Ellasjøen the Devonian dips about 15° W, below the younger formations. The upper limit of the Devonian is difficult to fix on account of the numerous faults, owing to which there is nowhere a certain sequence leading from the Devonian to the Culm, but we are inclined to believe that the upper limit of the Devonian is to be placed some 30—50 metres above the top seam of the coal series at Tunheim. In borehole No. 9 (at Vestre Flyvatn) coal-seams were encountered between 196 and 206 metres, and they are probably to be correlated with the Tunheim series.

Where the Devonian boundary here is to be fixed must await the determination of the fossils we have collected, but provisionally the boundary is placed 20 metres above the top seam (fig. 18).

The basal beds of the Devonian consist of conglomerates somewhat differently developed. At the south corner of Miseryfjell it is a coarse sandstone with bigger pebbles, and southwest of the mountain are found patches of a coarse, unpressed conglomerate resting on the slates and dolomites of the Hecla Hoek. In loose blocks of this rock ANDERSSON found fish-scales determined by A. SMITH WOODWARD (1900) as belonging to the genus *Holoptychius* (*H. giganteus* AG. and *H. monilifer* A. S. WOODWARD). HOLTEDAHL (1920 b) collected more material from the conglomerate. The fish scales were determined by J. KIÆR (op. cit., pp. 144—145) and all belong to the said genus. "The Upper Devonian of Bear Island connects Northern Europe faunistically with the Arctic Regions and North America".

North of Ellasjøen the conglomerate is 4 metres thick, but here the pebbles are much smaller. The irregular development of the conglomerate must be caused by the uneven Hecla Hoek surface, the coarser material being deposited in the depressions. The extremely coarse conglomerate south of Miseryfjell may represent a river bed or littoral conditions.

The lower part of the Devonian is best seen in the coastal slopes of Miseryfjell. The sequence is shown on sections A—E pl. II.

The bottom 180—200 metres of the formation consist of predominant sandstones with shales and sandy shales. Then follow a number of coal-seams, the Misery Series, so well seen in the seaward slopes of Miseryfjell. Borehole No. 5 at Ellasjøen and No. 6 (lower part) south of Tunheim have pierced this series. In No. 6 the hole stopped probably 60—70 metres from the Hecla Hoek.

The coal-seams of the Misery Series disappear below the sea at the northeast corner of Miseryfjell and are below the sea all along the east coast. Above this coal-series follow about 100 metres of chiefly

Fig. 17. Southern end of Miseryfjell.

Showing Devonian strata (in the centre) resting unconformably on the Hecla Hoek (to the left). The Devonian is overlain unconformably by the Upper Carboniferous Spirifer Limestone forming the precipitous edge of the mountains. The limestone is followed by a series of Triassic strata forming the summits. Big landslips are seen to have taken place on the seaward side. — B. Luncke phot. 29/8 1924.

sandstones, with no coals worth mentioning. This barren series is pierced by borehole No. 8.

In the middle, barren, series we also meet with conglomerates; such an horizon is well exposed at Rifleodden and Kapp Nordenskiöld on the east coast. The section here is as follows, in descending order:

		Grey sandstone.
3–5	metres	Coarse conglomerate; grey matrix with quartz pebbles (potato size)
4—6	„	Conglomeratic, coarse sandstone
0.5	„	Black shale with plant fossils
1.5	„	Grey conglomerate, small pebbles, with lenses of sandstone
2–4	„	Fissile grey shale with numerous plant remains and a little coal
2—4	„	Lenticular sandstone with little shale
12	(min.)	Soft, grey shale. Easily crumbling with yellowish-brown weathering. Poor, if any, bedding

The conglomerate from this section was reached by borehole No. 8 at Tunheim, and it outcrops west of the wireless station on the eastern slope of a valley, the latter being caused by a soft shale below the conglomerate.

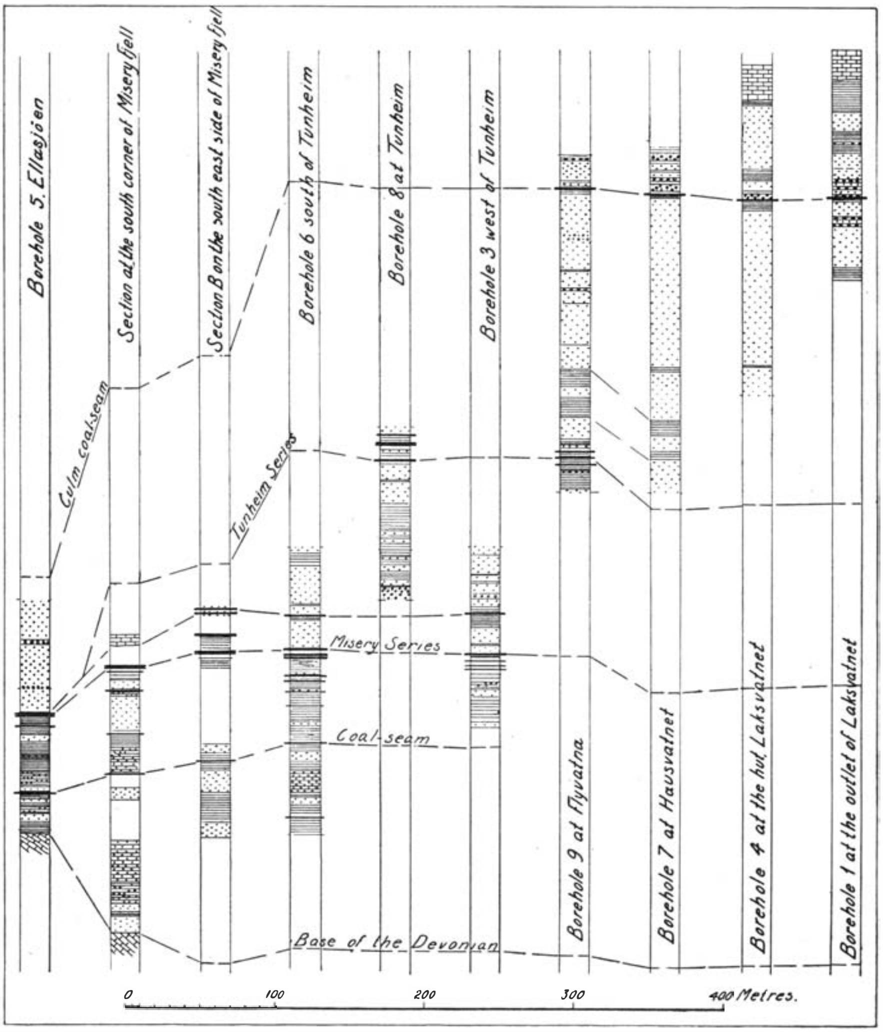


Fig. 18. Boreholes and sections from Miseryfjell.
The sections are placed in correct stratigraphical position. As the plant fossils from No. 9 bore have not yet been determined, the correlation of the bottom seams in this bore with the Tunheim series is not quite certain.

Then comes the Tunheim Series with three coal-seams, of which the bottom seam, called the A-seam, has been mined at Tunheim.

In 1868 NORDENSKIÖLD and MALMGREN collected plant fossils from this series, the locality being north of Engelskelva. The flora was described by HEER (1871) as being Lower Carboniferous (the Bear Island representative called by HEER the Ursa stage). In 1898 NATHORST, and in 1899 ANDERSSON, collected more material from the Tunheim horizon, and also from lower horizons (Kapp Levin and Miseryfjell). In his monograph on the fossils, NATHORST (1902) shows that the geological age is not Culm, but Upper Devonian (in 1916 true Culm fossils were found in a borehole in the interior of the island). Characteristic plants are: *Archaeopteris fimbriata* NATH., *A. Roemeriana* Gp. sp., and *Cyclostigma* ("*Bothrodendron kiltorkense* HAUGHTON sp."). The flora of the *kiltorkense* and *Roemeriana* beds shows that they are contemporaneous with the Upper Devonian of Ireland and Belgium. The fish scales furnish evidence in the same direction (NATHORST (1902)). NATHORST ((1910), p. 276) says that the fossils in Miseryfjell were found below the coal-seam, and that the fossils from Kapp Levin occur above the coals, not only above those of Miseryfjell but also above the coal-seams which outcrop in the cliffs from Kapp Nordenskiöld northwards, i. e., the area Miseryfjell—Kapp Nordenskiöld he considered to be a syncline. This is, however, not in agreement with the facts. The coal-seams north of Kapp Nordenskiöld belong to a horizon about 100 metres above the seams at Miseryfjell, and the fossiliferous horizon at Kapp Levin lies between the two.

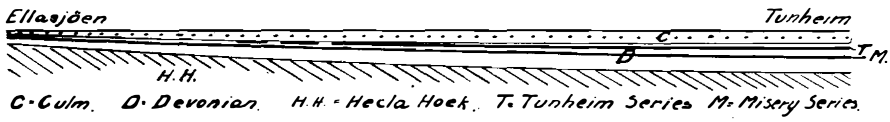


Fig. 19. Section from Ellasjøen to Tunheim,
showing the deposits of Culm and Devonian at the end of the Culm period.

With regard to the thickness of the Devonian it may be said that it increases considerably to the north. Granted that the lower part of the Devonian at Tunheim has the same thickness as in Miseryfjell (it is very likely more), we arrive at a thickness of the strata below the A-seam of 320 metres. Above the A-seam only 40 metres of strata are preserved on the east coast, and it seems fairly safe to assume them to be Devonian. Then the total thickness in the Tunheim area will be 360 metres.

Towards the south and southwest the thickness then decreases rapidly, and at Ellasjöen we have only 100 metres of Devonian strata.

In fig. 18 boreholes and sections from Miseryfjell have been correlated, and it will be seen that the total thickness of Devonian and Culm at Ellasjøen is nearly 400 metres less than in the northeastern part of the island. An unconformity between the formations would explain the difference in thickness, but not the fact that both the lower part of the Devonian and the Culm itself are less thick than in the northeast. The only feasible explanation appears to be that there is a general thinning out of the formations towards the south, as shown in fig. 19.

We have made a cursory examination of a few Devonian rocks: Borehole No. 8, Tunheim at 45.25 metres. Light grey sandstone. Grains of quartz and quartzite < 0.5 mm. Subangular and tightly packed with ferruginous cement. Tourmaline and flakes of mica rare.

Borehole No. 8 at 110.40 metres. Greyish-white conglomerate with pebbles (nut-size) of light and dark quartz, and also angular fragments of quartz and shale. In thin section are seen angular fragments of a quartzite much more pressed than any so-called quartzite now found in the island.

Borehole No. 8 at 111.50 metres. White sandstone. Reddish hue, and dark specks. Subangular quartz < 0.6 mm. Some of the grains consist of a much pressed quartzite. Ferruginous cement.

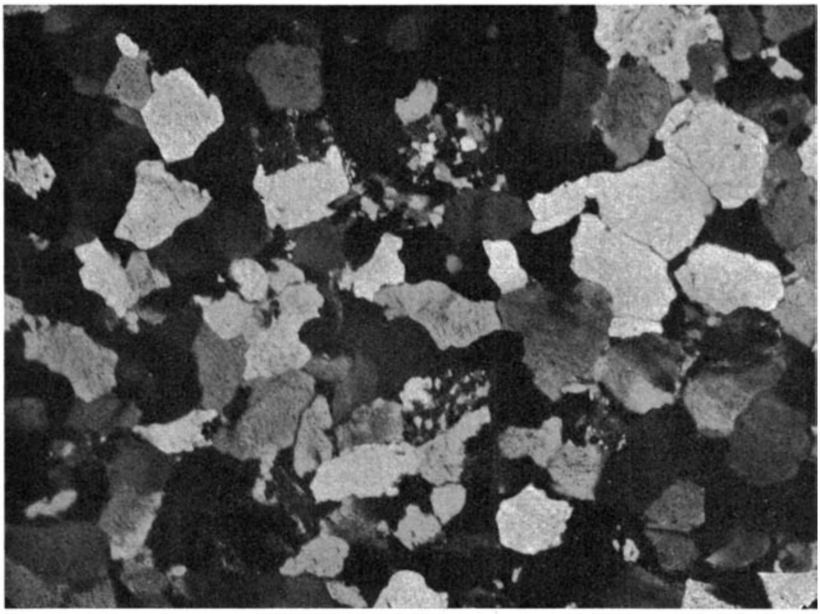


Fig. 20. Devonian sandstone.
From 45.25 m's depth in borehole No. 8 at Tunheim. — $\times$ 43. — O. Andersen phot. 1928.

Trig. sta. 58 near Kapp Levin. Rather hard sandstone. Quartz < 0.5 mm. Many grains of quartzite. Pyrites, traces of rutile and mica. Also shale fragments.

The quartzite, which is fairly frequent in the samples, is not found in the present Bear Island, and indicates that the Devonian deposits were derived from an area of more strongly metamorphosed rocks than those now to be seen.

Culm.

Considering the wide distribution of the Culm, it seems remarkable that it was not discovered until 1916. (ANTEVS and NATHORST (1917)). The reason is that the fossiliferous shale horizons of the Culm are very few and thin, and good outcrops are only found on the north coast in one or two rather inaccessible places. In the interior the shale weathers to a fine powder, and is almost entirely lost among the huge masses of débris of the sandstones which make up the bulk of the formation. From Devonian to Middle Carboniferous there is a continous sequence of chiefly arenaceous deposits, and it was not until ANTEVS brought forward the fossil evidence from a borehole (No. 1, at Laksvatnet), that the upper part of the sandstone series was recognised as being of Culm age.

When the formations are viewed as a whole there is a distinct lithological difference: The Devonian is made up of sandstones, shales,

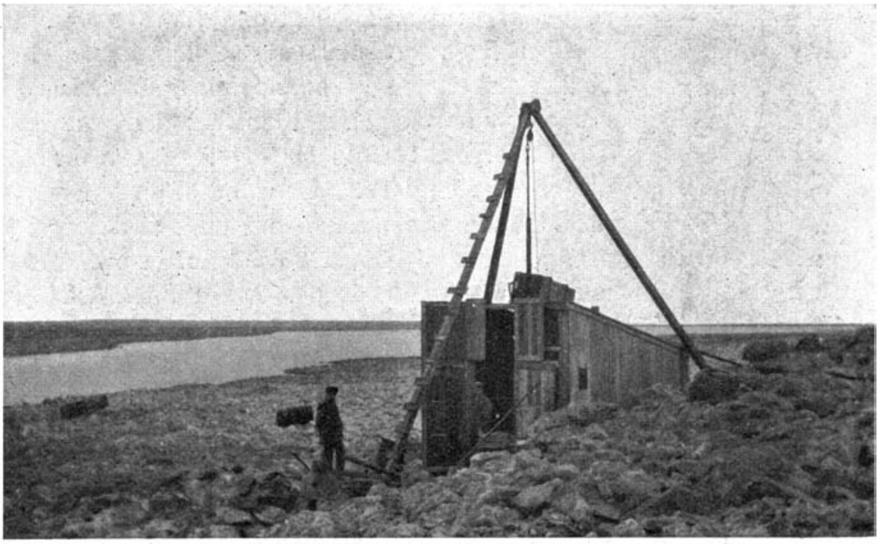


Fig. 21. Drilling at the southern end of Hausvatnet.
Borehole No. 7, 234 metres in depth. — G. Horn phot. 25/8 1924.

conglomerates, and many coal-seams, while in the Culm the sandstones make up nearly the whole series. There are a few shale horizons in the lower part, and a shale bed with a thin and irregular coal-seam near the top. The sandstones and conglomerates above the coal-seam form passage beds to the Middle Carboniferous basal beds, which consist of red conglomerates and sandstones passing upwards into a calcareous series.

It is impossible to fix the lower limit of the Culm accurately until the fossil evidence from borehole No. 9 has been determined. This bore, it is hoped, has pierced the basal beds of the Culm down into the Devonian. In its broad features it is not difficult to delineate this lower boundary. Owing to the amount of shale, the outcrop of the Devonian consists to a great extent of finely graded débris mixed with blocks of sandstone. Walking over this ground is not very difficult. The Culm, however, with its massive sandstones gives country with nothing but angular

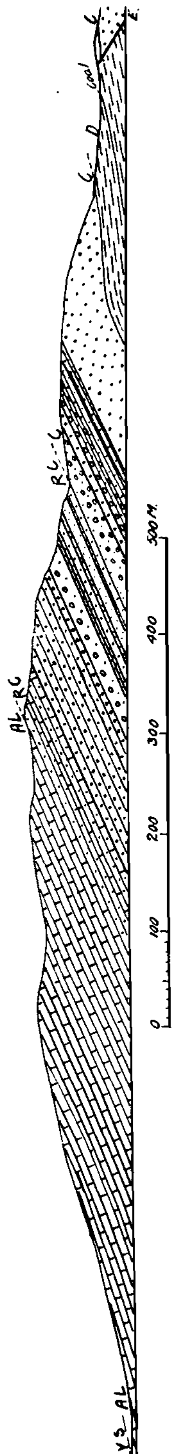


Fig. 22. Section through the Middle and Lower Carboniferous series on the north side of Landnørdingsvika.
Y S Yellow Sandstone, A L Ambigua Limestone, R C Red Conglomerates, C Culm, D Devonian.

sandstone blocks, making walking a very arduous task. In contrast to this, the Middle Carboniferous and succeeding series produce an even surface, very good to walk on. The upper limit of the Culm is also not very distinct, as some of the conglomerates must undoubtedly be included in the Culm.

The formation has been explored by means of four boreholes: two at Laksvatnet (Nos. 1 and 4), one at the southern end of Hausvatnet (No. 7), and one (No. 9), at Flyvatna, 2 kilometres southeast of No. 7. In No. 1 ANTEVS (op. cit. p. 651) fixed the boundary Culm-Middle Carboniferous on purely lithological grounds, below the lowest red bed, i. e. 36 metres above the coal. The limit is not based on any fossil evidence, as plants have only been found in the shale forming the foot wall of the seam, and in the shale horizon at the depth of about 150 metres, below termed the "first shale horizon". About the fossils we quote NATHORST (op. cit. p. 655): "We are here obviously dealing with a Culm flora. Some of the species — *Sphenopteris bifida*, *Cardiopteris* cf. *spetsbergensis*, *Adiantites* cf. *bellidulus*, *Stigmaria ficoides* occur in the Culm flora of Spitsbergen, and those that are missing there, e. g. *Adiantites* cf. *antiquus* are represented by allied species. The species characteristic of the upper Devonian flora of Bear Island are, however, entirely lacking." The other bore (No. 4) at Laksvatnet shows a similar development, but the "first shale horizon" occurs lower down, if it is the same. No. 7 bore at the south end of Hausvatnet was located just below the Middle Carboniferous, pierced the coal-seam, but never got out of the typical white Culm sandstone. The hole is the deepest on the island, 233.92 metres. No. 9 bore, about 2 kilometres southeast of No. 7, shows that the thick sandstone between the coal and the "first shale horizon" has thinned out in this direction. In No. 7 the sandstone has a thickness of 145 metres, and in No. 9 it is 110 metres.

In Landnørdingsvika, north of Kapp Harry, the following section of the boundary beds, Culm —Middle Carboniferous, was measured:

	Thickness in metres	
Middle Carboniferous	7.00	Light grey, hard sandstone
	19.00	Alternating layers of yellowish-green sandstone and slaty sandstone with red conglomerates on top
	3.00	Sandstone
	2.00	Red and green argillaceous, fissile sandstone
	1.00	Whitish-green sandstone
	0.50	Light green shale
	7.50	Alternating layers of light slaty sandstone and ordinary sandstone
	3.50	Yellowish-green sandstone with conglomerate in the middle
	10.00	Alternating layers of sandstone and red slaty sandstone
	2.00	Yellowish-green and reddish-brown argillaceous, slaty sandstone
	2.20	Massive yellowish-white sandstone
	5.00	Red argillaceous slaty sandstone
	0.60	Yellow fissile sandstone
	1.00	Red argillaceous sandstone (slaty)
Culm	20.00	Alternating layers of sandstone and conglomerate
	5.00	Greyish-white sandstone
	1.00	Fine conglomerate
	2.00	Greyish-white sandstone
	3.50	Conglomerate with sandstones up to 30 cm. thick
	1.80	Coarse conglomerate with pebbles (potato-size) and black flint
	5.00	Coarse greyish-white conglomeratic sandstone with layers of grey shale
	0.30	Grey shale
	1.30	Greyish-white sandstone with conglomerate
	3.50	Conglomerate. Greyish-yellow; red mottled matrix
	0.40	Light grey shale with coaly shale
	4.00	White fine-grained sandstone. Thin-bedded, partly fissile
	2.50	Greyish-white sandstone
	4.00	Reddish-brown and greyish-green argillaceous, slaty sandstone
	2.50	Whitish-grey slaty sandstone

Here the boundary is placed, as before, below the first red layer. The Culm coal horizon is represented by the layer (0.40) of shale and coaly shale. It would perhaps have been more correct to let the Culm finish just above the coal-seam, as the conglomerates which come immediately above the coal herald in the transgression of the sea and the end of continental conditions. However, the red layers are easy to follow up in the field, and have therefore been taken as the boundary beds.

A feature of the Culm is the thick sandstones which make up the bulk of the formation. In the south, west, and northwest this sandstone is of a pure white colour, frequently with flakes of muscovite. On the north coast from Herwigshamna and eastwards this sandstone is, however, not white but grey, and this is the case also in the eastern and central Culm area. We were at first inclined to think that we had two sandstone series, a grey one below a white one, but as the mapping proceeded we came to the conclusion that it was really only one series, but differently developed, the white sandstones representing a much purer deposition.

Details of the formation will be seen from the borehole sections (pl. III) and their description.

The thickness of the Culm is subject to great variations. At Ellasjøen it is 110 metres, at Flyvatna (centre of the island) 175 metres, at the south end of Hausvatnet more than 230 metres, and at Laksvatnet more than 150 metres (probably much more). There is thus a steady increase of the thickness towards the north.

Only one coal-seam occurs in the Culm viz., 15—35 metres below the upper limit of the formation. This seam is very irregular and utterly unworkable (details under Coal Deposits).

Fig. 23. Breccia of Culm sandstone.
From the fault zone between Kapp Forsberg and Kapp Olsen. Size 1/1.

The Culm has everywhere a westerly dip, and is much affected by faulting, this being particularly the case in the Nordkapp area and south of Laksvatnet. The faults cause a repetition of the strata, and make the thickness appear much greater than is really the case.

The following are descriptions of various Culm sandstones and shales.

Borehole No. 7, Hausvatnet at 188.25 metres. Dark slicken-sided shale. Consists of very fine-graded quartz and micaceous minerals. Traces of apatite and rutile.

Pit B24, Trestikkelen. Tough black shale. Not cleavable. Exceedingly fine-grained and only a few angular quartz grains and iron-ores can be distinguished.

Lakes Steinsjøane. Sandstone breccia from the fault zone. Grey angular sandstone fragments in a matrix of white sandstone. Sandstone has grains of quartz and quartzite < 0.5 mm. Fair amount of magnetite and pyrites. Rutile. The peculiar breccia may have originated thus: The grey sandstone has been broken up during the movement, and the white sandstone forming the matrix is really crushed grey sandstone which has become white through the dissolving action of percolating waters upon the impurities. Fig. 23 shows this breccia.

Pit (1923) at Laksvatnet. White sandstone. Quartz < 0.5 mm. A large number of the grains are quartzite. Finely divided pyrites common. Also in tiny crystals. Causes the rock to weather brownish. Also micaceous minerals.

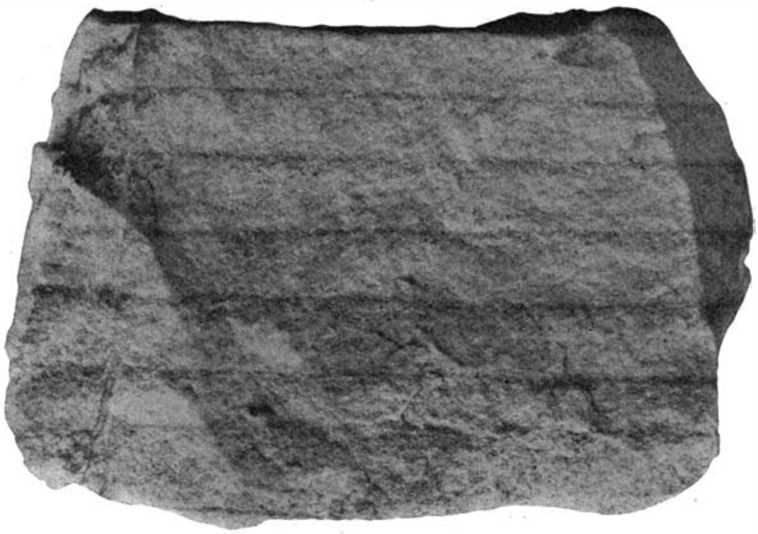


Fig. 24. White Culm sandstone.
North of Borehole No. 7, Hausvatnet. Size 1/1.

Pit (1921) south of Nordhamna. Sandstone from roof of the coal. Brownish-white with greyish-white weathering. Quartz: 0.1—0.6 mm. Some of the grains are quartzitic. Finely divided pyrites.

Nordkapp. Grey sandstone about 3 metres below the Culm seam. A few quartz pebbles. Rather rounded quartz (partly quartzitic), majority < 1 mm, some much larger. Between the grains finely divided pyrites and magnetite, and also muscovite.

North of borehole No. 7, Hausvatnet. White sandstone with parallel greyish-yellow laminæ at intervals of about 1 cm. Quartz grains (0.2—0.3 mm) surrounded by a little pyrites. Muscovite and a little biotite occur. In the coloured laminæ the quartz grains are smaller and the amount of pyrites greater. The dark stripes are thus due to the oxidation of the pyrites. The alterations of grade must be due to a slower and swifter flowing current, this in turn perhaps being a function of the rainfall (fig. 24).

Borehole No. 5, Ellasjøen. White sandstone with brown specks due to the oxidation of pyrites. Same sandstone as above, but without stripes. Grains smaller and more angular than in the former. Besides quartz, grains of quartzite. Flakes of muscovite and biotite. Pyrites and magnetite.

Middle Carboniferous.

As our task was to investigate the coal deposits we did not pay more attention than necessary to the non-coalbearing series, and the following notes on the Middle and Upper Carboniferous have been taken from ANDERSSON and HOLTEDAHL. The thicknesses have, however, been measured by us.

In Spitsbergen, and, as we have seen, on Bear Island, the Lower Carboniferous is continentally developed with sandstones, and subordinate shales and a coal-seam, and corresponding to the Russian facies of the Lower Carboniferous (Culm). Bear Island then formed part of a vast continent. But in Middle Carboniferous times (or earliest Upper Carb. of the West European time classification) the conditions were reversed. In the west of Europe continental conditions set in, while in the east and north — Bear Island — we got a transgression of the sea. Marine conditions lasted here throughout the Upper Carboniferous. To ANDERSSON (1900 b) and HOLTEDAHL (1920 b) we owe the stratigraphical divisions of the Bear Island Carboniferous, and their correlation with the Russian equivalents.

The formation admits of division into three members, given in descending order:

Yellow Sandstone series
Ambigua Limestone -
Red Conglomerate -

Nearly the whole of the island west of a line Kapp Harry—Kapp Kjellström is occupied by these beds.

Red Conglomerate Series. As already pointed out, no distinct boundary can be drawn between this series and the Culm. There is a gradual passage from the continental sandstones of the latter through coarse-grained sandstones, conglomerates, alternations of sandstones, conglomerates, argillaceous and calcareous sandstones, partly highly fissile and flaky, of a red or yellowish-green colour, to red and violet mottled limestones, and finally the massive grey Ambigua limestone with concretions of white and grey chert, i. e., typical marine deposits. Of the lower part of the passage beds a section is given on page 25.

On fossil evidence there is no reason to differentiate between the conglomerate series and the following one, but the lithological difference is so marked as to warrant a two-fold division. The upper boundary has been fixed, somewhat arbitrarily, above the bulk of the arenaceous deposits. Some red beds then come within the Ambigua limestone series, e. g., the red beds in Bogevika (Bow Bay) on the south-west coast.

The thickness is, as would be expected, subject to great variations. On the south coast it is 145 metres, but on the north coast the thickness is much less, about 50 metres, and the conglomerates here are not very conspicuously developed. The dip is everywhere westerly, 25°—30° in the south and 8°—10° on the north coast. Apart from the coastal sections, only the northern slope of Raudnuten (Red Peak) gives a good section. The dip here is 35° W. Isolated areas with this series occur south of Laksvatnet, here preserved by faulting. The conglomerates are here, however, only sparingly developed; red fissile sandstones mostly occur here. In Alfredfjellet the base of the red series is just preserved along the northwestern edge of the mountain. On account of the red colour the series is easy to follow up in the field, stretching more or less continuously as a red band across the island from south to north.

Ambigua Limestone Series. The lower part of this series contains red sandstones, and red and violet mottled limestones passing upwards into a massive grey limestone with chert concretions, indicating true marine conditions. However, in the limestones, beds of a whitish sandstone are met with.

Fossils have been found in Oswaldfjellet (Mount Oswald) by the expedition of NATHORST in 1898 and ANDERSSON in 1899. (ANDERSSON (1900 b)) and (NATHORST (1910)). "On the east side of the mountain, then probably in one of the older beds, I found a calcarous sandstone with a specimen of *Productus corrugatus* M'COY. In a limestone bed intercalated in one of the red sandstones I encountered a *Bellerophon* and two corals, *Diphyphyllum* sp. and *Clisiophyllum* sp. In a somewhat higher stratigraphical horizon quite near the sea-shore was discovered in 1898 a highly fossiliferous limestone, and much material was collected here in 1899. Of this may be mentioned:

Athyris ambigua SOW. Abundant.
Eumetria serpentina KON.?
Spirifer supramosquensis NIKITIN.
Productus corrugatus M'COY.
— *undiferus* KON." (ANDERSSON (1900 b), p. 13).

West of Kapp Kjellström on the north coast, HOLTEDAHL (1920 b) discovered a *Spirifer mosquensis* FISCH. in the limestone conglomerate on top of this series.

The series is displayed in a fairly broad belt from the southwest coast to the north coast. Detached triangular areas occur south of Laksvatnet. On the southwest coast the thickness is 175 metres, and in the north it is probably about the same, but here the thickness is difficult to estimate as the series is much faulted. The dip is everywhere westerly. In Oswaldfjellet it is from 10° to 45°, and on the north coast from 10° to 25°. The limestone series has on top a grey limestone conglomerate. The ground-mass is limy, partly sandy, and the pebbles consist of limestone and quartzite and, in places, red flint. This conglomerate is well developed north of Kapp Kåre on the southwest coast, and also at Bollevatnet (Bowl Lake) northwest of Røyevatnet (Char Lake).

Yellow Sandstone Series. Immediately above the limestone conglomerate comes a basal conglomerate of the yellow sandstone series. North of Kapp Kåre it is developed as a reddish-brown slaty sandstone conglomerate with pebbles and boulders of quartz and partly limestone,

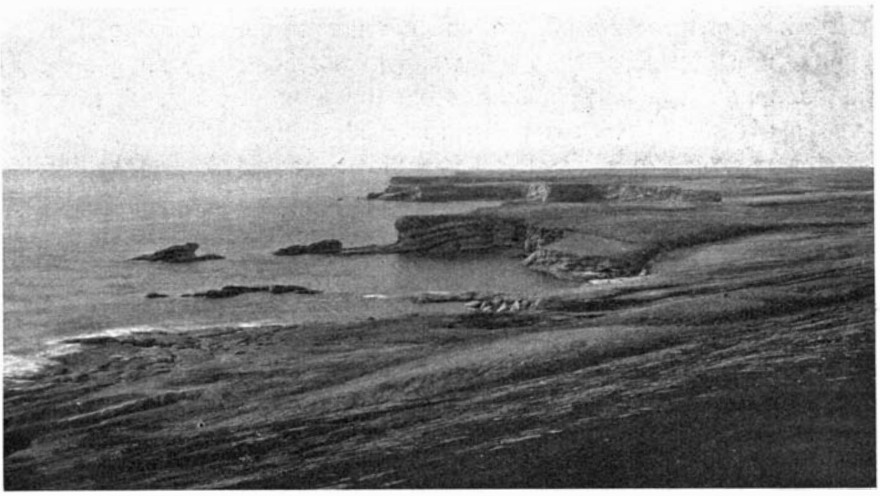


Fig. 25. West coast from Kapp Kåre to Kapp Hanna.
The plateau is 20—25 metres high. The Middle Carboniferous beds are seen to have a westerly dip.
B. Luncke phot. 4/9 1923.

8—10 metres in thickness. The lithological character of the beds proves a gradual submergence (Ambigua limestone) and a rise as shown by the conglomerates. The yellow sandstone is also a shallow water deposit. In its lower part, however, there is a 10-metre thick bed of limestone. It is a grey limestone and consists of a fine-grained mass of calcite with a few angular grains of quartz < 0.1 mm, and tiny crystals of pyrites. The yellow sandstone itself is highly calcareous. A sample two kilometres west of Kapp Kjellström shows a fine-grained brownish-yellow calcareous sandstone, darker when weathered. Microscopically: Angular quartz grains < 0.3 mm cemented by calcite. Flakes of muscovite. Quartz and calcite are present in about the same amounts (fig. 26).

No fossils fixing the age of the series have as yet been found. In a limestone layer east of Kapp Heinsius HOLTEDAHL (1920 b) found "specimens of a coral, probably a *Zaphrentis*, besides crinoid stems.

For any stratigraphical determination as to the question whether we are still in Middle Carboniferous beds, these fossils will be of little help." It is however reasonable to group the series with the shallow water Middle Carboniferous, rather than with the deeper water Upper Carboniferous.

The thickness is about 150 metres, the total thickness of the Middle Carboniferous thus becomes 470 metres.

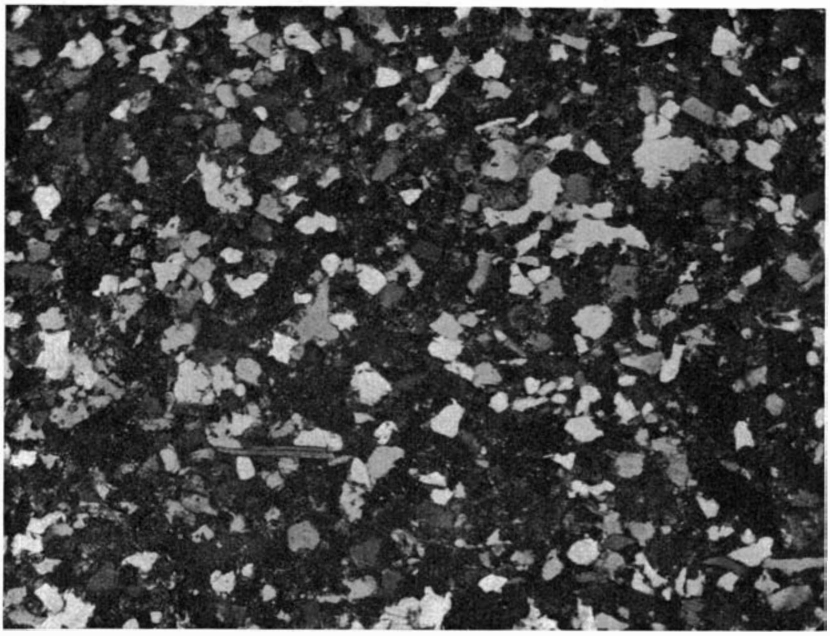


Fig. 26. Yellow sandstone.
2 km. west of Kapp Kjellström. — × 45. — O. Andersen phot. 1928.

Upper Carboniferous.

On Bear Island this formation is made up of three members, between the deposition of which earth movements and denudation have taken place.

Fusulina Limestone. This is a limestone series which follows the preceding sandstones conformably, and is made up of massive, brecciated, and shaley limestones. From the latter ANDERSSON ((1900 b) p. 19) gives the following fossils:

Fusulina cylindrica FISCHER.
Camerophoria isoryncha M'COY.
Syringopora ramulosa GOLDFUSS?

Based upon these finds ANDERSSON referred the Fusulina limestones to the Middle Carboniferous. TSCHERNYSCHEW is, however, of opinion (ANDERSSON (1900 b), p. 37) that the *Fusulina cylindrica* must more properly be regarded as being related to *Fus. montipara* EHRBG., and *Camerophoria isoryncha* to be *Cam. plicata* KUT., and that the Fusulina limestone of Bear Island could be correlated with the *Spir. Marcoui* zone of Timan. Then the Bear Island rocks belong to the lower part of the Upper Carboniferous as understood by Russian geologists.

The limestone is found in the extreme western part of the island with a westerly and flat dip, and has a thickness of about 75 metres. The series is traversed by two faults: one on the north coast and one at Kapp Dunér.

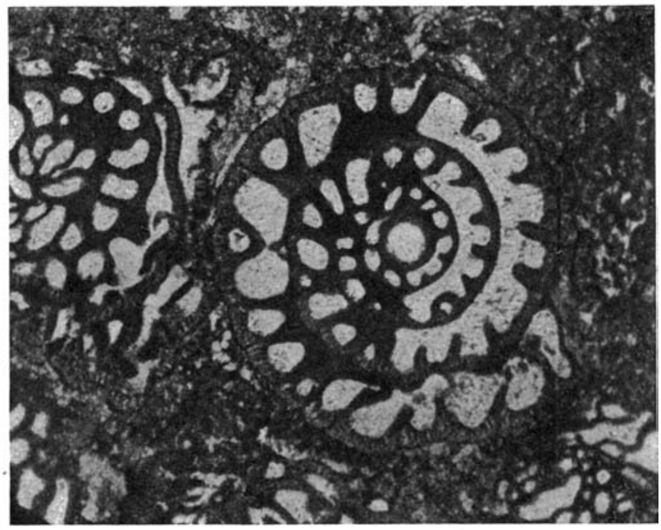


Fig. 27. Fusulina Limestone.
$1\,^1/_2$ km. north of Kapp Dunér. — $\times$ 43.

Cora Limestone. This series is only found below the Spirifer limestone capping the southern mountains: Alfred-, Hamberg- and Fuglefjellet, and rests unconformably on the Culm, Devonian, and Hecla Hoek. The lower part is made up of light sandstones with beds of coral limestone with *Petalaxis* sp., *Lithostrotion* sp., and *Syringopora* sp. The upper part consists of limestones with *Productus Cora* d'ORB, and otherwise a rich fauna (ANDERSSON (1900 b)). The preserved thickness of these series is about 50 metres. The Cyathophyllum Limestone in Spitsbergen corresponds to this series.

Spirifer Limestone. The youngest Carboniferous beds are represented by the Spirifer Limestone which rests unconformably on all the older formations. The limestone is of a dark grey colour, and is highly fossiliferous.

In Miseryfjell there is a bed of sandstone about 10 metres thick near the base, The sandstone indicates shallow water conditions. This is further supported by the find in this zone of a "pipe-rock", a *Scolithus* sandstone (HOLTEDAHL (1926)). On the north coast the limestone has a thin, fine, basal conglomerate.

As already mentioned, it caps the southern mountains and forms the plateau of Miseryfjell, here resting on Devonian strata. On the northern plain there is a small area of this limestone at Kapp Forsberg, and a large area around Laksvatnet, here resting unconformably on the Culm. In the cliffs on the north coast the unconformity is beautifully exposed, the limestone rising in steep cliffs from a low strip of Culm sandstone, from which the limestone has recently been worn away (fig. 28). Between Herwigshamna and Nordhamna there is also a small detached area of this limestone.

Fig. 28. Måkestauren (Gull Stack) from the west.
The cliff consists of Spirifer Limestone lying unconformably on Culm sandstone (low skerries).
B. Luncke phot. 1/8 1923.

The series lies everywhere with a slight northerly dip and is in places gently folded. Thus, on the north coast between Kapp Posadowsky and the Nordkapp the limestone forms a trough, and here the Culm sandstone is below sea-level.

The fauna is very rich. Of the brachiopods ANDERSSON (1900 b) mentions: *Productus uralicus* TSCHERN., *Pr. timanicus* STUCKENB., *Pr. Purdoni* DAV?., *Spirifer Keilhavii* v. BUCH, *Reticularia lineata* MART., *Rhynchopora Nikitini* TSCHERN. In Miseryfjell the thickness is 120 metres.

Triassic.

The presence of this formation was first recognised from fossil evidence brought home by the NATHORST expedition in 1898. More material was collected by ANDERSSON the year after, and the fossils were described by BÖHM (1899 and 1903), who fixed the age as being

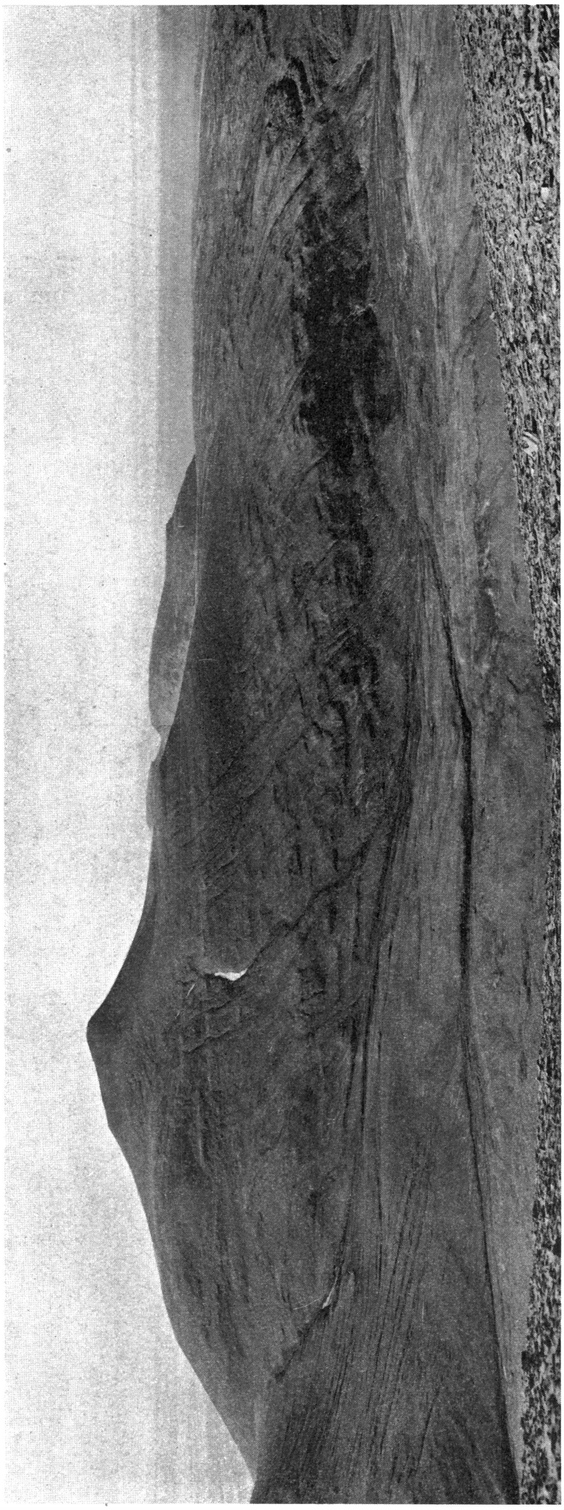


Fig. 29. Urd, Miseryfjell.

Urd, 536 metres above sea-level, is the highest peak on Bear Island. It is made up of Triassic beds, chiefly black shales. — A. Koller phot. 3/9 1923.

Carnian (Upper Triassic). "Of the entire fauna the bivalves make up 71 per cent. Most commonly are found: *Nathorstites lenticularis* WHITEAVES sp., *N. Lindströmi* JOH. BÖHM, *Sisenna Conwentzi* JOH. BÖHM, *Gryphaea Keilhaui* JOH. BÖHM, *Gr. Skuld* JOH. BÖHM, *Daonella Lovéni* JOH. BÖHM, *Pleurophorus Anderssoni* JOH. BÖHM, *Myophoria Nathorsti* DAMES, *Spiriferina Lindströmi* JOH. BÖHM. Not so common are: *Dawsonites canadensis* WHITEAVES sp., *Myophoria Tennei* DAMES, *Terebratula teres* JOH. BÖHM." (BÖHM (1903), p. 69). NATHORST correlates the Upper Triassic Myophoria sandstone of Bear Island with the upper strata of the Triassic of Spitsbergen, and holds that the transgressing Triassic sea spread to the Bear Island area later than in Spitsbergen.

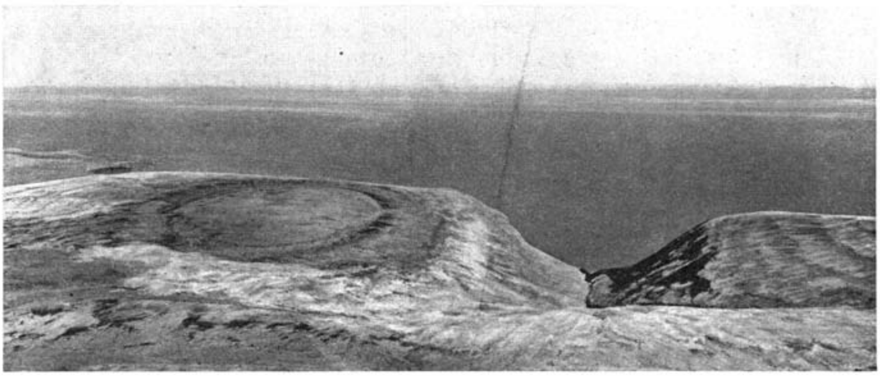


Fig. 30. View from Skuld on Miseryfjell.
Looking northeast. A detached circular area of Triassic beds resting on Spirifer Limestone is very conspicuous. The headland to the left is Kapp Nordenskiöld, and the typical U-shaped valley is Brettingsdalen.
A. Koller phot. 3/9 1923.

Below the fossiliferous horizon in Bear Island comes about 140 metres of non-fossiliferous strata, which ANDERSSON suggests may represent the lower parts of the Triassic. NATHORST, however, points out that, if this were so, the non-fossiliferous Triassic of Bear Island would correspond to the Daonella and Posidomya beds of Spitsbergen. But these characteristic and persistent zones are not found in Bear Island, as, he argues, they would be if the beds had there been of the same age, and he thinks it then more probable that the non-fossiliferous sequence corresponds to beds above the mentioned zones, i. e. also Upper Triassic. (NATHORST (1910), pp. 289—290).

On Bear Island the Triassic occurs only in Miseryfjell, forming the three peaks of this mountain, Urd, Verdande, and Skuld. Northeast of the last-mentioned, erosion has just left a thin layer of the formation (fig. 30).

ANDERSSON (1900 b) measured the following section in Urd, the southernmost peak:

"Myophoria sandstone." Fissile, grey, argillaceous sandstone with a rich fauna	20 metres	Carnian
Dark fissile shale with thin layers and lenticles of clay ironstone. Marine fossils (few)	44 —	Carnian
Dark shale with thin layers of laminated sandstone and limy concretions (stinkstone). Non-fossiliferous	140 —	
	204 metres	

According to our measurement the total thickness is a little less, about 190 metres. The peak Verdande does not reach up into the Myophoria sandstone, while the Skuld is just capped by the sandstone. In the limestone concretions are found calcite and an asphaltic mineral. When broken, the limestone emits a slight petroliferous odour.

The Triassic shales crumble to a powdery material, and are devoid of vegetation. On the eastern slope of Urd the Triassic débris has slid right down to the sea (fig. 17).

Structure.

The tectonic disturbances manifest on Bear Island can be referred to three different periods, viz., Silurian (or perhaps Upper Ordovician), Upper Carboniferous, and younger than Upper C., probably Miocene. The movements of the last period have only caused a rise and a slight tilting of the strata with minor faults. The orogenetic movements of the first period have only affected the rocks of the Hecla Hoek, and, judging from the conditions on this island, must be younger than Middle Ordovician, and older than Upper Devonian. In Spitsbergen, the Downtonian can be fixed as the upper limit. The general opinion is that the mountain folding is Caledonian.

The Kanin peninsula in North Russia presents features of interest in this connection. The mountain ridge Paë, running NW—SE, is built up of metamorphic rocks: phyllites, mica-schists, and quartzites with veins of granite. To the southwest of the main ridge occurs a small area of dolomite, also pressed. The general strike of the schistosity is NW with a dip towards NE, indicating a pressure from that direction. The metamorphic rocks are in one place found overlain by undisturbed Gotlandian limestone. The metamorphism is much stronger than in Bear Island, but not more so than that of the Spitsbergen Hecla Hoek. Ramsay (1911) believes that the age of these metamorphic rocks is Pre-Cambrian and Post-Archaic, the mountain folding being, of course, Pre-Gotlandian. On account of the similarity with the Bear Island and Spitsbergen rocks it is more likely that the rocks of the Paë are to be correlated with the Hecla Hoek. Ramsay also suggests that some parts of the Spitsbergen Hecla Hoek correspond to the Paë. HOLTEDAHL ((1918), pp. 252—53) is of the opinion that the dolomite with "*Gymnosolen*" of the Kanin peninsula is contemporaneous with the Porsanger dolomite of Finnmark (North Norway), and belongs to an Arctic-American area of deposition also extending across Bear Island and Spitsbergen, the age being probably Cambrian-Ordovician. In Bear Island the pressure has acted from the northeast, as in Kanin, giving rise to similar tectonic features. It may therefore be suggested that the mountain folding in Bear Island is of the same age as in the Paë, and its age would then be Upper Ordovician-Lower Silurian, and the Paë would represent the continuation of the Hecla Hoek of Bear Island, and be of Cambrian-Ordovician age.

YAKOVLEV (1921) points out the likeness between the Hecla Hoek in Bear Island and the rocks in the island of Kildin off the coast of

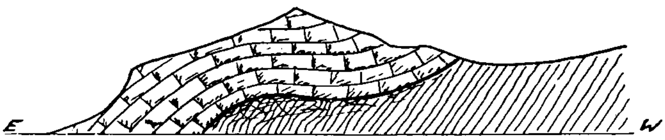


Fig. 31. Junction (thrust plane) between the older dolomite and the slate series northeast of Sørhamna.

Murmansk. Also in Kildin there are pressed sediments such as slates, sandstones, dolomites, and oolitic limestone of the same kind as in Bear Island. YAKOVLEV does not doubt that these rocks are of the same origin and age as the Hecla Hoek in Spitsbergen and Bear Island.

The folding of the Hecla Hoek is purely local and restricted to the slates. The limestones and dolomites are not folded, but the pressure has produced cracks and numerous fractures. The plications of the Slate-quartzite series are due to the effect of the big overthrusts. The area between Sørhamna and Miseryfjell, where the oldest series appear at the surface, is much disturbed. Between Sørhamna and Kvalrosshamna the older dolomites rest upon the slates, but, as pointed out by HOLTEDAHL, this junction is not normal, but is a plane of overthrust (fig. 31). Sørhamna, considered by ANDERSSON (1900 b) to be a downfaulted area, presents interesting tectonic features. On the east side, the plane of overthrust coming across from Kvalrossbukta has older dolomite to the east and slate to the west. Along the west side of the harbour runs the big overthrust coming from the mouth of Ymesdalen, with slates on the east side and younger dolomites on the west side.

South of Miseryfjell the slates follow the older dolomites conformably, the latter being very sandy and with quartzite in the upper part, forming a passage to the overlying slate series. The sequence is here, as already recognised by ANDERSSON, undoubtedly normal.

All these disturbances can be explained by a pressure from the northeast having caused a number of overthrusts, whereby the blocks on the east side of the fracture have been pushed over those on the west side. The planes of overthrust are very steeply dipping (to the east), so that the horizontal displacement does not become great. From the map will be seen that the pre-Devonian faults all have the same general trend, viz. roughly NW. In this direction they become covered by the younger formations.

The faults on either side of Ymesdalen ("Grabensenkung," of ANDERSSON (1900 b)) do not exist. The hills with carboniferous limestone on the west side of the valley have been brought down to their

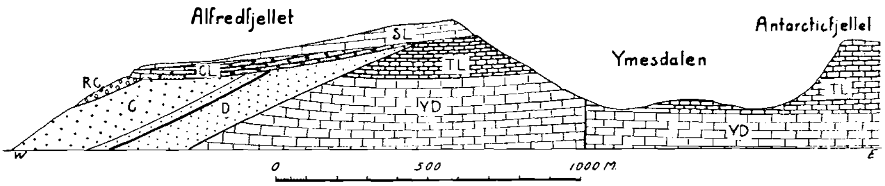


Fig. 32. Section across Alfredfjellet and Ymesdalen.
YD Younger Dolomite, TL Tetradium Limestone, D Devonian, C Culm, RC Red Conglomerate, CL Cora Limestone, SL Spirifer Limestone.

present position through landslips (p. 8). The sandstone at the head of the valley was considered by ANDERSSON to be Devonian and preserved by the mentioned faults. This would certainly be so if it were true that the sandstone was really Devonian and *in situ*. But neither is the case; we have in the bottom of Ymesdalen an area with loose blocks of Upper Carboniferous sandstone which have slid down from the summits of Fuglefjellet and Hambergfjellet, where the sandstone is found *in situ*. It is significant that the sandstone in Ymesdalen is not coarse, and does not contain a single pebble, which would undoubtedly have been the case had the sandstone been Devonian basal beds, which are everywhere else coarse and conglomeratic. Moreover, it seems rather extraordinary that the faults on either side of the valley should not be visible in the sea cliff. Therefore ANDERSSON lets the faults join at the bottom of the valley. In the northern part of the valley the Tetradium limestone crosses the valley undisturbed. Clearly there are no N-and-S faults in Ymesdalen. However, a fault runs from Ellasjøen and north of Alfredfjellet to the upper part of Ymesdalen. The throw is 125 metres, and the part east of the fault has been lowered. It is apparently a branch of the fault crossing from Evjebukta, north of Kapp Kolthoff, in a northwesterly direction between Alfredfjellet and Hambergfjellet, also having the downthrow on the east side.

The fault separating the Devonian from the Hecla Hoek north of Ellasjøen (map of ANDERSSON (1900 b)) does not exist, as the Devonian basal conglomerate is clearly seen resting on the Hecla Hoek. The position of the faults and overthrusts, together with their effects on the distribution of different series, is evident from the geological map and section, and no further explanation is necessary.

After the Caledonian movements were brought to a close, the land was denuded and submerged; Devonian sediments were then deposited on the Hecla Hoek surface. As the pre-Devonian erosion had exposed all the members of the Hecla Hoek, we find the Devonian resting on the oldest member (in the east) as well as on the youngest member of the Hecla Hoek (in the west). The Devonian and Carboniferous strata, up to and including the Fusulina Limestone, were deposited conformably. The Upper Carboniferous Cora Limestone can be seen to rest unconformably on the Hecla Hoek in Alfred- and Hambergfjellet, and the Upper Carboniferous Spirifer Limestone rests, in turn, unconformably on all the older series. In Upper Carboniferous times we thus have two periods of crustal movements, followed by denudation. The Spirifer Limestone lies fairly undisturbed, capping the southern mountains and forming the plateau of Miseryfjell, in which mountain the limestone slopes gradually towards the north, and north of Laksvatnet it occupies a considerable area. It goes without saying that the numerous post-Hecla Hoek faults are older than the Spirifer Limestone, but are they older or younger than the Cora Limestone? These faults will be seen from the geological map, and therefore need no detailed descriptions. In Alfredfjellet it is seen how the Devonian-Culm-Middle Carboniferous strata incline 35°—40° towards the west. The position of the Cora Limestone is nearly identical with the Spirifer Limestone (not quite, as there is a distinct unconformity between the two). In Alfredfjellet the Cora Limestone rests on Devonian, and in Hambergfjellet it rests on Hecla Hoek, both localities being in about the same position and elevation. The movements must thus be older than the Cora Limestone and younger than the Fusulina Limestone, e. g. Upper Carboniferous.

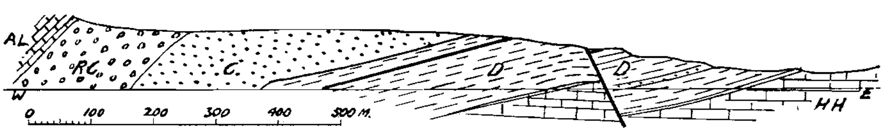


Fig. 33. Section on the north side of Ellasjøen.
HH Hecla Hoek, D Devonian, C Culm, RC Red Conglomerate, AL Ambigua Limestone.

This movement has produced a broad, slightly assymetric, fold with the western limb a little steeper than the eastern; its axis runs about north-and-south and plunges to the north. The axis of the western syncline passes roughly through Kapp Dunér on the west coast of the island, and the eastern synclinal line runs 1—2 kilometres off the east coast. On the crest of this 15-kilometres broad anticline were probably formed minor corrugations. In the southern part of the island, where there are no faults to modify the strike, the northern plunge is manifest by the convergence of the boundary Hecla Hoek-Devonian in this direction. At the apex of this boundary line a tongue of Devonian strata with synclinal dips indicates a minor fold with faults on the crest of the main fold. There can be no doubt that the folding originates from the application of lateral pressure. It is difficult to say whether the numerous strike faults, which are such a feature of the tectonics, are subsequent to the folding and caused by the pressure having relaxed, whereby the anticline has collapsed, or whether they have been formed simultaneously throug the action of the compressive forces. The faults

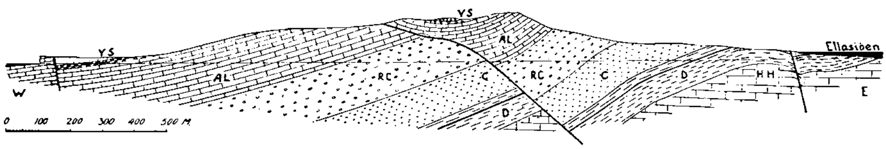


Fig. 34. Section of Oswaldfjellet between Ellasjøen and Bogevika.
Showing the fault running from Kapp Harry west of Ellasjøen. HH Hecla Hoek, D Devonian, C Culm, RC Red Conglomerate, AL Ambigua Limestone, YS Yellow Sandstone

west of the anticlinal axis have the downthrow on the east side, towards the axis, and the faults east of it have the downthrow to the west. Towards the south the faults show a tendency to converge. On approaching the Hecla Hoek massif they die out.

Denudation and marine abrasion were then brought into play, exposing Hecla Hoek rocks in the south, this part being the most elevated. Sandstones and the Cora Limestone were then deposited. This limestone corresponds to the Cyathophyllum Limestone of Spitsbergen, whereas the Fusulina Limestone of Spitsbergen — occurring in the upper part of the Carboniferous limestone — is younger than the Fusulina Limestone of Bear Island (NATHORST (1910), p. 281). In the Klaas Billen Bay area in Spitsbergen tectonic disturbances older than the Cyathophyllum Limestone are manifest, and it is extremely probable that they are contemporaneous with the movements in Bear Island just described. Crustal movements in Upper Carboniferous times were thus active in the area Spitsbergen—Bear Island. Can this movement be traced farther south? The nearest area with similar geological conditions is the Kanin peninsula in North Russia, already mentioned. Here we have Carboniferous limestones which are correlated with the Spirifer Limestone of Spitsbergen, and also Upper Devonian sandstones. Regarding the tectonic disturbances of these rocks RAMSAY says (op. cit.

p. 38). "Die Schichtenstörungen in den Devon- und Karbonablagerungen nördlich vom Paë weisen auf einen, allerdings nicht sehr bedeutenden, tangentialen Zusammenschub in der Richtung ENE—WSW. Die noch horizontalen karbonischen und permischen Schichten südlich vom Paë sind dieser Gebirgsfaltung entgangen. Nach TSCHERNYSCHEWS Angaben vom Timan haben dort auch permische Schichten an diesen Bewegungen Teil genommen. Diese orogenetische Erscheinungen sind wohl hercynischen Alters." The character of the movement is strikingly similar to that in Bear Island. In Kanin the movement seems to be somewhat older than that which has affected the same beds farther north. We do not lay too much stress upon the above, but have thought it worth mentioning, as it seems to indicate that in Upper Carboniferous — Permian times compressive forces were active along a line: Spitsbergen —Bear Island—Kanin (— Timan).

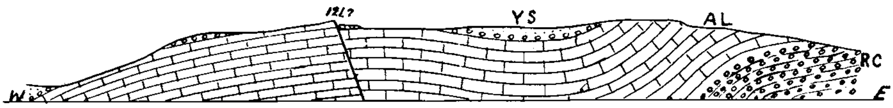


Fig. 35. Section showing the fault (same as in fig. 34) on the south side of Gluggdalen.
RC Red Conglomerate, AL Ambigua Limestone, YS Yellow Sandstone.

After the deposition of the Cora Limestone the land was slightly tilted and folded (in Alfredfjellet the limestone is slightly folded). Then marine abrasion removed the limestone, and only in the southern, most elevated part, small areas were left when the deposition of the Spirifer Limestone set in. The limestone was deposited in a very shallow sea of considerable extent (HOLTEDAHL (1926)). As Permian is missing, and the Triassic rests apparently conformably on the Carboniferous, a period of non-deposition must have intervened. At the close of the Spirifer Limestone period, the upper part of the deposit must have been practically awash and the increase of the deposit brought to a standstill. The Triassic of Miseryfjell is the youngest formation present, but it is highly probable that younger formations also were deposited, but have since been removed by erosion. The last tectonic disturbance, probably in Tertiary times, expressed itself by a rise of the land and a tilting of the beds towards the north. On the north coast the Spirifer Limestone lies at the sea-level, at the north corner of Miseryfjell it has an altitude of 105 metres, at the south corner 280 metres, and in Fuglefjellet about 300 metres. Small east-and-west faults with throws amounting to only a few metres traverse the Spirifer Limestone in a number of places. In Verdande, the middle peak of Miseryfjell, occurs a fault (E—W) with a throw of about 10 metres. This fault is younger than the Triassic, and it is probable that all these small faults are post-Triassic. The downthrow is invariably on the north side of the faults.

The geological history of Bear Island may be summarised as follows:

Lower Ordovician.	
Deposition of Hecla Hoek sediments.	Marine.
Upper Ordovician and/or Silurian.	
Folding and dynamic metamorphism of the Hecla Hoek.	
Lower and Middle Devonian?	
Denudation.	
Upper Devonian.	
Deposition of sandstones, etc.	Continental.
Lower Carboniferous (Culm).	
Deposition of sandstones.	Continental.
Middle Carboniferous.	
Transgression of the sea.	
Deposition of conglomerates, limestones, and sandstones.	Littoral and marine alternating.
Upper Carboniferous.	
Deposition of Fusulina limestone.	Marine.
Folding and extensive faulting.	
Denudation, and marine transgression.	
Deposition of sandstones and Cora Limestone.	Littoral and marine.
Slight rise of the land and again marine abrasion.	
Deposition of the Spirifer Limestone.	Marine
Cessation of the sedimentation.	
Triassic.	
Deposition of shales and sandstones.	Marine and Littoral.

Post-Triassic History.

Jurassic-Tertiary.

As stated above, the Triassic is the youngest formation present on Bear Island. About the geological history of the isle during the following periods very little is known. In Spitsbergen the Triassic, Jurassic, Cretaceous, and Tertiary have a wide distribution, and the latest investigations of the Norwegian Svalbard Expeditions have shown that they occur as far south as Sørkapp, which is only 120 naut. miles from Bear Island. In the Green Harbour region in Central Spitsbergen the thicknesses of the mentioned formations are 700, 320, 735, and 1420 metres respectively.

The island of Hopen, about 140 miles northeast of Bear Island, is built up of Mesozoic strata.

In North Norway, Jurassic rocks are known from the island of Andøy.

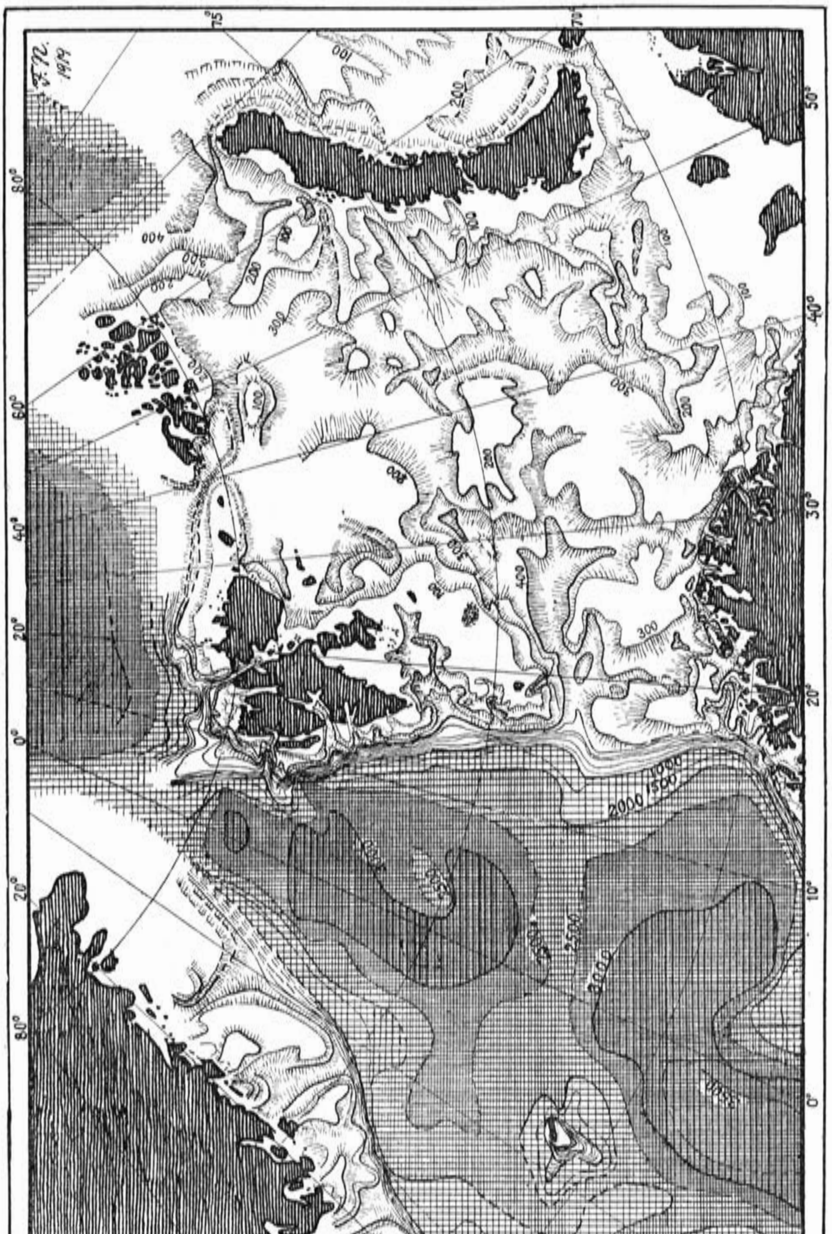


Fig. 36. Map showing depths in the Greenland and Barents Seas.

Contour lines down to 1000 metres are drawn at intervals of 100 metres, and for greater depths at 500 metres. (After Nansen (1920), p. 28).

The wide distribution of the Mesozoic and Tertiary rocks, and their considerable thickness, make it exceedingly probable that they were also deposited in the Bear Island area. Moreover, it is quite impossible that the soft Triassic shales would have remained, had they not been preserved by a considerable thickness of younger sediments.

Towards the close of the Tertiary period the land must have been situated at a high level, as can be concluded from the configuration of the sea-bottom, of which NANSEN ((1920), p. 28 and 31) has prepared very instructive maps based on the available soundings. The first map is reproduced here in fig. 36. From this map it will be seen that Bear Island is situated on the continental shelf stretching from Norway to Spitsbergen, and extending over the whole of the Barents Sea to Franz Josef Land and Novaya Zemlya. The depth nowhere exceeds 200—300 metres, except in two submarine valleys, one between Norway and Bear Island, and the other between that island and Spitsbergen, where the depth may reach 500 metres. The Spitsbergen bank extending from Bear Island to Hope Island and Edge Island of the Spitsbergen archipelago, is shallow with depths of 45—60 metres only, and is also fairly level. Towards the west the sea-bottom falls abruptly to the great depths of the Greenland Sea.

As pointed out by NANSEN and others, this huge shelf can only have been formed by subaerial denudation when the land was situated about 500 metres higher than now. When these valleys had been formed Bear Island then belonged to the western part of a mountain ridge, at least 1000 metres above sea-level, of which Hope Island and Edge Island also formed parts.

It is not improbable that the elevation of the land mentioned above owes its origin to the Tertiary folding and upheaval of the land manifest in Spitsbergen. As the trend of the folded zone is towards Bear Island it is very probable that the folding has also acted here.

In fig. 37 (a) is shown a hypothetical section through ancient "Bear Island" at the time of the formation of the submarine valleys. On account of the northern dip of the strata it is probable that the soft Mesozoic shales above the hard Carboniferous limestones caused the northern slope to dip more gently than the southern one.

The Quaternary Period.

It is impossible to give a connected statement of the geological history from the time when the Barents Sea was dry land up to the present time, because there are long periods of which we know nothing. We can only conclude that some time after the rise was over, a considerable submergence of the entire land mass must have taken place, during which the great banks now lying at a depth of less than 100 metres were formed. It is very difficult, however, to form a well founded opinion as to when these banks were formed, whether they were formed at the close of the Tertiary or in Quaternary time (fig. 37, b). This submarine plateau is at any rate of considerably greater extent than the marine plains of Bear Island to be described below, and it is certainly older than these. It is connected with the submarine platform outside the coast of Spitsbergen and must be contemporaneous with this.

As Bear Island is of very small extent the glaciers of the Ice Age have naturally left very few traces on the island, but we know that both south of the island and north of it, on the Scandinavian peninsula and on Spitsbergen, we have had several distinct glacial periods

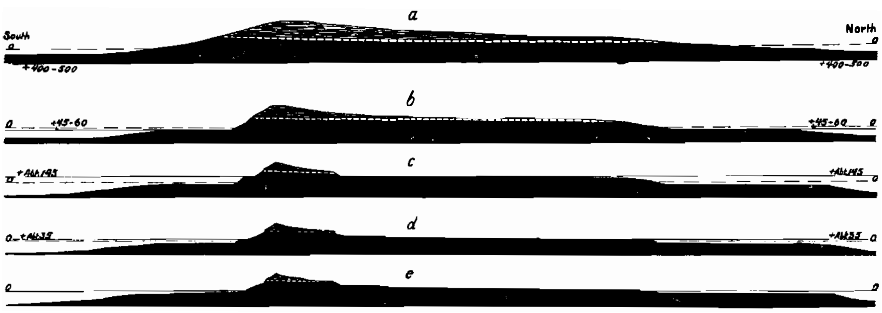


Fig. 37. Diagrammatic sections to illustrate the history of Bear Island from late Tertiary to recent times.

with interglacial periods intervening. Similar conditions have, of course, also obtained on Bear Island, but the only traces now remaining of the previous extent of the ice are derived from the very last stage of the Glacial Period. From the older periods of the Quaternary we have, however, traces of higher levels of the ocean, and these we will first consider briefly. On Bear Island there are several plains at different altitudes, and at least four of them are very distinctly marked. These have all the appearance of being of marine origin. They are observed especially in the northern part of the island. It was previously assumed that this part of the island formed a single plain rising gradually from the sea to an altitude of about 100 metres. This is not the case, however, as the lowland really consists of several distinct and quite horizontal steps. This is plainly seen in the profile sections in fig. 38, which are constructed exactly after the topographic map of Bear Island on the scale of 1 : 10000. This map has contour intervals of 5 metres, and also shows the exact elevations of a considerable number of lakes, etc. As will appear from these profiles there are

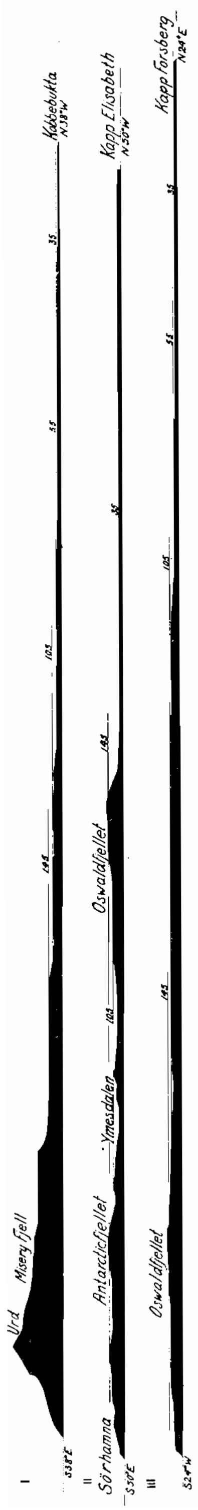


Fig. 38. Sections across Bear Island.

Showing four different plains of marine denudation, approximately 35, 55, 105, and 145 metres above sea-level (see map fig. 39).

four distinct plains at altitudes of 35, 55, 105, and 145 metres respectively. Between these steps there are no sharp boundaries, the inner edge being commonly covered by loose material produced through solifluction. Nor have beach deposits of the same age as these plains ever been observed. This is most likely due to the later glaciation by which the material has been carried away.

The extension of the various plains is seen on the map, fig. 39.

The largest and most prominent plain is by far the one at the 35-metre level. It extends over the entire northern part of the island, and is up to 7 km. wide. This great plain, which is no doubt the youngest of the four, is not quite level. It is dotted with lakes which occupy quite shallow trough-shaped depressions, especially in the softer rocks. These depressions in the surface are especially interesting because many of them have no outlets through which material may have been carried away. It might be thought that they were formed through the abrasion of the ocean, but in that case we should no doubt have found boulders, clay with shells, etc., but that is not the case. In and around the lakes no material is seen other than that formed *in situ* through disintegration by frost or deposition by the small local brooks. There is, therefore, no alternative but to assume that they have been formed by the ice.

The higher plains are all of less extent than the lowermost; and the higher the level, the older is their character with the surface more broken by valleys, and less distinctly a plain. The one at the 55-metre level is about 5 km. long and 1.5 km. broad, and extends from the upper part of Engelskelva towards the lake Hausvatnet along the southern edge of the lower plain.

The plain at the 105-metre level, the third from below, is as much as 7 km. long and 2 km. wide. It is situated west of Miseryfjell and is bounded toward the west by Gygreurda. The uppermost plain at the 145-metre level is the least distinct of them all. There is, however, no doubt that also the plains seen at this level on the north side of Miseryfjell, on Oswaldfjellet, and at a few other places, form the rest of an old abrasion surface.

During the deepest submergence Bear Island has consisted of two small islands, one around the present Miseryfjell and one forming the mountains in the southern part of the island.

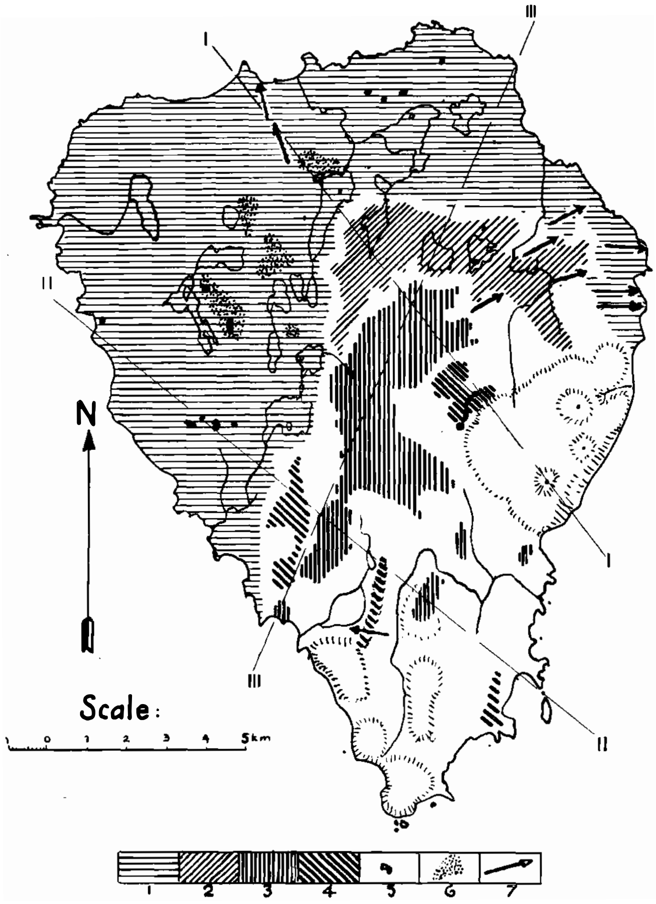


Fig. 39. Map of Bear Island showing plains of marine denudation, glacial striæ, and ice-transported material.

1. Plain about 35 metres above sea-level.
2. — 55 — —
3. — 105 — —
4. — 145 — —

5. Ice-transported blocks. 6. Old moraines. 7. Glacial striæ. I—II—III Section lines. (Sections see fig. 38).

There are also traces of lower plains around the 20-metre level at certain places along the coast, but these are now so indistinct that we have not sufficient data for definitely proving their existence.

As described, the highest trace of the ocean on Bear Island is observed at an altitude of 145 metres above sea-level. The island may have been more deeply submerged, but this is not probable, as a higher level of the ocean would have left traces on Miseryfjell. The prominent plain now seen on that mountain is not due to the action of the ocean, but is formed through denudation in very recent times. The soft Triassic shales have not had the same resistance as the underlying Spirifer limestone, and the result is this conspicuous plateau. It is also seen that this has the same dip as the junction plane between these two formations.

It seems remarkable that the marine denudation plains are only developed in the central and northern parts of the island, whereas the southern part hardly shows any traces of such a process. One might argue that platforms existed also here, and that a rapid landward erosion of the sea had removed the land showing such features. If that were so, a fairly broad marine bench at the actual sea-level would have been in evidence. Soundings, however, disprove this. The reason is of a more primary nature, in which the dip and different resistance of the rocks play the most important rôle. On account of this feature (fig. 37), the land has always been much higher and steeper in the south than in the north, and consequently also the cliff was higher in the south. In the south the cliff has mostly been cut into harder rocks, and the sea has been working, as it were, against the grain, whereas in the north the sea has only had to face low-dipping beds of a soft nature, and the advance of the sea has consequently been much more rapid. Further, in the south big landslips must constantly have taken place (as now on the east side of the Miseryfjell), and the volume of the débris which had to be removed by the sea thus became considerable, this naturally retarding the landward advance. In the north, however, the cliff was always comparatively low, and there was never more débris than could be easily carried away by the current. We are thus led to believe that the marine denudation plains, so well developed in the northern part of Bear Island, were never of any considerable extent in the south.

We will now consider briefly the formation and age of these plains. There can be no doubt whatever that their initial formation is due to abrasion by the ocean. Their general appearance with their largely even and quite horizontal surfaces permits of no other explanation. But it is equally true that after the ocean had carved out these plains glaciers passed over them. The traces left by these glaciers are numerous trough-shaped depressions and pits filled with water, glacial grooves, moraines, and boulders. These will be described more closely below. All these traces are no doubt to be ascribed to the very last glaciation of the island. The plains therefore must be older than this, but probability favours the conclusion that the lowermost plain, at any rate, is younger than the penultimate glaciation.

We will here also relate a fact that may support the assumption that these plains on Bear Island may be *younger* than the last glaciation of the island.

On Spitsbergen HOEL has measured a number of strand-lines and raised beaches that, in his opinion, are post-glacial. With regard to elevation these may be grouped in the following steps: 105, 77, 53—55, 34—36, 27—28, 14—15, all in metres above sea-level. (HOEL (1914), p. 30). After the publication of these measurements HOEL has also in a number of places measured a level of 145 metres above sea-level. It is thus seen that there is perfect agreement between the heights of the plains on Bear Island and four of the levels of terraces and raised beaches on Spitsbergen. This agreement is quite remarkable. The explanation that we have arrived at is the following: The two lowermost steps on Spitsbergen, those at the altitudes of 14—15, and 27—28 metres above sea level, are missing on Bear Island. At some places however, we find traces of the work of the ocean at about these altitudes. The level of 34—36 metres on Spitsbergen agrees exactly with the level of a beach barrier of boulders on Bear Island, to be considered more closely below. These boulder barriers are certainly post-glacial and formed simultaneously with the terraces of the same altitude on Spitsbergen. When an interglacial plain is observed at about the same altitude this is incidental. With regard to the higher levels common to Spitsbergen and Bear Island, they are, in our opinion, also on Spitsbergen of older interglacial age, formed simultaneously with the corresponding steps on Bear Island. There is however no reason why sedimentary deposits should not have been laid down in post-glacial time at about the same altitude on these old plains carved out in the solid rock. The altitude of a terrace is not only due to the height of the sea-level, but also to the depth of the sea bottom, where the material is to be laid down, and to the amount of material to be deposited. It is evident that when the sea bottom is raised before the material deposited on it has got any great thickness, the terrace and the rock below it will seem to be about the same level.

As is known, there is in Norway and Spitsbergen a rim of low land, the strandflat, extending between the ocean and the mountains within. In this strandflat two levels may be distinguished, one reaching about 20 metres above sea-level and the other 40—50 metres. Both these steps are generally supposed to have been formed during interglacial times. It is with this strandflat that our plains on Bear Island may be compared. There can hardly be any doubt that the two levels at 35 and 55 metres correspond to the levels at 20 and 55 metres. It is true that there is a disagreement, the two corresponding plains of the lowermost levels not lying at the same altitude. To this may be remarked, however, that the 20-metre plain on Spitsbergen and the 35-metre plain on Bear Island in other respects have so many points of similarity that their simultaneous formation is a matter not easily to be disregarded. The two highest steps on Spitsbergen and Bear Island, the 105 and 145 metre steps, do not belong to the strandflat.

We will then consider somewhat further the traces left on the island by the glaciers of the last glacial time and the conclusions to be drawn from them. Glaciers do not exist on Bear Island now, but glacial striæ and erratics clearly indicate that the island has been ice-clad also after the formation of the northern plain. In 1870 and 1898 NATHORST observed glacial striæ on Riffelodden on the east coast. "Whereas the direction of the striæ here are from W 17° S and W 10° N, or from due west, it is at Engelskelva W 35° S. On the eastern shore of Nordhamna I discovered striæ, the direction of which was from S 25° E (and S 29° E). At the shore east of Tobiesen's house I observed a fine moraine." (Nathorst (1899 b), p. 184). He comes to the conclusion that the ice-sheet had its centre in the middle of the island somewhere northwest of Miseryfjell. Striæ having the direction E 10° S and E 15° S were discovered by NATHORST in 1898 on the northern spur of Alfredfjellet, and erratic blocks of sandstone were found up to altitudes of 255 metres on the slopes of the southern mountains. Fig. 40 shows a typical example of one of these blocks. South of Daudmannsvatnet we have found rocks showing crag and tail, and striæ running N 35 ° E, and west of Storlona beautifully glaciated rocks with striæ N 55° E, manifesting a movement of the ice from the southwest. The striæ 150 metres north of borehole No. 8 have the direction N 80° E. The observed glacial striæ and other indications of glacial activity are shown on the map fig. 39.

It seems remarkable that a glaciated country like Bear Island should show no distinct moraines. It is true that peculiar heaps of obviously transported material are found in several places on the northern plain, for instance, a heap consisting of nothing but Spirifer limestone resting on a bedrock of sandstone, and sandstone on Upper Carboniferous limestone. Knorten south of Kapp Dunér is a fine example of such a heap (fig. 43). As the material in these heaps is always homogeneous, we are inclined to think that they must originally have been in the shape of big blocks which have been shattered to pieces by the action of frost. Low, more or less circular, hills of apparently moraine material are found in one or two places on the northern plain, but are difficult to recognise as moraines because they are so flat and smooth. Anyhow, all this material, as well as the blocks, must have been carried thither by the ice from the more elevated parts of the island. The direction of the striæ and the character of the transported material show, as already pointed out by NATHORST, that the centre of the ice-sheet was somewhere in the middle of the island. The thickness nowhere exceeded the highest mountains, and the summits on Miseryfjell formed

Fig. 40. Ice-transported block of sandstone, Antarcticfjellet.
Southern slope of the mountain and 260 metres above sea-level. — G. Horn phot. 20/8 1925.

Fig. 41. Glaciation. Eastern part of the island.
Showing smoothing and striation by ice. — G. Horn phot. 15/7 1925.

insular hills surrounded by the ice-sheet (nunataks). Ymesdalen was of course glacier-filled, the ice joining at the mouth of the valley the ice-flow coming from the north, the united flows debouching into the sea south of Miseryfjell. The above-mentioned striæ on the northern spur of Alfredfjellet, i. e. west of Ymesdalen, show that the ice has overflowed in that direction. With regard to the erratics of sandstone, we are of opinion that they represent the Carboniferous sandstone which is found *in situ* on the summits of Fuglefjellet and Hambergfjellet, and thus do not necessarily imply a movement of the ice from the north but merely show a movement of the ice down the valley between Antarcticfjell and Fuglefjell.

Geologists who have previously visited Bear Island have held the opinion that no traces of the action of the ocean younger than the last

Fig. 42. Hill of glacial material west of Miseryfjell.
The hill, about 14 metres high, consists exclusively of pieces of Spirifer limestone which occurs in Miseryfjell (to the left). — G. Horn phot. 14/9 1925.

glaciation were to be found, and that, therefore, no post-glacial submergence had taken place there. ANDERSSON ((1900 b), p. 279) thus argues that no post-glacial subsidence of the island has taken place because marine terraces are absent. Between Sørhamna and Kvalrossbukta, however, HOEL found in 1922 water-worn pebbles at an altitude of about 40 metres, and in the same year WERENSKIOLD found north of Laksvatnet, at an altitude of 35—40 metres, waterworn pebbles, undoubtedly representing an old shore-line. The pebbles are of a moderate size and the finer material seems to have been washed away. Are these pebbles older than the glaciers? This is not reasonable, as in that case they would certainly have been pushed away or have become much more scattered. We think it fairly safe to assume that the pebbles were formed during a recent subsidence of the land to that level.

It may perhaps seem strange that Bear Island could have been submerged to this level in post-glacial time without leaving more numerous traces than those now found on the plain, the larger part of which must have been below the water. The explanation, in our opinion, can only be that during the deepest submergence, the island was still covered with ice, like Kvitøya[1] at the present day, as indicated on the map

[1] Kvitøya or White Island is situated in about 80° lat. north, east of Spitsbergen.

fig. 44. Only the mountain tops protruded above the ice, and on the north and south sides there has been a little ice-free land where boulder barriers have been formed. At other places the ice front reached the sea, thus giving no space for the formation of boulder barriers. The morainal material which was carried from the mountains to the ice front along certain medial moraines, went straight into the sea and was drawn out from the coast by current and waves. This gives the explanation of the peculiar flat moraine hills in the western part of the island, which lie in groups in the directions which the medial moraines must

Fig. 43. Knorten.
Peculiar heap of ice-transported blocks of sandstone. West coast. — G. Horn phot. 13/8 1924.

have had. In the shallow sea outside the ice front all finer material was washed away by the current, which is very strong at Bear Island. When the entire island rose, a relatively thin dead sheet of ice was left. This carried no more morainal material with it, and thus younger undisturbed moraines are missing. The larger blocks of rocks were left behind when the ice melted away. Afterwards they were shattered by frost, and now form small hills of homogeneous material scattered over the western part of the island.

Finally we will consider briefly the conditions obtaining at the present beach.

As mentioned before, a new level in the strandflat is now being formed around Bear Island, as is also the case in Spitsbergen and Norway.

As is known, Greenland is subsiding; Spitsbergen is in equilibrium or perhaps slowly subsiding (VOGT (1927)). The Scandinavian peninsula has almost reached a state of equilibrium after a period of rise, and it would therefore be of considerable interest to be able to prove whether Bear Island is now moving in the one direction or the other.

We have previously described the cliff (p. 6), but one question of especial interest in judging of the movement of the island from the appearance of the cliff is deemed of such general importance that we shall consider it more closely.

It is commonly assumed that when a cliff is formed by slow subsidence or at a stationary position, then a beach will be exposed at the foot of the cliff, and from there the depth will increase gradually outwards. If there is relatively deep water outside such a cliff also at low water, one is apt to conclude that the land is sinking.

The conditions on Bear Island show distinctly that great caution must be exercised in drawing such a conclusion. It is seen all around the exposed coast of the island that, where there are sandstones or relatively insoluble rocks, there is such a boulder beach broad enough to walk on below the cliff at low water. Where the cliff consists of limestone or dolomite, on the other hand, this boulder beach is totally absent and there is still deep water on the outside at low water. Thus, this is the case everywhere on the west coast where the Middle and Upper Carboniferous limestone forms the brink, and also on the south point where the dolomites of the Hecla Hoek prevail, and perhaps most conspicuously on the north coast where the Spirifer limestone reaches the ocean. At the latter place it is very strikingly seen how on both sides of the limestone, and commencing where the boundary between the sandstone and the limestone emerges above the low-water line, there are sandy beaches and also brims of sandstone, which in places may be rather wide, all exposed at low water. The intervening section of limestone, on the other hand, has a steep front straight to the sea, even at low water.

The phenomenon just mentioned is evidently to be ascribed to the great solubility of the limestone, and not to any local submergence of the coast at places where limestone prevails. Considering the action of sea water on the cliff at other places, where caves up to 170 metres long may have been formed, this result is not surprising, but, on the contrary is quite obvious. This dissolving action of the sea water is very likely to persist to relatively great depths. Where the cliffs consist of limestone, no protecting layers of loose deposits are formed on the bottom. The bare rock is thus exposed to the salt water, which is kept in motion by currents and the surf.

Basing conclusions regarding the motion of the land on the appearance of a cliff, it thus becomes necessary first to consider the solubility of the rocks. In this respect the conditions obtaining in a limestone cliff must be regarded as of no value.

The conditions described above are also present at many places on Spitsbergen, especially at protruding points where the currents and waves of the sea are active.

The parts of the cliff on Bear Island that consist of the least soluble rocks, pure sandstones, do not show anything that point to any noticeable change in the level of the ocean in recent time, and particularly not to a subsidence of the land, because at low water, as before mentioned, there is exposed quite a broad rim of boulder and sand beach, and also in places enough bare rock to justify the belief that there has, if anything, been a little rise of the land. True enough

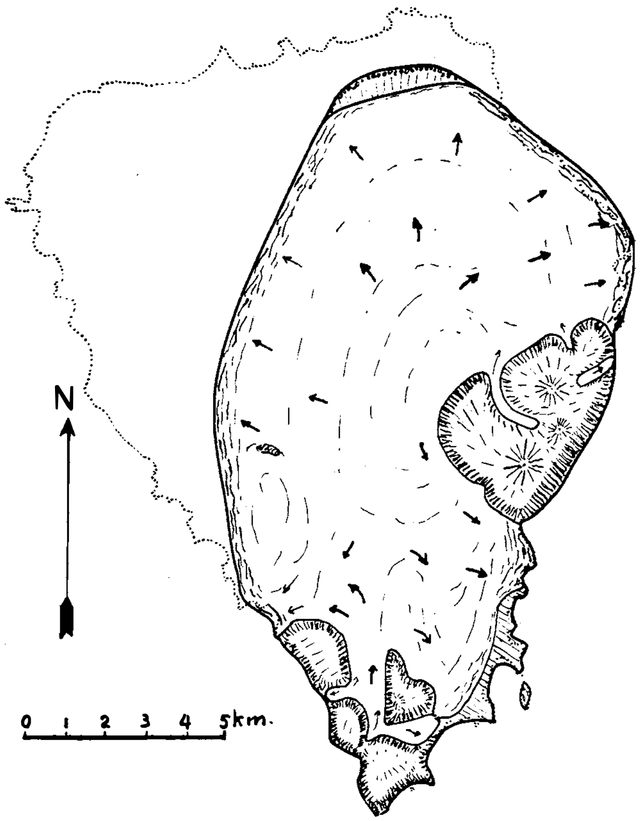


Fig. 44. Bear Island in a part of the last Ice-period.
The island was then lying about 35 metres lower than now.

there are places where there are beaches of large boulders immediately in front of the cliff even at high water, but these are places where the loose material has no doubt been thrown up by breakers. Unfortunately no soundings have been carried out on sandstone platforms in the immediate neighbourhood of the island, and thus there is no foundation for conclusions regarding a possible subsidence throughout a long period.

On the 19th of June 1864, at 4 p. m., NORDENSKIÖLD had an iron bolt driven into the rock in the southern part of Russehamna close to Borgmesterporten. At that time the bolt was four feet (119 cm.) above sea-level. (DUNÉR & NORDENSKIÖLD (1867), p. 16).

In July and August 1899 members of GUNNAR ANDERSSON'S expedition made a number of measurements of water-levels. (FORSBERG (1900), and ANDERSSON (1900 a)). Two new bolts were driven down on the shore of Russehamna. The elevation of these bolts, A and B, and NORDENSKIÖLD'S bolt C were calculated to be: A 90, B 152, C 113 cm. above mean water-level in July—August.

In order to find out whether there has been any change in level since 1864, K. WOLD and H. JELSTRUP of the Norwegian Geographical Survey have made accurate calculations on the basis of all available material, namely, NORDENSKIÖLD'S observations, and tidewater measurements from 1899 and 1922. It was found that NORDENSKIÖLD made his measurement of the water level exactly at mean water. In June 1864 the bolt had an elevation of 119 cm. above mean water-level, and in July—August 1899 of 113 cm. By comparing a large series of measurements made at Bergen in Norway it was found that the mean water-level is higher in July—August than in June. Thus to the elevation of 113 cm. observed in July—August a correction of 4 cm. must be added to make it comparable with NORDENSKIÖLD'S elevation observed in June. The corrected figure, 117 cm., differs only 2 cm. from the figure found in 1864, and the conclusion is that no measurable change of level has taken place in the intervening period.

In 1922 the Norwegian Svalbard expedition carried out water-level measurements in Sørhamna, and the bolts from 1899 were levelled in relation to a bolt Tp 16 a. It was found that this bolt in August had an elevation of 27.411 metres above the mean water-level for 1899 and 27.531 above the mean water-level for 1922, without corrections for variations in the mean water-level. By using the same corrections as above an increased difference is obtained, the elevation of the bolt being found to be about 20 cm. higher in 1922 than in 1899. Owing to frequent wind and rough sea it was difficult, however, to obtain quite accurate measurements in 1922. Moreover, the observations were not made at identical places in both years. It is also possible that local disturbances may have had an influence. If the latter measurements indicate any change in level it must be a rise of the land. Pending future measurements that may confirm or invalidate this result, the island should rather be regarded as being at rest or to be undergoing changes of level too small to be measurable.

There are now on Bear Island a number of triangulation points with copper bolts, the altitudes of which have been determined by trigonometric measurements in relation to Tp 16 a and the bolts in Russehamna. Tp 16 a (south of Russehamna), which is of iron, is plotted on the geological map. The bolts from 1899 are now becoming worn, and it might be well to have them replaced before long.

Coal Deposits.

The occurrence of coal has been known since 1609, and is mentioned in the accounts of nearly every expedition to the island. More or less detailed information about the coal has been published by KEILHAU (1831), ANDERSSON (1901 a), FREIMUTH (1909), NATHORST (1910), ANTEVS and NATHORST (1917), HOEL, KVALHEIM and SCHIVE (1918), and HOEL (1915, 1922 a and b, 1925).

Devonian.

This formation is the only one with coal-seams worthy of consideration. These coal-seams are of the oldest known in the world. As mentioned on page 18, the seams fall naturally into two groups, the lower Misery Series with 10—12 seams, and a thickness from the top to the bottom seam of about 85 metres, and the upper Tunheim Series with three seams, and a thickness from the top to the bottom seam of about 20 metres. The intervening barren series has a thickness of 105 metres. The thicknesses are subject to great variations, the figures given applying to the Tunheim area. The Misery Series is well exposed in the precipitous eastern slopes of Miseryfjell, the middle barren series is seen along the coast from this mountain to Kapp Nordenskiöld, and the Tunheim Series outcrops from that cape northwards along the coast to Kapp Forsberg.

Where the Devonian outcrops on the plains in the interior, bits of coal are found nearly everywhere. On account of the low dip the outcrops have often a very irregular run, and the numerous faults cause the same seam to occur again and again. The rocks of the formation are very similar, and where no good section is available it is well-nigh impossible to identify the different horizons and coal-seams. On account of the weathering the rocks near the surface are much broken up, and thus considerable work is necessary to get down to unweathered material. Lateral variation is another factor making correlation difficult. Sandstones often replace shales, and *vice versa*. The coal series persist more or less throughout the island, but the seam-sections vary considerably, making it difficult to correlate the seams.

The Misery Series.

The general development of this series, and the position of the coal-seams, will be seen from the sections of the boreholes (pl. III) and sections from Miseryfjell (pl. II), the sections having been placed in a correct stratigraphical position. It will be seen that a few stray seams occur below the main coal series, but they are all thin and without any value whatever. The Misery coal-seams are best exposed in the seaward slopes of Miseryfjell, and here they attain their full development with about a dozen seams. In the southwest, however, that is, in the

Ellasjø area, we find the Misery Series represented by a single coal-horizon only, about 80 metres above the base of the Devonian, which is here not more than 100 metres thick. That the coals of the Ellasjø area belong to the series with which we are now dealing is evident from the fact that they can be traced almost without a break from Ellasjøen to the area north of Miseryfjell, where the seams are certainly the same as those in the seaward slopes of this mountain. Further, the pit sections (H 25 and M 25) at Langen, about 3 kilometres north-northeast of Ellasjøen, show the same character as the pit sections north of Miseryfjell. At Ellasjøen the white Culm sandstone comes immediately above the coals, and the Tunheim and the intervening barren sandstone series are thus missing at Ellasjøen.

The Misery seams vary considerably in number: from two at Ellasjøen to a dozen in Miseryfjell. As stated above, the seams can be traced more or less continuously to the region north of the mountain. Here the dip is flat or to the east, at Ellasjøen it was to the west.

North of Ymesdalen a subsidiary fold (with faults) on the crest of the main anticline (pl. I) has produced a remarkable loop of the coal outcrop. West and northwest of Storlona the beds are practically horizontal and much faulted. The coal outcrops are numerous, but difficult or impossible to correlate. On the east side of Storlona and the upper reaches of Engelskelva the outcrops of the Misery seams are only slightly disturbed and dip regularly to the east. The outcrops ascend the northwestern slope of Miseryfjell, then disappear underneath the Spirifer Limestone in Trogdalen (Trough Valley), and re-appear at the southern corner of the mountain. Thence the seams are beautifully exposed in the eastern slopes (seaward) of the mountain, and disappear below sea-level south of Kapp Levin.

In Miseryfjell and north of it the dip is to the east and northeast; west and southwest of it the dip is to the northwest and west-northwest. The axis of the anticline then runs immediately west of the mountain in an approximately north-and-south direction, and with a considerable pitch to the north.

Most of the seams are thin and impure, but within an area north of Miseryfjell and east of Engelskelva the thickness of one seam is quite considerable, but unfortunately the seam is split up by shale partings, rendering mining very difficult. Details of this seam will appear from the following description of the various seams as exposed in cliffs and test-pits.

As already mentioned, the series is well exposed in the cliffs at Miseryfjell, hence the name. This is the only natural exposure, and here it is seen how the seams vary in character and number. In the section from the south corner of the mountain the seams themselves are not seen, but, judging from the loose material of coal found, they are thin and insignificant.

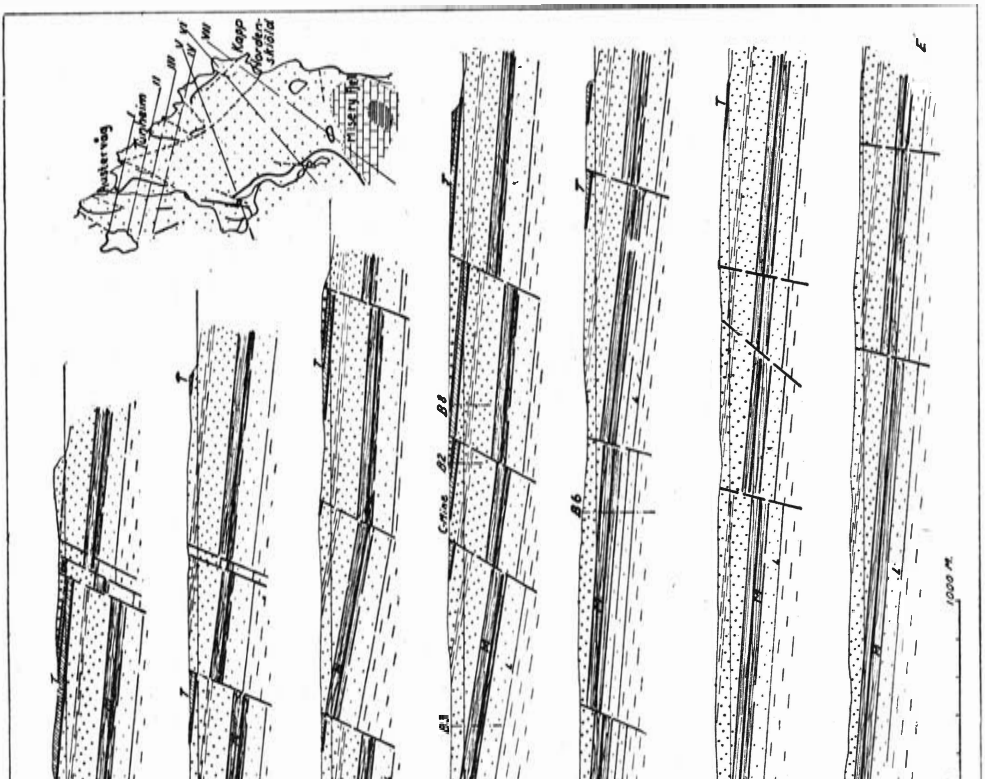


Fig. 45. Sections of the Devonian coal-series between Austervåg and Miseryfjell.
HH Hecla Hoek, L Lowest coal-seam, M Misery Series, T Tunheim Series, S Spirifer Limestone, B Borehole,

Below follow a number of sections from the seaward slopes of Miseryfjell (pl. II).

Section A—A, south corner of Miseryfjell.

Thickness in metres	
	Spirifer limestone with 10 metres of grey sandstone 25 metres above the base (Upper Carboniferous)
	Unconformity 275 metres above sea-level
12	Scree
11	Chiefly shale. A little coaly shale and coal. A few thin sandstones
6	Massive grey and greyish-brown sandstone
5	Fissile brown sandstone with some layers of very sandy shale
	Light sandy shale. In upper part layer of coaly shale and a little coal
	Shale
	Thin bedded greyish-brown sandstone
	Sandy shale
23	Grey massive sandstone. Some layers well-laminated
	Layers of shale?
	Grey and brownish sandstone
28	Black and greyish-green shale with a little coal in the upper part
	Brown thin-bedded sandstone
	Grey, brown and black sandy shale
	Thin-bedded and fissile grey sandstone. Dip: 20° N 30° E.
	Brownish-grey bedded sandstone. A few layers of shale
	Grey massive sandstone
	Brown thin-bedded sandstone
	Black earth (coal) and coaly shale
9	Scree
8	Massive sandstone
	Thin-bedded to fissile grey and brown sandstone. Dip: 10° N 45° E.
29	Scree
25	Thin-bedded grey sandstone
14	Scree
6.50	Massive bedded sandstone
1.50	Grey shale. Seams of sandstone in lower parts
12	Massive, thick-bedded, greyish-white sandstone. Coarse-grained in parts
	Unconformity 115 metres above sea-level
	Greenish slate. 20° N 60° E. (Hecla Hoek).

The thicknesses given above have been calculated from the angle of dip and the breadth of surface exposed. The effect of a fault has been eliminated.

Farther north the sections are:

Section B—B, east of Urd.

	Massive grey sandstone. 215 metres above sea-level
0.70	Grey shale
0.30	Coal (dull coal and coaly shale)
0.35	Shale
1.50	Grey sandstone
0.60	Grey shale
0.10	Coal and shale
0.15	Brown shale
0.05	Coaly shale
1.00	Grey shale
	Sandstone
	Scree
	Dark sandy shale
0.06	Coal
0.05	Shale and coaly shale
0.25	Coal and coaly shale
0.06	Coaly shale
0.36	Coal, impure in parts
0.02	Coaly shale

Thickness in metres	
9.25	Shale with streaks of coal. Partly débris
0.45	Coal, a little coaly shale
0.65	Dark shale
0.37	Coaly shale and coal
0.52	Coal, partly impure
2.70	Grey sandy shale
0.25	Coal and coaly shale
1.00	Dark shale
0.05	Impure coal
5.00	Sandy shale
	175 metres above sea-level
	Scree
6.00	Grey massive sandstone. Good bench. 115 m. above sea-level

Thickness in metres	
7.00	Brown and grey shale, very sandy in parts
0.22	Coal with a layer of shale
1.50	Light sandy shale
0.25	Sandstone
1.80	Light sandy shale
15.00	Brown and grey massive sandstone. Layers of very sandy shale
20.00	Shale, mostly sandy. Thin layers of sandstone and shaley sandstone. On top of one shale layer, 1 cm. coal and coaly shale
15.00	Sandstone. Partly laminated. Some massive benches. Rust-brown weathering
	50 metres above sea-level

Section C—C.

	Sandstone. 70 metres above sea-level
1.70	Shale
0.10	Dark shale
0.23	Bright coal
0.19	Impure dull coal
1.00	Dark shale with streaks of coal
0.05	Coal and coaly shale
0.05	Dark shale
0.25	Impure coal
3.75	Light shale with sandstone in lower part
0.10	Dark bituminous shale
0.06	Bright coal
0.02	Shale
0 23	Impure coal
2.05	Grey shale. Yellow weathering
0.13	Bright coal
0.06	Coaly shale
0.08	Shale
0.24	Coal
2.00	Dark bit. shale. Streaks of coal in lower part
0.13	Coal and coaly shale
0.10	Coaly shale and shale
0.15	Coal
1.35	Brown shale
0.15	Coal and coaly shale
0.60	Brown shale with bench of clayey sandstone
0.07	Coal and coaly shale
2.50	Grey shale with streaks and patches of harder rock
0.10	Coal
0.07	Coaly shale
0.60	Grey shale
0.10	Coal
0.10	Shale with coal
1.30	Brown shale
0 10	Impure coal
0.08	Coaly shale
0.12	Coal
0.13	Brown shale
0.12	Good coal
0.03	Coaly shale
0.13	Coal
0.02	Coaly shale
0.25	Impure coal
0.02	Soft brown shale
0.25	Brown hard shale
0.48	Coal and coaly shale
0.30	Dark brown shale
0.40	Shale and coaly shale
2.00	Shale and sandstone
5.00	Grey massive sandstone
2.40	Brown shale sandy in upper part
0.15	Good coal
0.03	Coaly shale
0.65	Brown shale
0.15	Coaly shale
0.50	Brown shale
0.20	Brown bit. shale

Thickness in metres		Thickness in metres	
0.60	Brown shale	0.10	Impure coal
0.07	Coaly shale	1.05	Sandstone
0.18	Shale	0.06	Dull coal
0.12	Coal and coaly shale	0.03	Coaly shale
0.06	Coaly shale	0.26	Coal
0.60	Grey shale	8.50	Grey shale with sandstone
1.55	Dark shale		Then follows 68 metres with scree to the level of the sea.
0.20	Coal and coaly shale		
21.50	Light shale. Sandstone in parts (much débris)		

Section D—D.

1.50	Massive sandstone with layers of shale. 30 metres above sea-level	0.04	Black bit. shale
5.30	Shale	3.50	Soft grey shale
0.04	Brown bit. shale	0.75	Hard sandstone
0.18	Coal	2.45	Grey shale
0.08	Black bit. shale	0.03	Coal and coaly shale
0.40	Grey shale	1.15	Shale
0.30	Sandstone	0.04	Coaly shale
1.50	Sandy shale	0.08	Coal
0.03	Poor coal	0.16	Coal and coaly shale
0.15	Shale	7.00	Grey shale, partly sandy and with sandstones
0.16	Coaly shale		Then scree, about 5 metres, to the sea.
0.08	Coal and coaly shale		

Section E—E.

	Sandstone	0.25	Coal, in parts impure
0.86	Grey shale	1.35	Dark shale, brown weathering
0.21	Coal	0.07	Bright coal
0.10	Coal and coaly shale	0.06	Shale
0.12	Dark shale, coal and coaly shale	0.15	Impure coal
0.08	Dark shale	0.80	Shale
2.25	Grey shale. Yellow and brown weathering	0.07	Bright coal
0.27	Coal, partly coaly shale	0.82	Light and dark shale
1.30	Grey shale	0.05	Bright coal
1.20	Dark shale with coal	0.27	Shale and coaly shale
0.05	Coaly shale	0.42	Dull coal and coaly shale
0.12	Coal	0.15	Bright coal
0.02	Black shale with coal	0.05	Dull coal
0.65	Dark shale, well laminated. Plant fossils	1.35	Shale. Rustbrown weathering
1.00	Grey sandstone	0.48	Coal with layers of coaly shale and coal
10.50	Dark shale with layers of sandstone	0.10	Shale
0.35	Impure coal and coaly shale	0.13	Coal
2.90	Shale, a little coaly shale in the middle	0.32	Coaly shale
0.06	Coaly shale	0.04	Grey shale
0.05	Bright coal	0.02	Coal
0.04	Shale	0.85	Grey sandy shale
		0.32	Poor coal and coaly shale
		2.40	Shale

Thickness in metres	
2.50	Grey massive sandstone
0.30	Coal and coaly shale
2.00	Shale and sandstone
0.06	Coaly shale
0.12	Bright coal
1.25	Grey shale
0.05	Black shale
0.08	Bright coal
0.05	Coaly shale
1.35	Shale with lime concretions
0.13	Dull coal
0.12	Bright coal
0.75	Light and dark shale
0.07	Black shale
2.50	Grey shale
0.09	Dull coal
0.03	Coaly shale
0.12	Bright coal
2.70	Grey sandy shale. A few lime concretions. Brown weathering
0.40	Sandstone and shale
0.20	Sandstone
0.40	Sandy shale
0.10	Bituminous shale
1.50	Grey shale

The top seam of this section reaches the sea-level 60 metres south of the ravine at the foot of the northern slope of Miseryfjell. The bottom shale of the section is found at the shore 790 metres south of the ravine.

At B we have 7, at C 12, and at E 14 seams, so the number apparently increases to the north. All the seams are thin and not workable. A feature is the constant splitting up by coaly shale and shale. South of C—C two detailed sections of the thickest seam have been measured (fig. 46, 1 and 2):

Thickness in metres	1.
	Dark shale, partly sandy
0.06	Coal, a little pyrites
0.07	Brown shale
0.07	Coal
0.04	Coaly shale
0.13	Coal
0.05	Bony coal
0.12	Coal
0.05	Coaly shale
0.17	Coal
0.03	Coaly shale
	Dark shale

Thickness in metres	2.
	About 100 metres from the foregoing:
	Shale
0.07	Coal
0.22	Coaly shale
0.19	Coal
0.08	Grey shale
0.05	Coaly shale
0.23	Coal
0.25	Coaly shale
	Shale

These sections represent the best on this side of Miseryfjell, but are, of course, absolutely valueless from a mining point of view. North of the mountain and east of Thetingtjørnene a number of test-pits have been dug, and although the results here are more satisfactory the seams are so split up by shale as to be unworkable at the present time. The pits O25, L25, F24, E25, D24, F25, and J25 are all believed to be on the same seam (24 or 25 signifies that the pit was dug in 1924 or 1925). The southernmost pit, O25, (south of Thetingtjørnene) was located on a good outcrop, but owing to thick overburden and heavy rains no detailed section was obtained. The seam consisted of alternations of coal, coaly shale, and shale. L25 was placed just below the former.

The section is as follows (fig. 46, L25):

Thickness in metres	
	Dark shale with streak of coal
0.10	Bedded brown sandstone
0.40	Dark shale
0.11	Coaly shale and bright coal
0.01	Shale
0.11	Bright coal
0.01	Shale
0.04	Bright coal
0.11	Dark shale
0.22	Impure coal
2.00	Grey shale, partly sandy Well bedded. Rustbrown weathering
1.80	Grey shale. Badly bedded. Rustbrown weathering
0.20	Impure coal
0.50	Shale

The dip is a few degrees east.

F24 farther north shows a considerable thickness with 1.61 metres of coal containing 7 shale partings having a total thickness of 0.75 metres. The section is as follows (fig. 46, F24):

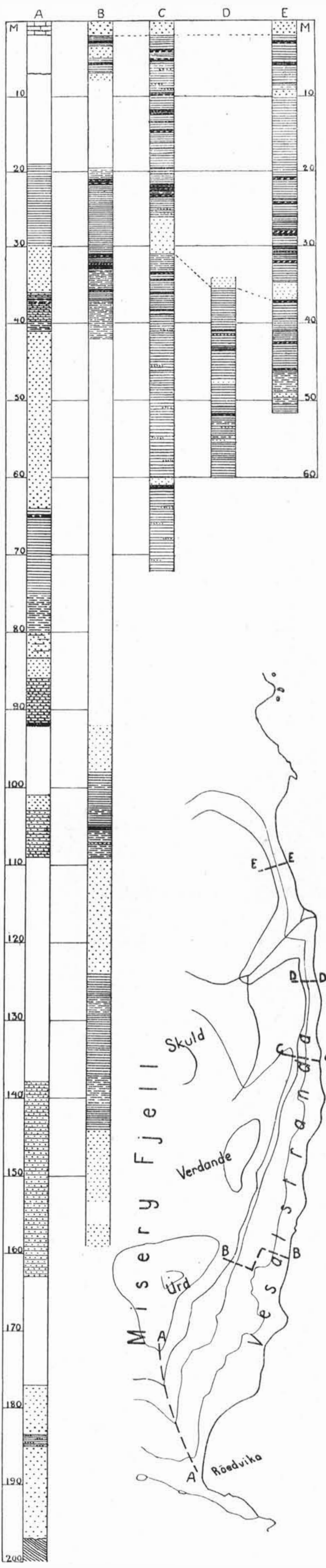
Thickness in metres		Per cent. ash[1]
	Light grey shale	
0.05	Coal	13.92
0.01	Shale	
0.16	Coal	15.50
0.15	Shale	
0.22	Coal	10.03
0.03	Shale	
0.13	Coal	8.67
0.41	Grey shale	
0.21	Coal	20.45
0.02	Dark shale	
0.40	Coal	17.95
0.07	Dark bit. shale	
0.18	Coal	23.22
0.07	Dark shale	
0.26	Coal	11.52
	Dark shale	

Analyses Nos. 2 and 3 are of the 4 bottom and 4 top layers.

Most of these shales are of a light colour and would be fairly easy to pick out in the mine, but still the product would not be marketable without some kind of dressing.

E25 lies 450 metres northwest of F24. The seam is similar to the latter, but has more coaly shale and the middle parting of shale is thicker.

[1] Determined by Dr. Gram.



Sections of Devonian strata, Miseryfjell.

The section is the following (fig. 46, E25):

Thickness in metres		
	Fissile dark shale. Rustbrown weathering	
0.15	Bright coal	
0.14	Coal and coaly shale	
0.06	Dark shale	
0.14	Bright coal (impure?)	
0.05	Dark shale	
0.12	Bright coal	
0.37	Grey shale. Reddish weathering	
0.04	Bright coal	
0.21	Grey shale. Reddish weathering	
0.04	Bright coal	
0.12	Bright coal	
0.40	Well-bedded dark shale	
0.74	Light grey shale. Badly bedded. Yellow weathering	
0.18	Bright coal................	8.73 per cent. ash
0.06	Coaly shale with bright coal	
0.05	Dark shale	
0.12	Bright coal..	9.45 per cent. ash
0.05	Coaly shale..	
0.03	Brown shale	
0.70	Bright coal. Locally 2 cm. shale. Impure in lower part?......................	14.17 per cent. ash (Dr. Gram)
0.03	Coaly shale and bright coal...........	
0.07	Bright coal..........................	
0.06	Dark shale with streaks of coal	
1.05	Greyish-white soft shale	
	Sandstone	

Analysis No. 4 is average of layers in brackets.
Dip: 8° N 30° E.

In D24 no good section was obtained on account of a local disturbance near the outcrop, but a lens with nearly one metre of coal was seen, so the thickness is therefore not less than in the other pits.

F25 at Storlona exhibits a seam similar to that met with before, although thinner. There is a total of 1.26 metres of coal divided on 6 layers and 0.61 metres of shale (5 partings). The middle shale has narrowed down to 0.20 metre.

The section is the following (fig. 46, F25):

Thickness in metres		Per cent. ash (Dr. Gram)
	Grey shale	
0.16	Bright coal	7.65
0.17	Dark shale	
0.19	Bright coal	21.75
0.02	Dark shale	
0.29	Bright coal (impure in lower part)	
0.20	Grey shale. Yellowish weathering	
0.13	Bright coal	13.40

0.29	Bright coal with some streaks of shale	7.50
0.09	Coaly shale	
0.20	Bright coal	11.70
	Light grey shale	

Analysis No. 5 is of layers of which ash percentages are given.

The northernmost pit on this more or less continuous outcrop is J 25, on the flat land bordering the east side of Storlona. As the upper part of the seam has been removed by erosion, the section is not complete (fig. 46, J 25):

Thickness in metres	
3.20	Big stones, gravel, and sand
0.80	Alternating layers of coal, coaly shale, and shale
1.50	Light grey to white shale

About 12 metres above this seam comes another which has been uncovered in two places. E 24 is the southern pit and has the following section (fig. 46, E 24):

Thickness in metres		
	Grey fine-grained sandstone	
0.02	Coal	
0.20	Grey shale. Yellow weathering	
0.11	Coal	
0.05	Brown shale and coaly shale	
0.76	Brown to black shale	Per cent. ash (Dr. Gram)
0.54	Coal......................	12.05
0.18	Coaly shale with some layers of bright coal.............	42.75
0.75	Greyish-brown shale	
	Sandstone	

Analysis No. 8 is of the 0.54 layer.

The seam is certainly too thin to be of any value. The northern pit on the same seam is K 25, but here the coal thickness of the lower layer is only 0.33 metre.

The section is the following (fig. 46, K 25):

Thickness in metres	
	Grey and brown sandstone
0.23	Grey sandy shale
0.30	Bright coal with coaly shale
1.40	Light grey soft shale, in lower part darker and more shaley
0.11	Bright coal
0.02	Dark shale
0.22	Bright coal (locally up to 0.34 pure coal)
0.02	Dark shale
1.50	Light grey shale. Badly bedded
	Sandstone

In the area east of Storlona and Thetingtjørnene we have thus one of the Misery seams developed with a coal-thickness rendering the seam workable in times of high coal prices. The area is very limited, only 2—3 sq. kilometres, and does not extend north of borehole No. 6, as the thickest seams in this bore are only 0.40 and 0.65 metre with impure coals.

Pit P25 was dug to expose the thin layer of coal 26 metres above the main coals of the Misery Series west of Tunheim.

The section is the following (fig. 46, P25):

Thickness in metres	
	Grey shale. Red weathering
0.13	Bright coal and coaly shale
0.40	Grey bedded sandstone
	Light grey shale

This layer as well as the Misery seams was pierced by the No. 3 bore west of the wireless station, but the results (p. 85) are not reliable, as proved by the pit C24—25 at Engelskelva, 350 metres west of the bore. The drillers' log of the hole suggests 2 seams of workable thickness but the pit has shown that this is utterly impossible, as is evident from the section of the pit (fig. 46, C24—25):

Depth in metres	
1.00	Weathered material
2.80	Coal. Weathered and broken up
6.80	Shale
	Fault
11.38	Dark and light sandstone
15.55	Dark shale
16.35	Dark bedded sandstone
17.30	Dark shale with plant fossils
17.80	Sandstone
18.00	Sandstone and shale
18.20	Dark shale with plant fossils
18.23	Coal
21.90	Grey sandstone. In lower part with lenses of pyrites
21.93	Coaly shale
22.06	Bright coal
22.20	Bright coal and coaly shale
25.64	Dark shale
25.70	Black shale
25.76	Coal
26.45	Grey shale
26.90	Grey sandstone (lenticular)
28.30	Grey shale
28.55	Coaly shale 0.12, bright coal 0.08, coaly shale 0.05
29.13	Grey shale
29.34	Coal
30.41	Shale
30.84	Sandstone
30.94	Shale
32.44	Sandstone
32.49	Coaly shale
38.48	Sandstone
38.60	Bright coal 0.07, coaly shale 0.05
39.05	Shale
43.72	Partly dark shale mixed with sandstone
45.12	Sandstone
45.67	Dark shale
47.52	Coarse sandstone
48.57	Dark shale
49.02	Light shale

The thick seam at the top is the A-seam of the Tunheim Series brought down to the level of the Misery Series by a fault running from Austervåg southwards, and the pit was, by chance, located just on the fault (not visible on the surface). The fault is well seen in the upper part of the pit, and below it come the Misery strata with thin coal-seams, which are here of no value whatever.

In the area between Holmevatnet and Haabethvatnet the seams are practically horizontal, lie near the surface, and cannot for that reason be mined even with a workable thickness.

If we follow the seams southwards west of Miseryfjell, the results are very discouraging: In G25 (fig. 46) a pit started on a good outcrop, but the section reveals only a very poor seam:

Thickness in metres	
1.50	Grey and brown sandstone, partly with coal
0.15	Soft grey shale
0.06	Coaly shale and dark shale
0.04	Soft grey shale. Yellowish weathering
0.05	Lenticular grey hard sandstone
0.18	Grey shale. Brownish to reddish weathering
{0.12	Bright coal
0.02	Dark shale
{0.05	Bright coal
0.03	Coaly shale
0.06	Bright coal
0.08	Shale
{0.16	Bright coal
0.01	Coaly shale
0.15	Bright coal
0.05	Coaly shale
0.37	Grey shale
	Grey Sandstone

Dip: 35°—40° N 60° W.

Analysis No. 6 is of layers in brackets.

Farther south, north of Langen, two pits were dug with the following result (fig. 46, H25):

Thickness in metres	
0.75	Débris
0.25	Grey and brown sandstone, partly conglomerate
1.55	Soft grey shale-clay
2.30	Light grey sandy shale. Brown weathering
0.10	Coal
0.40	Grey shale

Dip: 30° WNW.

As this pit did not reach the coal-seam, a new pit was dug a few metres up the dip and showed the following section (fig. 46, M25):

Thickness in metres	
	Débris
0.35	Grey shale
0.07	Coal
0.06	Grey shale
0.08	Coal
0.05	Light grey shale
0.22	Bright coal (impure)
0.04	Dark shale
0.08	Light grey shale
0.22	Bright coal
2.00	Light grey shale

Thickness in metres			
0.35	Light brown shale		
0.03	Coal		
0.09	Dark shale		
0.17	Bright coal		Analysis No. 7
0.03	Grey shale	Per cent. ash in 0.17 + 0.27 layer: 11.35	
0.27	Bright coal		
0.03	Dark shale		
0.10	„ „ yellow weathering		
0.33	Bright coal		
0.06	Dark shale	Per cent. ash in 0.33 + 0.07 layer: 11.54	
0.07	Bright coal		
0.03	Grey shale.		
0.05	Coaly shale		
0.08	Dark shale		
0.13	Coaly shale, a little bright coal		
1.00	Light grey to white shale		
	Sandstone		

The upper seam has a total of 0.59 metre of coal in 4 layers and the lower has 0.87 in 5 layers. On account of the many shale partings the seam is hardly workable. North of Ymesdalen, HOLTEDAHL uncovered this seam in 1918. The thickness was 0.80—0.85 metre with 5 cm. of shale. Pieces of clean coal gave 4.1 per cent. of ash.

On the line of outcrops north of Ellasjøen 2 pits were dug: N 25 on the upper line, but revealed only a stripe of coal. The other pit, I 25, a little lower, has undoubtedly uncovered the same seam as in M 25.

The section of N 25 is (fig. 46):

Thickness in metres	
0.20	Dark shale
0.20	Shale with a little coal
0.50	Dark fissile shale
0.20	Grey sandstone
1.50	Dark shale with plant fossils
0.07	Impure coal
2.00	Light grey shale. In lower part darker
	Reddish weathering

and the section of I 25 is (fig. 46):

Thickness in metres	
	Alternating beds of shale and sandstone
0.05—0.1	Impure coal
0.80	Soft grey shale
0.40	Bedded grey sandstone
0.22	Dark shale. Red weathering
0.17	Bright coal, upper part coaly shale
0.03	Grey shale
0.12	Grey sandstone with lenses of pyrites
0.06	Grey shale

Thickness in metres	
0.15	Coaly shale with streaks of bright coal
0.06	Bright coal
0.01	Shale
0.06	Bright coal
0.03	Shale
0.11	Bright coal
0.02	Dark shale
1.80	Grey shale. Brown weathering
0.02	Coal
0.10	Shale
0.02	Coal
1.00	Grey shale. Brown weathering

The coal outcrops can be traced southwards to Ellasjøen, and chips of coal were still found on the northern slope of Alfredfjellet. Unquestionably the coals also occur in the sea-cliff south of the mountain.

Borehole No. 5 pierced these coals and the drillers stated a thickness of coal of 1.45 metres divided on 2 layers, 1.00 and 0.45 metres thick, separated by a shale parting (p. 86). The ash content is reported to be 13.3 and 33.5 per cent. respectively. *Bjørnøen A.S.* in 1923 investigated the outcrops between the lake and the borehole, but with poor results. According to the report of the manager, Mr. THETING, the thickness was very variable, reaching 0.70—0.80 metres, but always with intercalations of shale.

The above data clearly show that the Misery seams are not workable anywhere, except possibly in a restricted area north of Miseryfjell, but even here only in times of high coal prices.

The Tunheim Series.

The seams of this series are well exposed in the cliffs from Kapp Nordenskiöld to a little beyond Kapp Forsberg. The series contain 3 seams, A, B, and C. The A-seam is the lowest, and mining has been confined to this. At Tunheim the B-seam is situated 9—10 metres above A, and C 4—5 metres above B. The two upper seams are both thin and certainly unworkable. The dip is everywhere east and southeast, and consequently the seams visible in the cliffs outcrop inland not far from the coast, the distance being 200—600 metres. The coal areas therefore are very small. In pl. IX is shown a coastal section from Kapp Nordenskiöld northwards, which illustrates better than any lengthy explanation the occurrence of these seams.

A number of faults having a northeasterly direction split up the coal area into several blocks. One of these faults has already been mentioned as throwing the Tunheim seam A down to the level of the Misery seams. In fig. 45 are shown seven sections of the area between

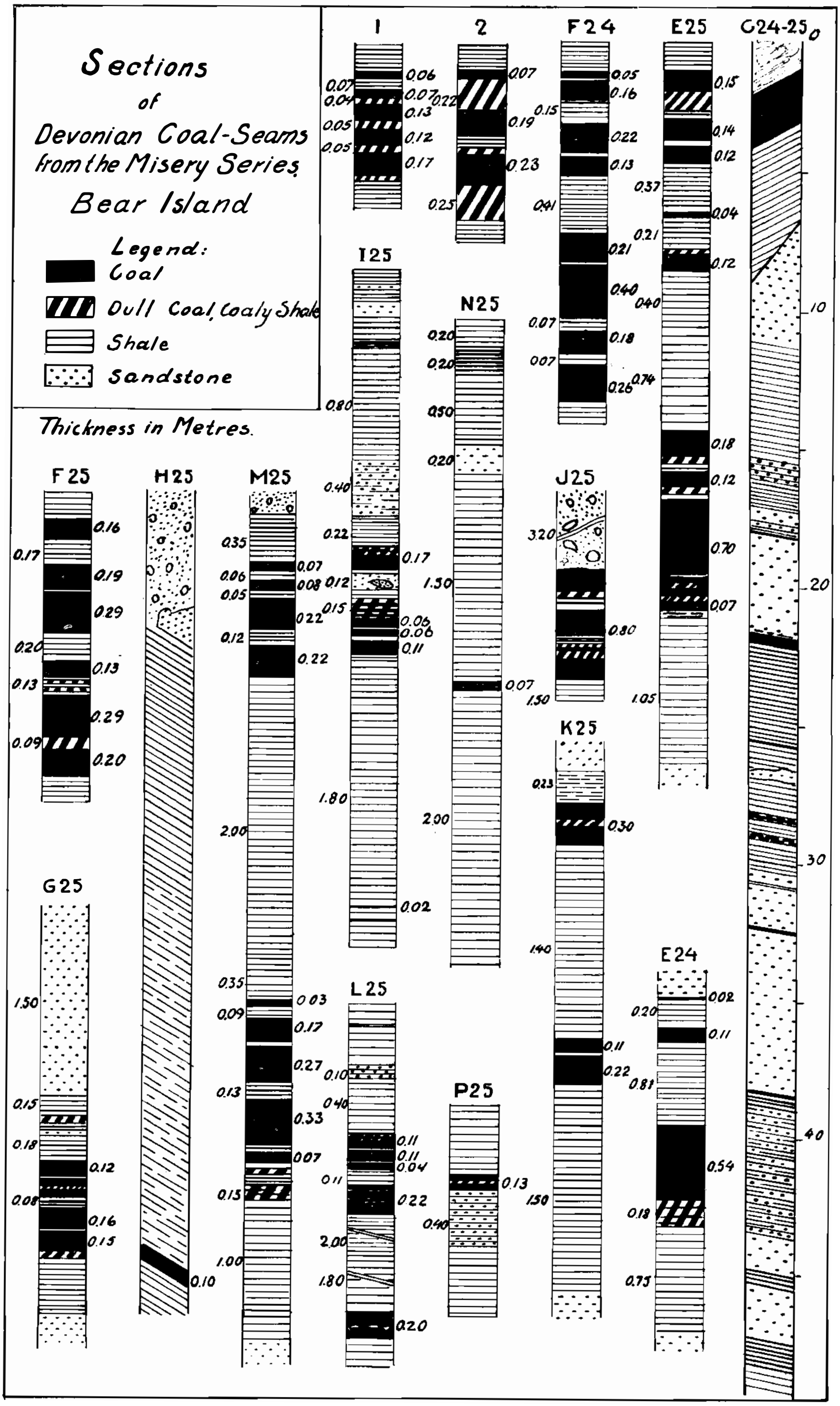

Sections
of
Devonian Coal-Seams
from the Misery Series
Bear Island
Legend:
Coal
Dull Coal, Coaly Shale
Shale
Sandstone
Thickness in Metres.
1
2
F24
E25
G24-25
I25
N25
J25
K25
F25
H25
M25
G25
L25
P25
E24

Fig. 46.

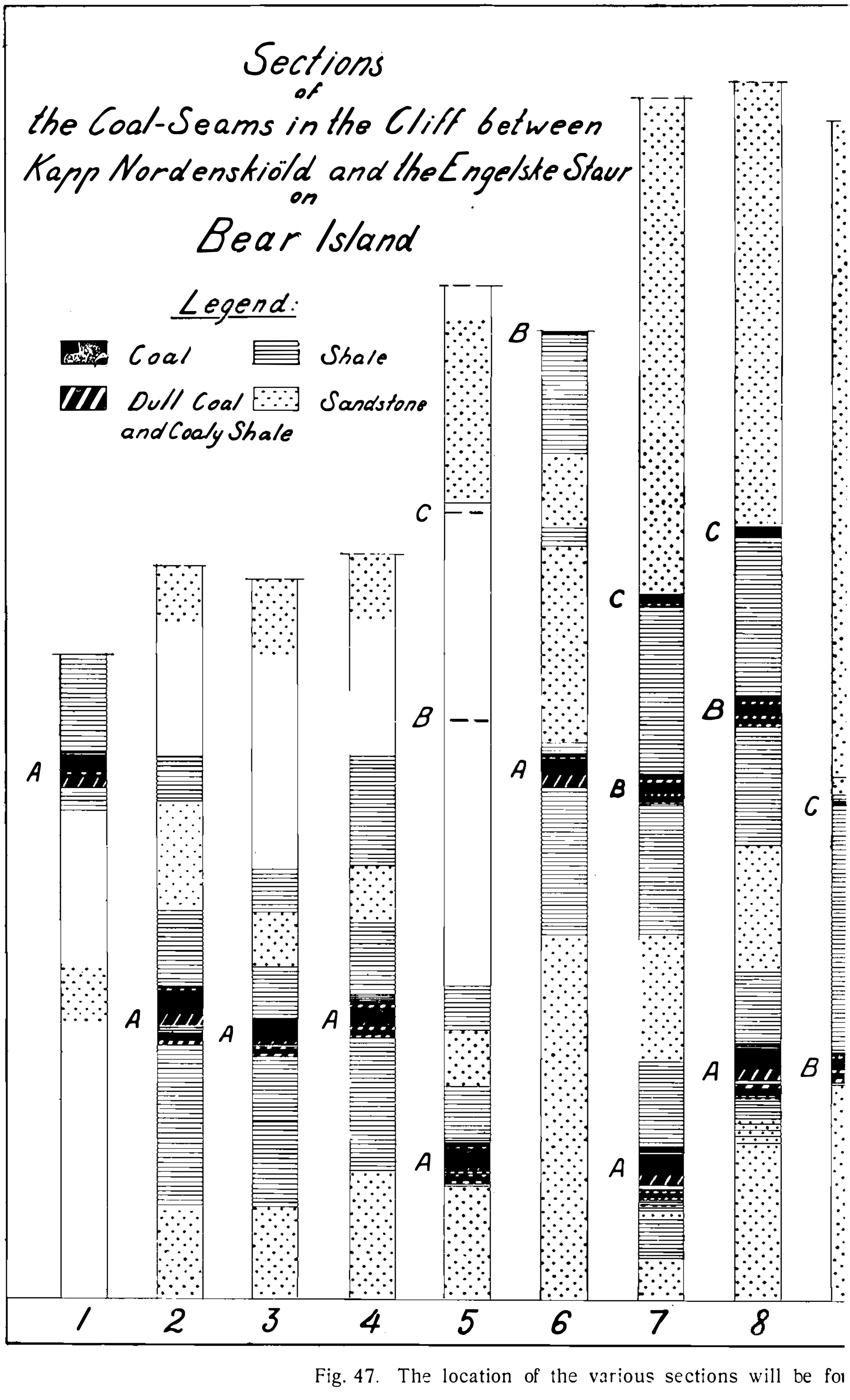
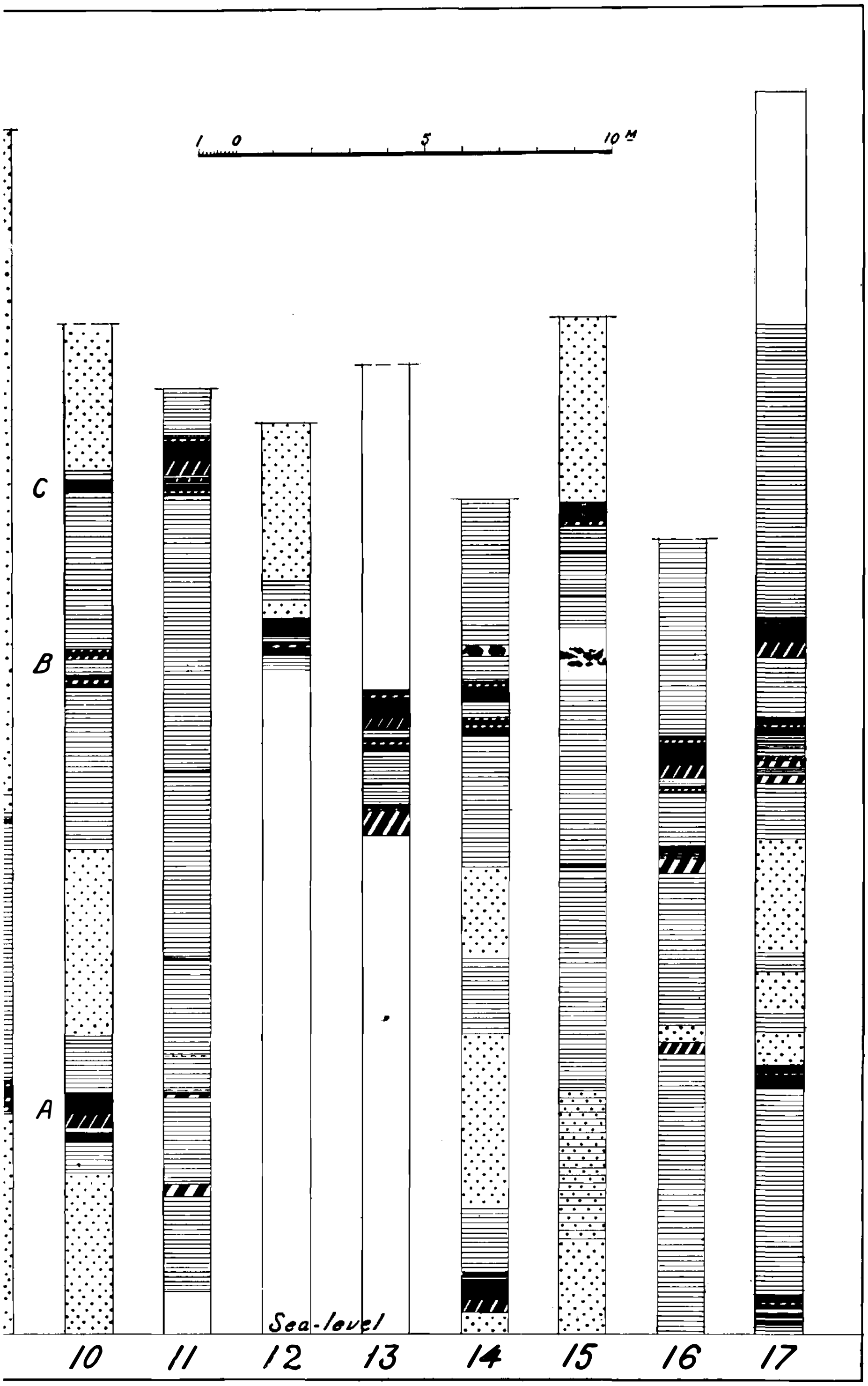


Fig. 47. The location of the various sections will be fo



d in pl. IX, and detailed sections of the seams in fig. 48.

Austervåg and Miseryfjell, giving some idea of the faulting which has affected the coal areas. It should be noted that the downthrow is always to the west of the fault on the eastern flank of the mentioned anticline (p. 40).

Mining has been confined to the block immediately to the south of Tunheim, which block is now exhausted together with parts of the adjoining block separated from the former by a fault with a throw of 16 metres. If we calculate 0.8 tons of cleaned coal per sq. metre, about 90,000 tons is left in the "new" mine. In the block Fugleodden—Kapp Nordenskiöld there are about 70,000, and in the area to the west of it 125,000 tons. The latter area is, however, somewhat doubtful, and both areas are probably unworkable, as the seam is situated too near the surface. The block near the coast is moreover too narrow to be worked at a profit. In the block south of Austervåg there are 130,000 tons. Northwards the seams deteriorate, become split up, and are certainly unworkable.

In the Tunheim area the A-seam consists of an upper part with 0.65—0.70 metre of good coal, underlain by about 0.30 metre of dull coal high in ash. Then follows a shale parting 0.10 metre, and then 0.35 metre of alternating layers of coal and coaly shale. Only the upper part with good coals is worked (see p. 102). As the strata have an easterly dip the seams also occur below sea-level, but the distance to the sea-bottom is too small to permit submarine workings.

The Tunheim Series come just below the Culm, and should therefore be expected to occur in the interior of the island near the boundary Culm-Devonian, but this boundary is nearly everywhere a faulted one, and in the south, where there is a normal sequence, the Tunheim Series is poorly developed or entirely absent. It is highly probable that the coals at the bottom of borehole No. 9 represent the Tunheim Series; this cannot be said with certainty until the paleontological material from this bore has been examined.

Below follow detailed sections of the seams from various localities. Cliff sections (17) will be found in fig. 47, and details of a number of the coals in fig. 48.

For analyses, see table p. 96.

Sections of C and B seam (fig. 47).

	Thickness in metres	
		7.
		Sandstone
C	0.24	Good coal
	0.07	Coaly shale
	4.50	Grey shale with plant fossils
B	0.13	Coal
	0.06	Coaly shale
	0.30	Coal
	0.10	Coaly shale

	Thickness in metres	
B	0.14	Coal
	0.07	Coaly shale
		Grey shale
		8.
		Sandstone
C	0.25	Coal
	0.03	Black shale
	1.20	Dark shale, sandy in parts

	Thickness in metres	
	3.00	Dark fissile shale. Brownish weathering. Thin layer of coal in the middle
B	0.12	Coal
B	0.08	Coaly shale
B	0.25	Coal
B	0.13	Coaly shale
B	0.11	Coal
B	0.08	Coaly shale
		Grey shale, sandy in parts

9.

	Thickness in metres	
		Brown and grey sandstone
	0.20	Grey shale
C	0.17	Coal and coaly shale
	6.80	Grey shale
B	0.14	Coal
B	0.06	Coaly shale
B	0.25	Pure coal
B	0.10	Coaly shale
B	0.12	Coal
B	0.04	Coaly shale
	0.04	Shale
		Sandstone

10.

	Thickness in metres	
		Grey sandstone
	0.22	Grey shale
C	0.23	Bright coal
		Grey shale
	?	Coaly shale
		Coal
		Coaly shale
B	0.32	Grey shale
B	0.14	Bright coal
B	0.05	Coaly shale
B	0.22	Bright coal
B	0.07	Dull coal
B	0.12	Shale
B	0.08	Bright coal
		Shale

Section of the A-seam in pit A 25 west of Tunheim (fig. 48, A 25):

Thickness in metres	
	Grey sandstone
3.45	Thin-bedded dark shale. Rust-brown weathering
	Nodules of clay-ironstone
0.04	Dark fissile shale ("draw-slate")
0.08	Bright coal
0.04	Bright coal and coaly shale
0.55	Bright coal
0.28	Dull coal
0.12	Dark shale
0.43	Alternating layers of bright and dull coal, and coaly shale.
	Grey shale
	Dip: 7°—8° N 55° E.

The following two sections from the C-mine are typical (fig. 48, Mine C).

Thickness in metres		
		Sandstone
1.40	2.00	Shale
0.10	0.07	Shale which follows the coal ("draw slate")
0.66	0.60	Bright coal. Locally impure in upper part (coaly shale)
0.25	0.35	Dull coal
0.10	0.10	Shale
0.35	0.50	Impure coals with shale
1.00	0.30	Shale
		Sandstone

Below follow detailed sections of the A-seam as shown in the cliff sections (fig. 47). The detailed seam sections are shown in fig. 48. The numbers correspond to those in fig. 47 and pl. IX.

Thickness in metres

1.

Thickness in metres	
	Shale
0.05	Bright coal
0.02	Dull coal and coaly shale
0.56	Bright coal
0.38	Dull coal
0.19	Shale
0.20	Bright coal
0.13	Coaly shale
	Shale

5.

	Shale
0.10	Bituminous shale
0.09	Bright coal
0.02	Dull coal and coaly shale
0.58	Bright coal
0.09	Dull coal
0.12	Coaly shale and bright coal
0.10	Bright coal
0.07	Coaly shale
	Shale

6.

	Sandstone
0.20	Grey shale
0.04	Black shale
0.30	Bright coal
0.01	Impure coal
0.44	Bright coal
0.30	Dull coal
	Dark shale

8.

	Grey shale
0.12	Black bit. shale
0.60	Bright coal
0.30	Dull coal
0.10	Shale
0.12	Impure coal and coaly shale
0.16	Coal
0.03	Sandstone
0.04	Coaly shale
	Greyish-brown shale

10.

	Dark shale
0.56	Bright coal
0.38	Dull coal
0.10	Grey shale
0.28	Bright coal
	Shale

Thickness in metres

11.

	Grey shale
0.03	Black shale
0.08	Bright coal
0 09	Coaly shale
0.43	Bright coal (with some pyrites)
0.44	Dull coal
0.07	Grey shale
0.09	Dull coal
0.05	Black shale
0.20	Bright coal with a little pyrites
0.08	Coaly shale
0.03	Bright coal
	Shale

13.

	Black shale
0.14	Bright coal
0.04	Coaly shale
0.52	Bright coal
0.37	Dull coal
0.18	Shale
0.11	Coal (dull coal)
0.07	Coaly shale
0.19	Bright coal
0.82	Grey shale
0.05	Bright coal
0.62	Grey shale
0.06	Bright coal
0.07	Dull coal
0.53	Coaly shale
	Shale

16.

	Grey shale
0.08	Black shale
0.09	Bright coal
0.06	Coaly shale
0.56	Bright coal
0.32	Dull coal
0.16	Grey shale
0.07	Coal
0.06	Coaly shale
0.02	Bright coal
0.75	Grey shale
0.05	Coal
0.55	Shale
0.14	Bright coal
0.56	Coaly shale
	Grey shale

17.

	Black shale
0.10	Black bit. shale
0.11	Bright coal

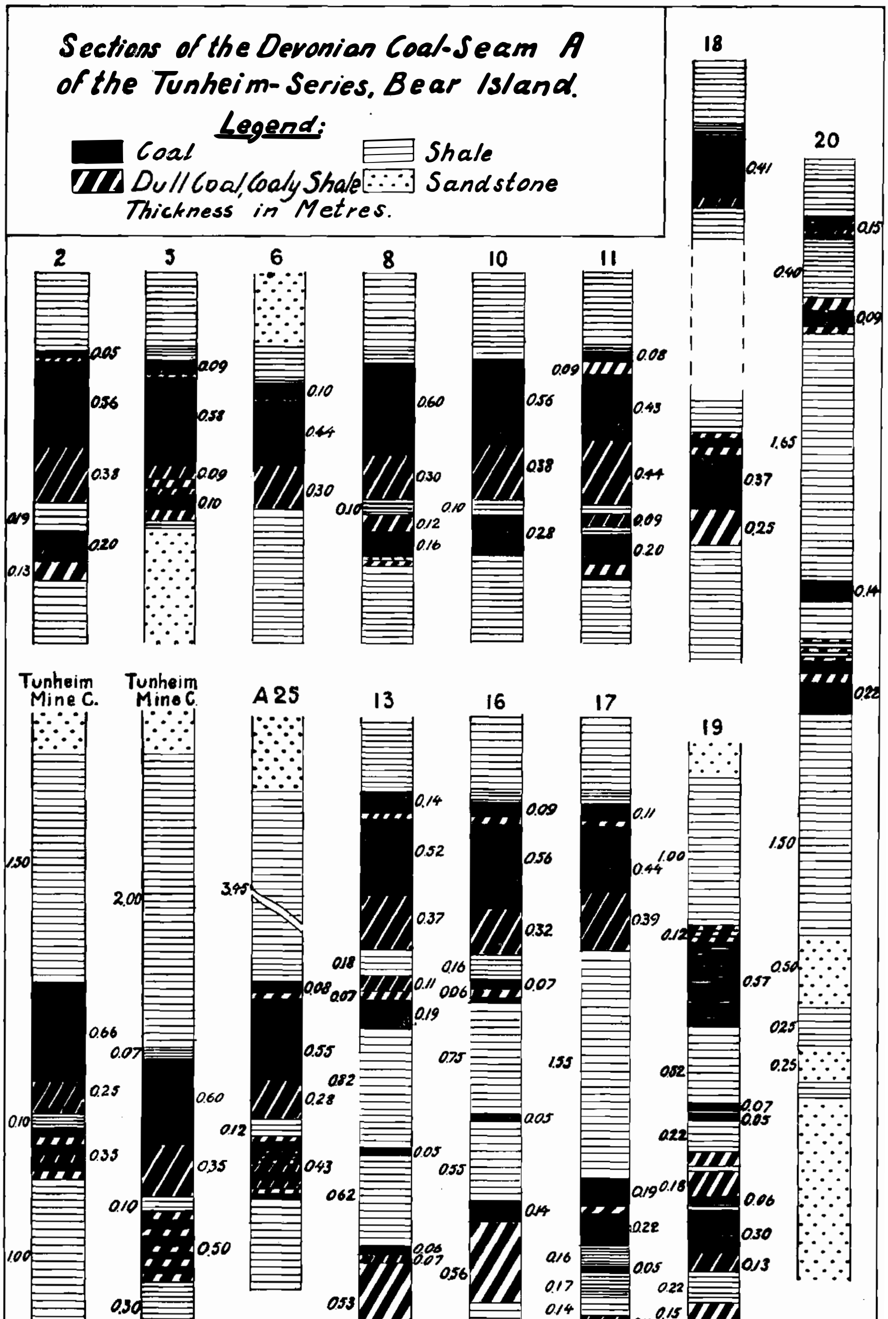

Sections of the Devonian Coal-Seam A
of the Tunheim-Series, Bear Island.
Legend:
Coal
Shale
Dull Coal, Coaly Shale
Sandstone
Thickness in Metres.
2
3
6
8
10
11
18
20
Tunheim Mine C.
Tunheim Mine C.
A 25
13
16
17
19

Fig. 48.

Thickness in metres	
0.04	Coaly shale
0.44	Bright coal
0.39	Dull coal
1.55	Grey shale
0.19	Coal
0.04	Coaly shale
0.22	Bright coal
0.16	Bit. shale

Thickness in metres	
0.05	Coal
0.17	Black shale
0.14	Grey shale
0.11	Dull coal
0.14	Coaly shale.
0.20	Grey shale
0.20	Coaly shale
	Grey shale

Section of the A-seam and the second lowest seam, south of the Engelske Staur (fig. 48, 18).

	Thickness in metres	
		Shale
	0.08	Bit. shale
A	0.41	Bright coal
A	0.07	Laminated dull coal
		Shale
		Scree
		Thin-bedded shale

Thickness in metres	
0.04	Coaly shale
0.06	Bright coal
0.06	Coaly shale
0.37	Bright coal
0.25	Coaly shale
	Shale

Section of the A-seam 650 metres south of Kapp Forsberg (fig. 48, 19):

Thickness in metres	
	Grey sandstone
1.00	Grey shale
0.12	Coal shale with streaks of bright coal
0.57	Bright coal (impure in parts?)
0.52	Shale, partly with coal
0.07	Bright coal
0.01	Shale
0.05	Bright coal
0.22	Shale
0.10	Coaly shale
0.04	Dark shale

	Thickness in metres	
	0.18	Coaly shale
	0.06	Bright coal
	0.05	Bit. shale
	0.30	Bright coal with streaks of pyrites
A	0.13	Dull coal
	0.22	Dark shale
	0.15	Coaly shale
	0.41	Bright coal with streaks of pyrites
	0.20	Brown shale
	1.00	Sandstone (to the sea)

Section of the uppermost seam in the cove west of Måkestauren (fig. 48, 20):

Thickness in metres	
	Well bedded shale
0.15	Bright coal and coaly shale
0.40	Dark shale. Crushed and with plant remains
0.08	Coaly shale
0.09	Bright coal
0.05	Coaly shale
1.65	Shale, crushed in parts
0.14	Bright coal
0.25	Shale

Thickness in metres	
0.15	Coaly shale and shale
0.08	Bright coal
0.06	Coaly shale
0.22	Bright coal
1.50	Crushed shale
0.50	Dark sandstone
0.25	Light shale
0.25	Sandstone
0 10	Shale
	Bedded dark sandstone (to the sea)

Culm.

The occurrence of Culm coal was discovered by ANTEVS in 1916 (ANTEVS and NATHORST (1917)) in Borehole No. 1 at the outlet of Laksvatnet (Analysis of the core, see table, No. 35), and in 1918 HOLTEDAHL found the same seam in No. 4 bore 1,400 metres south of No. 1. The seam gave very bad cores, and the thicknesses given are therefore not reliable. Most of the "coal" of the drillers is black and/or coaly shale, as proved by the subsequent uncovering of the seam in pits. In 1921 H. SYVERTSEN of the *Bjørnøen A. S.* measured the section in a pit south of Nordhamna, where there is a good outcrop of Culm coal.

The section is the following (fig. 49):

Thickness in metres		Per cent. ash[1]
	Sandstone	
0.02	Clay	
0.61	Coal	7.9
0.06	Coal (hard)	44.0
0.09	Shale	
0.42	Coal	4.7
0.15	Shale	
	Sandstone.	
	Dip: 8° SW.	

No. 36 (table pp. 96 and 97) gives a complete analysis of this coal. The seam pinched out, however, about 40 metres from the surface.

South of the Spirifer Limestone area the Culm seam outcrops in several places: east of Hausvatnet, Stevatnet, and Spelvatnet, and on the plateau south of Lygna. It is the same seam that is repeated by faulting. The bore (No. 7) at the south end of Hausvatnet was drilled in order to find out whether the many outcrops represented one or several seams. The hole was located just below the upper boundary of the Culm and was carried down to 234 metres, but only one seam was encountered, viz. the seam already known from the bores at Laksvatnet. No core of the coal was obtained, but the thickness of coal and coaly shale is probably 0.80 metre. A pit, G 24, was dug on the outcrop east of the hole and revealed a seam of no value.

The section is the following (fig. 49, G 24):

Thickness in metres	
	Greyish-white sandstone
0.46	Light grey shale with small lenticles of sandstone
0.10	Light sandstone
0.25	Weathered, greenish-grey shale
0.40	Dark shale
0.10	Impure coal
2.20	Grey shale

[1] Determined at the mine laboratory.

Thickness in metres	
0.40	Grey sandstone (lenticular) with pyrites
0.09	Bright coal, 9.05 per cent. ash
0.11	Coal and coaly shale
0.15	Dull coal, 24.20 per cent. ash
0.63	Dark shale, partly carbonaceous
0.04	Bright coal
0.30	Dull coal. Columnar fracture, 19.45 per cent. ash
0.05	Dark shale with coal
0.06	Dull coal
0.20	Bright coal, 11.55 per cent. ash
0.10	Crushed dark shale
0.25	Dark shale

Analyses Nos. 39 and 40 are of the 0.20 and 0.30 layers.

In a pit, H 24, dug 1,800 metres farther north, the seam was much poorer, as it only showed 0.10 metre of coal.

The section is as follows (fig. 49, H 24):

Thickness in metres	
2.63	White sandstone
0.20	Shale
0.01	Coaly shale
2.20	Dark shale with some nodules of pyrites
0.10	Coal
0.33	Coaly shale and very bituminous shale
0.12	Greyish-green shale
0.06	White sandstone
0.05	Greyish-green shale
	White fine-grained sandstone

On the outcrop between Spelvatnet and Lygna the pit B 25 was sunk with the following result (fig. 49, B 25):

Thickness in metres	
1.00	Grey sandstone
1.20	Clay (soft shale) weathering red and brown
1.00	Light grey shale. Soft, badly bedded
0.03	Dark shale
0.10	Bright coal
0.05	Coaly shale
0.10	Bituminous shale
0.24	Grey shale
0.15	Bright coal and coaly shale
0.25	Grey shale
1.00	Dark sandy shale. Fairly bedded. Plant fossils and nodules of pyrites

The pit D 25 south of Lygna shows the following section (fig. 49, D 25):

Thickness in metres	
	Conglomerate
3.00	Grey coarse sandstone
0.04	Dark shale
0.13	Bright coal (impure)
0.09	Dark shale, partly with coal

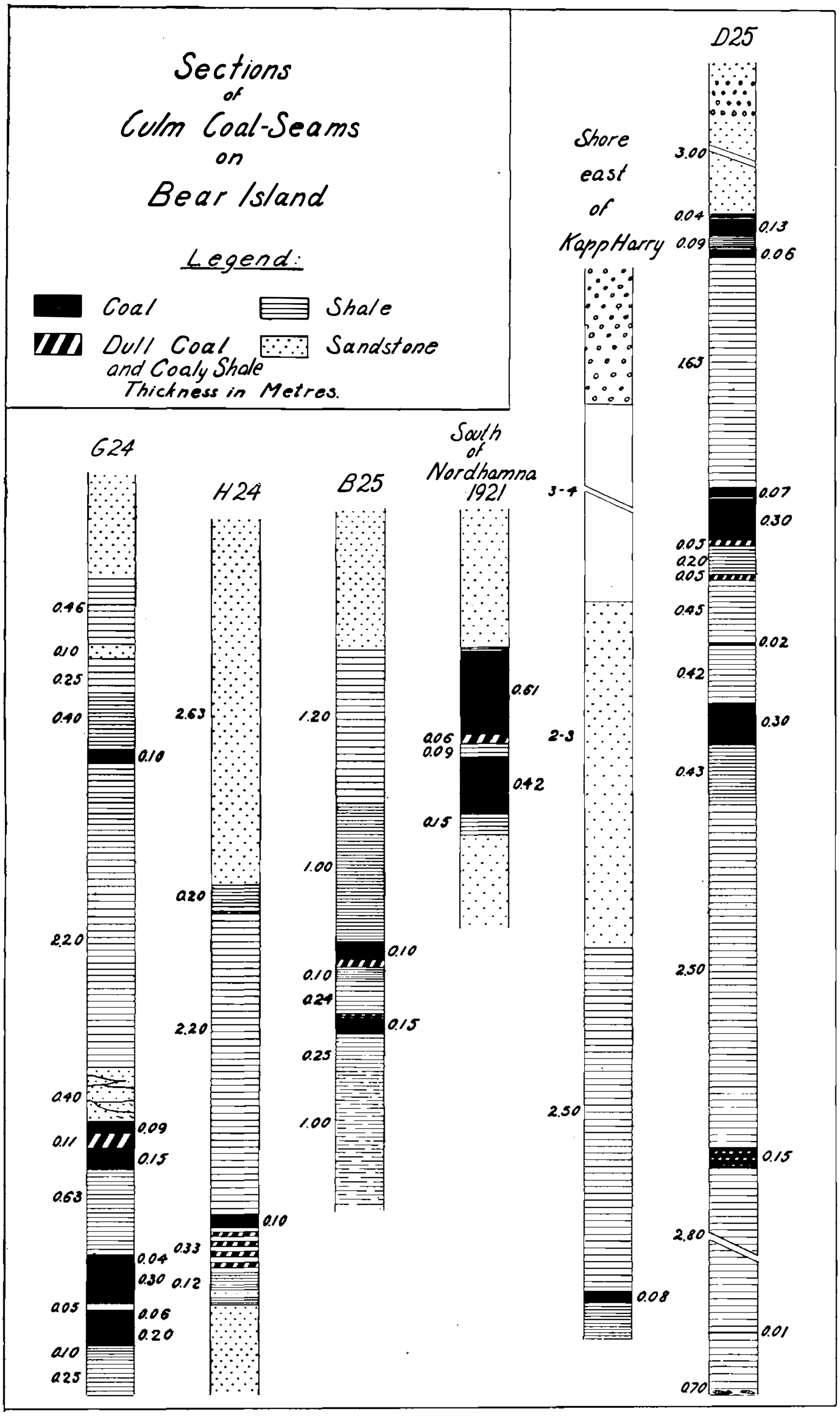

Sections of Culm Coal-Seams on Bear Island
Legend:
Coal
Shale
Dull Coal and Coaly Shale
Sandstone
Thickness in Metres.
G24
0.46
0.10
0.25
0.40
0.10
2.20
0.40
0.09
0.11
0.15
0.63
0.04
0.30
0.05
0.06
0.20
0.10
0.25
H24
2.63
0.20
2.20
0.10
0.33
0.12
B25
1.20
1.00
0.10
0.10
0.24
0.15
0.25
1.00
South of Nordhamna 1921
0.61
0.06
0.09
0.42
0.15
Shore east of Kapp Harry
3-4
2-3
2.50
0.08
D25
3.00
0.04
0.13
0.09
0.06
1.65
0.07
0.30
0.05
0.20
0.05
0.45
0.02
0.42
0.30
0.43
2.50
0.15
2.80
0.01
0.70

Fig. 49.

Thickness in metres		
0.06	Bright coal	
1.65	Grey shale with plant fossils (α)	
0.07	Bright coal	Analysis No. 41.
0.01	Dark shale	
0.30	Bright coal, impure in lower part	
0.05	Coaly shale	
0.20	Dark shale	
0.05	Bright coal and coaly shale	
0.45	Dark shale	
0.02	Bright coal	
0.42	Grey shale	
0.30	Bright coal	
0.43	Black shale with some streaks of coal	
2.50	Grey shale, mixed with a little sandstone	
0.15	Bright coal and coaly shale	
2.80	Grey shale. In lower part plant fossils (β)	
0.01	Coal	
0.70	Grey shale. Lenses of pyrites.	

A borehole has proved 0.50 hard shale and 0.75 dark sandstone with layers of shale below the bottom of the pit.

Dip: 18° N 35° W.

Both these pits are undoubtedly on Culm seams, but this statement is solely based on structural evidence and the general character of the rocks. Plant fossils have been collected from these localities, but have not as yet been examined.

The Culm area from Hausvatnet to Alfredfjellet in the south has been closely examined, and only in a few places are traces of coal to be found, so that it may be taken for granted that no important seam exists here. At the shore below Alfredfjellet and east of Kapp Harry a streak of coal is found at the horizon of the Culm seam in the north.

The section east of Kapp Harry is as follows (fig. 49):

Metres	
	Conglomerate
3—4	Scree
2—3	Sandstone
2.50	Dark shale
0.08	Coal
	Dark shale
	Dip: 22° WNW.

At Nordkapp a coal-seam occurs against a fault in the grey Culm sandstone. Fig. 50 gives the section and shows how the seam has just escaped denudation. From Kapp Olsen to Kapp Kjellstrøm the Culm sandstone is strongly faulted (pl. IX), and it is therefore difficult to place this seam, as the plant fossils have not as yet been determined, but we believe it is the Culm seam.

This seam has thus everywhere proved to consist of thin layers of coal and coaly shale, altogether unworkable, and it may be disregarded altogether.

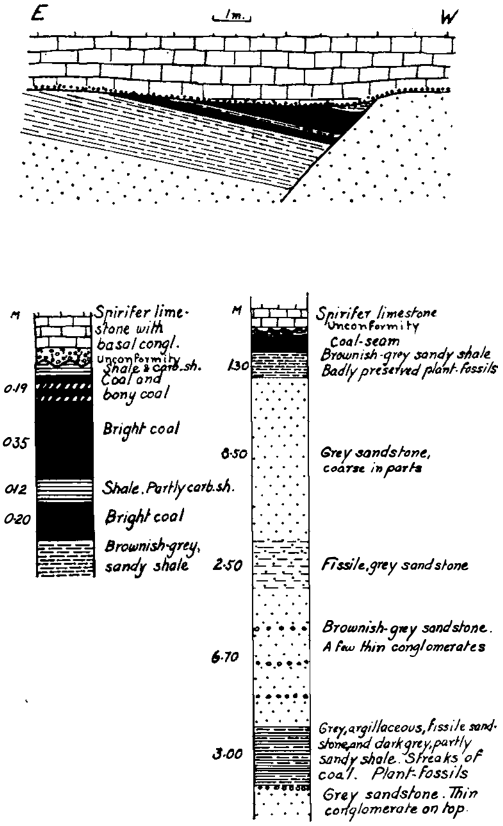


Fig. 50. Sections of the Culm seam in the cliff at Nordkapp.

Figure on top shows the Spirifer Limestone resting unconformably on the Culm. Analysis No. 37 is of the 0.35+0.19 layer, and No. 38 of the 0.20 layer.

Sections of Boreholes.

Drilling has been carried out in eleven places in order to explore the coal-bearing formations and find new seams. As already mentioned, the Culm seam, whose existence was never suspected, was first discovered in a borehole (No. 1).

Pl. III shows graphically the borehole sections, and fig. 18 establishes a general correlation of the bores.

Below follow depth and description of the strata pierced by the drill; in regard to two of the boreholes, viz. one north of Miseryfjell (1916), and one in Herwigshamna (1912), it has not been possible to obtain records. The former was drilled for *Bjørnøen A. S.* by the *Svenska Diamantbergborrnings Aktiebolaget,* and, judging from cores found on the site, it is evident that they never reached the Hecla Hoek. The site is not good, as it is below the lowest Devonian coal-seam. The drilling of the other hole was done by the *Deutsche Seefischerei-Verein,* and is said to have reached 140 metres with nothing but sandstone. The location is below the Culm seam, so this result is what might have been anticipated.

Borehole No. 1.

Location: Outlet of Laksvatnet. Elevation: 40 metres. Drilled, summer 1916. Diamond drilling by *Svenska Diamantbergborrnings Aktiebolaget*, Stockholm. Cores. 32 mm. Direction of hole, vertical. Dip of strata, 18° W. Reduction of thickness as given below, 5 per cent. Section by E. ANTEVS.

Geological Section:

Depth in metres	
20.98	Spirifer limestone. Unconformity
21.60	Red shale
21.99	Sandstone
22.55	Greyish-green shale
28.00	Red shale
28.68	Grey hard sandstone
41.15	Red shale with minor intercalations of grey sandstone
53.83	Grey sandstone, partly conglomeratic. Towards the bottom passing into shale
54.25	Grey shale
59.20	Red shale
59.90	Grey shale. In lower part sandstone
60.85	Red shale passing into grey
62.38	Grey sandstone
68.25	Dark-grey shale, hard in parts
68.55	Conglomerate and sandstone
78.00	Grey massive sandstone with a few thin layers of shale. Conglomeratic in parts
78.60	Dark-grey shale
79.20	Grey massive sandstone
81.50	Conglomerate and sandstone
81.80	Grey shale
83.77	Grey massive sandstone
84.07	Conglomerate and sandstone
85.00	Massive sandstone with a little shale
87.80	Mostly conglomerate. Massive sandstone in parts
90.55	Massive sandstone, a little conglomerate
92.43	Alternating beds of sandstone and conglomerate
95.50	Whitish-grey massive sandstone
97.10	Conglomerate and sandstone
99.15	Coal
100.70	Shale with coal. Towards the bottom less coal
103.00	Laminated sandstone with layers of shale
110.12	Greyish-white sandstone
112.50	Conglomerate
115.60	White fine-grained sandstone
117.58	Chiefly conglomerate
120.00	Fine-grained sandstone
122.00	Coarse sandstone
124.00	Bedded sandstone with a little coal
127.50	Fine-grained sandstone
144.20	Coarse sandstone
151.50	Shale with coal
152.00	Coarse sandstone

By measurement of the hole the depth was found to be 154.50 metres.

Borehole No. 2.

Location: Tunheim. Elevation: 36 metres. Drilled, summer 1918. Diamond drilling by *Svenska Diamantbergborrnings Aktiebolaget*, Stockholm. Direction of hole, at right angles to the bedding. Section by drillers.

Geological Section:

Depth in metres	
4.00	Coarse sandstone
5.69	Shale
6.00	Coal; C-seam
11.48	Shale
12.01	Coal; B-seam
12.81	Shale
18.00	Coarse sandstone
21.58	Fine-grained sandstone
22.48	Coal; A-seam
25.00	Shale
32.27	Dark coarse sandstone
32.50	Light shale
48.51	Dark coarse sandstone
50.35	Light fine-grained sandstone
51.85	Light conglomerate
52.75	Black shale impregnated with coal
57.75	Light fine-grained sandstone
58.50	Light shale
59.40	Dark shale
61.40	Light shale
61.60	Fine-grained sandstone
67.00	Light-grey shale
74.10	Fine-grained sandstone
76.30	Dark shale
78.30	Fine-grained sandstone
79.00	Coarse sandstone
79.10	Shale
80.14	Fine-grained sandstone

Borehole No. 3.

Location: Tunheim. Elevation: 33 metres. Drilled, summer 1918. Diamond drilling by *Svenska Diamantbergborrnings Aktiebolaget*, Stockholm. Direction of hole, vertical. Dip of strata, 10° E. Reduction of thickness as given below, 1.5 per cent. Section by drillers.

Geological Section:

Depth in metres	
6.08	Sandstone
6.48	Sandstone mixed with shale
18.24	Coarse sandstone
18.74	Grey shale
23.06	Coarse sandstone
23.98	Conglomerate
24.48	Fine-grained sandstone
24.73	Grey shale
26.48	Fine-grained sandstone
27.08	Light shale
31.83	Coarse sandstone
34.43	Conglomerate
37.08	Fine-grained sandstone
39.98	Coarse sandstone
44.17	Grey shale
44.42	Coal
44.57	Grey shale
44.62	Coal
47.95	Grey shale
48.00	Coal
49.20	Grey shale
50.63	Shale mixed with sandstone
50.93	Shale with coal
53.89	Shale mixed with sandstone
60.00	Fine-grained sandstone with pyrites
64.30	Coarse sandstone
65.50	Light shale
67.35	Coarse sandstone
67.75	Light shale
71.02	Coarse sandstone
71.08	Pyrites
71.47	Coal
73.63	Grey shale
73.92	Coal
75.77	Shale
76.47	Coal
78.96	Grey shale
79.67	Coal
82.00	Shale (very loose clay)
82.20	Coal
84.32	Grey shale
84.67	Coal
87.64	Grey shale
88.82	Coal
92.17	Grey shale mixed with sandstone
93.29	Coal
93.49	Shale with coal
94.30	Grey shale

Depth in metres		Depth in metres	
99.17	Coal-bearing sandstone	115.25	Dark shale, coal-bearing in a few places
99.84	Coal	116.50	Shale mixed with sandstone
100.00	Shale	117.75	Sandstone
100.10	Coal	118.00	Coal-bearing sandstone
105.25	Light shale	120.11	Fine-grained sandstone

Borehole No. 4.

Location: Near the hut at Laksvatnet. Elevation: 36 metres. Drilled, summer 1918. Diamond drilling by *Svenska Diamantbergborrnings Aktiebolaget*, Stockholm. Direction of hole, 80° E. Dip of strata, 20° W. Reduction of thickness as given below, 1.5 per cent. Section by drillers.

Geological Section:

Depth in metres		Depth in metres	
23.20	Spirifer Limestone. Unconformity	90.45	Coal
26.60	Grey shale	93.30	Coal-bearing shale
38.00	Sandstone and shale	93.55	Coal
69.10	Conglomerate and sandstone	97.30	Coal-bearing shale
76.50	Grey shale	199.50	Fine-grained sandstone, conglomerate in parts
83.30	Sandstone	200.50	Grey shale
85.00	Grey shale	219.58	White sandstone and shale
89.25	Sandstone and conglomerate		

Borehole No. 5.

Location: West of Ellasjøen. Elevation: 45 metres. Drilled, summer 1918. Diamond drilling by *Svenska Diamantbergborrnings Aktiebolaget*, Stockholm. Cores: to 12.45 m., 42 mm., to 169.36 m., 32 mm. The hole is perpendicular to the stratification (20° W). Section by drillers.

Geological Section:

Depth in metres		Depth in metres	
27.35	Fine-grained sandstone	78.28	Shale with coal
30.00	Conglomerate	78.73	Coal
57.00	Fine-grained sandstone	79.00	Coal-bearing shale
59.70	Coarse sandstone	80.30	Light shale
60.00	Conglomerate	83.90	Shale mixed with sandstone
63.80	Fine-grained sandstone	84.90	Coal-bearing sandstone
63.95	Dark shale	84.93	Coal
65.07	Fine-grained sandstone	90.35	Shale mixed with sandstone
65.70	Shale mixed with sandstone	95.80	Fine-grained sandstone
71.25	Fine-grained sandstone	103.40	Shale mixed with sandstone
75.50	Coal-bearing sandstone	105.00	Light shale
76.80	Grey shale	105.55	Sandstone
77.13	Dark shale with coal	108.50	Red shale
78.13	Coal	108.84	Light shale

Depth in metres		Depth in metres	
116.76	Red and light shale	140.41	Light shale
123.70	Shale mixed with sandstone	143.63	Shale mixed with sandstone
125.00	Red shale	144.10	Conglomerate
128.00	Fine-grained sandstone	148.50	Fine-grained sandstone
128.60	Grey shale	153.50	Red and grey shale
129.30	Coal-bearing shale	153.90	Coal-bearing shale
132.45	Shale mixed with sandstone	155.45	Red and grey shale
135.98	Fine-grained sandstone	155.75	Sandstone
137.60	Grey and red shale	156.25	Red shale. Unconformity
138.90	Shale mixed with sandstone	169.36	Dolomite

Driller notes quartzite, but this must be a mistake for dolomite, as is evident from the cores found on the drilling site.

Borehole No. 6.

Location: South of Tunheim. Elevation: 35 metres. Drilled, July 16 to Sept. 6, 1924. Chilled-shot drilling by the Norwegian Svalbard Expeditions with outfit from *Norsk Diamantborings A/S*, Oslo. Cores: to 11.82 m. 3″, to 190.30 m. 2¼″. Direction of hole, vertical. Dip of strata, 5° E. Reduction of thickness as given below, 0.4 per cent. Section by the writers.

Geological Section:

Depth in metres	
4.00	Grey massive sandstone
10.80	Clay; no core
11.82	Light-grey shale, badly bedded
23.15	Light and dark-grey sandstone with traces of pyrites
23.50	Light-grey soft shale
32.65	Grey, partly coarse sandstone. Streaks of conglomerate. Some pebbles of black flint and white quartz. Partings of brown shale and traces of pyrites
34.01	Grey fine-grained sandstone with a brownish hue and carbonised plant remains
36.70	Grey sandstone, partly conglomeratic. A few carbonised plant remains
37.70	Grey soft shale with plant fossils. A few lenses of sandstone
40.50	Grey to brown sandstone
44.64	Alternating beds of grey sandstone and grey argillaceous sandstone
44.75	Brown shale
45.15	Coal with some layers of carbonaceous shale
45.30	Dark shale
45.38	Coal
47.56	Grey soft shale
52.00	Grey sandstone, partly coarse
52.50	Dark heavy fine-grained sandstone
54.80	Grey medium-grained sandstone
58.74	Grey massive sandstone
61.60	Grey sandstone
62.80	Grey coarse sandstone with a little shale and pyrites
?	Grey shale with plant fossils
63.79	Grey coarse sandstone with black fragments of shale
67.30	Grey, partly coarse sandstone with a little dark shale
67.95	Coal. Thickness somewhat uncertain
70.40	Grey shale

Depth in metres	
70.55	Dark bituminous sandy shale with a little pyrites
70.95	Dark shale and carbonaceous shale with bands of coal; core: 28 centimetres
71.59	Grey shale
71.74	Coal
71.89	Bit. and carbonaceous shale
72.03	Alternations of coal and carbonaceous shale
74.97	Dark shale with streaks of carbonaceous shale
75.02	Dark bituminous shale
77.78	Grey shale, darker parts with plant fossils
78.15	Grey hard shale, ferruginous?
82.50	Grey shale, darker parts with plant fossils. Carbonaceous shale in lower part
83.35	Grey sandstone
?	Grey shale; core: 50 cm.
85.50	Grey coarse sandstone and shale; core: 65 cm.
85.60	Dark bituminous and carbonaceous shale
85.75	Coal and carbonaceous shale alternating
86.24	Grey and brown shale
89.00	Dark sandy shale and grey sandstone
?	Carbonaceous shale, core: 30 cm.
90.70	Grey shale mixed with carbonaceous shale in lower part, core: 50 cm.
91.94	Grey shale
92.35	Dark heavy sandstone
93.35	Light-grey shale
94.35	Greyish-brown shale with plant fossils
94.45	Dark and light banded sandy shale
96.15	Grey fine-grained sandstone, partly fissile
99.25	Dark (black) shale
105.00	Light-grey shale; core: 4.10 m.
?	Coal; core: 15 cm.
107.52	Grey shale; core: 1.05 m.
113.40	Grey shale
113.50	Brown bituminous shale
113.75	Grey sandstone and shale in stripes
114.25	Dark shale with light partings and pyrites
114.75	Whitish sandstone with much carbonaceous plant remains
115.55	Grey shale
117.85	Grey fine-grained sandstone with a few carbonaceous plants
?	Grey shale; core: 1.05 m.
120.60	Dark shale; core: 20 cm.
128.71	Greyish-brown shale
?	Black bit. shale, slickensides; core: 25 cm.
129.80	Dark shale; core: 50 cm.
130.00	Carbonaceous shale
130.25	Coal, no core
133.85	Dark shale with plant fossils
134.77	Sandy shale, alternations of dark and light
141.75	Grey fine-grained sandstone, somewhat bedded
143.25	No core, driller notes shale
148.00	Light shale with a few plant fossils
148.50	Greyish-green sandy shale
149.55	Light fine-grained sandstone
149.80	Grey shale

Depth in metres	
150.95	Grey sandy shale
151.15	Grey sandy shale with layers of sandstone
152.20	Grey and greenish sandy shale
153.30	Alternating layers of grey shale and sandstone
154.10	Grey fine-grained sandstone
155.00	Alternating layers of grey shale with plant fossils and fine-grained sandstone
163.90	Grey fine-grained sandstone with dark streaks
165.20	Grey soft shale, slickensides, plant fossils and carbonaceous shale
170.85	Grey fine-grained sandstone with a few shale partings
172.75	Grey sandy shale? no core
178.95	Greyish-green sandy shale, badly bedded
179.10	Black shale with a little coal and carbonaceous shale
179.90	Dark shale, crushed
181.22	Greyish-green, slightly sandy shale with irregular bedding
181.70	Dark shale
182.50	Greyish-green sandy shale
186.55	Grey sandy shale
186.60	Black bit. shale, slickensides
187.90	Brown sandy shale with plant remains
189.00	Greenish-grey sandy shale
190.30	Grey banded sandstone, well bedded

Borehole No. 7.

Location: Southern end of Hausvatnet. Elevation: 33 metres. Drilled, Aug. 1 to Sept. 23, 1924. Chilled-shot drilling by the Norwegian Svalbard Expeditions with outfit from *Norsk Diamantborings A/S*, Oslo. Cores: to 121.50 m. 3″, to 213 m. 2¼″, to 233.92 m. 1¼″. Direction of hole, vertical. Dip of strata, 15° W. Reduction of thickness as given below, 2 per cent. Section by the writers.

Geological Section:

Depth in metres	
?	White coarse sandstone, a few pebbles of quartz
4.36	Soft grey clay
7.66	Reddish-brown, slightly sandy shale with poor bedding. Lower part is soft clay
9.05	White coarse and fine-grained sandstone with pebbles of quartz
13.36	White sandstone, coarse in parts. Fragments of green shale and white argillaceous rock
13.80	White coarse sandstone
14.80	White fine-grained sandstone
15.45	Dark-grey shale
16.00	Grey shale with white sandstone
19.40	Fine-grained, almost white sandstone with olive-green spots (pyrites). A few small quartz pebbles
20.20	White coarse and conglomeratic sandstone. Shale chips, white, grey, and green
24.25	Fine-grained white sandstone with some large grains of quartz and fragments of shale
26.24	Conglomerate. Matrix: greyish-white, pebbles: white and red quartz, pea to walnut size. White, yellow, and green angular bits of soft argillaceous rock
26.50	Grey argillaceous sandstone

Depth in metres	
26.96	Dark sandy shale
28.80	Greyish-white fine-grained sandstone with a few pebbles and green spots of pyrites
32.86	Whitish-grey sandstone with a few layers of conglomerate
33.30	Black soft shale, slickensides and with plant fossils
33.90	Dark sandy shale. Dip: 25°
34.25	Shale with sandy partings
34.73	Grey fine-grained argillaceous sandstone
35.14	Dark shale, slickensides
35.92	Coal, no core
38.10	Dark shale with slickensides and plant stems. Some dark-grey fine-grained argillaceous sandstone with mica
60.60	White fine-grained sandstone with mica on bedding planes, well bedded
83.00	White sandstone with mica, somewhat bedded
85.50	White sandstone, partly coarse
107.80	White fine-grained sandstone with some mica
109.75	White sandstone with a few partings of grey sandy shale in upper part
124.17	White fine-grained sandstone, partly with mica
124.43	Green shale
150.10	White sandstone
152.00	Probably shale, no core
153.10	Greyish-green shale, very sandy in parts
176.24	White sandstone
176.44	Greyish-green, very sandy shale
178.45	White sandstone
178.55	Green shale
185.76	White sandstone
186.10	Grey fine-grained sandstone
186.60	Grey shale
189.35	Dark shale, poorly bedded. Slickensides. Partly sandy. A few nodules of pyrites
189.50	Black bituminous shale
191.35	Dark shale, partly sandy
191.75	Dark, very argillaceous sandstone
195.80	Black bituminous shale. Carbonaceous in parts. Lenses of pyrites and sandstone
196.75	Grey sandstone, a few partings of grey shale
197.15	Brown micaceous sandstone
205.90	Whitish bedded sandstone, much silvery mica on the bedding planes
206.65	Light green shale with plant fossils
209.38	White, slightly reddish sandstone with some mica
211.10	Greenish, very sandy shale
211.65	White fine-grained sandstone with a reddish hue
212.97	White sandstone with some mica
233.92	White fine-grained sandstone.

Borehole No. 8.

Location: Tunheim. Elevation: 34.06 metres. Drilled, Sept. 8 to Oct. 1, 1924. Chilled-shot drilling by the Norwegian Svalbard Expeditions with outfit from *Norsk Diamantborings A/S*, Oslo. Cores: 3″ to the bottom. Direction of hole, vertical. Dip of strata, 8° E. Reduction of thickness as given below, 1 per cent. Section by the writers.

Geological Section:

Depth in metres	
5.72	Grey sandstone
5.88	Coal; C-seam
11.68	Grey shale with a few small lenses of sandstone
12.03	Coal } B-seam
12.70	Grey shale with plant fossils } B-seam
12.90	Coal } B-seam
14.05	Grey shale
17.70	Grey massive fine-grained sandstone
20.00	Dark sandy shale
20.45	Grey sandstone
21.69	Grey sandy shale
22.68	Bright and dull coal; A-seam
23.34	Coal, carbonaceous shale, and black shales
24.32	Grey shale
31.55	Grey fine-grained sandstone, massive and hard
32.57	Grey normal-grained sandstone
32.82	Grey shale
34.97	Grey sandstone
35.65	Grey shale
36.30	Brown sandy shale, poor bedding
36.65	Sandy shale, almost sandstone
44.70	Grey sandstone with darker bands
45.10	Grey shale and sandstone with shale
48.10	Grey, rather fine-grained sandstone
48.40	Greyish-white sandstone
48.70	Grey and greyish-green shale
50.05	Grey, rather coarse sandstone
50.75	Sandstone and shale alternating
51.05	White coarse sandstone
51.90	Brown, very sandy shale
52.30	Dark fine-grained sandstone with pyrites
62.05	Greyish-green and brownish, slightly sandy shale
62.46	Greyish-white sandstone
67.00	Grey and greyish-brown shale, very sandy in parts
67.20	Grey sandstone
68.09	Dark grey sandy shale
68.50	Sandstone and shale
68.82	Grey fine-grained sandstone
71.83	Almost white sandstone
72.28	Dark shale
73.97	Dark shale with partings of grey sandstone
77.83	Grey sandstone, darker in parts
80.78	Grey sandy shale
81.30	Dark shale, some carbonaceous shale
81.75	Grey shale
81.79	Coal
82.50	Shale, carbonaceous shale, and a little coal
83.00	Grey shale
84.40	Greyish-white sandstone
86.18	Grey shale with sandstone and sandy shale in lower part

Depth in metres	
88.07	Grey sandstone. A few layers of grey shale
89.20	Grey sandstone
89.93	Grey shale
91.18	Light grey, coarse sandstone, conglomerate in parts
91.78	Shale, sandstone, and again shale
96.06	Greyish-white sandstone, partly coarse
96.60	Conglomerate and coarse sandstone
97.05	Grey sandy shale
100.05	Grey sandstone and shale alternating
101.53	Grey coarse sandstone, conglomerate in parts
105.95	Greyish-white sandstone
106.53	Grey shale and dark coarse sandstone
110.20	Dark coarse sandstone and conglomerate
110.56	Grey conglomerate
111.85	Whitish-grey coarse sandstone, conglomerate in parts
112.64	Grey conglomerate

Borehole No. 9.

Location: Vestre Flyvatn. Elevation: 81 metres. Drilled, July 14 to Sept. 3, 1925. Chilled-shot drilling by the Norwegian Svalbard Expeditions with outfit from *Norsk Diamantborings A/S*, Oslo. Cores: 4″ to 27.63 m., 3″ to 223.50 metres. Direction of hole, vertical. Dip of strata, 18° W. Reduction of thickness as given below, 5 per cent. Section by G. Horn.

Geological Section:

Depth in metres	
1.50	Whitish-grey, coarse sandstone
3.00	White sandstone conglomeratic
7.50	White massive sandstone. Mica scarce, yellowish weathering
14.60	White massive sandstone, in some places much sheared
15.40	Greyish-white sandstone
16.50	Grey sandstone
18.00	Dark grey sandy shale
20.70	Grey quartzitic sandstone with carbonaceous plant remains. Pyrites
21.15	Dark shale, partly bituminous
21.93	Dark shale with layers of coal, 5 and 7 cm.
24.52	Brownish-grey shale, partly sandy. Slickensides
26.00	Sandy brownish-grey shale and dark argillaceous sandstone. Much mica
27.63	Fissile greyish-white sandstone with current-bedding. Partings of grey shale
51.00	Whitish-grey sandstone witth current-bedding. Much mica
57.00	White coarse sandstone with a reddish hue. A few layers of conglomerate
65.00	Greyish-white sandstone, partly fissile
66.50	Greyish-white coarse sandstone, partly with conglomerates
70.00	Greyish-white sandstone
73.00	White sandstone, partly with dark spots
76.00	White normal-grained sandstone
76.30	Grey sandy shale
82.09	White normal-grained sandstone
82.75	White sandstone with dark spots

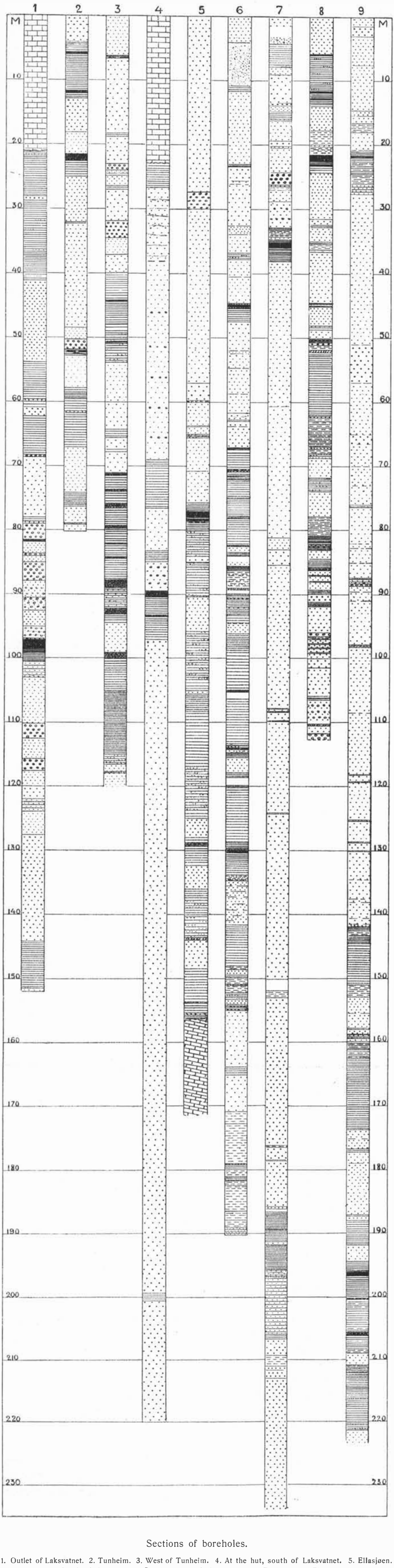
Depth in metres	
85.00	White saccharoidal sandstone
87.38	Greyish-white, partly spotted sandstone
87.64	Greyish-green fissile shale
88.00	White sandstone
88.25	Greyish-white, very coarse sandstone
88.55	Conglomerate: brownish-grey matrix and pebbles of quartz, and soft white limestone
89.55	Greyish-white sandstone, partly coarse
91.00	Greyish-white banded sandstone, partly spotted
97.80	White saccharoidal sandstone with mica
97.86	Greyish-green shale
98.01	White sandstone
98.05	Grey shale. Dip: 18°
108.50	Greyish-white saccharoidal sandstone with mica. Grey in parts, more or less fissile
118.06	White fine-grained massive sandstone with mica
118.18	Fissile sandstone with mica
119.25	White sandstone
119.43	Fissile sandstone with mica. Dip: 17°—18°
125.26	White sandstone with mica
125.32	Light greyish-green shale
128.60	White sandstone
128.68	Light grey shale
130.10	White sandstone
130.15	Light grey shale
134.48	White sandstone with mica
137.50	White sandstone
138.00	Grey, massive, and hard sandstone
140.60	Greyish-white fine-grained sandstone
141.50	Greyish-white sandstone, darker than the foregoing
141.90	Dark-grey, partly brownish-black sandstone
142.65	Brownish-grey to black shale
143.15	Dark sandy shale, with band of light sandstone with pyrites and carbonaceous plant remains
144.43	Dark shale with slickensides
151.00	Dark shale
152.92	Dark shale, partly sandy
155.50	Dark massive sandstone, shale partings and partly with coal. Difficult drilling
157.80	Greyish-white sandstone with carbonaceous plant remains
158.00	Dark greyish-brown shale
158.70	Slaty light-grey sandstone, some shale
158.80	Brownish-black shale
159.15	Grey sandstone
159.45	Dark shale
160.00	Grey sandstone
161.24	Grey shale, sandy in parts
173.70	Dark shale, sandy in parts and with partings of light sandstone
175.20	Greyish-white sandstone with carbonaceous plant remains
176.80	Grey sandstone
177.30	Dark shale
179.00	Greyish-white massive sandstone
187.50	Grey sandstone, coarse in parts

Depth in metres	
187.53	Pyrites
188.00	Grey sandstone
191.90	Grey shale
194.40	Grey sandstone, coarse and loose
196.15	Grey shale
196.25	Dark bituminous and carbonaceous shale
196.75	Bright coal, thickness and quality uncertain; core: 10 cm.
196.85	Dark bituminous shale
200.20	Grey shale
200.30?	Dull coal
200.40	Shale, partly carbonaceous
205.53	Grey shale, sandy in parts
205.58	Carb. shale
205.66	Dark shale
206.05	Bright coal, partly dull coal; coal-core: 24 cm
208.32	Grey shale, sandy in parts
209.00	Grey sandy shale
211.00	Grey sandstone
212.10	Dark shale, sandy in upper part
212.15	Bright coal
212.90	Dark shale
213.10	Grey sandstone
214.65	Dark shale, sheared and soft
214.75	Carbonaceous shale
216.50	Dark shale
216.65	Grey sandstone
220.00	Grey shale, very soft
221.50	Dark shale with stripes of sandstone
223.50	Grey massive sandstone.

Quality of Coals.

As mentioned previously, the coals occur in three different horizons, the two lower of Devonian, and the upper of Culm age. Of the lowermost horizon, the Misery Series, only a few samples of the more important seams have been analysed. The middle coal horizon, the Tunheim Series, contains the A-seam which has been mined, and of these coals a large number of analyses are available. Only a few samples of the thin and unworkable seam of the Culm formation have been analysed. All the analyses will be found in the table on page 96 and 97.

Misery Coals. The analyses show an average yield of the pure (moisture- and ash-free) coal of 22.27 per cent. of volatile matter, and 77.73 per cent. of coke (fixed carbon). The fuel ratio, $\frac{\text{fixed carbon}}{\text{volatile matter}}$, is therefore 3.5. The gross calorific value of the pure coal averages 8348 cals., and the net value, 8100 cals. The average ash content is 13.8 per cent. Only one complete analysis of these coals is available, according to which the pure coal substance contains:



Sections of boreholes.

1. Outlet of Laksvatnet. 2. Tunheim. 3. West of Tunheim. 4. At the hut, south of Laksvatnet. 5. Ellasjøen. 6. South of Tunheim 7. Southern end of Hausvatnet. 8. Tunheim. 9. Flyvatna.

Carbon	84.6	per cent.
Hydrogen	5.3	—
Oxygen + Nitrogen ...	10.1	—

The samples were all taken near the surface, and this accounts for the high content of moisture. (See table).

Tunheim Coals. The average yield of volatile matter of the pure coal is 22.22 per cent., and of coke, 77.78 per cent. The fuel ratio is 3.5. The gross calorific value of the pure coal averages 8519 cals., and the net value, 8256 cals. The ash content is high: cargo analyses ("large" and "nuts") show from 9.5 to 16.3 per cent. The "smalls" have a much higher ash content. Three cargoes in 1924 had 20.9 per cent.

The coals yield a hard and dense coke (Gram (1919)) suitable for metallurgical use. The high content of ash and sulphur will, however, seriously diminish the value of this coke.

The coals burn with a rather short flame, and give little smoke. They closely resemble the "Fettkohlen" of the Ruhr district in Germany.

The mean composition of the pure coal substance is:

Carbon	87.3	per cent.
Hydrogen	4.8	—
Oxygen + Nitrogen ...	7.9	—

The ratio of oxygen to nitrogen is about 3. The average sulphur content of the ash- and moisture-free coal is 1 per cent. The specific gravity varies from 1.3 to 1.5, according to the percentage of ash.

Two samples of ash have been analysed by Rødland (1924):

	I	II
SiO_2	42.89	49.93
TiO_2	2.32	1.87
Al_2O_3	31.71	42.28
Fe_2O_3	15.89	1.77
MnO	0.02	Trace
MgO	0.81	0.58
CaO	0.53	0.46
Na_2O	0.81	0.73
K_2O	2.43	1.50
H_2O	0.73	0.47
P_2O_5	0.13	0.05
SO_3	0.29	0.10
	98.56	99.74

The low total of I is due to some unburnt coal.

I. Cargo 1923.
II. Bear Island. No locality.

Analyses of

No.	Seam	Moisture	Ash	Coal substance	Carbon	Hydrogen	Sulphur	Nitrogen	Oxygen	Coke
	Devonian									
	Misery Series									
	Main Seam									
1	"g" Miseryfjell	0.48	18.53	80.99	67.32	4.20	1.44	8.03		80.58
2	Bottom layers (4) Pit F 24	0.43	17.07	82.50	-	-	-	-		80.55
3	Top — (4) - —	1.85	11.92	86.23	-	-	-	-		81.00
4	Pit E 25, Thetingtjørnene	1.15	12.65	86.20	-	-	0.86	-		80.00
5	- F 25, Storlona	2.80	14.35	82.85	-	-	0.63	-		78.50
6	- G 25, Mjogsjøen	2.93	12.60	84.47	-	-	0.81	-		79.00
7	- M 25, Langen	1.50	11.40	87.10	-	-	1.96	-		70.30
8	Uppermost seam, Pit E 24 Thetingtjørnene	1.40	12.05	86.55	-	-	-	-		80.15
	Tunheim Series									
	A-seam									
9	Upper part of seam. A-mine, Tunheim	1.20	2.50	96.30	83.36	4.20	0.60	8.14		80.25
10	do. Kapp Nordenskiöld	0.70	2.60	96.70	84.92	4.20	1.05	6.53		80.25
11	Upper 65 cm. Tunheim	0.40	20.40	79.20	68.81	3.62	0.93	5.84		83.25
12	Lower 45 - —	0.38	21.20	78.42	64.37	3.88	1.38	8.79		82.45
13	— part —	0.35	26.75	72.90	62.35	3.35	0.85	6.35		81.65
14	Average of seam —	0.38	27.03	72.59	61.04	3.89	1.06	6.60		81.35
15	Average of upper part —	0.40	12.85	86.75	70.31	3.76	0.96	11.72		80.25
16	0.1—0.4 m. below roof, A-mine	0.47	6.44	93.09	83.41	4.32	0.73	1.17	3.46	78.11
17	Average of upper part, Tunheim	1.09	4.64	94.27	83.26	4.80	0.60	1.35	4.26	75.97
18	Upper part of seam Austervåg	0.75	7.27	91.98	82.10	4.41	0.91	1.24	3.32	77.29
19	Upper part of seam, Tunheim	0.92	22.37	76.71	66.84	3.48	0.39	0.66	5.34	81.62
20	A-seam	0.60	6.70	92.70	81.18	5.06	1.25	0.90	4.31	-
21	Upper 60 cm. Tunheim	0.40	18.50	81.10	-	-	2.03	-	-	81.40
22	Lower 35 - —	0.52	14.94	84.54	-	-	1.17	-	-	82.68
23	Bottom seam 15 cm. —	0.78	23.12	76.10	-	-	0.77	-	-	81.47
24	A seam	0.70	12.40	86.90	-	-	2.66	-	-	81.00
25	—	0.80	10.50	88.70	-	-	1.63	-	-	79.80
26	—	0.61	16.24	83.15	-	-	(1.13)	-	-	77.92
27	—	0.64	4.67	94.69	-	-	(1.28)	-	-	76.17
28	Cargo 1920	0.90	16.25	82.85	71.43	4.27	0.43	6.72		84.20
29	Average of 2 cargoes 1921	0.65	15.30	84.05	-	-	-	-		81.10
30	Average of cargoes 1920-22	0.71	15.91	83.38	-	-	-	-		-
31	Cargo (unscreened) 1923	0 81	14.93	84.26	-	-	-	-		-
32	3 cargoes (large) 1924	2.12	9.54	88.34	-	-	-	-		-
33	Average of 3 cargoes (smalls) 1924	4.81	20.94	74.25	-	-	-	-		-
34	B-seam, Tunheim	0.90	16.05	83 05	69.91	3.71	0.48	8.95		82.23
	Culm									
35	Core from borehole No. 1	0.54	25.45	74.01	64.17	3.34	2.71	0.87	2.92	82.04
36	Pit south of Nordhamna	0.70	12.10	87.20	76.75	3.89	3.37	3.19		82.90
37	Upper bench, Nordkapp	1.40	23.65	74.95	-	-	-	-		84.20
38	Lower — —	1.28	13.35	85.37	-	-	-	-		83.20
39	Bright coal, Pit G 24, Hausvatnet	0.97	11.55	87.48	-	-	-	-		81.30
40	Dull — — —	0.90	19.45	79.65	-		-	-		82.80
41	Pit D 25 Flyvatn	3.85	6.08	90.07	-	-	0.92	-		79.05

[1] The percentages of moisture, ash, carbon, etc. refer to coal as delivered. The same thing applies to the calorific value. Coke, volatile matter, and calorific value of the pure coal substance are also given.

Bear Island Coals[1].

No.	Volatile matter	Gross calorific value (cals.)	Net calorific value (cals.)	In pure coal: Coke	Volatile matter	Gross calorific value (cals.)	Net calorific value (cals.)	Remarks	Analyst
1	18.94	6,880	6,551	76.62	23.38	8,495	8,215		Dr. J. GRAM 1918
2	19.02	7,086	6,878	76.94	23.06	8,589	8,341		— 1924
3	18.57	7,357	7,081	77.50	22.50	8,532	8,284		— —
4	18.85	7,099	6,883	78.13	21.87	8,235	7,982		— 1927
5	18.70	6,700	6,482	77.43	22-57	8,088	7,845		— —
6	18.07	6,766	6,543	78.61	21.39	8,010	7,767		— —
7	19.20	7,472	7,261	77.94	22.06	8,579	8,386		— —
8	18.45	7,148	6,907	78.68	21.32	8,259	7,984		— 1924
9	18.55	8,190	7,956	80.74	19.26	8,505	8,270		Dr. J. GRAM 1918
10	19.05	8,294	8,064	80.30	19.70	8,577	8,343		—
11	16.35	6,712	6,514	79.35	20.65	8,475	8,228		—
12	17.17	6,489	6,277	78.10	21 90	8,275	8,008		—
13	18.00	6,087	5,904	75.24	24.76	8,351	8,093		—
14	18.27	6.038	5,826	74.83	25.17	8,328	8,036		—
15	19.35	7,309	7,104	77.69	22.31	8,425	8,193		—
16	21.42	8,167	7,931	76.99	23.01	8,781	8,530	Sintering, hard, and strong coke	Dr. N. SAHLBOM 1917
17	22.94	8,138	7,873	75 67	24.33	8,633	8,353	Sintering, hard, and strong coke	—
18	21.96	8,089	7,847	76.12	23.88	8,796	8,537	Sintering, porous coke Sp. G. of coal: 1.32	—
19	17.46	6,329	6,137	77.24	22.76	8,286	8,013	Poor coke Sp. G. of coal: 1.53	—
20	-	8,110	7,856	-	-	8,767	8,497		Chem. techn. Versuchsanstalt Berlin
21	18.20	6,878	6,652	77.56	22.44	8,481	8,195		Dr. J. GRAM 1918
22	16.80	7,131	6,841	80.12	19.88	8,435	8,149		— —
23	17.75	6,245	6,007	76.68	23.32	8,206	7,910		— —
24	18.30	7,500	7,271	78.94	21.06	8,631	8,372		— 1920
25	19.40	7,631	7,418	78.13	21.87	8,603	8,369		— —
26	20.34	-	-	74.15	25.85	-	-		FENNELL
27	21.91	-	-	75.51	24.49	-	-		—
28	14.90	7,075	6,840	82.01	17.89	8,540	8,262		Dr. J. GRAM
29	18.25	7,195	6,980	78.28	21.72	8,560	8,301		—
30	-	7,181	6,965	-	-	8,612	8,357		—
31	-	7,235	-	-	-	8,587	-		—
32	-	7,711	7,475	-	-	8,728	8,480		— 1924
33	-	6,320	6,103	-	-	8,512	8,270		—
34	16.87	6,951	6,761	79.69	20.31	8,370	8,119		— 1918
35	17.42	6,318	6,052	76.46	23.54	8,421	8,070	Sintering, rather hard coke	Dr. N. SAHLBOM 1917
36	16.40	7,575	7,360	81.19	18.81	8,687	8,453		—
37	14.40	6,143	5,949	80.79	19.21	8,253	8,005	Powdery coke	Dr. J. GRAM 1924
38	16.52	7,248	7,028	80.65	19.35	8,489	8,241		— —
39	17.73	7,492	7,246	79.73	20.27	8,564	8,289		— —
40	16.30	6,694	6,493	79.54	20.46	8,404	8,156		— —
41	17.10	7,330	7,088	81.13	18.87	8,138	7,895		— 1927

[1] Of the analyses given below, No. 20 has already been published by DITTMER (1901), No. 35 by HOEL, KVALHEIM and SCHIVE (1918), Nos. 1, 9—19, 24—30, and 34 by GRAM (1923), and Nos. 31 and 36 by HOEL (1925).

Culm Coals. As already mentioned elsewhere, the Culm seam is unworkable, but analyses have been made to ascertain the character of these coals as well, and it appears that they are essentially of the same character as the Devonian. They yield about 20 per cent. of volatiles and 80 per cent. of fixed carbon. Fuel ratio: 4. The average gross calorific value is 8422 cals., and the net value, 8130 cals. The ash content is about 16 per cent. The average mean composition of the pure coal substance is:

Carbon	90.8	per cent.
Hydrogen	4.6	—
Oxygen + Nitrogen ...	4.6	—

Coal Reserves.

Misery Series. In the area north of Miseryfjell there is an actual reserve of two million tons. In the central and southwestern part there are large potential reserves, mostly situated below sea-level.

Tunheim Series. Between Austervåg and Kapp Nordenskiöld there is, in three separate areas, an actual reserve of 290 000 tons. Otherwise no reserves of Tunheim coals should be reckoned with.

Culm. No coal reserves.

The investigations carried out have shown clearly that Bear Island has no coal deposits worth working under present conditions. We have seen that the seams are all thin and split up by partings of stone, and that the coals are, as a rule, high in ash. The seams are also irregular, and on account of the many faults the coal areas are small and scattered, and not suitable for mining.

With regard to the various coal horizons, we know that the Culm seam, about which such great hopes have been entertained, is utterly valueless. The A-seam of the Tunheim series is found with a workable thickness only in the Tunheim area, but only in detached blocks, and with an insignificant tonnage remaining. The Misery series contains a seam which, in the area north of Miseryfjell where the beds are also but little disturbed, may possibly be found workable in times of high coal prices, but not under present conditions.

Fireclay.

As quaternary marine deposits are entirely absent, no typical clays occur in Bear Island. The Devonian, however, contains many horizons of clay-shale, of which several might come under the heading fireclay. (Clays which, in the shape of a Seger Cone, do not bend until a temperature of 1580° C (Cone 26) is reached).

Analyses and tests have been carried out only with the shales above and below the A-seam, as, in the event of the tests yielding favourable results, these shales could easily be mined with the coals. ANTEVS brought home samples of these shales in 1916, and they were tested by *Aktiebolaget Raméns Patenter*, Helsingborg, and *Statsprøveanstalten*, Copenhagen.

Sample No. 1. Shale (1—4 metres thick) below the coal.

Sample No. 2. Shale (1—3.5 metres thick) above the coal.

At the request of ANTEVS the following tests were made:

a. Fusibility of the clay (shale).

b. Making of small test bricks to determine plasticity, texture, shrinkage, and colour at different temperatures.

c. Chemical composition of the clay.

a. The fusibility was determined in Copenhagen with the following results: No. 1 had a softening point between Seger Cone 29 and 30 (1665° C). No. 2 melted at Seger Cone 12 (1350°) but did not lose shape at Seger Cone 6 (1200°). The latter shale is therefore not refractory. b. In order to make test bricks the shale was ground and sifted (14 meshes per inch), moistened, and shaped into bricks of the size of 71 × 35 × 17.5 mm. These were then dried and burnt in a furnace at Seger Cones 6, 12, and 13 corresponding to temperatures of 1200°, 1350°, and 1380°.

	1	2
1200° Colour	Yellow like ordinary chamotte	Reddish-brown, well sintered, with yellow non-vitrified grains
Shrinkage (burnt)	7, 8.6, 5.7 per cent.	1.4, 1.5, 5.5 per cent.
1350° Colour	Yellow like chamotte, but denser than ordinary chamotte	No. 2 is not a refractory clay, as the brick at this temperature becomes fused and sinters with a porous texture
Shrinkage (burnt)	4.2, 3, — 10 per cent.	
1380° Colour	Brownish-yellow like strongly burnt chamotte. Rather dense	
Shrinkage (burnt)	4.4, 2.9, 5.7 per cent.	

That the shrinkage of the thickness of the brick was negative is due to the stronger pressure to which this brick has been subjected during the shaping, hence the enlargement. Both clays were non-plastic when mixed with water, but became plastic when kneaded. They both showed a tendency to swell. No. 2 gave off gas when the sample sintered. Organic matter, pyrites, and partly lime may cause evolution of gas.

c. Chemical composition of the clay. The clays have been analysed by *Statsprøveanstalten* in Copenhagen with the following result (in percentages):

	1		2	
	As delivered	Dried at 120°	As delivered	Dried at 120°
SiO_2	44.0	44.6	58.0	58.4
Fe_2O_3	2.6	2.6	4.8	4.8
Al_2O_3	32.1	32.5	24.1	24.3
CaO	-	-	-	-
MgO	0.4	0.4	0.3	0.3
Ignition loss	16.3	16.5	8.6	8.7
Hygroscopic water	1.3	-	0.7	-

The Al_2O_3 content in No. 1 is rather high, wherefore a melting point higher than Seger Cone 30 (1670°) should be expected, but Fe_2O_3 and "rest" (alkalies) are considerably higher than in the Swedish fireclays, the fusibility point and compositions of which, compared with the Bear Island clays, will be found in the following table:

Fusion point	Test brick, shape as given above. Total shrinkage by			Composition of heated sample					Alkalies & rest
	S.C. 6	S.C. 12	S.C. 13	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	
Bear I. No. 1 S.C. 29—30 1665°	7.8	3.6	3.7 per cent.	53.7	3.2	39.2	-	0.5	4.4
Bear I. No. 2 S.C. abt. 12 1350°				64.3	5.3	26.7	-	0.3	3.5
Höganäs S.C. 29—30 1665°				63.72	2.80	30.80	0.52	0.53	1.63
Bjuf K S.C. 31—32 1700°				59.36	2.27	36.43	0.72	0.44	0.78
Bjuf F S.C. 33—34 1735°				55.16	2.62	41.32	0.42	0.15	0.33

To sum up: No. 1 sample of shale below seam A at Tunheim is a fireclay shale suitable for the manufacture of refractory bricks of a quality corresponding to the Swedish brand "Höganäs". Freshly dug the shale is nearly non-plastic; to become plastic it must weather or undergo wet grinding.

No. 2 sample of shale, above the same coal-seam, is of no value as a fireclay on account of its point of fusion not being higher than 1350°.

The question of exploiting the fireclay deposits has no actuality at the present time, especially after the closing down of the mine, but if in the future the fireclay should, for some reason or other, become of value, the results of the investigations already made would be useful, and we have therefore incorporated them in this paper.

Minerals.

The occurrence of galena has been known since 1603 (p. 111). In his list of minerals from Spitsbergen and Bear Island NORDENSKIÖLD (1875) gives from the latter the following minerals: Barytes, blende, galena, silver (?), and witherite. To these should be added calcite and pyrites. The reputed occurrence of silver recorded by NORDENSKIÖLD is only correct if thereby is meant silver contained in the galena. No other silver minerals have ever been found.

Pyrites occur as small lenses and impregnations in some of the Devonian sandstones, giving rise to rust-coloured zones.

The mineral occurrences of economic importance are all situated within the Hecla Hoek area, where veins of galena, with or without blende, and with barytes as a gangue, are found in a number of places. The veins, nearly always thin, strike E—W, in some cases N—S, and occur in the dolomites and limestones, more frequently in the former. The Slate-quartzite series is never traversed by mineral veins. The veins of the Older Dolomite series (see geol. map) appear to be more regular than the deposits in the Younger Dolomite and the Tetradium Limestone, these being more of a patchy nature.

In the cliff north of Russehamna is seen a conspicuous vein of barytes with galena, and in 1916 a little work was done here (conducted by ANTEVS). The vein is steeply dipping, and strikes N 80° W. According to ANTEVS the width in the cliff is 0.32 metre, being the same for 37 metres inland. For the next 80 metres the vein has little or no galena, then come 30 metres with galena, whereupon the vein seems to pinch out. Ten metres from the pinch-out the width is 0.11 metre. The percentage of galena was estimated at 50 (by volume). A little to the north there is another vein, but it is very thin and of no value. The galena contains 86 per cent. Pb, and, according to an analysis by Professor HØYER, nearly 0.03 per cent. Ag.

The galena occurs in idiomorphic crystals, particularly near the walls of the vein. The crystals are developed with cube and octahedron. South of Kapp Nilsson there is a vein of barytes with little or no galena. Some work was done here in 1918.

In October 1924, Messrs. THETING and ORVIN discovered loose pieces of galena on the eastern slope of the hill west of Krillvatnet, southwest of Russehamna. In 1925 exploratory work was commenced. The location of the occurrence is 60 metres east of the trigonometric station on the hill, Blyhatten, and 105 metres above sea-level. The distance, as the crow flies, to Norskehamna is 600 metres, to Russehamna 1 kilometre, and to Kvalrossbukta the same. The deposit occurs in dolomite and consists of intersecting veins of coarse galena and barytes. The steeply dipping veins strike E—W and N—S.

Good patches of galena occur, particularly where the veins intersect. Light-coloured blende is found as a rarity. Lenses of galena are also found: the biggest had a length of 3 metres and a maximum width of 0.40 metre. The total width of the ore-bearing zone is about 15 metres and the length 25 metres. Trenches north and south of this zone have only revealed traces of barytes, but no galena.

During the winter 1925—1926 a crosscut and levels were driven in order to explore the deposit further, but only impregnations and small patches of galena were met with, and work was therefore suspended as the deposit proved too limited. During the summer of 1926 75 498 kilogrammes of lead-ore were shipped from Russehamna in two cargoes, analyses of which gave 70.70 and 76.475 per cent. Pb.

In the same year a new occurrence was discovered west of the big bend of Russeelva, and at an elevation of about 75 metres. Here good lumps of galena were found, and the place was examined by SYVERTSEN with two trenches 5 metres apart. They both showed rock with lumps of galena (and barytes) over a width of 4 metres. Prospecting work in the summer of 1927 has shown that the ore-bearing vein of barytes occurs in a mass of calcite about 8 metres thick, and is striking north-and-south and dipping from 10° to 60° E. The length along the strike is, at the surface, about 50 metres, and a width varying from 0.5 to 2 metres. The galena occurrence is situated near the big fault, the course of which is from Sørhamna, along the right side of Russeelva to the mouth of Ymesdalen. Here galena and blende are quite common in the brecciated rock near the fault. The mineral-bearing solutions have, one is led to believe, especially circulated along the faults, these being the easiest channels of approach.

Galena has been found in several other places: at the mouth of Russeelva and on Måkeholmen (Gull Island). In the former place the veins are only 5—6 cm. thick; dip vertical, and strike ENE. The minerals are blende with galena and barytes. The country rock is a dark dolomite breccia. In the southern part of Måkeholmen a vein of galena occurs, being quite rich on the east side, but pinches out towards the west. Galena is said to occur in big lumps in Ymesdalen, but so far the place has not been refound. Weathered galena is of a grey colour very similar to the dolomite and limestone, and is therefore only found by chance.

Mining.

Mining was commenced at Tunheim in 1916. All the workings were started on the outcrops of the A-seam just to the southeast of the camp. The first workings were quite near the sea. In 1919 a new mine, the A-mine, was opened up about 200 metres inland. This mine was abandoned in 1923 and work transferred to the C-mine, 270 metres SSW of the A-mine, and opened up in 1920. The C-mine was closed down on Sept. 19, 1925 and coal-mining on Bear Island was thus brought to an end. The following description of the workings apply to the conditions in the summer of that year.

The coal worked was the A-seam, the lowest seam of the Tunheim series. This series outcrops in the cliffs east of Tunheim, parts of the outcrop being below sea-level. The dip is fairly uniform, in the C-mine the average rate of inclination is 8° SE. The seams rise land-

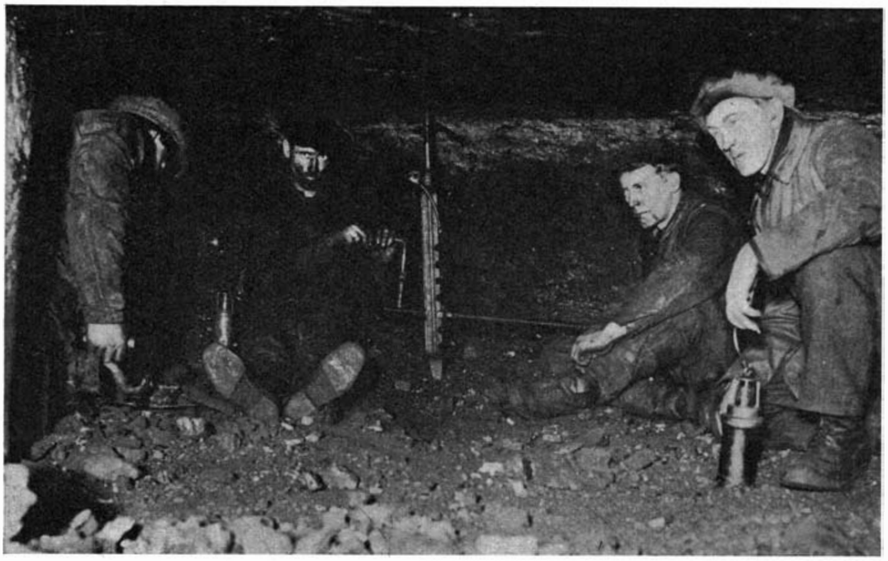


Fig. 51. C-Mine, Tunheim.
Underground working-place. — P. Berge phot. 1924.

wards, so that they all outcrop on the plateau, the distance of the outcrops from the coast being from 0.2 to 0.6 kilometre. The distance from the most northerly (Austervåg) to the most southerly outcrop is 3 kilometres. Two faults split the area south of Tunheim into three units. The faults strike northeast and hade 20° NW, with downthrow on the northwest side. The vertical throw of the fault nearest Tunheim is 16.6 metres, and of that south of it about 50 metres. Mining has been confined to the two northern units, and from 1917—1925 116 094 tons was exported (incl. bunkers).

The yearly exports will be seen from the table on page 138. The north block has been almost worked out, so that there remains only coal near the outcrop and in inferior areas of the seams. The middle block contains about 130 000 tons, of which about 25 000 tons has been extracted. Making allowances for outcrop coal, about 90 000 tons of extractable coals is left in the mine. The Southern area is very narrow; the seam lies near the surface and is therefore hardly workable.

Now to the seam itself. The roof consists of dark shale, fairly strong and tough, and has a thickness of from 0.50 to 1.50 metres. Above the shale comes hard grey sandstone. About 7 centimetres of the shale, immediately on top of the coal, always came down when the coal had been removed, and was partly picked out in the mine ("draw slate"). The thickness of the good coal varies from 0.60 to 0.70 metres, averaging 0.66 metres. The good coal has a bright lustre, and is as a rule very pure. Occasionally there is found a thin band of impure coal in the upper part of the seam. Streaks of pyrites are not uncommon.

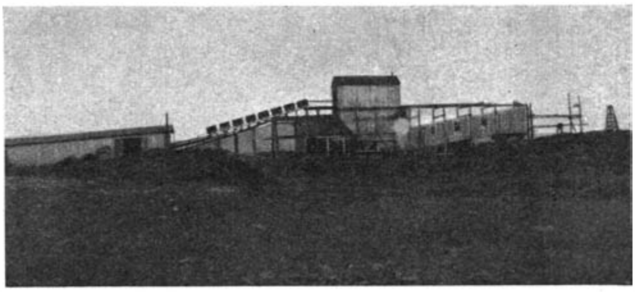


Fig. 52. A-Mine, Tunheim.
Dr. Irrall phot. 1923.

Below the good coal comes a peculiar hard-burning coal with a dull lustre, having a thickness of from 0.15 to 0.35 metre, averaging 0.30 metre. Its ash-content is high, and this coal was left in the mine. Then comes 0.10 metre of shale followed by 0.50 metre of coal and shale, then 0.5—1.0 metre of shale, and finally sandstone of great thickness.

Broadly speaking, the structure is quite regular, but mining revealed a number of small faults, pinching-outs, and other irregularities not visible at the surface, making work in some places very troublesome.

The main slope of the C-mine has the bearing S 63° E and an average rate of inclination of 8°. The distance from the mouth to the first fault is 270 metres. On the other side of the fault, on the up-throw side, the seam lies 16.6 metres higher. From the slope a rise was driven to the seam behind the fault, and after reaching it, the slope was continued in the coal in the same directions as the slope from the surface. When work was suspended in 1925 the slope had advanced 350 metres from the fault, and had then 120 metres to go to reach the next fault.

The coals were worked outward from the main slope, all being taken out at the first working. To protect the main slope and air-course, pillars of a thickness of 10 metres were left. From the main slope, at every 40 metres, places 12 metres wide were driven along the strike, which was roughly at right angles to the main slope, and with packwalls on either side. The material for these walls was obtained from the ripping (removing the floor for the purpose of admitting wagons). Such a place formed a mother-gate, and was a winning-place. On the up-dip side, at intervals of 12 metres, openings were left through the packwalls as the place proceeded. From these openings gateways were carried forward to a distance of 28 metres, when they holed into

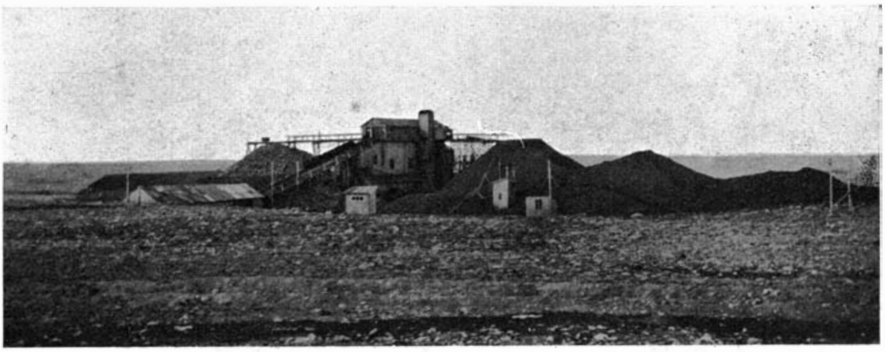


Fig. 53. C-Mine, Tunheim.
View from the east. — G. Horn phot. 26/8 1924.

the mother-gate of the adjoining flat. The gateways were carried forward with a front of 12 metres, that nearest to the main slope ahead of the next, and the working face thus formed a step-line (longwall in steps).

The method of ventilation was very simple. By a fan the air was brought along the working face with the help of brattices and doors, and after having passed the working places finally reached the return. To ventilate the workings south of the fault a rise was driven to the surface, where a small fan was installed. The air current always blew against the tramming of the full wagons.

In the A-mine the coal was partly undercut by machine (Diamond Coal Cutter). The cut was placed in the upper part of the hard coal, and the seam was then wedged or shot down. The hard coal and the underlying shale were then ripped and used for packwalls. At a later date all the coal was shot from the solid by handdrilling and blasting with coal dynamite. Per kilogramme of dynamite about two tons of cleaned coal was obtained. The volume excavated corresponds to 30—35 per cent. increase on that figure. The coals make little dust, and as the air is very humid there was very little danger of coal-dust explosions occurring. Fire-damp was never noticed[1]. Electric safety lamps, mostly of the Oldham type, were however in general use. In each winning place were two hewers, and they also had to tram their wagons to the main slope. The main haulage was effected by means of a winding engine placed at the mouth of the slope. The direct-rope system was used.

The rates of pay were per wagon (460 kilogrammes net) and included hewing and tramming. With a tramming distance of up to

Fig. 54. C-Mine, Tunheim.
Showing engine, wagons, steam-shovel, and stock-pile. — P. Berge phot. 1924.

100 metres the rate was Kr. 2.50 per wagon, with an additional Kr. 0.10 for every 100 metres increase of the tramming distance. The rate for ripping was Kr. 15.00 per metre. Ammunition, etc. was provided by the men. From the price a deduction was made proportionate to the percentage of waste rock removed in the screening plant. Should the waste exceed 20 per cent, this deduction would be more than 20 per cent. With a tramming distance of 100 metres, two men could do 25—30 wagons per shift of 9 hours, and per month about 500 wagons or 250 tons. The average earnings of the hewers were Kr. 2—2.50 per hour,

[1] In this connection it should be mentioned that when borehole No. 7 (1924) was visited in 1925, a little gas was noticed to escape, especially when stirring the water in the hole. The gas was odourless and inflammable and must have been methane, originating from the thin Culm coal-seam pierced by the hole at a depth of 35 metres. As this seam outcrops close by, the gas found must have been trapped by a small fault. This suggests that gas may be found behind faults.

day-work was paid at the rate of Kr. 1.40. Food, cooking, cleaning of the men's quarters, and so forth, were paid by the men at cost-price, and averaged about Kr. 120.00 per month. The above prices were those ruling in 1925[1].

When the coal had been raised from the mine it was sorted on shaking screens into three sizes: *Large* above 1 1/2 inches, *nuts* above 1 inch, and *smalls* below 1 inch. Stone and the poor coal from the bottom of the seam were removed on two picking belts. The amount of waste rock was about 17—20 per cent. of the total tonnage raised.

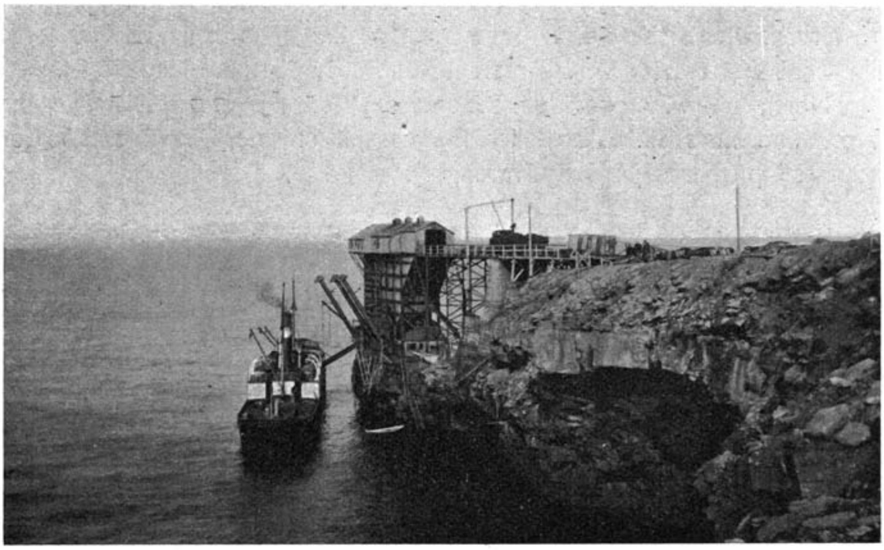


Fig. 55. Coal-pocket, Austervåg.
Steamer (1 180 tons dw.) loading. Looking east. — G. Horn phot. 5/7 1924.

	Oct. 1, 1923—Sept. 30, 1924		Oct. 1, 1924—Apr. 30, 1925	
	Tons	Per cent.	Tons	Per cent.
Run-of-mine	27 749.0		26 441.8	
Cleaned Coal	22 689.3	81.8	21 012.9	79.5
Waste	5 059.7	18.2	5 428.9	20.5

In the period Oct. 1, 1923—Sept. 30, 1924 the output per shift of 9 hours was (in tons):

	Per hewer	Per underground hand, foremen included	Per underground & surface hand[2]
Run-of-mine	3.92	2.32	1.09
Cleaned	3.22	1.90	0.89

[1] In 1925 the average exchange value of the *krone* was 5.77 in relation to the U. S. dollar (the par value is 3.73).

[2] Includes all persons paid by the company.

In the period Oct. 1, 1924—Apr. 30, 1925 the quantities produced of the different grades were as follows:

		Per cent.	Per cent. ash*
Large	10,245.0 tons	48.76	10.95
Nuts	1,664.6 —	7.92	18.96
Smalls	9,103.3 —	43.32	21.60

* Determined in the mine laboratory.

The stock-pile was situated at the mine entrance. *Large* and *nuts* were stored and shipped together.

During the shipping season, June—September, the coal was transported 1.2 kilometres by rail (gauge 1 metre) to the loading plant in Austervåg, where there is storage accommodation for about 1,000 tons. The coal was carried in steamers of about 1,200 tons deadweight.

North Norway provided the market for the Bear Island coals. *Large* and *nuts* were used by the coastal steamers, and *smalls* for industrial purposes (A/S Sydvaranger).

Drilling.

Drilling in an Arctic country like Bear Island, where the upper part of the ground is permanently frozen, presents some features of interest, and the following notes may prove of some use for future drilling operators. The notes are based upon the report of the engineer in charge of the drilling in 1924, H. MERCKOLL, and our own experience in 1925.

A light drilling plant (oil-engine driven, 5 hp. Bolinder) from *Norsk Diamantborings A/S*, Oslo, was used. The apparatus consists of a drill crown with a slot cut in it, being attached to a core barrel which is in turn attached to a barrel for collecting the mud, and the whole is coupled to a column of hollow rods that is rotated at the surface. Chilled shot or steel grit is introduced in the flush water, and finds its way beneath the crown and grinds an annular space. The ground rock is brought to the surface with the flushing water, part of the mud sinking and gathering in the mud barrel, whilst the core mounts in the core barrel and is retained in it by pumping down rock débris which jams the core.

This method proved suitable for the rocks encountered, predominantly hard sandstones, but also shales, conglomerates, and coal-seams, although it was not always easy to get full cores of the friable coals. In certain soft shales the steel grit got pressed into the shale, and the advance in such strata was therefore slow.

The diameters of the crowns used were: 5¼″, 4¼″, 3¼″, and 2¼″, giving cores of 4″, 3″, 2¼″, and 1¼″.

The drilling speed is almost independent of the diameter, and with the 4¼″ crown more than 40 metres per week has been attained in holes of less than 100 metres (2 shifts of 12 hours). As the hole gets deeper the lowering and raising of the tools will naturally retard the advance. The wear of the crown is 1—2 centimetre per metre drilled, varying with the character of the rocks penetrated. The consumption of steel grit is about 3 kilogramme per metre.

The precentage of core depends upon the diameter and the character of the rocks pierced, small diameter and caving strata giving, of course,

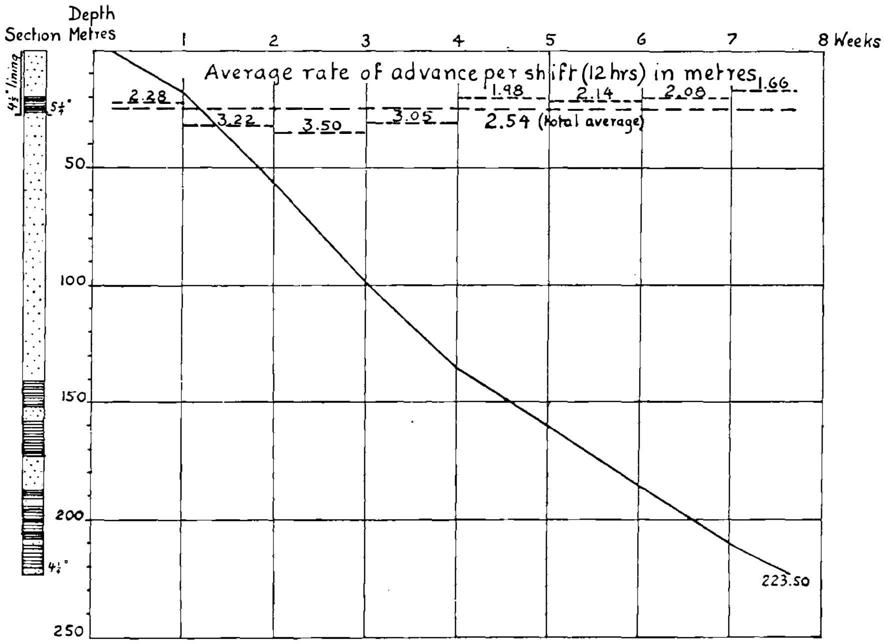


Fig. 56. Borehole No. 9. Weekly drilling, and average advance per shift.

little core. Under favourable conditions the percentage of core has been 90. To get good cores a crown of not less than 4¼″ should be used. The coals are rather friable and give little core, unless great care is exercised. In 1924 toothed crowns were used successfully through coal-seams.

As the upper part of the hole is apt to cave, partly owing to thawing, lining tube should be inserted down to, say, 25 metres. The frozen ground on the island extends down to a depth of 50—75 metres. When drilling with a larger diameter it was not found necessary to use a low freezing solution as flush water, as the lake water had a sufficiently high temperature to prevent freezing; however, when drilling was interrupted for a protracted period it was necessary to pour a strong solution of ordinary salt or calcium chloride into the hole, to prevent the formation of ice. The drilling itself thus gave no special difficulties, the difficulty consisted in transporting the heavy pieces of the plant across the stony wastes. If possible, the outfit should be brought to the drilling site when the ground is covered with snow.

Below follow various data from No. 9 Bore in the central part of the island.

Depth of hole: 223.50 metres.

72 per cent. sandstone, 28 per cent. shale, sandy shale, and coal.
$5^{1}/_{4}''$ crown to 27.63 metres, lining tube to this depth.
$4^{1}/_{4}''$ crown to 223.50 metres.

Core percentage:

With $5^{1}/_{4}''$ crown: 71 (low on account of caving strata near the surface).
With $4^{1}/_{4}''$ crown from 27.63 to 141.90 metres: 92.
With $4^{1}/_{4}''$ crown from 27.63 to 223.50 metres: 86.
Total for the hole: 84.

The weekly advance and average rate of advance per shift will be seen from fig. 56.

The maximum advance per shift was 6.40 metres.

During the drilling was used:

600 kilogrammes steel grit, i. e., 2.7 kilogrammes per metre.
6 barrels (160 kg) solar oil, i. e., 4.3 kg per metre.
40 litres kerosene (for starting up the engine).
90 kg lubricating oil.
1 $5^{1}/_{4}''$ crown.
6 $4^{1}/_{4}''$ crowns.
Crown wear 1 cm per metre drilled, or, as the wearing part of the crown is 327 mm, 30 metres drilled per crown.
3 core barrels.
3 mud barrels.

List of Boreholes.

Borehole	No. 1.	1916	Laksvatnet	S.	154.50	metres	154.50	metres.
—	„ 2.	1918	Tunheim	„	80.14	—		
—	„ 3.	—	—	„	120.11	—		
—	„ 4.	—	Laksvatnet	„	219.58	—		
—	„ 5.	—	Ellasjøen	„	169.36	—	589.19	—
—	„ 6.	1924	Tunheim	N.	190.30	—		
—	„ 7.	—	Hausvatnet	„	233.92	—		
—	„ 8.	—	Tunheim	„	112.64	—	536.86	—
—	„ 9.	1925	V. Flyvatn	„	223.50	—	223.50	—
							1 504.50	metres

In 1918 and 1924 two drilling plants were used:
S. Svenska Diamantbergborrnings Aktiebolaget, Stockholm.
N. Norsk Diamantborings A/S, Oslo.

History of Bear Island.

Probable Norse Discovery in the Middle Ages.

In the "Icelandic Annals" the discovery of a land called "Svalbard" is recorded for the year 1194, and it may be that this land is identical with our Spitsbergen. The Norsemen, as we know, hunted along the edge of the drift-ice east of Greenland, and in some years the ice-edge may run towards Bear Island. It is therefore probable that the daring and skilled Norse navigators during their hunting and other cruises also came across the isolated arctic isle of Bear Island. However, no records have been left of such a discovery, and we shall probably always lack definite information on this point.

Dutch Discovery, and Dutch and English Hunting in the 16th and 17th Centuries.

In 1596 a Dutch expedition was sent out from the Netherlands for the purpose of discovering a northeast passage to China. The expedition consisted of two vessels, one of which was commanded by JACOB VAN HEEMSKERCK and the other by JAN CORNELISZOON RIJP; WILLEM BARENTS accompanied HEEMSKERCK with the rank of chief pilot, and was the virtual leader of the expedition. On June 8 they sighted an island, which was reached the next day. The latitude was determined 74° 30′. (DE VEER (1598). GERRIT DE VEER accompanied Barents on his expeditions, and has written the account of the voyages).

On the following two days they went ashore, collected eggs, and had some dangerous experiences in the steep cliffs.

On the 12th an incident happened that gave rise to the name of the isle. That morning they saw a polar bear "which we rowed after, thinking to cast a rope about her neck". They had a fight with the bear, which was at last killed with an axe, whereupon "we brought her into JAN CORNELISZOON'S ship, where we flayed her, and found her skin to be twelve feet long. This island we called the Bear Island." (Het Beyren Eylandt). On June 13 they departed, sailing a northerly course.

In 1603 an English expedition with the ship "Grace" of fifty tons fitted out by Sir FRANCIS CHERRIE (a member of the Muscovy Company) and headed by STEPHEN BENNET, visited the island. In the work by PURCHAS (1625), we find the narrative of the voyage by WILLIAM GORDON, and it is related how they went ashore, where "at our comming on Land, wee did see two Foxes, one white, the other Blacke. Thus spending most part of the day, wee returned aboard our ship without any profit: only one of our men tooke up a piece of Lead. . ." The "lead" found on the shore was, of course, galena, which occurs in veins in the southern part of the island.

In 1604, BENNET on board the "God Speed" of sixty tons, belonging to Mr. WELDEN, a merchant, visited the island again to catch walruses. They arrived on July 8. When they had returned to London it was decided to call the island Cherrie Island ("Cherie Island") after the patron of the expedition, so BENNET was evidently not aware of the Dutch discovery. Cherrie Island, later corrupted to Cherry I., is to a certain extent still used on British maps, but the name Bear Island certainly has the priority.

In 1605 they returned in the same ship. BENNET found galena in the solid rock, and brought 30 pounds of it to London. That summer they nearly lost the ship, tells JONAS POOLE, in a cove south of "Mount Misery", which got its name when they were in this distress. It is not quite clear which of the mountains the name was applied to. It may also have been the hills now known as Antarcticfjellet.

In 1606 BENNET and WELDEN with the "God Speed", accompanied by a pinnace of twenty tons were again on Bear Island from July 3 to 29. They made a huge catch of walruses. When there was no ice the animals came on land in great numbers, and in six hours BENNET and his companions killed between seven and eight hundred.

In 1608 another voyage was made by BENNET and WELDEN, and when they returned that year they had "31. tunnes of Oyle, and one Hogshead, one barrell, and one terce of Morses teeth: besides 400, other teeth." There was also a second ship here this year, namely the "Dragon", belonging to a brewer of St. Catharine's (BARROW (1818)).

On the expedition in 1609, JONAS POOLE, who had taken part in the previous expeditions since 1604, claimed the island on behalf of the Muscovy Company in London "and set up an Ensigne in token of our possession of the Iland". On Måkeholmen, he found "three Mynes of Lead Ure", and on the northeast coast they made the first discovery of coal: "The eighteenth day, wee went to the North side of the Iland [i. e. Bear I.], and in our way wee found good Sea-coales[1] to burne: some wee tooke with us to try them, and found them good". Many polar bears were killed that summer. Also in 1609 another English ship was at the island for hunting purposes. In 1610 POOLE passed the island twice, but could not land on account of the ice. In 1611 POOLE also made a short visit to the island with the "Elisabeth", but he scarcely landed that year. The next year, 1612, he was again sent by the Muscovy Company with two ships' "Whale" and "Seahorse". On his arrival at Bear Island he found a ship from Holland with an Englishman, ALAN SALOWES, as pilot.

[1] Old term alluding to the fact that Newcastle coal was from early times brought by sea to London.

This ship must certainly have belonged to a merchant Kijn because Salowes related that his merchant later in the summer "had broke his necke down a cliffe", which Kijn actually did on Prince Charles Foreland.

In the seventeenth century Spitsbergen became the centre of a most flourishing and profitable whale fishery, hundreds of ships resorting here in the season. The record of Bear Island is practically a blank in this period, but it is very likely that the island was constantly visited by the whalers on account of the good hunting.

In Spitsbergen the first wintering (by English whalers) occurred in 1630. The first wintering in Bear Island took place, as far as we know, in 1700. In the autumn of that year the Dutch ship "de Jonge Arend" was on the return voyage from Archangel; off North Cape she encountered a storm and was driven northwards to Bear Island (Nov. 3). The ship was wrecked and the crew was forced to winter. Half of the crew died during the winter, and in the middle of July, 1701 the surviving five men left the island in a small boat, and reached North Cape safely on the 25th (Adriaensz. (1702)).

Russian Hunting in the 18th Century.

In the following years Russian trappers commenced hunting and spent the winter on the island. They called it Medvyed, i. e. the Bear. Little is known about Russian activity, but they are known to have wintered several times, one man even seven years. They disappeared, however, towards the end of the 18th century. The Russians have, it should be mentioned, shown a remarkable aptitude for facing the solitude and climatic rigours of extreme Arctic countries like Bear Island and Spitsbergen. Remains of Russian huts are known from Russehamna, mouth of Engelskelva, and Nordhamna.

Norwegian Hunting in the 18th and 19th Centuries, and Keilhau's voyage in 1827.

In the year 1790 Peder Erichsen undertook a hunting voyage to Bear Island in the brig "Nicolay" of Hammerfest. On account of the ice it was not possible to get close to the island. The same year another hunting vessel, "De trende Brødre", Skipper Houge, was hunting in Bear Island waters and at Spitsbergen. (Hagemann (1888)). Again in 1795 a merchant in Hammerfest, in partnership with some Russians, sent an expedition to Spitsbergen to hunt and fish. The same merchant is said to have participated in the fitting out of a ship from Copenhagen for fishing cod at Bear Island (Keilhau (1831), p. 232). In 1819 a British trading concern in Bodø sent a sloop with eleven men to try the hunting at Bear Island and Spitsbergen. Bear Island was missed, however, but they gave good accounts of the hunting in Spitsbergen.

This expedition seems to have marked the establishment of the Norwegian hunting industry in Bear Island (and Spitsbergen), and from that year vessels frequently crossed to the Arctic islands, where parties of hunters often wintered.

An Englishman, ARTHUR DE CAPELL BROOK, ((1827), pp. 127--129) who visited Finnmark (perhaps in the year 1823) tells us that early in the summer of 1820 Mr. KLERCK, Alten, had despatched a vessel to Bear Island, which he had fitted out for walrus fishing. A catch of more than one hundred was made, but when the vessel was loaded and ready to return to Alten a furious storm arose, and the vessel was driven by a tremendous wave so far ashore that she was left dry and undamaged. It was impossible for the crew to get her off. They then took a supply of provisions and a compass, and left the island in an open boat to try to make North Cape. For eight days they suffered great hardships. Not far from land they met an English brig, probably returning from Archangel, but the waves were so high that it was quite impossible for them to get on board. At last they reached land near North Kyn, whence they continued their voyage to Hammerfest. The length of the boat used was only fourteen feet. The year before the very same boat had returned from Bear Island under almost similar circumstances, thus preserving the lives of the crew left on the island because their vessel had been driven away in a storm. Early in the following season, 1821, Mr. KLERCK sent another vessel to get out the cargo, but, unfortunately, it was found to be spoiled and useless.

The same story is related in a somewhat different way by KEILHAU ((1831), p. 127) and HENKING ((1901), p. 34), who has heard it related by C. ROBERTSON, a Hammerfest merchant. They tell us that merchants from Hammerfest in 1820 despatched a vessel with a crew of eight men to Spitsbergen, but they came to Bear Island where the crew went ashore. Storm and fog forced the skipper to return to Hammerfest, leaving the eight men on the barren island. Thus marooned the crew made their way to Norway in an open boat. It took them eight days to cross the sea and they landed at North Kyn. In Hammerfest they were re-engaged by the same skipper for a fresh trip, and they once more went to Bear Island, where they anchored at Nordhamna. However, when the vessel was due home with 180 walruses, it was shipwrecked on the island. The men had for the second time that summer to make the passage to Norway in an open boat. In spite of the bad weather and the heavy sea they landed at Magerøy after a ten days' voyage.

KEILHAU and HENKING thus relate that the two voyages took place in the summer of 1820. According to CAPELL BROOK the first voyage must have taken place in 1819.

It seems most likely that the first voyage must have taken place in 1819. CAPELL BROOK had first-hand information from KLERCK himself. He also says that the second voyage took place *early* in the summer of 1820. Therefore it is quite unthinkable that an expedition had already been on the island the same year. ISACHSEN ((1921 b), p.163) also says that, according to ANDREAS BUCK'S records, KLERCK must have sent his first expedition about the year 1819.

In the two following years we do not hear about any wintering in Bear Island, but KEILHAU ((1831), p. 114) tells us that the houses at Nordhamna were built in 1822 by two Hammerfest merchants (believed to be AKERMAND and AAGAARD), and thus it is very likely that there were winterers on the island also the following winter.

In the winter of 1823—24 we hear that SIGFRIED AKERMAND Senr. and AAGE AAGAARD, merchants, had nine men on the island (Finmarksposten (1874), p. 34). They lived in the above-mentioned hut at the present Herwigshamna. The catch was three schooner loads of blubber, hides, and the tusks of 680 large and 70 small walruses.

In 1824—25 there wintered 8 men from Hammerfest, sent by Mr. CROWE, Kaafjord in Alten. They arrived in September and repaired the houses during the autumn. They made a good catch, 677 walruses, 30 foxes, and 3 polar bears. Three men and a part of the catch were fetched on July 23, 1825. Three weeks later the vessel returned to fetch the remainder of the catch and the remaining five men, who in the meantime had fished 5—6 barrels of cod. (KEILHAU (1831), p. 128—132).

The next year some of the same people wintered, but the catch was then less. It was a severe winter with northerly winds, and there were many polar bears, of which seven were shot.

CAPELL BROOK ((1827), p. 130) says that "Mr. Crowe has recently established small settlements there [Spitsbergen and Bear Island], on the plan of the Hudson's bay company. With respect to Cherie Island, where the experiment was first tried, it proved satisfactory in all respects; the fifteen persons who had been sent out returned in good health, after a residence of about a year, bringing with them sufficient proofs that the adventure had succeeded as a mercantile speculation". CAPELL BROOK does not mention in what year this happened.

From Hammerfest 26 men wintered in 1825 and 1828, says HENKING ((1901), p. 34), but in the latter year they did not make such a large catch of walruses as in 1825. We know nothing further about the expedition in 1828.

I 1827, B. M. KEILHAU, Professor of Geology at the University of Christiania (Oslo), set out with a German hunting expedition with the "Haabet" under BARTO V. LÖWENIGH to Bear Island and Spitsbergen. KEILHAU was the pioneer of scientific explorers in these parts and has related his experiences in a fascinating little book (1831). The days from Aug. 20 to the 23. were spent ashore on "Beeren Eiland", which name was then the usual one. KEILHAU made several geological observations. He noticed that a limestone from which he collected several fossils, later described by v. BUCH (1848) as being of Carboniferous age, was overlying the coal-bearing sandstone series. In the paper by v. BUCH is also to be found a small outline map of Bear Island, being the first attempt at mapping this isle. About the coal in Kolbukta he says (1831): "None of these seams is more than two feet thick, and they could not be of any important use." He considers it remarkable to find coal in such a high latitude. He gives a vivid picture of the hut in Nordhamna, and the place where it stands: "The landing place is marked by a few wooden crosses from the Russian period, placed on the projecting crags, and several stone cairns erected by the Norwegians. Here were two or three old boats, and some barrels and fish-oil vessels lay scattered on the shore. On a large, absolutely even field, a few paces higher up, there stood a long wooden building composed of three smaller houses, namely, a dwelling hut, a store house, and a shed. The houses were covered on the outside with walrus skins which had the fleshy side turned outward. These skins were full of green scum and a reddish putrefaction. Several such skins were lying on and between the rocks around the building. Outside it stood a sledge, two old pulkhas and a grindstone; further there were large heaps of aulk skins and a multitude of egg shells of gulls and Arctic petrels. Inside we found the living room eminently suited to our purpose, it was well timbered, had one window, four big bedsteads, a chimney and an oven; in the ceiling there was a small air-pipe, which could be opened when the chimney pipe was shut. . ."

KEILHAU'S description illustrates well the typical appearance of these huts.

ISACHSEN ((1921 b), p. 164) says that an expedition from Hammerfest was fitted out for Bear Island in 1827. They sailed in a small sloop, the "Haabet", and during the winter the seven men made a catch of 700 walruses. The next year they were fetched by a small schooner, the "Fortuna", which had to make three trips to carry the catch home. This expedition was fitted out by AAGAARD, AKERMAND, and HARTVIG JENTOFT. JENTOFT has certainly also taken part in the fitting out of the earlier expeditions of AAGAARD and AKERMAND.

This narrative reminds us very much of the expedition in 1823—24 and it is not unlikely that the expedition referred to took place at that time. KEILHAU used a vessel called "Haabet" in 1827, and there could not have been many vessels of that name in Hammerfest.

1829—30 seven men wintered on the island (HENKING (1901), pp. 34—35). They got 120 walruses. They were brought to the island by FREDR. TOLLEFSEN, schooner "Trifan", owned by AAGAARD and AKERMAND. On the same trip he fetched three Finlanders who had been on the island that summer (1829) to repair the houses for the winter. These Finlanders are said to have lived on walrus meat for the last two months. How long they had then stayed on the island is not mentioned.

In 1832, probably, a new expedition was fitted out by the same men and led by a Quain. They came to grief, however, as all but one died (ISACHSEN (1921 b), p. 164)). In 1833—34 seven persons wintered in Russehamna; the next year they wintered again, but all died. Here was formerly a Russian hut, but a new one was erected by EBELTOFT and PETTERSEN from Tromsø in 1833 or 1834. The latter year is usually given (ISACHSEN (1921 b)), but, as the men who wintered there in 1834—35 also wintered the year before, it is more likely that the hut dates from that year, as the Russian hut was hardly fit to live in. The Norwegian hut is mentioned by J. G. ANDERSSON in 1899, when it was still there. In 1901, however, Skipper FROSTAD says that nothing was left of the hut but a heap of logs. As it is not very likely that the house has fallen to pieces in two years, most of the material has probably been carried away by hunters. Nothing is now left but the foundation.

In 1841 a Norwegian expedition led by LARS BRUN IRGENS wintered. One of the members was HANS ISMAEL EBELTOFT from Berg in Tromsøysundet (ISACHSEN (1921 b)).

In 1850 the sloop "Anna Margrethe" of Steinkjer, Skipper ANTON KLEVEN, lost her mast off the Norwegian coast, and drifted northward to Bear Island, where the crew wintered in the hut in Russehamna. The ship was wrecked in a cove farther south. The next year the men were rescued by DANIEL DANIELSEN, a skipper from Hammerfest, with the sloop "Nordcap", (Spitsbergen Gazette (1897); ISACHSEN, (1921 b)).

In the following years the island was only occasionally visited, as hunting had not proved very remunerative.

In 1864, on August 17, the smack "Kardine" of Vardø with Skipper PEDER E. PAULSEN and three sailors, was wrecked on the northern point of the island. The vessel ran ashore in a fog under double reefs, the wind being from ENE. On August 22 they left the island in a whaler and reached Galten on Sørøy. (HENKING (1901), p. 26).

In 1865—66 SIVERT TOBIESEN, hunter and skipper from Tromsø, wintered, and this wintering is well known through TOBIESEN having kept a diary. For the first time on Bear Island continuous meteorological observations were made by him, published by A. E. NORDENSKIÖLD (1870). His diary has been published in the year-book of the Norwegian Geographical Society (ISACHSEN (1921 a)). With six men and provisions and materials for a house, TOBIESEN was put ashore in Nordhamna on July 29, 1865. The ship, "Lydianna" of Tromsø, left the island as early as Aug. 3.

The men at once proceeded with the erection of the house adjoining the old one, which was used temporarily as living quarters, and on Sept. 2 the new house was ready for use.

During the autumn provisions for the winter, such as cod-fish and young gulls, were collected, and many excursions on the island were undertaken. Thus, on Aug. 9, the hut in Russehamna was visited. TOBIESEN says about this: "Shortly before I left Tromsø I bought this house, which was erected by the crew who wintered there in 1834—35. They were seven men, all told. Below the house were found the skeletons of five men. The sixth we could not discover[1]. The seventh, and the one who lived longest, and was the leader, was carried to Norway by his brother and buried in Havøsund. As far as I can remember, he was alive until the month of March. I cannot describe my emotions when I held one of the skulls in my hand. I, who 31 years ago, then a boy of thirteen, was cook on board the same vessel that carried them across, and could still remember the names of every one of them, wondered whose head I had in my hand now. An inspection of the house showed it to be so damaged that it could not be repaired, as it needed much material which we have not got." West of his house in Nordhamna, TOBIESEN found the remains of at least 11 persons, and he believed they were Russians, killed by the men who were to bring them home so that they might get possession of the catch. The wintering of TOBIESEN ended satisfactorily, though he got only one walrus, three bears and about forty foxes, and on June 19 the members of the expedition were brought home to Norway. In 1892 the house of TOBIESEN was sold by Mrs. MARTHA TOBIESEN to ANDREAS E. SCHRØDER of Tromsø, and in 1899 the Tromsø Fishery Association (*Tromsø Fiskeriforening*) was granted 4,000 Kr. by the Government to purchase the house, on the condition that Norwegian fishermen and hunters should be allowed free use of it. (Res. Dec. 13, 1899). In 1900 the Tromsø Fishery Association got a special grant of 2,500 Kr. for the necessary upkeep, and Skipper FROSTAD was at the island with his sloop the "Anna" from July 27 to Aug. 30, 1901. In a letter dated July 27, 1910, to the Norwegian Ministry of Foreign Affairs, the Tromsø Fishery Association announces that, by the purchase of the house of TOBIESEN in 1900, they consider they have acquired a claim to the whole of the island. In 1921 the house was taken over by the coal company, *Bjørnøen A.S.*

Inscriptions in the houses of Bear Island indicate that the island has been visited several times by Norwegian hunters. HENKING has noted some of these names, which show that there have been such visitors in 1868, 1874, 1889, 1891, and 1900.

Scientific Expeditions in the 19th and 20th Centuries.

We have already mentioned the pioneer expedition by KEILHAU. In 1839, on July 21, the French expedition in the "La Recherche" visited Bear Island *en route* for Spitsbergen (MARMIER). They mention

[1] In 1924 we found an old skeleton west of Daudmannsvatnet. Perhaps it may have been one of these winterers.

a Norwegian hut on the north coast (erected by AAGAARD), and the old Russian hut west of the former. The Swedish Spitsbergen expeditions in 1858 and 1861 had not been able to call at the island on account of the ice and bad weather (CHYDENIUS (1865), p. 24), but in 1864 the island was visited by the Swedish expeditions under A. E. NORDENSKIÖLD (DUNÉR & NORDENSKIÖLD (1867)). A rough sketch map of the island was drawn (*ibid.* p. 32). In 1868 the Swedes were again there from July 22 to 27 (NORDENSKIÖLD (1868)). On a cruise around the island the steamer of this expedition, the "Sofia", partly used coals picked up ashore, this being the first time Bear Island coals were used for raising steam.

Fig. 57. Tobiesen's Hus.
House in Herwigshamna built in 1865 by the Norwegian sealing captain, Sivert Tobiesen of Tromsø.
G. Horn phot. 16/9 1925.

The sketch map of this expedition is found in the publication by HEER (1871), but was certainly no improvement, quite the reverse. A great number of fossil plants were collected. Two years later (on July 12, 1870) A. G. NATHORST paid a brief visit to Bear Island to make geological studies, and in 1878 the Norwegian North Atlantic Expedition visited the island three times on July 4, 23, and 31 (MOHN (1882)).

In 1891 LEO CREMER (1892) visited the island, being the mining expert of a German expedition in the S. S. "Amely" (VON ZEPPELIN (1892)). On June 18, 1892 A. HAMBERG collected a few plant fossils in Kolbukta (HAMBERG (1894)). In 1898 the Swedish Polar Expedition under NATHORST (1898) also visited Bear Island, and a survey carried out by C. J. O. KJELLSTRÖM and A. HAMBERG gave us the first correct outline of the island. The map, on the scale of 1 : 100 000, was published by NATHORST (1899 b). The same year (1898) the Spitsbergen expedition of the PRINCE OF MONACO called at the island on July 30 (RICHARD (1899)). In 1899, J. G. ANDERSSON, who had been with NATHORST in 1898, headed an expedition, and with his two companions, G. SWENANDER and C. A. FORSBERG, remained on the island from June 23 to Aug. 19.

The results have been published by ANDERSSON (1900 b) and are the first exhaustive work on the geology of the island. More information about the geological work of the various expeditions will be found in the geological part.

In the vicinity of Bear Island fishing has been prosecuted by Norwegians for several years, also for scientific purposes. But also oreign scientific expeditions have been engaged in these waters. Thus a Russian steamer, "Andrei Perwoswanny", of the Scientific Murman Expedition and commanded by W. M. JAKUBOWSKY, visited Bear Island on April 16 and 17, 1900. Dr. LEONID BREITFUSS, who was a member of the scientific staff, has been good enough to give us some information about this and succeeding voyages, in which he also took part. The second time this ship visited the island was on October 24—25, 1902. BREITFUSS went ashore at Nordhamna on the 24th with his assistant W. ISSOTSCHENKO and three sailors, and erected a shelter with maximum and minimum thermometers. On account of bad weather they were forced to spend the night ashore. The next day they got on board, thanks to the efforts of the captain, A. SMIRNOW. On July 27, 1906 he again visited Nordhamna with the same ship, but the thermometer shelter was then damaged. He placed new thermometers under the roof of the German House, but he has never heard of them since.

In 1921, the Oxford University Expedition to Spitsbergen visited the island (June 13 to 23) and made studies of the flora and fauna in the southern part. (GORDON (1922); SUMMERHAYES and ELTON (1923)).

Scientific Investigations, Exploitation of the Coal Deposits, and Hunting in the 20th Century.

German Activity.

Up to 1898 the investigations which had been carried out were, as a rule, of a scientific nature. The island was regarded as "no man's land", and no attempts had been made to exploit its coal resources and to claim land for this purpose.

In 1898, a German expedition, whose main purpose was zoological studies, left Tromsø on June 8, for a cruise in Arctic waters in the trawler "Helgoland". The ship was commanded by HUGO RÜDIGER, an officer of the German Navy. On board was also a journalist, THEODOR LERNER. The ship made a short stay at Bear Island, where these two gentlemen went ashore and staked off a small piece of ground adjoining the north side of Sørhamna as their private property, by means of stones painted in the German colours (claim *a* on fig. 58). The expedition then continued to Spitsbergen. The same year, on July 4—7, a German naval vessel, the "Olga", called at the island, being on a training cruise in Arctic waters. (DITTMER (1901)). On board was also a commission headed by Dr. HARTLAUB and appointed by the *Deutsche*

Seefischerei-Verein. Their task was to investigate the fishing resources of the waters around Bear Island. Small huts, of about 2×2 metres, were erected on LERNER'S claim at Sørhamna and Kvalrossbukta, and were signed: "Station des Deutschen Seefischerei-Vereins". At Kolbukta a hut was built with the inscription: "Vermessungen S. M. S. Olga", and the entire northern part of the island north of a line from Rifleodden to Kapp Rose (now Kapp Hanna) was claimed by the association, (claim A on fig. 58).

Early in the spring of 1899 they dispatched another expedition, this time a big one, whose task it was to carry out experiments in deep-sea fishing, whaling, and coal-mining. Three vessels were employed: the trawlers „August" and "Elma" for deep-sea fishing and whaling, and the schooner „Vigilant" with supplies of coal and material for the building of a land station. In addition to the crew of the "Vigilant", the expedition consisted of 38 men and was commanded by FRIEDRICH DUGE, the harbourmaster of Geestemünde. Amongst the members were also KESSLER, a mine surveyor, and a miner for the practical examination of the coal-seams. When this expedition came to the knowledge of LERNER, he became alarmed, and succeeded in getting a Hamburg firm to make ready an expedition immediately, and only three days after the departure of the "Seefischerei" expedition, LERNER went north on board the seagoing tug "Terschelling". The "Seefischerei" expedition was forced to remain in Hammerfest until the middle of June owing to the drift-ice around the island, but the enterprising LERNER forced his way through and reached it safely on May 28, whereupon he went ashore with three men, while the ship returned to Tromsø. Lerner now

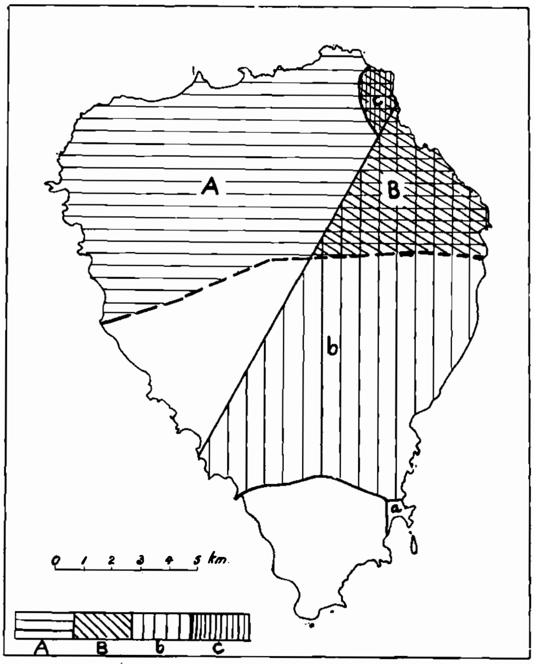


Fig. 58. Map showing the claims of Lerner and Deutsche Seefischerei-Verein.

a Privat property of Lerner of June 13, 1898,
b Lerner's claim of June 5, 1899.
c Lerner's cla m of June 28, 1899.
A Claimed in 1898 by Deutsche Seefischerei-Verein.
A minus B Owned by Deutsche Seefischerein-Verein 1898, 1889, 1900, 1912.
B Owned by Deutsche Seefischerei-Verein and Knöhr & Burchard Nfl.

claimed the area *b* on fig. 58, and at Russehamna he planted a flag and claim-board with the following inscription: "Deutsches Privat Eigentum. Erwerbsurkunde vom 5. Juni 1899". In a canvas bag at the back was placed a property declaration (Eigentums-Erklärung) an extract of which reads as follows:

"Am Montag, den 5 Juni 1899, habe ich, der unterzeichnete deutsche Staatsangehörige, THEODOR LERNER aus Linz am Rhein für mich und die deutschen Firmen *Knöhr & Burchard Nfl.* Hamburg, LOUIS STEIN, Magdeburg und OTTO KAUFMANN, Charlottenburg das unten näher beschriebene, und durch eine Kartenskizze bezeichnete, bis dahin herrenlose Land auf der keinem Staatsverbande zugehörigen Bäreninsel im nördlichem Eismeer ausgemessen, abgegrenzt und zum Zwecke der Ausnutzung für Bergbau, Fischerei und Jagd, hauptsächlich Trantierjagd in Privatbesitz genommen.

Für diese dem deutschen Reichskanzler angezeichnete Erwerbung, sowie alle Rechte auf Land und Wasser, besonders die Häfen wird der Schutz des deutschen Reiches in Anspruch genommen."

Then follows a statement about the boundary of the claimed area, and a list of persons (one of them being the Norwegian KLAUS THUE) who were present when the claim was staked out. Further, certain instructions are given to be followed by expeditions and tourists when visiting the claimed area. The area was marked with claim-boards and flags. A document identical with the one in Russehamna was found in a big cairn in Kvalrossbukta (Olgahamna). Huts were built at Russehamna and Ellasjøen. The claimed area embraces about half of the island and includes all good anchorages and the whole of the coal-bearing area as then known. On a reconnaissance on June 28, LERNER discovered that the coal area extended farther north, whereupon he promptly claimed another piece of land as "Privat Eigentum" (*c* on fig. 58).

Not until the middle of June did one of the ships of the *Deutsche Seefischerei-Verein* succeed in reaching the island after having made four attempts that were frustrated by drift-ice. In Kolbukta a few men were put ashore and the ship returned to Hammerfest. On June 18, the entire expedition left Norway and arrived at Bear Island five days later, the delay being due to the dense fog which usually envelops the island in summer. As its southern part was occupied by LERNER, a station was established on the north coast, at Herwigshamna ("Herwigs Hafen") east of Nordhamna, the harbour getting its name after Dr. HERWIG, the president of the D. S. V. Arrangements for the starting of test pits on the seams in Kolbukta were made by two members of the expedition, whose duty it was to investigate the coal deposits at Kolbukta, i. e. within the area of LERNER. The latter, however, pulled down their hut, along with the claimboard of the D. S. V., and confiscated the timber.

As the leader of the expedition, DUGE, would not renounce in writing his object of carrying out practical investigations, he and his men were forbidden by LERNER to approach the latter's area. He also confiscated a theodolite which the D. S. V. had been careless enough to leave in a tent. When DUGE came to take it, he did not receive a very cordial welcome; indeed, he was threatened with fire-arms and had to retire hastily.

On July 27, the secretary-general of the D. S. V., Professor HENKING, arrived. His original intention was to leave a wintering party, but this idea was given up, and on Aug. 7 and 8 the expedition left.

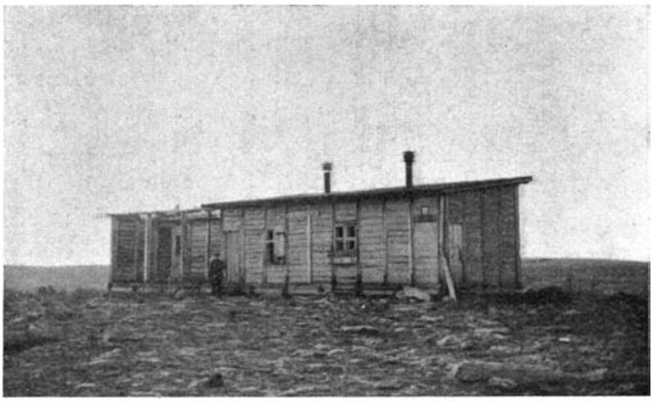


Fig. 59. Tyskehuset. (The German House).
House in Herwigshamna built in 1899 by the Deutsche Seefischerei-Verein of Berlin.
G. Horn phot. 16/9 1925.

To return to LERNER: At his request, MÖLLMANN, a German mining engineer, and two miners came to Bear Island in July. A hut was put up in Kolbukta, and in the cliffs south of this bay two short adits were driven into the seam, wherewith 80 tons of coal were obtained; this was tested by the "Terschelling", which crossed to Norway several times.

For the purpose of wintering two houses were built, one in Kolbukta and another in Sørhamna. The wintering plan was abandoned, however, and in October the miners left the island; LERNER had departed earlier.

The syndicate which had provided him with funds was dissolved in the spring of 1900, and their rights and property on the island were sold by auction on May 9 to the Hamburg firm of *Knöhr & Burchard Nfl.* By agreement between this firm and the D. S. V., the island was divided, the D. S. V. getting the northwestern and northern part, i. e. the area claimed by that association in 1898, (A minus B, fig. 58) and D. S. V. and *Knöhr & Burchard Nfl.* becoming joint owners of parts of the area claimed by LERNER in 1898 (B on fig. 58).

Jointly these companies dispatched in 1900 an expedition in the fishing steamer "St. Johann", with Professor HENKING as the leader and DUGE as second-in-command, ERNST HARM represented the firm of *Knöhr & Buchard Nfl.*, and O. HAGEN of Berlin acted as harbour expert. In addition to the crew (9) there were 10 men, of whom three were miners. The object of the expedition was to study harbour conditions, the problem of shipping coal, and, time permitting, to carry out fishery investigations. The expedition left Geestemünde on June 25, and arrived at Sørhamna on July 4; they departed on the 12th and came home on the 21st. During this short visit prospecting work was not carried out to any great extent. Coal samples were taken in the cliffs south of the Engelske Staur and south of Engelskelva. Some coal was extracted from one of the adits of LERNER, and HARMS started two new adits. Seven tons of coal were taken on board, and all the claims were renewed. The expedition's list of their property in 1900 reads as follows (fig. 60):

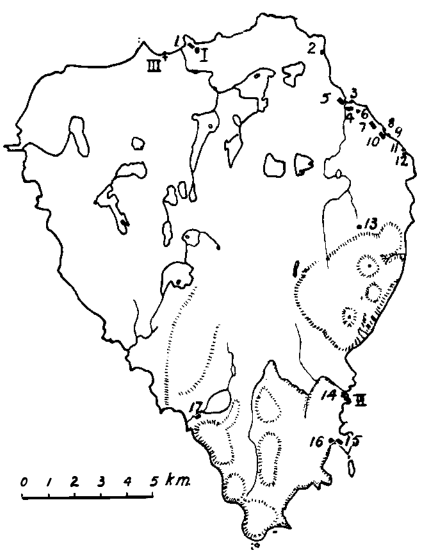


Fig. 60. Map of houses on Bear Island 1899.

1. House in Herwigshamna. 20 by 6 metres. Built 1899 by the *Deutsche Seefischerei-Verein.* (It is still (1927) standing, although somewhat dilapidated).
2. & 3. Two adits worked 1899; one between the Engelske Staur and Måkestauren and the other just east of the mouth of Engelskelva. The latter was retimbered in 1900. (Both adits have now disappeared).
4. Hut (1898), property of the D. S. V., on the brink south of Engelskelva. (Removed later).
5. Hut (1899), property of the syndicate. On the north side of Engelskelva. (Only foundation now visible).
6. Half-finished pit (1899), south of the mouth of Engelskelva.
7. House (1899), property of the syndicate.
8. & 9. Two adits (1899) south of the house. On the brink a storehouse, also belonging to the syndicate. In 1900 one of the adits was continued to the depth of 15 metres.
10. Store-house.
11. & 12. Two adits (1900) at Kapp Nordenskiöld. By *Knöhr & Burchard Nfl.*

13. Plank hut (1899) of the syndicate, north of Miseryfjell. (Blown down, but the materials were there in 1925).
14. Plank hut of the syndicate in Russehamna.
15. A large wooden house (1899) of the syndicate in Sørhamna. (Only foundations left now).
16. Hut (1898) in Sørhamna with the inscription: "Station des Deutschen Seefischerei-Vereins".
17. Hut (1899) of the syndicate at Ellasjøen.

Norwegian establishments:

I. Tobiesen's house.
II. Hut in Russehamna.

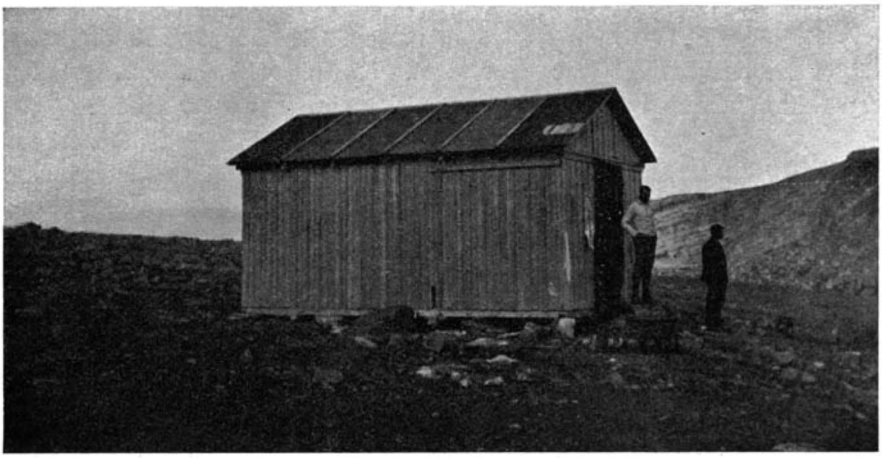


Fig. 61. Ellahytta.
House on the southwest coast, near Ellasjøen. G. Horn phot. 21/7 1924.

Russian establishment:

III. Remains of house in Nordhamna with flagstaff, cairn, and claim post. ("Belongs to Russia" etc.).

In 1912 the *Deutsche Seefischerei-Verein* dispatched another expedition to renew their claims. The leader was Dr. KURT FLEGEL, of Berlin, the other members being: Dr. A. HEINSIUS, ERNST EDEL, and CHRISTIAN RECKER. They remained on the island from June 15 to July 10. The claims were renewed, and the southern boundary from Kapp Hanna (Kapp Rose of the D. S. V.) to Rifleodden was marked with six claim boards painted black, white, and red, and having the inscription "Eigentum des Deutschen Seefischerei-Verein Berlin". They were numbered G. P. 1, etc. A bottle containing the report of the claim was deposited one metre north of each post. The expedition did not use their own vessel, but arrived in S.S. "Poseidon", which went to Spitsbergen to erect the German meteorological station in Ebeltofthamna, and to claim land in Spitsbergen for certain German interests.

From FLEGEL's diary it appears that towards the end of June deep drilling was carried out near the house of TOBIESEN in Herwigshamna. Thirty-four metres southeast of the house the hole is still to be seen. Diamond-drilling was used, but the depth and section is unkown to us. It is said that the hole is 140 metres with nothing but sandstone. The portable engine provided in 1899 for treatment of the blubber probably supplied power for the drilling work. This engine is still to be seen on the shore, but is now in a most dilapidated condition.

Twelve years later, on Aug. 20, 1924, representatives of the *Deutsche Seefischerei-Verein* arrived at Nordhamna in the German fishery-control boat "M 134". Ten men landed to inspect the property, to renew the old claim boards and erect new ones. The latter bore the inscription: "Eigentum des deutschen Seefischerei-Verein. Erneuert 1924".

By a Norwegian Order in Council of May 22, 1925, the amount of Kr. 200,000 was placed at the disposal of the German occupants, *Deutsche Seefischerei-Verein* and *Knöhr & Burchard Nfl.* as compensation for their claims in certain parts of the island and as payment for buildings erected by Germans and now occupied by the Norwegian company.

Russian Activity.

The news — grossly exaggerated, of course — about claim controversies between LERNER and the *Deutsche Seefischerei-Verein* in 1899 reached the various European capitals, and excited a certain amount of interest. Thus the Russian Government decided to dispatch a naval vessel to Bear Island. On July 21, the cruiser "Svetlana", commanded by Captain ABAZA, reached the isle with instructions to investigate the doings of the Germans, and to hoist the Russian flag where remains of Russian hunting cabins could be ascertained. When Captain ABAZA sought to put this into effect at Russehamna, he was turned back by LERNER. He then sailed to the north coast, where he found a skeleton with Russian boots, and here the Russian merchant ensign was hoisted, and a wooden board erected with the inscription: "Belongs to Russia Appertient à la Russie Capitaine ABAZA Croisseur "Svetlana"."

In 1916 the Russian Ministry of Trade and Industry received an application from Count K. G. TOLSTOJ and Captain P. P. GURSHI requesting permission to seek for and exploit coal on Bear Island, where they stated they had discovered a coal-bearing formation. They also stated that they had driven in 15 claim pegs delineating the boundary of the claimed area, extending from Sørhamna to Engelskelva (Fig. 62). The actual date of this visit to the island is not known.

The heirs of TOLSTOJ and GURSHI notified the claim (84.4 sq. kilometres) to the Svalbard Commissioner (the official nominated to settle the claim disputes in Svalbard). However, this claim — with other Russian claims — was withdrawn against payment by the Norwegian Government of £ 1,800 to the Russian claimants. (Stort. forh. (1927 b)).

In 1921, on the 18th of July, there arrived at the island a Russian expedition from Archangel in S/S "Koupava". The expedition was led by the chief of the port of Archangel, D. M. IVANOV, and on board were also N. N. YAKOVLEV, professor of geology, P. K. BOSHITSHI, hydrographer, ABOLIN, a Soviet commissioner, and others (YAKOVLEV (1921)). The object of the expedition was to mine in the course of one month 300,000 poods of coal (about 5,000 tons). It is most possible that the real intention was to claim the island for Russia. Before anchoring in Sørhamna they went northward along the east coast to look at the coal in Kolbukta, and were greatly surprised to find an establishment already there. The Norwegian company would not permit them to do any work ashore, whereupon the Russians confined their activity to the collecting of plant fossils at Miseryfjell; they also made some cursory geological investigations around Sørhamna. They left the island after a short stay on July 20.

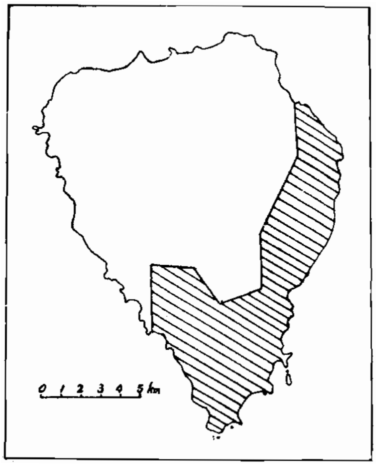


Fig. 62. Map showing the claim of Tolstoj and Gurshi.

Norwegian Activity.

In the period 1900—12 there was no activity on Bear Island excepting the work done by M. A. INGEBRIGTSEN, who had a land station for whaling in Kvalrossbukta from 1905 to 1908.

During the last year in which whaling was prosecuted off the coast of Finnmark, the whalers had to a large extent hunted around Bear Island and towed the carcasses to Norway. Thus INGEBRIGTSEN in June 1900 killed 11 whales at Bear Island. When whaling was prohibited in Norwegian waters in 1904, the whalers had to turn their attention to other grounds, and in 1905 we find the INGEBRIGTSEN company on Bear Island, hunting with one whaling-boat from a land station in Kvalrossbukta. Although they got a number of whales, chiefly finners (*Balænoptera musculus*), but also humpbacks (*Megaptera boops*), the enterprise met with but little success, INGEBRIGTSEN closing down his establishment in 1908. During these years the catch was (RISTING (1911)):

	Whales caught	Barrels of oil
1905	46	1200
1906	60	2060
1907	81	1700
1908	44	830
	231	5790

Since 1908 no whaling has been done from Bear Island.

On June 7, 1909, INGEBRIGTSEN communicated to the Norwegian Ministry of Foreign Affairs that he claimed the area between Kvalross-hamna and Miseryfjell, with the object of exploiting the deposits of galena and coal. In a letter dated May 18, 1915, he informs the Foreign Ministry that he has claimed that part of Bear Island situated east of a straight line from the head of Sørhamna to the head of Nordhamna.

In 1908—09 KLAUS ANDERSEN and another man wintered at the closed establishment in Kvalrossbukta owned by INGEBRIGTSEN. They made a catch of 16 polar bears and 30 arctic foxes — 4 white and 26 blue.

From Aug. 1910 to June 1911 the Norwegian skipper, HJ. M. JENSEN, with companions, wintered on the island; he kept a meteorological diary.

We shall now proceed to give a short account of the Norwegian colliery undertaking, *Bjørnøen A.S.*

On Sept. 23, 1915, the whole island was claimed by *I/S Bjørnøens Kulkompani*, a syndicate whose chief members were: K. SANDVE, O. HAABETH, and BRØDRENE HAABETH, all of Stavanger. The claim was notified to the Norwegian Ministry of Foreign Affairs in a cable from Tromsø on Oct. 4. On Dec. 30 of the same year the syndicate bought INGEBRIGTSEN's claims, including the buildings, which were then repaired. In 1915—16 only two men wintered, and the first ship arrived on May 19. During the summer 35 men were at work for the syndicate. To investigate the coal-bearing formations, diamond-drilling was proceeded with north of Miseryfjell (depth unknown) and at Laksvatnet (depth 154.50 metres) by the *Svenska Diamantbergborrnings Aktiebolaget* of Stockholm, under the supervision of the Swedish geologist, Dr. ERNST ANTEVS. The latter also did geological work, particularly in the area Kapp Forsberg—Miseryfjell, where he took a coastal section. The most important result of these investigations was the discovery in the bore-hole at Laksvatnet of a series of white sandstone and a coal-seam, which, from the abundant plant fossils in the shales, proved to be of Culm age, a formation hitherto unknown on Bear Island (ANTEVS and NATHORST (1917)). With regard to the borehole north of Miseryfjell, it must have been a failure more or less, but it has been impossible to obtain the results. The hole is located below the lowest coal-bearing series, and from the cores it is evident that the hole has not reached the Hecla Hoek formation. Further, ANTEVS sampled the seams, the analyses being done by Dr. NAIMA SAHLBOM, Stockholm. He also took samples of fireclay occurring together with certain coal-seams, and they were tested in Denmark and Sweden. Soundings as well as surveying and construction work were also done that summer. Mining was started at Tunheim, the name given to the camp, and a few hundred tons of coal was won. The work was conducted by E. SØRUM and the brothers HAABETH. The last boat left the island on Oct. 14.

Fig. 63. Ingebrigtsen's whaling station at Kvalrossbukta. Now only remains are left.

In 1916—17, 13 men wintered and L. VARMING was manager. About 1000 tons of coal was mined and the constructional work continued. On June 23 the first boat arrived. During the summer 34 men were working at Tunheim, and SØRUM continued his work with the soundings. A few small cargoes of coal were shipped, and on July 2 the first cargo of coal (200 tons) from Bear Island arrived at Tromsø in S.S. "Bjønongen". That summer the Norwegian Government established a post-office on the island. The last boat left the island in the middle of October.

1917—18. Twenty-one men wintered, doing mining and constructional work. O. STAXRUD was manager. A small quantity of galena was also won from the veins north of Russehamna. In the autumn of 1917 the British steamer "Buxton", which had taken a northerly course to avoid German submarines, went ashore at Miseryfjell and was totally wrecked. The syndicate states that up to Jan. 1, 1918, 2 mill. Norw. Kroner had been expended. In the spring of 1918 a new company was formed at Stavanger with the object of taking over the properties and rights of the syndicate, and of continuing the work from Jan. 1, 1918. The *Bjørnøen A.S.* was formed on June 3, 1918 with head offices at Stavanger, the share capital being 4,000,000 Kr.

The directors were: SIGVAL BERGESEN, ODD ROALKVAM, TRYGVE OLSEN, OLAV HAABETH, and CORN. HOLMBOE. Further, a shareholders' committee of ten members with OLE RØED as chairman was elected. The following day a meeting of the board of directors elected BERGESEN as chairman and ROALKVAM deputy chairman. H. GRAHMBERG became

Fig. 64. "Bjønongen" arrives at Tromsø on July 2, 1917.

general manager, and H. EGGE manager on the island. On April 17, 1918, the first boat arrived, taking the winterers back to Norway. About 60 men were employed during the summer, houses being built, storage ground for coal prepared, etc. During the season the boats of the company, S. S. "Bjønongen" and M/Aux. "Onsø", called eighteen times at the island. The last boat left on Nov. 21. In the same year Dr. OLAF HOLTEDAHL of Oslo was engaged by the company to do geological work, locate sites for boreholes, and supervise the borings which in that year were carried out by the Swedish drilling company on behalf of *Bjørnøen A.S.* Two holes were drilled at Tunheim, one at Laksvatnet and the other at Ellasjøen, of the total length of 589.19 metres.

CLAUS SCHIVE, consulting engineer, was engaged upon the work of surveying and sounding the harbours.

1918—19. Eighty-seven men wintered, with EGGE as manager. 9,000 tons of coal was won and a power station erected. The "Bjønongen" arrived on May 8, and EGGE was succeeded by F. NANNESTAD.

A storage pocket for coal was built at Austervåg, north of Tunheim, and railway equipment and engines bought. The storage pocket was ready for use on Sept. 20. It had a capacity of 550 tons, and was connected with the mine by a railway 1,200 metres long. This railway was built during the summer of 1919. A staff house, a new power station of 120 hp., workmen's dwellings, workshops, stores, etc., were also erected. A new mine (the A-mine) was opened up, but no coal was won here. The island received 21 steamship calls, of which 17 were by S.S. "Bjønongen", and 2,000 tons was shipped, most of it being used by the company for bunkers.

In the summer of 1919 there were, on the average, 120 men on the island. E. RICHTER (1919) investigated the question of harbour facilities, and the coal deposits were examined by an English consulting engineer, CHARLES W. FENNELL, of the firm of *Fennell, Green & Booth*, Wakefield. His report to the company of Oct. 24 is very optimistic, and he estimates the coal resources of the island at 200 million tons. The last ship of the season called on Nov. 21. Towards the end of 1919 the whole of the share capital had been spent, and the sum of two mill. Kr. was furnished by the Government as an advance against future coal deliveries. A loan was also raised with the Bank of Norway for an amount of up to 530,000 Kr., and guaranteed by some of the directors. In the autumn a wireless station was erected and the first telegram was received in Norway on Dec. 24.

1919—20. This winter there were 65 persons at the island, with A. LINDBOE as manager. On Febr. 26 the power station was destroyed by fire, and on the 29th the first boat M/Aux. "Olav" arrived. When this boat in company with M/Aux "Ringsæl" returned with the winterers, they encountered a violent gale and the "Olav" went down with all hands, 28 men. The first collier arrived on March 26, and up to Nov. 24 20,460 tons was shipped. The total number of calls was 102. During the year the following improvements were carried out: The storage bin in Austervåg was extended to a capacity of 1000 tons. The new Diesel power station of 150 hp. was ready for use on Aug. 1. Screening plant at the A-mine, daily capacity 200—250 tons. Further were erected: Building for stores, mess-room with kitchen for the miners, stables, office building, and servants' house.

The C-mine was opened that year, and a screening plant was built and storage ground prepared. At the A-mine a storage ground (4,000 sq. metres) was also prepared. The railway was extended from the A- to the C-mine. During the summer there were employed 200 men, one-third of whom were doing constructional work.

In that year the Coal Committee, appointed by the Department of Trade to control the companies delivering coal to the Government, visited Bear Island. The committee consisted of B. STUEVOLD-HANSEN,

A. K. HILLESTAD, and HJ. BATT, with LUDV. FOLTMAR as secretary. P. BOOTH, consulting engineer from Wakefield, England, inspected the properties of the company.

1920—21. The total number of wintering people was 182, of which 170 were workmen. In the mine were 65, and 15 on the screening plant. The manager was H. SYVERTSEN. O. ROALKVAM was that year elected managing director. During the winter a screening plant was erected at the C-mine, having a capacity of 75 tons per shift (8 hours). It was put into operation in March 1921. On May 3 the screening plant of the A-mine was destroyed by fire. The first boat, M/Aux. "Johannes Bakke", arrived on April 8. Coal was shipped in the period June 6—Oct. 18. Total number of calls: 31. On June 25 the men went on strike and were sent back to Norway on July 12. The last collier, S.S. "Tormod Bakkevig" (1180 tons dw.), left Tromsø on Nov. 1, arrived at the island on the 5th, but had to return to Norway on account of ice and stormy weather. This was most unfortunate, as the winter supply of provisions was on board. Three sealing vessels were then chartered and they succeeded in reaching the island on Nov. 23 and 26, and Jan. 26, 1922. Amount of coal shipped in 1921: 19,727 tons. During this year constructional work was carried out as follows: Workmen's mess room finished, and provisional screening plant at the A-mine erected. TOBIESEN's house in Herwigshamna was purchased and repaired. A hut was built at Laksvatnet. From June 1, 1921, the mine was worked according to the longwall method, and JOHN BROOK, an English mining engineer, was put in charge of the mine. T. HAABETH was appointed manager. Towards the close of the shipping season the number of persons employed was 160. Mr. BATT of the Norwegian Department of Trade and Industry and member of the Government Coal Committee, visited the island that summer. The output from Nov. 1, 1920 to Oct. 31, 1921 was 24,306 tons, but the accounts showed a deficit owing to the tremendous fall in prices of coal that winter, from 202 Kr. c. i. f. North Norway in Oct. 1920, to 75 Kr. the following summer.

1921—22. The number of wintering persons was 85, of which 80 were paid by the company. T. HAABETH was manager. 7943 tons were raised during this winter and shipped during the following summer. The first boat arrived on Jan. 26 and the last on Dec. 7, 1922. Coal was exported from Apr. 29 to July 23. At Laksvatnet a shaft was started to find the Culm coal-seam uncovered by the borehole near by in 1918. At Tunheim development work in the C-mine was continued.

As far back as 1909 Norwegian scientific expeditions had commenced to work in Bear Island. In June of that year the Spitsbergen expedition, commanded by GUNNAR ISACHSEN, spent two days on the island doing geological and topographical reconnaissance work. The ISACHSEN expedition called at the island again in 1910 on its northward voyage, and during a stay of two days Norskehamna was sounded, and certain survey work was done between Kvalrossbukta and Russehamna (Isachsen (1912 b)).

As the coal deposits grew in economic importance the lack of an accurate topographical map of the island made itself felt. Such a map would also serve as the basis of a detailed geological map, most necessary for the future of the mining industry. The State-subsidised Norwegian expeditions to Svalbard (led by ADOLF HOEL) had visited the island every summer since 1918 on their way to Spitsbergen, and, in addition to its work in Spitsbergen, the expedition commenced in 1922 a topo-

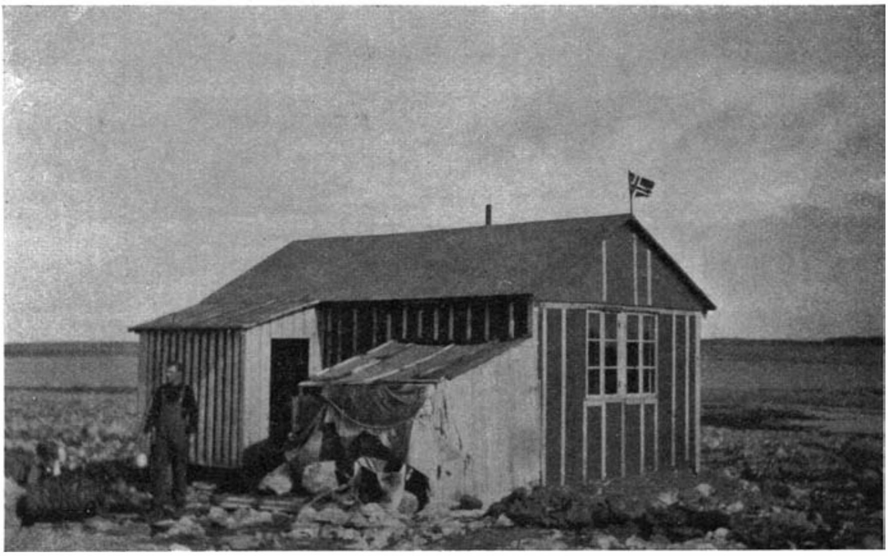


Fig. 65. House at Laksvatnet.
G. Horn phot. 28/7 1925.

graphical survey of the island. The members of the party were: A. KOLLER, W. SOLHEIM, E. IVERSEN, and W. WERENSKIOLD, the latter also doing geological work. ADOLF HOEL, the leader of the Norwegian Svalbard expeditions, did reconnaissance work in parts of the coal-bearing areas.

KOLLER and SOLHEIM surveyed the route for a projected aerial ropeway from Laksvatnet to Sørhamna on the scale of 1:2000, and Sørhamna was charted on the scale of 1:1000. Preparatory work for the mapping of the island on the scale of 1:10 000 was also done. A total number of fourteen persons were engaged on these surveys. That summer thirty-one men were employed by the company at Tunheim doing mining work.

1922—23. Twenty-three men and four officials, with SYVERTSEN as manager, wintered on the island. The main slope of the C-mine was continued, and in April production was resumed. The shaft at Laksvatnet was continued (down to 47 metres, of which 27 metres were in

Spirifer limestone) and a gallery (39 metres) also driven. The work was given up, however, as no coal-seam was met with, probably owing to an unknown fault between the shaft and the borehole. The working force was brought up to 250 men in the course of May. On Aug. 4 a dispute with the men broke out, operations stopped, and the men were sent home. Fresh men were engaged and work was resumed on Sept. 30. In the mine the fault already known in the cliff was encountered. In the period May 14 to Aug. 26, 13,374 tons were lifted, 12,934.6 tons (including bunkers) being shipped during the season. In 1923 the first boat arrived on March 30, and the last one on Oct. 20. The Norwegian

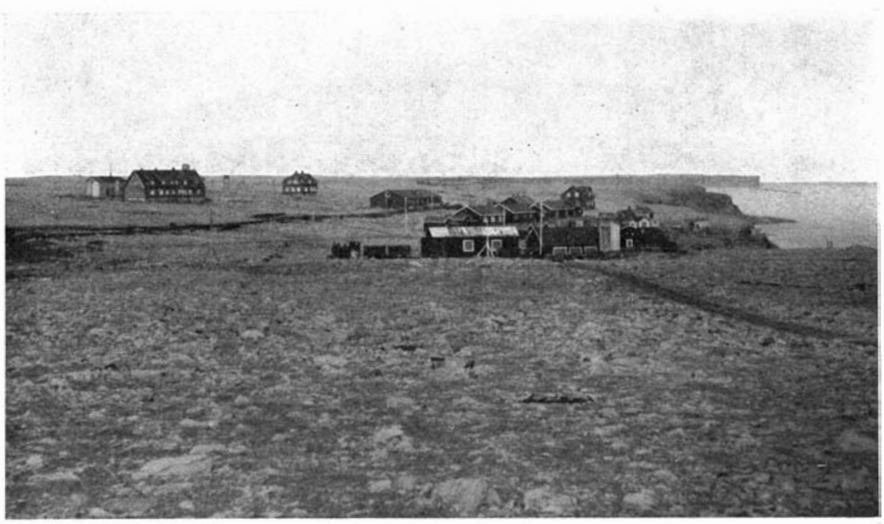


Fig. 66. Tunheim. P. Berge phot. 1924.

Svalbard Expeditions continued the topographical survey, commenced the previous summer, under KOLLER, SOLHEIM, and B. LUNCKE, employing eleven persons all told. At Tunheim, Dr. HANS HENIE made an accurate determination of the geographical co-ordinates of a point at Tunheim with the following results:

Latitude: 74° 28′ 57″ N.
Longitude: 19° 13′ 33″.3 east of Gr.

In the summer of 1923 the Norwegian Government established a complete meteorological station on the island.

1923—24. A total of 91 persons wintered. Of these 41 were in the mine, 15 at the screening plant, 14 on the surface, 8 on the staff, and 13 were servants, cooks, etc. In Norway the company employed 4 persons. During the summer about 100 persons were on the island. F. THETING was manager, a position which he held until the mine was closed down in 1925. From May 7 to Sept. 24, 20,827 tons were shipped to various places between Svolvær and Kirkenes in Norway. During the year ending Oct. 31, 1924, the wages per hour were on the average: Underground Kr. 1.92, surface Kr. 1.62, and screening Kr. 1.25. The men were provided with free quarters, light and fuel, but were charged for food at the rate of Kr. 3.63 per man per diem. The coals were delivered f. o. b. Bear Island at the price of Kr. 28.97, and c. i. f. North Norway Kr. 39.66, the shipping expenses then being Kr. 10.96 per ton.

A detailed geological survey of the coal resources was commenced by the Norwegian Svalbard Expeditions, as a topographical map on the scale of 1 : 10 000 was now available with only insignificant areas to

Fig. 67. View of Tunheim.
Showing office (to the left), and mess for the staff. — P. Berge phot. 1924.

be finished that summer; this was done by B. LUNCKE and K. GLEDITSCH. The geological mapping was carried out by ANDERS K. ORVIN and GUNNAR HORN, assisted by H. MARSTRANDER. A number of pits and trenches were dug to get sections of the coal seams and three boreholes were drilled to obtain reliable information about the sequence in the Devonian and Culm formations. *Norsk Diamantborings A/S* of Oslo supplied the drilling outfits and drillers, H. MERCKOLL being in charge of the drilling operations. Three boreholes were drilled, two at Tunheim and one at Hausvatnet, the aggregate length being 536.86 metres. The bore at Hausvatnet was drilled to a depth of 233.92 metres, this being the deepest hole on the island. The Norwegian Svalbard Expeditions employed a total of 27 persons that summer.

On Aug. 20, an expedition arrived to renew the claims of the *Deutsche Seefischerei-Verein* (see p. 126).

1924—25. During this winter the company had the following employees:

Underground workers (incl. 3 foremen)	68
Workers at the screening plant	27
Other surface hands	20
Servants, cooks, etc. paid by the employees.	13
Staff	11
	139

The staff in Norway numbered 4 persons. The number of people wintering in the island was 141, and THETING was again the manager. The output from Oct. 1, 1924 to Sept. 19, 1925 was 36,399 tons,

Fig. 68. Mjogsjøhytta.
House built by Bjørnøen A.S. in 1925 at Mjogsjøen in the central part of the island.
G. Horn phot. 18/7 1925.

of which 30,537 tons were shipped and 1,465 tons used for bunkers, a total of 32,002 tons. The consumption of coal on the island was 719 tons. Of exports, 17,000 tons were taken by the State-subsidised coasting steamers in the north of Norway, 5,000 tons were stored at various places along the coast, and 8,000 tons of *smalls* were stored in Sørvaranger. On the island 2,000 tons were consumed and used for bunkering small craft, and 5,000 tons, chiefly *smalls*, remained at the mine. The last coal steamer left the island on Sept. 21.

Much cod was fished this summer quite near the coast.

On Aug. 14, 1925, Norway's sovereignty of Svalbard was proclaimed and this event was celebrated in the island. The treaty granting to Norway the sovereignty was signed in Paris on Feb. 9, 1920 (Stort. forh. (1924 a)).

The Norwegian Svalbard Expeditions finished their work this summer; it comprised geological mapping of remaining areas, digging of trenches and pits to examine the seams and deep drilling. HORN and MARSTRANDER, with two assistants, 5 drillers, and 7 workmen, a total of 16 persons, were engaged upon this task. A bore (rig from *Norsk Diamantborings A/S*) was put down at Vestre Flyvatn and carried down to a depth of 223.50 metres. In 1924 and 1925, trenches and pits were dug at 24 places, whereby 600 cubic metres of earth and rock was excavated, and pits were driven of an aggregate length of 120 metres, and adits of 15 metres. The aggregate length of the 4 boreholes drilled in 1924 and 25 is 760.36 metres, which, with previous holes, gives a total length of all holes drilled in Bear Island of 1 504.05 metres. The lengths of the holes north of Miseryfjell and at Herwigshamna are unknown.

For the purpose of the topographical survey, geological mapping and exploration, and drilling during the years 1922—25, Kr. 390 000 was voted by the Norwegian Government. The low coal prices ruling at the end of 1925, and the results of the geological survey showing that coal-seams of a thickness and purity necessary to make mining there a profitable undertaking do not exist, made it clear that the mine would have to be closed down. This was done on Sept. 19, and the men were shortly afterwards sent home.

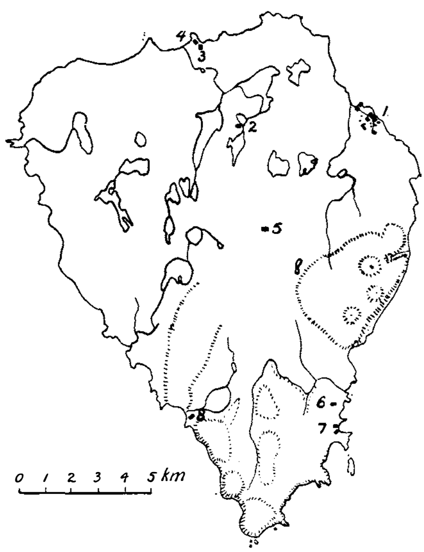


Fig. 69. Map of houses on Bear Island 1925. 1 Tunheim, 2 Laksvasshytta, 3 Tobiesen's House, 4 House built by Deutsche Seefischerei-Verein 1899, 5 Mjogsjøhytta, 6 Houses at Krillvatnet, 7 Ingebrigtsen's whaling station, 8 House at Ellasjøen.

The capital invested in the undertaking is quite considerable:

Up to 1918 the syndicate had used	2.0	mill. Kr.
Bjørnøen A.S., used private capital	2.0	—
Loan from the Government (31/12 1925)	7.4	—
	11.4	mill. Kr.

Of this sum Bjørnøen A. S. used 9.4 mill. kr. thus: Constructional and development work is responsible for 6.2 mill., exploration 0.7 mill., and 2.5 mill. Kr. have been lost on the working of the mines.

1925—26. In the autumn of 1924 loose blocks of galena were quite accidentally discovered by Messrs. THETING and ORVIN near Krillvatnet southwest of Russehamna, and in Aug. 1925 prospecting works was started with two men. In September two buildings were moved from Tunheim to Krillvatnet, and in the winter of 1925—26

5 men were engaged in development work on the galena deposit, by which 45 tons of lead ore were won. At Tunheim only the meteorological and wireless station was maintained.

In June 1926 the screening plant at the C-mine was destroyed by fire. The pile of small coals was ignited through spontaneous combustion, and, despite the efforts of the men, the fire spread to the building. During the summer, work on the galena deposit was continued with 5 men. At Tunheim 6 men were employed on maintenance work. 75.5 tons of galena were shipped. As, however, the ore disappeared in depth the mining work was stopped. In the meantime a new and promising lead occurrence had been discovered farther north in the valley of Russeelva, but no prospecting work was done that summer.

1926—27. This winter the force numbered only three men, one foreman (SYVERTSEN), one wireless operator, and a cook. From June 16 to Oct. 1 (1927) prospecting work was carried out on the newly discovered deposit in the valley of Russeelva. Five men were employed, and about 70 tons of ore was won. Nothing was shipped. The first ship arrived on June 7, and the the last one left on Oct. 10. It is of interest to note that this summer very good hauls of halibut were made at Bear Island some 10—15 miles off the coast.

1927—28. The wintering force numbers only four, namely, wireless operator, his wife, one cook, and one odd man. The meteorological service is being, and in all probability will be, kept up, because of its great importance for the weather forecast of North Norway.

Number of men employed			Exports (incl. bunkers) (in metric tons)
			Coal
Winter	1915—16	2	
Summer	1916	35	—
	1916—17	13	
	1917	37	200
	1917—18	21	
	1918	50	—
	1918—19	80	
	1919	120	2,000
	1919—20	65	
	1920	200	20,460
	1920—21	180	
	1921	188	19,727
	1921—22	104	
	1922	31	7,943
	1922—23	27	
			50,330 tons

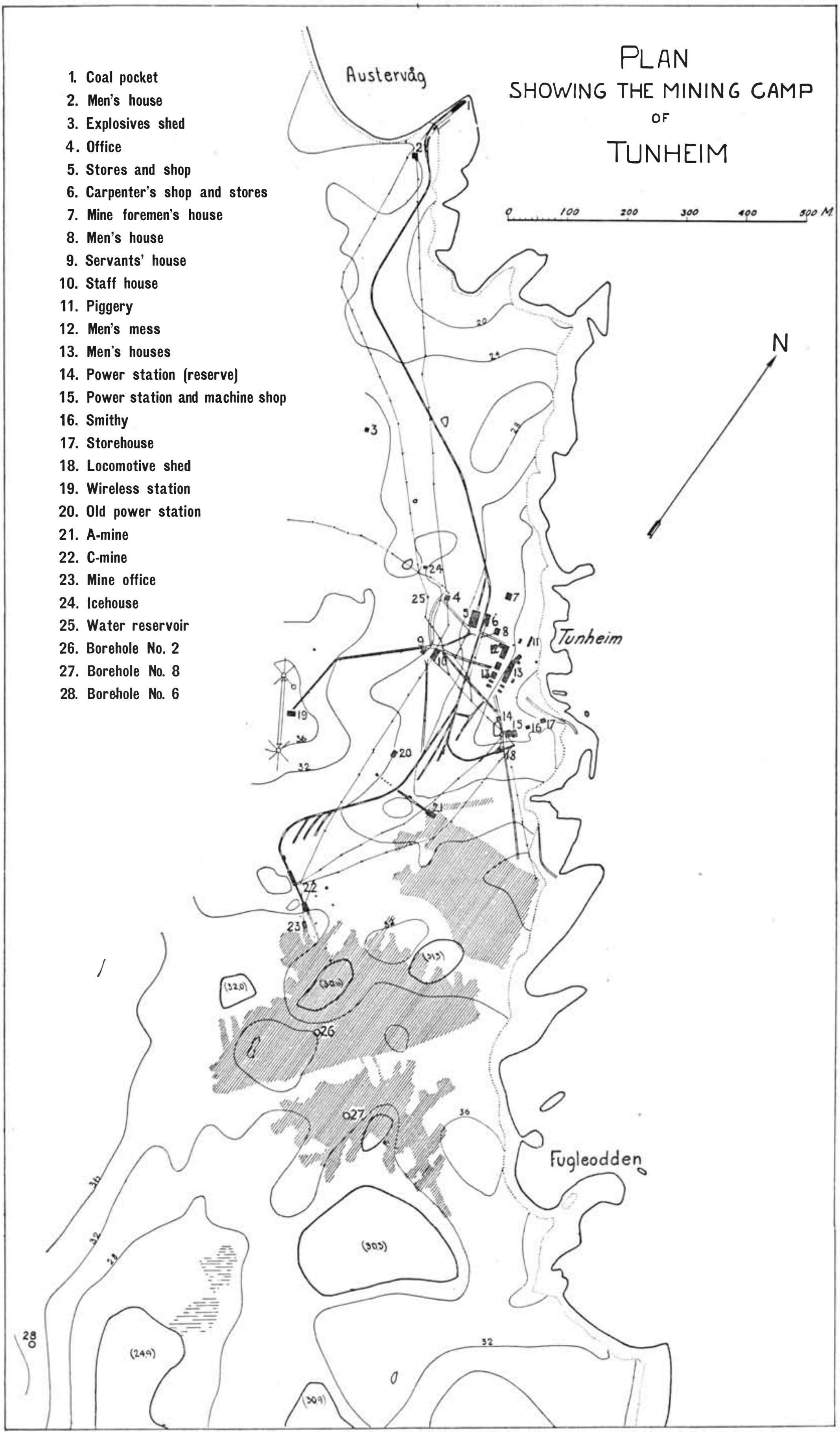


Fig. 70. Shaded areas: Mine workings.

	Number of men employed	Exports (incl. bunkers) (in metric tons)	
	Transport	50,330 tons	
1923	260	12,935	
1923—24	82		
1924	102	20,827	
1924—25	123		
1925	163	32,002	
1925—26	5		Lead-ore
1926	11	—	75.5
1926—27	3		
1927	9	—	—
1927—28	3		
		116,094 tons	75.5 tons

Summary.

Bear Island is the southernmost island of Svalbard, which is the name given to the Norwegian possessions in the Arctic Ocean, and is situated between 74° 20.5′ and 74° 31.3′ N. Lat., and 18° 46′ and 19° 17′ Long. E. o. Gr. It has the shape of a triangle pointing towards the south, and its length nowhere exceeds 20 kilometres and its breadth 15.5 kilometres. The area is 178.07 sq. kilometres or 68.75 sq. miles.

The distance from Norway is 240 nautical miles. Considering the high latitude the climate is mild, the average temperature of the year being —3.8° C. In the summer the isle is frequently enveloped in fog. No glaciers exist, but snow occasionally remains throughout the summer.

The northern part is a level plain 30—40 metres above sea-level, with numerous shallow lakes and ponds, and terminating seawards in steep cliffs. On Bear Island there are about 700 lakes covering an area of 18.8 sq. kilometres or 10.6 per cent. of the total area. The southeastern and southern parts are mountainous, with peaks which in Miseryfjell reach an altitude of 536 metres (the Urd peak). The south coast is a steep sea cliff up to 400 metres high.

The oldest geological formation present is the Hecla Hoek, consisting of dolomites, limestones, slates, and quartzites. Fossils have been found in a few horizons, fixing the age as Middle Ordovician. The minimum thickness is 1 215 metres.

Unconformably on the Hecka Hoek follows a series of Upper Devonian strata consisting of sandstones, conglomerates, shales, and a number of coal-seams. Plant fossils are of frequent occurrence. In the south the thickness in 100 metres, but in the Tunheim area it is much greater, about 360 metres.

The Devonian is followed by the Culm, also having a continental development, but with more sandstones. A thin coal-seam occurs near the top. The thickness is 110 metres in the south and 230 metres or more in the central part.

Middle Carboniferous strata follow the Culm with red conglomerates and sandstones at the base, followed by grey limestones and yellow calcareous sandstones; the thickness is 470 metres.

The Upper Carboniferous is made up of three members: the Fusulina, Cora, and Spirifer Limestone. The first rests conformably on the Middle Carboniferous. The Cora Limestone, occurring only in the south, rests unconformably on the Hecla Hoek and Devonian. The Spirifer Limestone rests unconformably upon all the older formations and caps the mountains, forming typical plateaus. On the northern plain there are one large and two smaller areas with this limestone. The thickness is about 120 metres.

In Miseryfjell the series is followed, apparently conformably, by shales and sandstones of Triassic age, having a thickness of 190 metres.

The tectonic disturbances manifest on Bear Island can be referred to three different periods, Silurian, Upper Carboniferous, and younger than the latter, possibly Tertiary. The movements of the Silurian have only affected the Hecla Hoek rocks, causing faults and over-thrusts running NW—SE. The rocks have also been slightly metamorphosed. The pressure came from the northeast. Towards the end of the Carboniferous period earth movements again supervened. There were two periods of crustal movements with subsequent denudation, manifest by strong unconformities. The first movement has produced a broad, slightly assymmetric, anticline with axis running about north-and-south. A feature of this anticline is the numerous strike faults with downthrow towards the crest.

Very little is known about the geological history of the island after the deposition of the Triassic beds. It was probably the extensive Tertiary movements which caused an upheaval and tilting of the land until it was about 500 metres above the present sea-level. Then the big, now submarine, valleys north and south of the island were formed. A subsidence of the land then followed with the formation of the platform now 45—60 metres below sea-level, perhaps in an inter-glacial period. In a later period a further lowering of the land down to 145 metres took place, and then an intermittent rise of the land with the formation of several abrasion plains. The levels of the various plains correspond to the levels of strand-lines and terraces in Spitsbergen.

The last movement of the land in post-glacial times consisted in a sinking to about 35 metres above the present level, followed by an uplifting to the present level.

The occurrence of coal has been known since 1609. The Devonian contains coal-seams in two horizons. The lower, the Misery series, contains up to 12 seams, and the upper, the Tunheim series, has three seams. They are separated by 105 metres of barren rocks. The seams of the Misery series are very irregular in point of both occurrence and thickness. The outcrop runs from north of Miseryfjell to Ellasjøen. In the cliffs on the east side of this mountain the seams are well exposed. The Tunheim series is best known from the Tunheim area in the northeastern part of the island. It has three seams, of which the lowermost, the A-seam, with 0.65—70 metre of good coal, has been mined.

The Culm has a single thin seam uppermost in the series, but this seam is entirely unworkable.

The seams have been uncovered in pits and cuttings, of which detailed sections are given. Nine boreholes have been drilled, sections of which are also given.

The coals belong essentially to the same type, i. e. caking coals, and the pure coal substance yields about 22 per cent. of volatile matter. They furnish a good coke. The net calorific value of the moisture and ash-free coal is 8 100—8 250 cals. The ash content is high, up to 16 per cent.

The coal reserves are large, running into many millions of tons, but no definite figures are given on account of the irregularity of the deposits.

Mining has been carried on at Tunheim, and from 1917 to 1925 116 094 tons (metric) were exported. In 1923—1924 the output per man per shift (9 hrs.) was, in tons:

	Per hewer	Per underground hand, foremen included	Per underground and surface hand
Run-of-mine.	3.92	2.32	1.09
Cleaned coal	3.22	1.90	0.89

Deposits of galena occur within the Hecla Hoek area, and from 1925 prospecting work has been done here. In 1926 75.5 tons were shipped.

The shale below the A-seam is a fireclay suitable for the manufacture of refractory bricks.

Bear Island was discovered by the Dutch navigator, WILLEM BARENTS in 1896, but was probably known to Norse seafarers long before that time. In 1603 the English came to the the island, and in the 17th century it was often visited by English and Dutch whalers. The first wintering happened in 1700. In the beginning of the 18th century Russian trappers commenced hunting on the island, and about the year 1800 Norwegian activity began.

In 1827 the Norwegian geologist, B. M. KEILHAU, visited the island for scientific purposes, and since that time the island has been thoroughly explored and mapped by a number of Norwegian and Swedish expeditions.

From 1905 to 1908 there was a Norwegian whaling station on the island.

In 1898, 1899, and 1900 German interests dispatched expeditions to the island to investigate the conditions for deep-sea fishing and to explore the coal-seams.

In 1915 the whole island was claimed by the Norwegian company *Bjørnøen A. S.*, and this company mined coal from that year to 1925, when the mine was closed down. From 1925 the company has done prospecting work on galena. On August 14, 1925, Norway's sovereignty of the island was proclaimed according to the treaty signed in Paris on Feb. 9, 1920.

A wireless station is maintained by the Bjørnøen A. S., and in connection herewith a meteorological station by the Norwegian Government.

Literature.

Most of the papers dealing with Spitsbergen contain some information also about Bear Island. Such papers are not included in this list unless the information given is important. The list includes papers dealing with the history, geography, geology, and mining of Bear Island, arranged alphabetically. Some papers are also included although they are not dealing with the island directly. Where an author has published several papers they are arranged in order of date; two or more in the same year have letters appended. Only the pages with information about matters relating to Bear Island are given.

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