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13. Observations on the movement of lake ice in Lake Sommen 1918 and remarks on the geographical distribution of similar phenomena.

By

Axel Hamberg.

I.

The formation of ice ridges (Swed.: råkar), which presupposes, of course, a certain motion of the lake ice, is a phenomenon that is well known to the Swedish country people and is already mentioned by Olaus Magnus.[1] Another cognate phenomenon, which has been an object of interest to American, Swedish and German geologists, is the working up of the edge of the ice against the land, as it causes the removal of large stones and the development of ramparts. The dislodgement of stones towards the shore was the first phenomenon to be observed, and attention was drawn to it as early as the 'twenties' by J. Adams[2] and C. A. Lee.[3] The formation of lake ramparts was mentioned by C. H. Hitchcock[4] and C. A. White[5] in the 'sixties'. Even these writers connect these phenomena with the expansion of the ice in freezing, but G. K. Gilbert[6] was the first to succeed in explaining why the expansion of the ice on a

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[1] Historia de gentibus septentrionalibus. Lib. I. Cap. XXVII. Roma 1555.

[2] On the Movement of Rocks by the expansive power of freezing Water. — Amer. Journ. Sc., Vol. 9, 1825, p. 136.

[3] On certain Rocks supposed to move without any apparent cause. — Amer. Journ. Sc., Vol. 5, 1822, p. 34. — — Remarks on the moving rocks of Salisbury. — Amer. Journ. Sc., Vol. 9, 1825, p. 239.

[4] Lake Ramparts in Vermont. — Proc. Amer. Ass. Adv. Sc., Vol. 13, 1860, p. 335.

[5] The Lakes of Iowa. — The American Naturalist, Vol. 2, 1869, p. 148.

[6] The topographic features of lake shores. — Fifth Annual Rep. U. S. Geol. Survey 1884.

lake attains such a considerable magnitude: »The ice on the surface of a lake expands while forming so as to crowd its edge against the shore. A further lowering of temperature produces contraction, and this ordinarily results in the opening of vertical fissures. These admit the water from below, and by the freezing of the water are filled, so that when expansion follows a subsequent rise of temperature the ice cannot assume its original position. It consequently increases its total area and exerts a certain thrust on the shore», etc.

A very interesting study of the pressure exerted on the shores by the covering of ice and the formation of ramparts by the shove of the ice has been carried out by E. R. Buckley[1] at Lake Mendota and Lake Monona in Wisconsin. During Dec. 1898—Feb. 1899 there was almost continual frost and an ice-covering about a metre thick was formed. During this time the average daily amplitude of the temperature of the air was about 8° C. and the snowfall was very small. The effect of the gradual expansion of the ice was in many cases great, but it depended very much on the nature of the shore. 1) Where it slopes gradually and consists of sand and gravel, the ice freezes fast on the bed, and when it is shoved up on to the shore, it brings with it a mass of gravel from the bed, which it unloads as a thin mantle, often extending six or eight feet inland. 2) Where the shore is steep and very firm, the ice works together in front of it, but if it consists of loose material (clay, moraine clay or turf), this is shoved together instead into a rampart, which reaches a height of four feet on an average, sometimes twice as high. Even large trees may take part in this movement. 3) On swampy shores with loose beds the frozen layer at the bottom is shoved together into one or two folds parallel to the shore. The first shove of a fold of ice or frozen material at the bed or of a rampart takes place suddenly with a great crash; then no accumulation of tension takes place, but the subsequent reliefs proceed »at a uniform rate.»

Both Buckley himself and the eminent geologist van Hise make interesting comparisons between the deformations in an ice-covering of a lake and the tectonic movements of the crust of the earth.

G. Braun[2] has made similar observations at a North German lake, the Löwentiner-See. Here, too, moderately high ice-ramparts were formed in loose shore material.

There is not much information in scientific literature from our Scandinavian country, which is so rich in lakes, with regard to phenomena of motion in lake-ice. In the early publications of the Academy of Science I have only found one account dealing with ice ridges (råkar), etc.

In more modern times, however, there is a good study by the Swedish geologist J. P. Gustafsson[1] on the marks that have been left on the shores by the ice-shove on some lakes in Småland. These shore marks vary in character. When the shore has a gradual slope a rampart arises from the ice-shove which in exceptional cases may attain a height of two metres; on steeper shores a terrace is formed. Large or small stones are pushed against this rampart or terrace. Even very large stones may in this way be displaced over fairly large distances, and on their lee-side are found real grooves on the bed according to the path they have been pushed along. Gustafsson thought that he could trace a concentration of the stone material against the rampart or terrace respectively. Among other observations may be mentioned a dislocation of the points of a glacifluviatic ås in towards the land.

It will be seen that Gustafsson's observations do not completely agree with Buckley's system. It is to be noticed, in addition, that the former observations were made exclusively during the summer in studying strata of loose soil. G. also collected information, however, from the inhabitants of the place as to the movement of the ice in winter and the formation of cracks, and this information seems to correspond exactly with the actual facts.

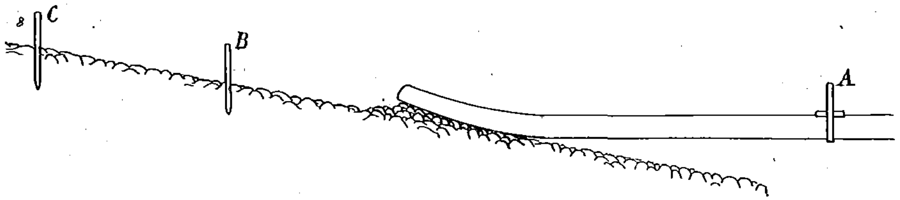

Fig. 1. Schematic picture of the arrangement of the marks for measuring the movement of the lake ice.

During a stay at the Romanäs sanatorium as a patient I had an opportunity to make observations of the gradual expansion of the ice-covering on Lake Sommen during the period from Feb. 17th to March 18th. The lake had frozen on the 28th Dec. On the 15th Jan. the ice was 10 cm thick, 25 cm on 1st Feb. and 28 cm on March 1st. When on Feb. 17th, after lying in bed for a month, I was able for the first time to go on the ice, I found that it had already begun to push up on shore to some extent and to draw with it stones and gravel. Remembering Gustafsson's essay, I made a hasty decision to take measurements of the movement of the ice with a tape-measure. These measurements were taken as follows: two sticks were put down at an interval of about four metres in the slopes of the shore in a line at right angles to the edge of the ice and in the same line a mark of the construction shown at A in fig. 1 was bored in the ice. The distance from this to the edge of the ice was

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[1] Ice ramparts. — Transact. Wisconsin Acad. Sc., Vol. 13, I, p. 141.

[2] Eiswirkung an Seeufern. — Schriften d. phys. ökon. Ges. zu Königsberg in Pr., Jahr. 47, 1906, p. 8 and 104.

[1] Om stranden af några småländska sjöar. — Geol. Fören. Förh., Bd. 26, 1902, p. 145.

about 5 $^1/_2$ m and to the nearest mark on the shore 7 $^1/_2$ m. By measuring the distance A—B and the distance A was to the side of the line B—C the movements of the ice both perpendicularly and parallel to the shore could be determined. As the maximum and minimum temperatures of the air were ascertained daily at the sanatorium, the connection between the changes in temperature and the movement of the ice could be followed to some extent, although the temperature on the ice was of course somewhat different to that at the sanatorium. The principal observations are collected in Table 1.

Table 1.

Date	Temp. of the air		Distance A—B m	Movement of ice towards the shore cms per 24 hours	Total movement	
	Min.	Max.			⊥ shore cm	‖ shore cm
Feb. 21	—8°	—3°	7,485	—	—	—
» 22	—12	—5	7,482	?	—	—
» 23	—5	+3	7,485	?	—	—
» 24	—2	+7	7,482	?	—	—
» 25	0	+2	The stick A got loose by melting	?	—	—
» 26	—2	+4		?	—	—
» 27	—1	+5		?	—	—
» 28	—4	+2	7,502	?	—	—
March 1	—8	—1	—	—	—	—
» 2	—9	0	7,495	0,35	0,7	—
» 3	—12	—1	—	—	—	—
» 4	—6	—4	7,456	2,0	4,6	—
» 5	—1	+3	—	—	—	—
» 6	—4	+4	7,440	0,8	6,2	—
» 7	—4	+3	7,417	2,3	8,5	—
» 8	—9	+2	7,310	10,7	19,2	—
» 9	—8	+7	7,230	8,0	27,2	11,0
» 10	—7	+7	7,177	5,3	32,5	16,0
» 11	—2	+2	7,156	2,1	34,6	—
» 12	—0	+4	7,157	0,1	34,5	—
» 13	—1	+3	—	?	—	—
» 14	—2	+3	—	?	—	—
» 15	—4	+5	—	?	—	—
» 16	—5	+6	7,165	—	—	—
» 17	—7	+7	7,103	6,2	40,7	21,8

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[1] According to readings taken at 8 a. m. at the sanatorium, about 15 m above the level of the lake.

During the first few days no movement was observed in the ice, although the temperature was low and the difference between the night and day temperatures was large. A thaw then ensued, during which no perceptible alteration of the position of the ice took place either. On the 28th Feb. a period of cold nights commenced and this lasted till the 11th March. During this time there was an incessant shove of the ice towards the shore, so that at the end of the period the distance of A—B was decreased by 34,6 cm. After a few days' thaw cold nights came on again, and the displacement was increased to 40,7 cm by the 17th March, when the observations ceased, as I left the sanatorium soon afterwards. During the period of observation there was only quite an insignificant snow-fall. During the whole period of perceptible movements in the ice-covering a powerful and almost incessant rumbling was heard from it, especially during calm nights.

At the same time as the displacement *towards* the shore a displacement also took place *parallel* to the shore in a northerly direction. Only three observations, however, were made of this component, and according to these, the movement in this direction amounted to almost exactly half of that towards the shore.

In order to verify the theory of the origin of the movement measurements of the distance A—B were taken for a few days, March 8th to 12th, both at 9 a. m. and at 6 p. m. The results are collected in Table 2. In the main they confirm the theory, inasmuch as the great pushes occurred during the daytime. There even seems to have been some retrogression sometimes during the night.

Table 2.

Date	Temperature of the air		Distance A—B 9 a. m. m	Difference 6 p. m.—9 a. m. cm	Distance A—B 6 p. m. m	Difference 9 a. m.—6 p. m. cm
	Min.	Max.				
March 8	—9°	+2°	—	—	7,310	—
» 9	—8	+7	7,310	0,0	7,230	8,0
» 10	—7	+7	7,259	—2,9	7,177	8,2
» 11	—2	+2	7,166	1,1	7,155	1,1
» 12	0	+4	7,158	—0,3	7,157	0,1

It may be of interest to compare these measurements with what the theory requires. This obviously presupposes that the edges of the ice are so fixed to the shore that, because of the slight resistance of the ice to tensile stresses (about 7—8 kg per cm^2), the contraction can be quite relieved by the formation of cracks. If these are then filled with water, which freezes, and the consequent expansion of the surface of the ice cannot take place except by pushing the edge of the ice on to the shores, and as, in addition, the linear coefficient of expansion of the ice is about 0,00005, it follows that, at the creek of Sommen, which is about half a kilometre in breadth at the place where the measurements were taken, a shove of $12\,^1/_2$ cm of ice might be expected on each shore after a fall in the temperature of 10° below freezing point during the night and a subsequent rise to 0°. We see that the values that were found agree,

Photo. A. H. $^7/_3$ 1918.

Fig. 2. Thrust of lake ice on the shore of Lake Sommen between Blåvik and Liljeholmen.

as least as far as the order of magnitude is concerned, with those calculated. One can scarcely expect any closer agreement, as the formation of cracks in the ice takes place irregularly and the observations of temperature were made not on the ice itself but on shore at a good distance from the lake and at a level of about 15 metres above its surface.

The effects of this gradual but considerable expansion of the ice were perceptible everywhere round the shores of the lake. As the latter consisted chiefly of firm and steep moraine strata, one would have expected the application of BUCKLEY's second case, i. e. that ridges of ice should be shoved up in front of and at a short distance away from the shore, but it was the first case that was developed throughout. This is perhaps due to the fact that the ice in Lake Sommen was only 30 cm thick, while

the ice in the lakes in Wisconsin was a metre in thickness. In the case of Lake Sommen the edge of the ice was not frozen very fast, so that the expansion of the ice-covering took place simply by the thin ice pushing up on to the shore, whereupon a rather steep bending upwards of the edge took place. Using a term that has been accepted in the case of the processes in the formation of mountains, we may characterize the pushing of the ice up on to the shore as thrusts. Very little of the stone material that was frozen fast at the bottom of the ice accompanied this movement. At the wider parts of Lake Sommen, such as between Blåvik and Liljeholmen, where the ice is more than two kilometres in breadth,

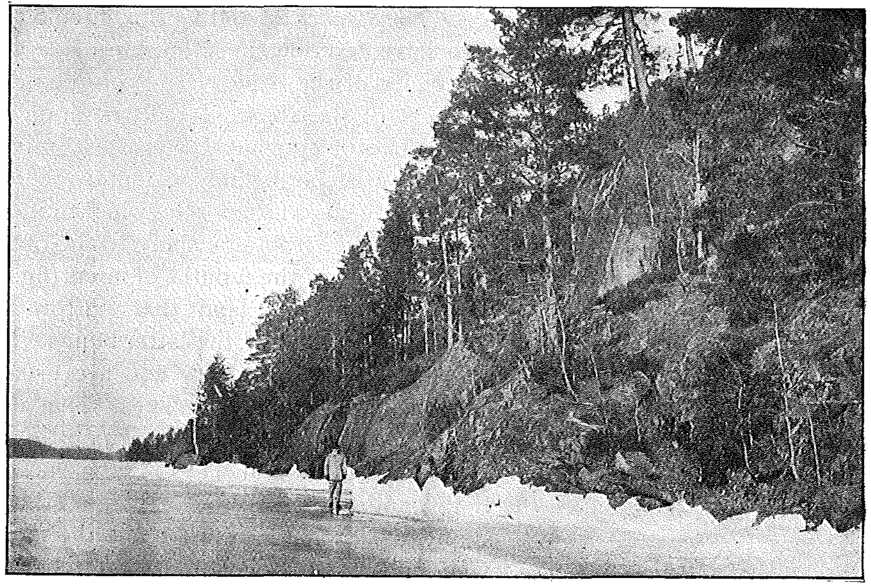

Photo. A. H. $^5/_3$ 1918.

Fig. 3. A border of ice bent vertically upwards at a precipitous shore near Torsudden, Lake Sommen.

the over-thrust amounted to several metres, as is seen in fig. 2. Scarcely any transference of large stones was observed, but on the other hand there were very serious dislocations of various landing-places. There was scarcely any effect even in front of precipitous rocky shores, but only a bending upwards of the edge even at right angles (fig. 3).

It is not inconceivable that a certain fall in the level of the water in the lake may have contributed to this bending upward of the edge and facilitated the thrust. But folds are also formed, however, where the shore consists of loose sand. In some places the edge had bored firmly into the sand and the expansion of the ice found its relief by starting folds at a greater or smaller distance from the shore (fig. 4). The boundary between such a strip of ice and the adjacent ice that expanded by pushing on to the land consists of a fault in which an ice breccia was being formed (fig. 4).

In exceptional cases folds were observed with their axes directed straight out from the shore, and these disappeared even at a short distance from the shore. These folds occurred at points of the land, round which the covering of ice had presumably described a slight torsional movement.

The absence of ramparts pushed up by the existing ice covering was obvious. These were only found where the shore was very loose and consisted of brushwood and remains of vegetation with only a rather slight admixture of stones and gravel.

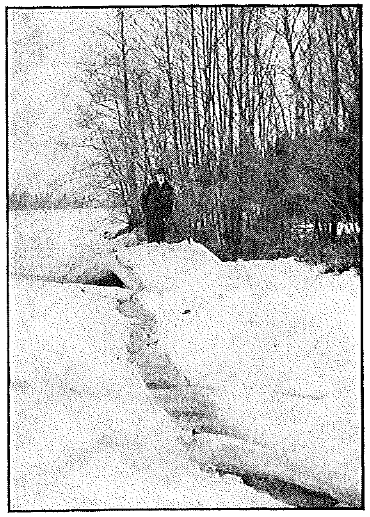

Photo. A. H. 8/3 1918.

Fig. 4. A strip of ice that could not be pushed over has formed a fold and at the same time a fault has arisen relative to the adjacent ice. In the fault there is a breccia.

The American and German geologists who have described in so meritorious a way the effect of the ice covering on the development of the shore scarcely mention the occurrence of transverse ridges (= råkar). These consist, as is known, of narrow zones of very much crushed ice which extend across a lake, from one shore to the other. They appear at the mouths of inlets (fig. 5), between points of land that narrow the watercourse or where the latter bends. The cracks are tectonic folds and are usually anticlines, sometimes synclines. The latter are probably filled with water, which freezes and effaces the syncline in the surface. If the anticlines increase in height, then a slight declension of the ice at their side takes place on account of the weight of the ice, and pools of water form, which soon freeze. As fresh ice is continually being pressed in towards the ridge from both sides during the growth of the ice covering, all regular folding is soon destroyed and a zone breakage arises with displacements below and above (fig. 6).

The transverse ridges are an interesting testimony to the fact that in a lake of a complicated shape the expansion movements of the ice covering cannot be considered as issuing from one centre or from a central line, but from several centres, and that the surface of the ice is divided into several regions of movement with separate centres. It is easy to see why a boundary line between two regions of motion arises at the mouths of inlets, at points of land and at places where the surface of the water course bends. It would obviously need much greater work for the ice to expand in all directions from one centre and push masses of ice over

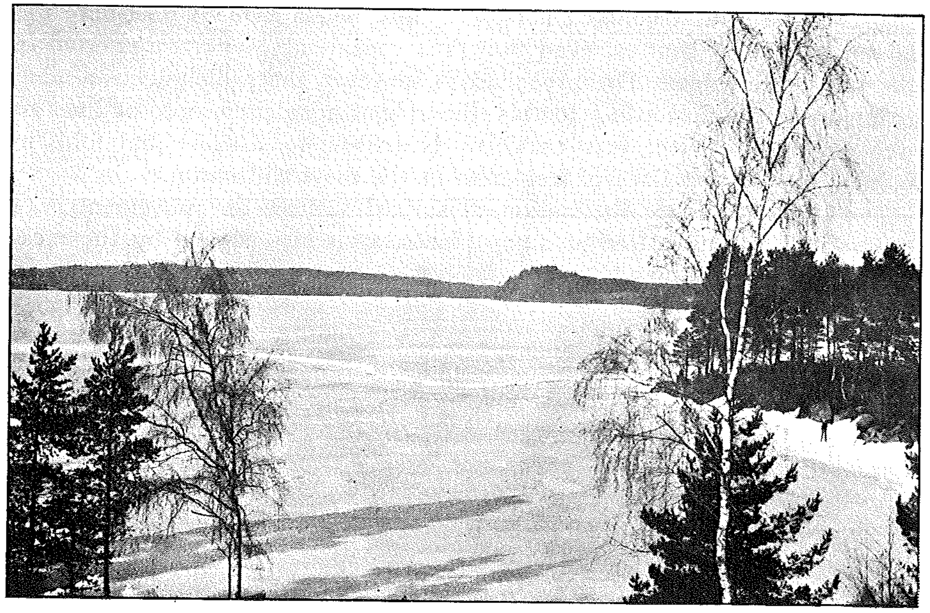

Photo. A. H. 6/3 1918.

Fig. 5. Ans-shaped transverse ridge at the mouth of the inlet between Blåvik and Torsudden, Lake Sommen.

Photo. A. H. 19/2 1918.

Fig. 6. The eastern part of the ridge across the creek at Romanäs, Lake Sommen.

points of land and islands, small creeks and bends than to distribute the labour at several centres, even though a considerable effort is exerted in the transverse ridges. The procedure is, however, that which needs a minimum of effort. According to this the ridges arise preferably at lines of weakness in the ice, just as there is reason to assume that folds in mountains occur at lines of weakness in the mountain strata.

In spite of the distribution at several centres the movement is of course rather complicated at many places, as is also shown by the measurements given above, which indicate that at the place where the observations were taken the movement did not proceed at right angles to the shore, but formed an angle of 25° to 30° with the normal of the edge of the shore.

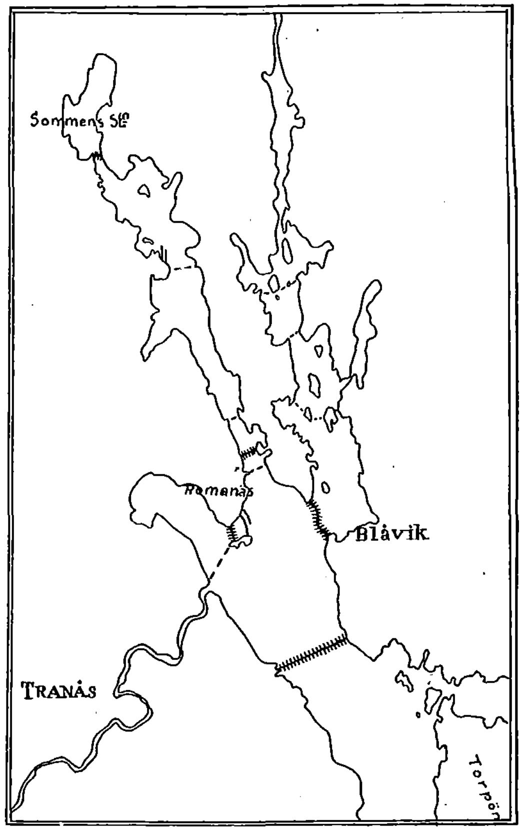

Fig. 7.

Map (in 1 : 150 000) of the north-western part of Lake Sommen, showing
‖‖‖‖ the position of transverse ridges in March 1918,
—— » » » certain cracks » » 1918,
– – » usual position of ice ridges according to the statements of the inhabitants.

During my stay at Romanäs I made a tour round the ice on the northern part of Lake Sommen and made a note both of the position of the transverse ridges at that time and also of their usual position according to the statements of the people living there. This information is reproduced in the small map in fig. 7. From this it can be seen that their positions vary and that a large number of ridges were absent in 1918 that usually existed at other times. These variations may be due to changes in the level of the water and the current at the time immediately after the formation of the ice and to the intensity and duration of the cold.

II.

The movement of the ice in our lakes is a grand and interesting phenomenon and, although a subject of a rather popular nature, it seems to deserve notice in scientific literature. In the case of Sweden, these phenomena seem to occur chiefly in the southern and central parts of the country. I have on several occasions made long journeys during February, March and April on the chain of lakes between Kvikkjokk and Jokkmokk in Lapland at about 67° N. lat., but have never seen any traces either of ridges or of shoving up on to the shores.

It is true that at the time of my winter journeys in Lapland the ice on these lakes was covered with deep snow, but high ridges would undoubtedly have risen over the covering of snow if any had existed. Nor did I hear the inhabitants mention the occurrence of any phenomena in North Lapland such as have been described above from a lake in South Sweden.

The cause of this is probably the absence of daily variations in the temperature as long as the lake-ice is to some extent free from snow. The daily periodical amplitude of the temperature decreases both with increasing proximity to the sea and also with the latitude, and is zero at the poles. It also decreases, on the whole, from the warm season to the cold. In order to illustrate this phenomenon I have in the tables below grouped the differences between the mean temperatures for the coldest and warmest hours for observations taken at Uppsala (lat. 59° 51',5), Vassijaure (lat. 68° 25') and those recorded by the Swedish expeditions to Spitzbergen, 1872—3, 1882—3 and 1899—1900 at their winter stations, the mean latitude of which may be put at 79° 25',5.

Although at the last-mentioned high latitude the sun is beneath the horizon for about four months, yet even during this time there are variations in temperature, but these occasional variations are, however, generally very slight and do not, of course, depend on the time of the day. The highest temperature may occur equally well during the night as in the daytime. Thus the changes of temperature are quite irregular; there are few great variations and numerous small ones, but the latter are in-

Table 3.

Monthly differences between the mean temperatures during the coldest and warmest hours.

Uppsala:[1] Lat. N. 59° 51,'5, Long. E. fr. Greenw. 19° 15',5, height 24 m.

	1905	1906	1907	1908	1909	1910	Mean
Jan.	1°,83	3°,69	2°,41	1°,67	1°,52	1°,65	2°,13
Febr. . . .	3,96	2,40	2,66	3,23	5,27	1,70	3,22
March . . .	3,34	5,14	6,17	7,02	3,35	5,74	5,13
April . . .	6,99	8,56	6,47	7,18	6,91	8,13	7,37
May	9,28	10,36	7,59	10,21	8,47	10,00	9,32
June	11,18	9,48	8,16	10,00	10,42	10,50	9,96
July	8,38	10,71	7,47	10,78	8,89	8,01	9,04
Aug. . . .	7,26	8,94	8,09	8,98	7,14	8,51	8,00
Sept. . . .	6,80	7,38	8,27	7,59	6,95	5,95	7,16
Oct.	2,75	5,24	2,58	4,95	3,66	5,41	4.10
Nov. . . .	1,86	1,61	1,68	3,12	2,98	1,80	2,17
Dec.	1,93	1,07	1,47	1,12	0,73	0,94	1,21

Vassijaure:[2] Lat. N. 68° 25'. Long. E. fr. Gr. 18° 11', height 505,8 m.

	1905	1906	1907	1908	1909	1910	Mean
Jan.	—	0°,88	1°,24	—	—	0°,55	0°,89
Febr. . . .	—	1,29	1,81	—	—	1,50	1,53
March . . .	—	1,95	1,83	—	—	1,80	1,86
April . . .	—	3,17	3,45	—	—	2,97	3,20
May	—	2,60	2,96	—	—	3,05	2,87
June . . .	—	2,90	4,48	—	—	3,48	3,62
July	(4°,72)	4,51	3,98	—	—	4,27	4,37
Aug. . . .	4,30	3,88	—	—	3°,45	—	3,88
Sept. . . .	3,45	3,25	—	—	2,50	—	3,07
Oct.	1,02	1,50	—	—	1,48	—	1,33
Nov. . . .	0,61	0,85	—	—	0,86	—	0,77
Dec. . . .	0,88	0,72	—	—	0,59	—	0,73

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[1] The hourly means are taken from Bulletin mensuel de l'observatoire météorologique de l'université d'Upsala, Vol. 37 (1905)—42(1910).

[2] The hourly means from following works: B. ROLF, Observations Météorologiques â Vassijaure $^{10}/_{7}$ 1905—$^{31}/_{7}$ 1906: O. A. ÅKESSON et E. BERGSTRAND, Observations météorologiques à Vassijaure $^{1}/_{8}$ 1906—$^{31}/_{7}$ 1907; E. H. NORINDER, Observations météorologiques à Vassijaure $^{1}/_{8}$ 1909—$^{31}/_{7}$ 1910. — Bihang t. Meteor. Iakttagelser i Sverige utg. af K. Sv. Vet.-Akad. Ser. II, Bd. 34 (1906), Bd. 36 (1908), Bd. 39 (1911).

Spitzbergen.[1]

Locality Lat. N. Long. E. Height	Mossel bay 79° 53' 16° 4' 12 m		Cap Thordsen 78° 28',5 15° 43' 83 m		Treurenberg Bay 79° 55' 16° 51',5 22 m		Mean 79° 25',5 — 39 m
Year	1872	1873	1882	1883	1899	1900	
Jan.	—	1°,23	—	00,72	—	00,68	00,88
Febr. . . .	—	1,03	—	0,48	—	1,40	0,97
March . . .	—	1,42	—	1,93	—	2,19	1,85
April . . .	—	3,29	—	3,46	—	2,78	3,18
May	—	2,90	—	3,19	—	2,18	2,76
June	—	1,96	—	1,94	—	1,13	1,68
July	—	—	—	1,83	—	1,76	1,80
Aug. . . .	—	—	10,92	2,48	10,80	2,19	2,10
Sept. . . .	1,°35	—	0,91	—	1,58	—	1,28
Oct.	1,12	—	0,36	—	0,65	—	0,71
Nov. . . .	0,77	—	0,58	—	0,92	—	0,76
Dec.	0,61	—	0,41	—	1,32	—	0,78

significant. The same state of affairs is also found in Lapland during November, December and January. But it is, of course, conceivable that in exceptional cases the unperiodical variations in temperature may, both here and in the Arctic regions, attain to such an amount that a considerable expansion of the lake ice may result.

The freezing of the Lapland lakes takes place chiefly in November, but the absence of frequently occurring and sufficiently large variations of temperature during the months immediately following prevents the formation of ridges and ice shoves. When, as early as February, the sun becomes more effective and a daily period appears in the temperature of the air, there is usually such a thick covering of snow on the ice that the variations of temperature cannot penetrate this covering.

In South Sweden, on the other hand, the lakes do not, as a rule, really freeze before the end of the year. There, however, the daily period of the temperature of the air is perceptible even in January, but it increases

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[1] The differences are calculated from the means of the hourly observations in the following works: A. WIJKANDER, Observations météorologiques de l'expédition arctique suédoise 1872—1873. — K. Sv. Vet. Akad. Handl., Bd. 12, No. 7, Stockholm 1875. — — N. EKHOLM, Observations météorologiques. — Exploration internationale des régions polaires 1882—1883. Observations faite au Cap Thordsen, Spitzberg, par l'expédition suédoise publiées par l'Académie royale des sciences de Suède. Tome I: 3. — — J. WESTMAN, Observations météorologiques faites en 1899 et en 1900 à la Baie de Treurenberg, Spitzberg. — Missions Scientifiques pour la mesure d'un arc de méridien au Spitzberg entreprises en 1899—1902 sous les auspices des gouvernements suédois et russe. Mission suédoise, Tome II, Sect. VIII, A, Stockholm 1904.

very considerably during February and March. It is thus only necessary for there to be no great fall of snow during a comparatively short time after the freezing for an expansion of the ice surface to take place.

From the above argument it will easily be seen that the phenomena described above can attain far greater dimensions in great parts of Asia and North America than in Sweden. The small lakes in Wisconsin where BUCKLEY made his investigations are situated about 15 degrees of latitude more south than Lake Sommen in Sweden and in an enormously greater continent; it is therefore natural that as the winter is about equally cold in both places, the ice movements due to variations in temperature will attain far greater dimensions in Wisconsin than in Sweden.

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14. Über die spätquartäre Geschichte der Küstengegenden Östergötlands und Smålands.

Von

U. Sundelin.

(Hierzu Pl. X.)

Vorwort.

Der nachfolgende Aufsatz ist eine Zusammenfassung der wichtigsten Resultate einer grösseren Arbeit, die seit einiger Zeit druckfertig vorliegt, deren Veröffentlichung aber wegen der gegenwärtigen hohen Druckkosten vorläufig aufgeschoben werden muss.

Wenn jemand, der sich für die hier erörterten Probleme interessiert, Näheres über die Spezialbehandlung betreffs des einen oder anderen hier angeführten Lokals (vgl. die Übersichtskarte mit dazugehörigen Erklärungen) zu wissen wünscht, stehe ich indessen gern zu Diensten.

Meine Untersuchung umfasst hauptsächlich die von den Ancylus- und Litorinameeren bedeckten Teile Östergötlands und Smålands von der Gegend Linköpings und Söderköpings im Norden bis zu der Kalmargegend 20 Meilen südlich davon.

Die Feldarbeiten, die durch Unterstützungen der Geologischen Landesanstalt Schwedens und der Stipendienfonds Bjurzons und Liljewalchs ermöglicht worden sind, wurden im Sommer 1914 begonnen und grösstenteils im Spätsommer 1915 und 1916 zu Ende geführt, obwohl auch in den Sommern 1917 und 1918 Ergänzungen gemacht wurden.

Professor H. MUNTHE hat mir liebenswürdig erlaubt, eine von ihm angefertigte, vorher nicht veröffentlichte Karte der grössten Ausbreitung des Ancylussees und der Isobasen der Ancylusgrenze in Östergötland und Småland zu publizieren.[1] Dr. phil. ASTRID CLEVE-EULER hat gütigst eine grössere Anzahl Diatomeenpräparate bestimmt. Kand. phil. CARL MALMSTRÖM hat sich die Mühe gegeben, mein Material von *Trapa natans* zu untersuchen und einige schwerbestimmbare Pflanzenreste zu bestimmen.

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[1] Auf dieser Karte habe ich auch die untersuchten Lokale und die Isobasen der Clypeus-(Litorina-)grenze, hauptsächlich nach meinen Bestimmungen, ausgezeichnet.