ON SOME ICE-DAMMED LAKES IN THE FREDERIKSHÅB DISTRICT, SOUTH-WEST GREENLAND

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Three ice-dammed lakes in the Frederikshåb district which periodically empty by subglacial drainage are described. All available observations of their water levels and time of drainage are recorded. Two of the lakes drain regularly, annually. The third lake drains at two to three year intervals. Drainage of two of the lakes appears to be initiated by hydrostatic uplift of the ice dam, and in the case of the third lake plastic flow at the base of the ice dam may also be a contributary factor. Various aspects of the drainage of ice-dammed lakes are discussed.

Ice-dammed lakes are of common occurrence at or near the margins of ice sheets and glaciers. According to their mode of run-off Weidick has distinguished three categories of lakes (Weidick, 1963, p. 112): those with superglacial or englacial run-off; those which drain across thresholds to other valley systems; and those which empty or drain suddenly by subglacial outbursts. Marcus (1960) notes eight types of lakes of the third category on or in ice, or ice-dammed, which drain periodically. Their drainage may last from a few hours to several days and may cause severe flooding. After emptying, or draining to a certain level, such lakes slowly refill during a period of one to several years. When the water level once more attains its critical height sudden drainage recurs. Lakes of this type have been described from Greenland (Fabricius, 1788; Rink, 1862; Weidick, 1959, 1963; Helk, 1966), Canada (Kerr, 1934; Marcus, 1960), Iceland (Thorarinsson, 1953), Norway (Liestöl, 1956; Howarth, 1968), Alaska (Stone, 1963; Lindsay, 1966), the Andes (Nichols & Miller, 1952) and the Alps (Dyson, 1963, p. 81).

In the Frederikshåb district of South-West Greenland a number of ice-dammed lakes occur along the margin of the Inland Ice. Of these several drain periodically, and the three examples for which most observations are available form the subject of this paper (fig. 1). The northernmost of these lakes, Imaersartoq, is quite well known. Tordensø and the temporary lake in North Midternæs have not previously been described. Information on these lakes has been gleaned from examination of all available aerial photographs of the region, and from observations by geologists of the Geological Survey of Greenland (Grønlands Geologiske Undersøgelse = GGU) who were engaged in the systematic geological mapping of the Frederikshåb region between 1963 and 1968.

Imaersartoq

The lake Imaersartoq is situated on the south side of Sermilik Bræ and 15 km east of the glacier front. Imaersartoq is bounded to the north by a large nunatak, to the east and west by glaciers whose surfaces rise in altitude away from the lake, and to the south by the mainland. About 3 km west of Imaersartoq a second smaller ice-dammed lake occurs at the margin of the glacier (fig. 2). This second lake has a considerably larger catchment area than Imaersartoq and is fed by much larger visible rivers (plate 1). Both lakes have at any specified time much the same water level and it seems certain that they are connected beneath the glacier which separates them; a large part of this glacier is afloat at high water levels (fig. 3). The periodic, simultaneous drainage of both these lakes is presumed to take place beneath the glacier north-west of the lakes.

Sermilik Bræ is the most productive glacier in the Frederikshåb district (Weidick, 1959). It calves into the fjord Sermilik which is over 37 km in length. The settlement of Narssalik is situated a short distance beyond the mouth of Sermilik (fig. 1), and periodic ice-congestion in the neighbourhood of Narssalik and Neria was at a very early period linked to the drainage of Imaersartoq. Like many Greenlandic names Imaersartoq is descriptive and may be translated as "that which is customarily emptied of its contents" (Schulz-Lorentzen, 1927).

Otto Fabricius was in the Frederikshåb area from 1768 to 1773, and in the last 3 to 4 years of his stay spent much of his time at and around the small settlement of Iluilârssuk a few kilometres north-west of the mouth of Sermilik. His description of the manner in which water drains from fresh-water lakes in the Inland Ice, and sweeps the ice from the fjords out to sea to form congested masses of considerable extent, very probably refers to Imaersartoq and conditions in Sermilik (Fabricius, 1788, p. 72).

Rink (1852 & 1857, 1862) noted that Sermilik frequently produced massed groups of icebergs which took up to two weeks to disperse. He also describes Imaersartoq itself (Rink, 1862) and states that at a certain time during the summer the basin fills with water, to be emptied suddenly. Two very large springs appear just in front of the calving ice edge of Sermilik Bræ and cause a commotion in the fjord. Later references to Imaersartoq include those of Charlesworth (1957) and Weidick (1959, 1963).

For convenience the main lake of Imaersartoq is referred to in this account as Imaersartoq 'A', and the smaller lake to its west as Imaersartoq 'B'.

Imaersartoq 'A' has a surface area of 4.7 km^2 at maximum water levels, and Imaersartoq 'B' an area of 2 km^2. Both figures include the area of very large numbers of floating icebergs, but not floating parts of the main glaciers. The highest water levels recorded appear to be only a few metres below the top of the clearly marked trim line which surrounds the area of the lakes (plate 1). The minimum areas of the lakes corresponding to the lowest water levels are 3.3 km^2 and 1.4 km^2 respectively. The difference between high and low water levels is about 50 m. On the basis of these figures about 285×10^6 m^3 of water is periodically emptied into Sermilik,

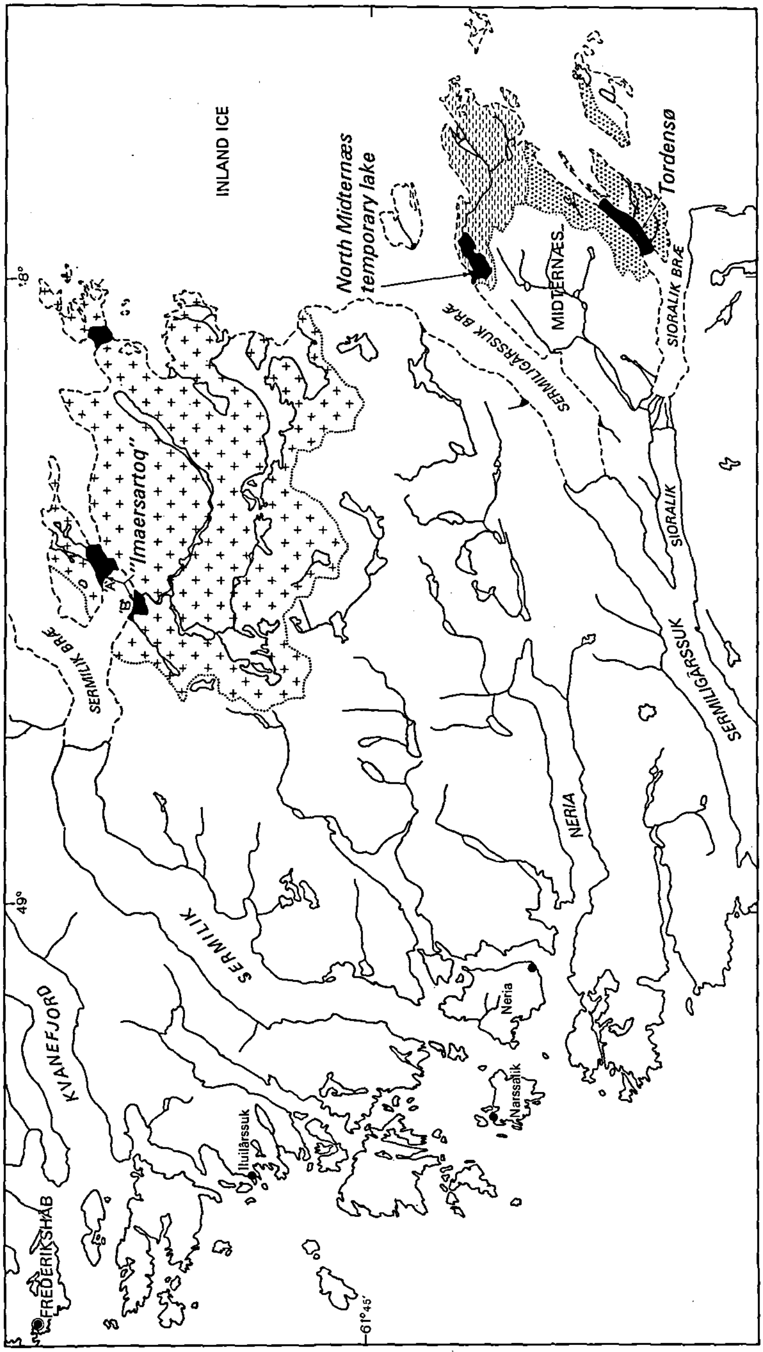

Fig. 1. Sketch map showing the ice-dammed lakes of the Frederikshåb District (in black) and the location of the three lakes described. The shaded areas are the catchment areas of the three lakes. Scale: 1 : 600,000.

but this figure does not take into account the appropriate volume of icebergs left stranded at the sides and bottom of the lake, or the considerable volume of water supporting the extensive floating parts of the main glaciers during high lake levels (fig. 3); the actual volume of water released is probably considerably greater than the figure quoted above.

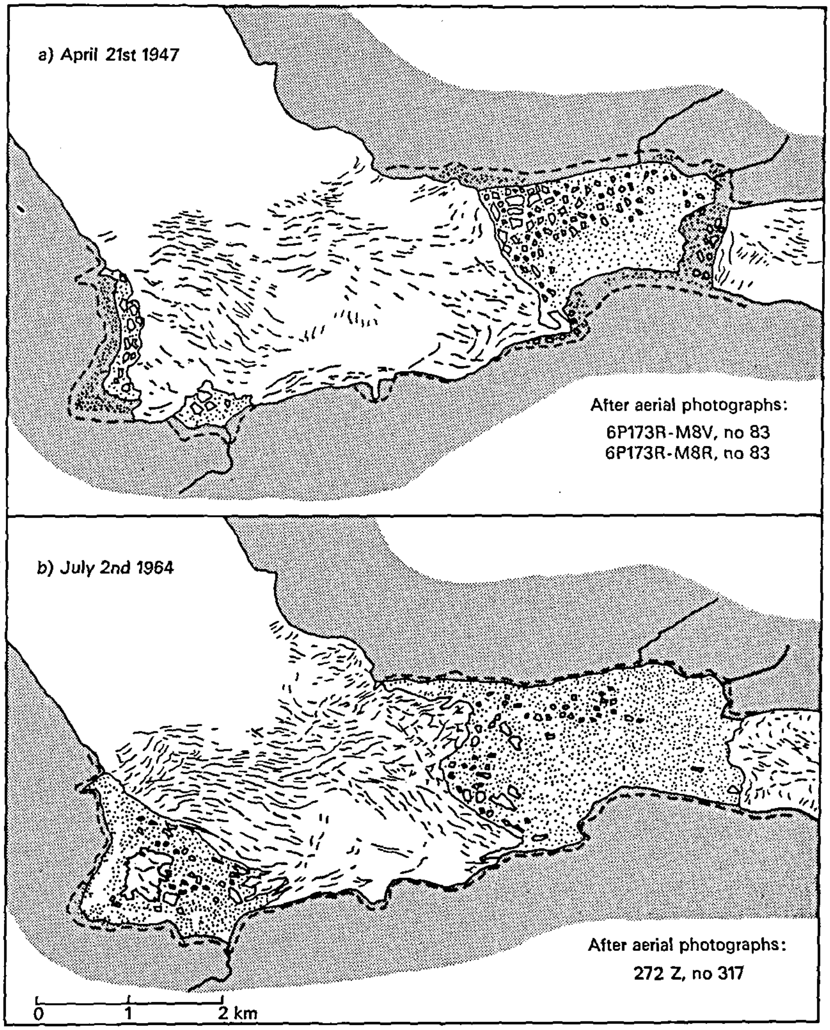

Fig. 2. *a)* Imaersartoq at a rather low level. *b)* Imaersartoq at a fairly high level. The land areas are shaded. The dashed line indicates the top of the trim line. Floating and stranded icebergs are slightly schematically indicated, the smaller icebergs by dots.

The previous accounts of Imaersartoq indicate that it empties regularly. To gain some idea of the frequency of drainage all available aerial photographs were examined, and for the years 1963–68 observations from geologists working in the vicinity of Imaersartoq and Sermilik were assembled. The information thus obtained is set out in table 1, p. 393.

To summarise, it seems certain that Imaersartoq drains regularly every year, usually in early August. Occasionally, as in 1946, it appears to have drained abnormally late, or as in 1964, somewhat earlier than usual. The release of the large volume of water into Sermilik pushes icebergs and icefloes down the fjord where they cause considerable congestion and are a hindrance to local shipping.

Imaersartoq has apparently been in existence and draining periodically for a considerable period of time; possibly as much as 200 years (Fabricius, 1788). Rink's (1862) estimate of its diameter compares well with the present dimensions of Imaersartoq 'A'. Since 1946 slight oscillations in the east glacier front position have been noted, and the shape of the broad west glacier front has varied slightly from year to year; the situations for 1947 and 1964 are presented in fig. 2.

Imaersartoq 'B' has increased its surface area dramatically between 1947 and 1964, although the change is largely a consequence of break-up of a section of floating glacier. Very extensive sections of the glacier

Fig. 3. Imaersartoq in late August 1966 from a point on the south side of lake 'A' looking westwards. The maximum level of the lake is indicated by the stranded blocks of ice beside the figure in the foreground. The heavily crevassed glacier in the left middleground floats at high water levels. Photo: H. Masson.

between the two lakes normally float at high water levels, and subside onto the lake floor at low water levels (fig. 3; plate 1).

Icebergs stranded on the lake bed after drainage may diminish in size, but mostly survive until floated off by the rise in lake level the following year. For lakes of the Imaersartoq type with annual drainage the presence of stranded icebergs does not necessarily indicate particularly recent drainage.

North Midternæs temporary lake

About 20 km north-east of the front of Sermiligârssuk Bræ and at its south side occurs the site of a temporary lake. When the outlet at the base of the glacier dam is closed the lake develops by spreading backwards to flood a sandy plain in north Midternæs. A large number of terraces at the western end of the lake testify to different lake levels (fig. 5b). At the maximum water level the area of the lake surface is about 3 km^2. Periodically it drains almost completely leaving a lake of only 0.2 km^2 area (plate 2). The glacier dam has a maximum height above the lake floor of 60 m to 70 m, and the maximum depth of water is about 50 m (fig. 5); these figures were obtained from aerial photographs by parallax bar determinations. The mean depth of the lake at high water level is about 20 to 25 m, and the approximate volume of water released at times of drainage is 70×10^6 m^3.

There are no previous descriptions of this lake. However, while Geodetic Institute maps (61 V.2 Arsuk Bræ) mark the site of the lake as a sandy plain crossed by braided streams, the lake itself is indicated on USAF Aeronautical charts (sheet 109, D II). Rink (1862) noted that large springs had been seen ahead of the calving ice-front of Sermiligârssuk Bræ and that rather far inland in the Inland Ice itself was a lake alternately filled and emptied through channels in the ice. There are a few lakes at present in the Inland Ice but none of significance in this area; there are, however, several at the margins of glaciers of which the north Midternæs lake is most important (fig. 1).

Examination of aerial photographs and geologists observations for the years 1964–67 have yielded the information presented in table 1, p. 395.

It seems very probable that the temporary north Midternæs lake develops every year, and that upon reaching a certain critical height, usually in late July, it drains. Three of the five July observations show the lake present. Two late July and all the August observations indicate no lake, but different distributions of stranded icebergs from year to year imply the lake had been present.

There have been very slight variations in the glacier front position from year to year (fig. 4) but the water outlet position has, at least since 1946, been located on the same site at the west side of the front, which is the lowest point of the ice-dam. The braided stream pattern on the lake bed alters constantly. Observations in 1966 show that the lake that year drained when several metres below the highest terrace (fig. 5a). It may be

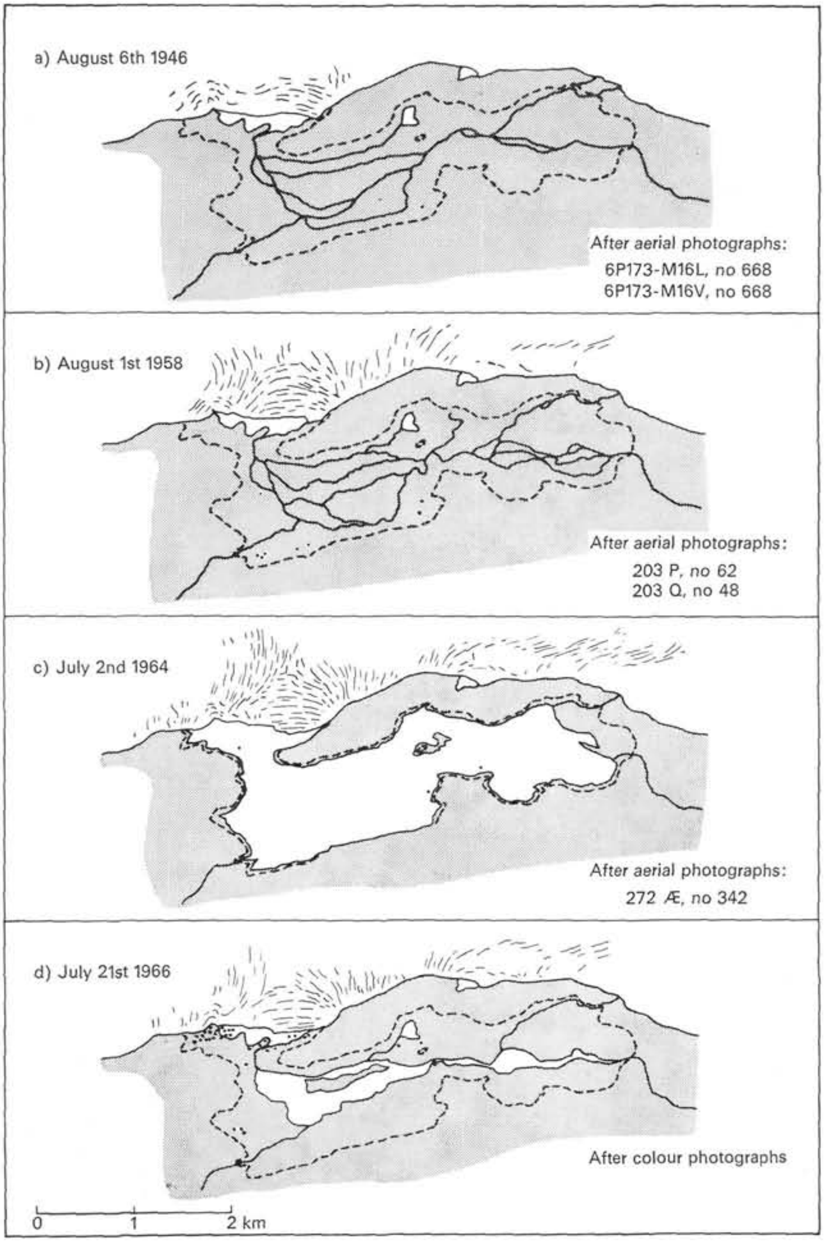

Fig. 4. Various states of the north Midternæs temporary lake. The shaded areas are land. The dashed line indicates the maximum extent of the lake. Stranded icebergs are schematically represented by dots.

a)

b)

Fig. 5. *a)* The north Midternæs lake on July 19th 1966 at its maximum water level. The highest terraces had not been reached by the rising water. *b)* The site of the lake on July 21st 1966. Note the numerous terraces.

that the critical water level varies from year to year, or that the higher terraces were formed when the glacier front was differently placed or the glacier dam higher.

There are normally few icebergs actually floating in the lake, and after drainage stranded icebergs occur in relatively small numbers usually at the west end of the lake bed (plate 2). Stranded icebergs have been noted to be present up to a month or two after drainage of the lake.

Tordensø

Tordensø is situated about 15 km east of the front of Sioralik Bræ between the mainland of Midternæs and a large nunatak. Glaciers dam the lake at the east and west ends, their surfaces rising in altitude away from the lake (plate 3). Its situation is comparable in many respects to Imaersartoq.

Tordensø has not been previously described, but on 1:250,000 topographical maps (sheet 61 V.2 Arsuk Bræ) the Geodetic Institute has recorded water level variations from 350 m to 460 m altitude, a difference of 110 m.

The surface area of Tordensø at highest water levels is about 4.8 km², and at the lowest water levels about 2.8 km². The maximum difference in levels was estimated from photographs and personal observations at 160 m, or 50 m more than indicated on the Geodetic Institute maps. The approximate volume of water released when Tordensø drains is of the order of 605×10^6 m³, a figure which does not take into account the appropriate volume of stranded icebergs, or the water which supports the floating part of the west glacier at high water levels. The lake is presumed to drain beneath the west glacier, as it does not overflow.

Observations of Tordensø water levels from all available sources are given in table 1, p. 396.

The observations indicate that Tordensø drained sometime between August 1946 and April 1947, and did not drain again until August 25th 1948: an interval of 16 months to 2 years. For the years 1949 to 1963 information is scanty. Tordensø also drained sometime between August 1964 and August 1965, and then not until early August 1967: an interval of 2 to 3 years. It is inferred that Tordensø probably empties regularly, but at intervals of 2 years or thereabouts.

The shape and size of Tordensø have not changed to any great extent since 1947 (fig. 6). There has been appreciable shrinkage of the eastern glaciers, but the glacier front position has altered very little. Large sections of the west glacier appear to break off quite commonly when the lake is at a high level and the glacier afloat; subsequently these sections break up into numerous smaller icebergs. The frontal position of the west glacier has, however, remained fairly stable, indicating that movement of the glacier approximately keeps pace with wastage.

A large proportion of the many icebergs stranded on the lake bed and sides at times of drainage survive until picked up by the next rise in water level.

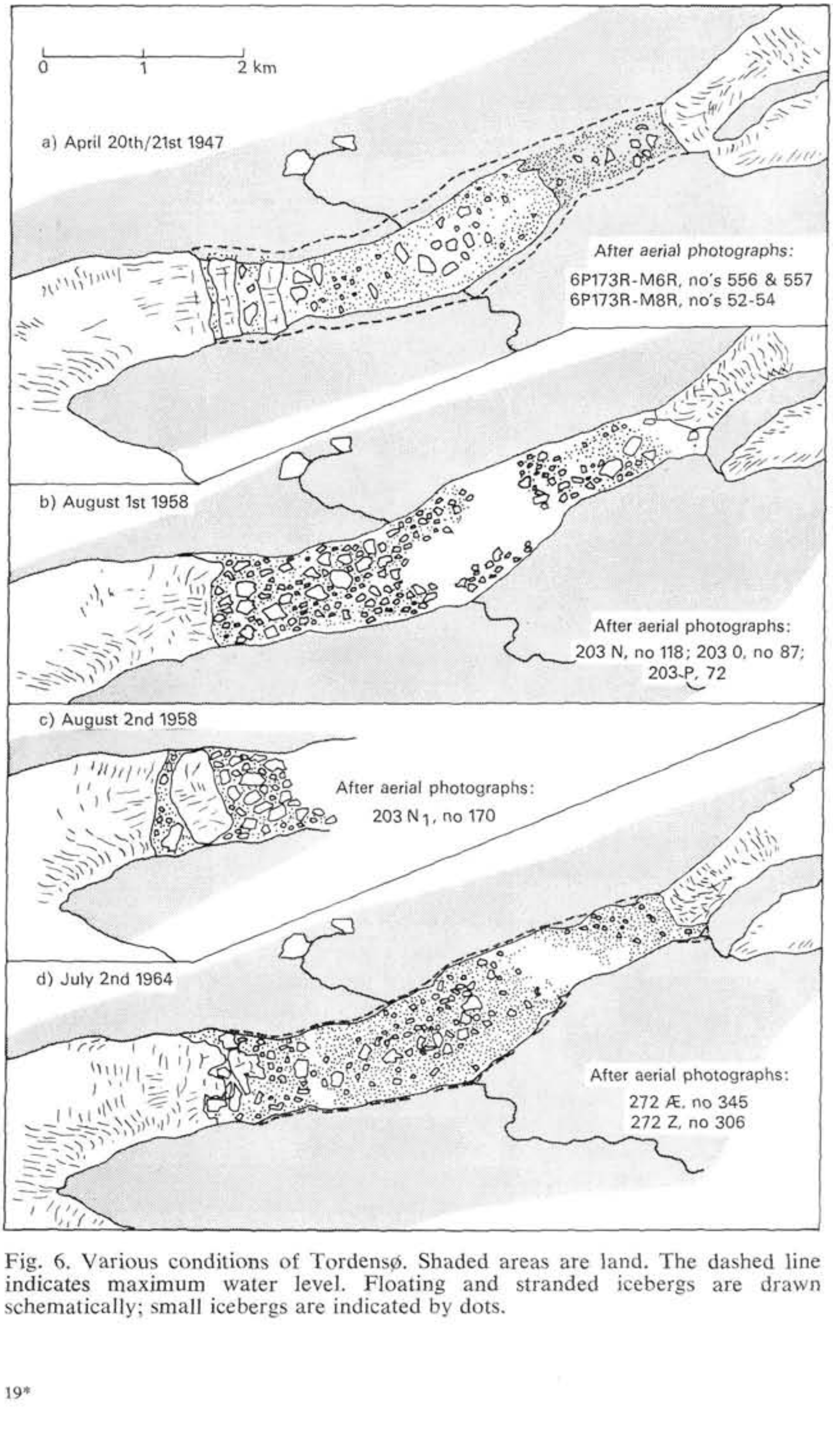

Fig. 6. Various conditions of Tordensø. Shaded areas are land. The dashed line indicates maximum water level. Floating and stranded icebergs are drawn schematically; small icebergs are indicated by dots.

Discussion

Many explanations have been put forward to explain the periodic drainage of ice-dammed lakes. Fabricius (1788) supposed that the openings of fresh water lakes in the Inland Ice were blocked by floating icebergs, the water level then rising until the block was broken down. Rink (1862) considered Imaersartoq to empty suddenly by lifting the ice barrier when it was full, and another lake in the Inland Ice in the vicinity of Sermiligârssuk Bræ he describes as filling and emptying through channels in the ice. Kerr (1934) thought that Tulsequah (Talsekwe) Lake, British Columbia, overflowed when it reached a certain level, and he envisaged an escape tunnel in the ice usually blocked after drainage by icebergs, which periodically opened by the breaking away of an iceberg permitting the water to escape. Marcus (1960), however, described Tulsequah Lake to fill until capable of floating its ice barrier whereupon the water escaped through subsurface pipes left partly open from the previous years outburst. For Grimsvötn, Iceland, Thorarinsson (1953) concluded that the water was released when the water level reached nine-tenths of the height of the ice dam and lifted it. Liestöl (1956) considered that water penetrated and escaped through small cavities under the ice opened up by movement of a glacier over an irregular surface, the cavities being rapidly widened by melting once flow had been established; Marcus (1960) also considers the latter process important. Glen (1954) reasoned that plastic flow in ice would occur when the water pressure at the lowest point of a lake exceeded the corresponding ice pressure, an effect expected to come into play at depths of 150 to 200 m; it was predicted that the water would rapidly dig itself a tunnel beneath the glacier and the lake suddenly empty. Weidick (1963) noted that a number of present and former ice-dammed lakes in the Narssarsuaq region of South Greenland had similar depths of 120 to 150 m, and suggested that this might point to a uniformity of their drainage mechanism most adequately explained by accepting Glen's theory of outbursts. Lindsay (1966) observed that 94 % of the ice cliff of a lake beside the Casement Glacier, Alaska, was covered by water before the ice barrier was lifted allowing the water to escape. Howarth (1968) noted that the lake at Tunsbergdalsbreen, Norway, lifted a section of the glacier prior to the escape of its waters in 1962. Lake George, Alaska, overflows each summer according to Dyson (1963 p. 78) and cuts a channel between the glacier edge and the valley side which rapidly deepens so that the lake is drained; movement of the glacier closes the channel each winter.

The water level variations of Imaersartoq and the north Midternæs Lake being only of the order of 50 to 60 m cannot be explained simply in terms of plastic flow. Imaersartoq supports at high water levels extensive sections of floating heavily crevassed glacier which at low water levels subside onto the lake floor. It may be that drainage of Imaersartoq is initiated when a section of the glacier normally in contact with the glacier bed becomes buoyant. The criticisms of hydrostatic uplift that drainage will cease as soon as the glacier regains contact with the glacier floor and that it is unlikely that several kilometers of glacier could be floated at once may not be relevant if, as Marcus (1960) envisages, hydrostatic uplift merely triggers the initial escape of water.

The north Midternæs lake drained in 1966 when the water depth above the outlet was about 50 m (fig. 5a). The effective hydrostatic head may be somewhat greater than 50 m depending upon the depth in the glacier at which the drainage outlet was sealed. The day prior to drainage a large section of the glacier front broke away into the lake suggesting that hydrostatic uplift had begun to take effect. It is quite evident that the amount of uplift this rather small lake could exert upon the great bulk of the Sermiligârssuk Bræ must be extremely small and limited to the margin of the glacier, yet it appears it may have been sufficient to initiate drainage. The rate of drainage was at first slow, but increased rapidly towards the end of the drainage period. The outlet tunnel beneath the glacier dam occurs at the lowest point of the dam and has occupied the same site at least since 1946 (fig. 4 and plate 2).

After the north Midternæs lake has drained the natural overflow of water from the remaining small lake is sufficient to maintain the drainage outlet open for the remainder of the summer. It would appear that the tendency for the outlet to close by plastic creep is during the summer balanced by the melting of ice by heat transfer from the flowing water. Marcus (1960) also noted that the escape channels of the Tulsequah glacier remained open following drainage in 1958, and it seems likely that this may be the general case for ice-dammed lakes. If the outlet channels in an ice barrier close only at the onset of winter when rivers cease to flow and lakes freeze and there is no longer anything to counter the tendency for channels to close by plastic creep in the ice, it becomes easy to understand why so many lakes drain only once a year and do so at about the same date each year. It seems unlikely that icebergs contribute significantly to the blocking of drainage outlets as supposed by Fabricius (1788), Kerr (1934) and Marcus (1960).

It would seem that the drainage of a large number of ice-dammed lakes is initiated by the lifting of the edge of the ice barrier, but there remains the problem of explaining the passage of the escaping water through the often extensive part of the glacier which was not lifted up. It seems likely that in many instances the escaping water breaks into part of the existing ground water system within a glacier (*cf.* Marcus 1960). It also seems reasonable to suppose that crevices opened up by movement of the glacier along an irregular floor, or opened up beneath or within the ice barrier at the time of hydrostatic uplift, will be widened by melting due to the passage of water (Liestöl, 1956; Marcus, 1960). However, should the glacier barrier be essentially impervious, and Mathews (1964) considers that except in their shallower and marginal parts this may be the case, it is difficult to envisage the drainage of some lakes without invoking plastic flow in the manner predicted by Glen (1954). In lakes such as Tordensø, which has a water level variation of up to 160 m, plastic flow at the base of the ice dam may contribute to drainage. In lakes of lesser depth hydrostatic uplift may initiate drainage by permitting percolation of water to depths in the glacier such that the increased head of water could lead to plastic flow and the excavation of an escape channel.

The extent and nature of ground water systems within glaciers is little known but is probably very complex and subject to constant change. It has been noted that the water escaping from Tordensø on August 25th 1948 emerged at the front of Sioralik Bræ at several different points (plate 4), and similar observations were made by Marcus (1960) at the front of the Tulsequah Glacier. Mathews (1964) considers the South Leduc Glacier, British Columbia, to be essentially impervious except in the shallower and marginal parts, whereas Dewart (1966) investigating the Kaskawalsh Glacier received the impression that the free ground water system may be very deep. Dewart also notes that the surface drainage changes significantly from year to year and a consequent change in the internal drainage pattern may be inferred. The opening and closing of crevasses accompanying glacier movement will also have profound effects on the ground water system.

It may be speculated that the unusual oscillations in water level of an ice-dammed lake beside the Casement Glacier in Alaska recorded by Lindsay (1966) after its initial drainage by floating of its ice dam might be a consequence of a link up with the ground water system of the glacier. They may be compared to the water level variations in the Granduc Mine, British Columbia, described by Mathews (1964), which followed the establishment of a hydraulic connection with free water in the upper layers of the neighbouring South Leduc Glacier.

It is a remarkable feature of ice-dammed lakes that at the onset of winter the escape channels in the ice barrier become completely sealed, presumably by plastic flow, so that the lake reforms each succeeding summer. It would be surprising if the internal drainage system within the glacier was not profoundly modified by the same processes, and it is perhaps unlikely that remnant escape channels in a glacier are generally re-used in successive seasons as suggested by Marcus (1960) for the Tulsequah Lake drainage through the Tulsequah Glacier.

The length of time for a lake to fill to its critical level is clearly dependent upon such factors as the dimensions of the reservoir, the catchment area, ablation, precipitation and general climatic conditions. The date of emptying of annually drained lakes might be expected to be sensitive to climatic variations, and Marcus (1960) has linked the unusually early drainage of Tulsequah Lake in 1958 with a warm winter and spring, and unusually late drainage in 1955 with heavy snow and late melting. The abnormal late drainage of Imaersartoq in 1946 can be correlated with exceptionally cold July temperatures throughout West Greenland (Annual Reports of the Meteorological Institute, Copenhagen) and its early drainage in 1964 is probably also linked to climatic conditions.

While many lakes such as Imaersartoq and the north Midternæs lake empty annually, others such as Tordensø take 2 or 3 years to fill to their critical level. Helk (1966) has described a lake (Iluliagdlup tasia) 75 km north-east of Sukkertoppen, West Greenland which emptied about every 6th year; Koch & Wegener (1930 p. 383) reported a lake near Jakobshavn Isbræ with about 10 years between discharges; and Freuchen (1915) estimated that Nyeboes Randsø in North Greenland emptied at about 25 year intervals.

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Dansk sammendrag

Tre isdæmmede søer i Frederikshåb distriktet tømmes periodisk ved subglacial tapning. Samtlige forhåndenværende observationer af søernes vandstandsniveauer og tidspunkter for tapning er anført. To af søerne tømmes regelmæssigt én gang om året, mens den tredie tømmes hvert andet eller tredie år. Tapningen af de to af søerne synes at blive sat igang af hydrostatisk hævning af den opdæmmede is; for den tredie søs vedkommende kan plastisk flydning nederst i isen være en medvirkende faktor. Forskellige aspekter af tapningen af isdæmmede søer diskuteres.

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Plate 1. Imaersartoq on July 26th 1948. Both lakes are at fairly high levels. Large sections of glacier have broken away and are afloat in lake 'B'. The rivers in the left foreground drain into lake 'B', the smaller of the two lakes. Aerial photograph: 504 D1-N, no 4005. Copyright Geodetic Institute.

Plate 2. The site of the north Midternæs temporary lake on August 25th 1948, looking southwards. The former extent of the lake may be appreciated from thedistribution of stranded icebergs. The lake drains beneath Sermiligârssuk Bræ through the outlet visible in the right foreground. Aerial photograph: 504 C2-S,no 6577. Copyright Geodetic Institute.

Plate 3. Tordensø at a low level on August 25th 1948, and probably still in the process of draining. At the east (right) end of the lake, large icebergs are stranded on the lake bed. Parts of the west glacier which float at high levels rest aground in the shallow lake. The maximum water level is clearly marked by a deposit of rock flour. Aerial photograph: 504 B2-N, no 6598. Copyright Geodetic Institute.

Plate 4. Sioralik Bræ and the fjord Sioralik on August 25th 1948. A large volume of water presumably emanating from Tordensø can be seen emerging from several points (arrowed) at the front of Sioralik Bræ. Cloudy water normally discolours the water in the fjord for a few hundred metres, but on this date could be traced 25 km down the fjord. Aerial photograph: 504 B2-N, no 6605. Copyright Geodetic Institute.

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Table 1. Imaersartoq

Year	Date	Observations	Source
1942	July 24th	Lake 'A' moderately high but well below the trim line. Dense concentrations of ice in inner Sermilik, and scattered ice further out and around Narssalik.	Air-photos: B39R, no 127; B39L, no's 121 & 122.
1943(?)	–	Undated photographs show lake 'B' at the highest level noted, a few metres below the trim line; a large segment of adjacent glacier was afloat.	Air-photos: A49A, no's 28 & 29.
1946	Aug. 6th	Lake 'A' and 'B' both at a rather low level, but dense concentrations of ice in inner Sermilik suggest that the lakes had not emptied during the year. Stranded icebergs were aground at the margins of the lakes and in the shallow water at the east end of lake 'A'.	Air-photos: 6P173–M16L, no's 365 & 366; 6P173–M16V, no's 468–470; 6P173–M16R, no 617.
1947	April 20th & 21st	Lake 'A' and 'B' at a lower level than in August 1946, estimated using a parallax bar at 50 m below the trim line, and with a greater number of stranded icebergs at the lake margins. The lakes appear to have filled and drained between August 1946 and April 1947, and this impression is supported by the observation that Sermilik on the latter date was clear of ice except for local patches of winter ice. Broad expanses of lake bed were exposed in the April photographs particularly at the east and south margins of lake 'A'.	Air-photos: 6P173R–M6R, no's 365 & 366; 6P173R–M8R, no's 82, 83 & 86; 6P173R–M8V, no's 82 & 83; 6P173R–M8L, no's 82 & 83.
	July 6th	Large numbers of icebergs accumulated in the inner part of Sermilik and cemented by winter ice.	Air-photos: 503 B–Ø, no 545.
	July 16th	Both lake levels at a moderate height, but well below the trim line.	Air-photos: 503 E–V, no's 36000 & 36001.
1948	June 9th	Lakes 'A' and 'B' both at a fairly low level and bordered by exposed lake bed. Densely packed ice in Sermilik.	Air-photos: 503 C–Ø, no 61.
	July 23rd	Much ice present in inner Sermilik, but only scattered ice in outer Sermilik. and around Narssalik.	Air-photos: 503 B1–Ø, no 26049.
	July 26th	Both lake levels fairly high (plate 1).	Air-photos: 504 D1–N, no's 4002 –4007.
1955	Aug. 10th	The inhabitants of Narssalik stated that there was still winter ice between the icebergs in Sermilik, and that Sermilik had not yet produced in its customary manner.	Weidick (1959) p. 111.
1963	July 20th to 25th	M/S Steenstrup encountered difficulties with densely packed icebergs in the vicinity of Narssalik and Neria on the 25th, whereas no difficulties were recorded	Logbook of M/S Steenstrup; Diaries of W. S. Watt and

Year	Date	Observations	Source
		on the 20th. The onset of bad ice conditions between these dates probably coincided with the emptying of Imaersartoq.	S. B. Jensen.
1964	July 2nd	The lakes were at a fairly high level estimated with the parallax bar at 20 m below the trim line (fig. 2b). Inner Sermilik was filled by icebergs and winter ice, and scattered icebergs were present in outer Sermilik.	Air-photos: 272 Z, no 317; 272 X, no 13; 272 V, no 82.
	July 8th to 10th	Navigational difficulties due to dense ice were encountered around Narssalik and Neria during this period, but not earlier in the season. It seems probable that Imaersartoq drained between 2nd and 8th July.	Logbook of M/S Steenstrup.
	Aug. 6th to 9th	Scattered icebergs were present in outer Sermilik and around Neria, but presented no difficulty to navigation.	Pers. comm. J. D. Friderichsen; Photos by N. Henriksen.
1965	c. July 4th	Both lakes at a moderate height with numerous stranded icebergs on the lake bed to within a few metres of the trim line. Dense winter ice in inner Sermilik, and more scattered ice in the outer parts.	Photos by H. Masson.
	July 17th	Water level quite high, perhaps about the same as on July 2nd 1964 (air-photos).	Photos by H. Masson.
	Aug. 4th to 8th	Distant photographs suggest a very high level on the 4th. M/S Steenstrup experienced no difficulties in passing Narssalik and Neria on August 4th, but was delayed by dense ice in the approach to Neria on August 8th; Imaersartoq probably emptied between these dates.	Photos by H. Masson; Logbook M/S Steenstrup; Writer's observations.
1966	July 11th	Lake 'A' was at a moderately high level.	Photos by H. Masson.
	July 31st	Both lakes at rather high levels, perhaps 10 m below the trim line.	Photos by Z. Mizar.
	Aug. 5th	A spring of the order of 100 m in diameter was noted on the northern side of Sermilik in front of Sermilik Bræ. During a period of 24 to 36 hours the ice in Sermilik was pushed about 20 km down the fjord.	Pers. comm. Capt. Jan E. Hansen.
	Aug. 6th to 8th	Dense ice halted M/S Steenstrup north of Narssalik on the 6th and caused difficulties for several days.	Logbook M/S Steenstrup.
	Aug. 23rd to 31st	Photographs taken during this period show numerous stranded icebergs around both lakes and a water level about 50 m below the trim line (fig. 3); the lakes are presumed to have emptied on Aug. 5th.	Photos by H. Masson.
1967	Aug. 4th	Winter ice cementing icebergs was present at the front of Sermilik Bræ.	Writer's observations.
	Aug. 12th	Massive movement of the ice down the Sermilik was noted together with the emergence of a large volume of water at the glacier snout, the glacier calving	Pers. comm. J. Andrews.

Year	Date	Observations	Source
		heavily where the water emerged. To judge from the noise the process continued for at least a couple af days. These events were presumed to be caused by the drainage of Imaersartoq.	
1968	Aug. 4th to 9th	Dense winter ice was present in Sermilik on the 4th, clear water patches among the ice on the 7th, and on the 9th clear water extended for 1.5 km in front of Sermilik Bræ. The latter observation could be significant and might indicate that Imaersartoq had begun to empty.	Pers. comm. A. Arnold and M. Ryan.

North Midternæs temporary lake

Year	Date	Observations	Source
1942	July 24th	Lake appears to have drained.	Air-photos: B39L, no's 134 & 135.
1946	Aug. 6th	The lake had drained, but a few pieces of stranded ice were present at the margins of the lake bed (fig. 4a).	Air-photos: 6P173–M16V, no 668; 6P173–M16L, no 668.
1947	April 20th	The lake bed was dry except for a thin cover of snow; the lake had presumably not yet begun to develop.	Air-photos: 6P173R–M6R, no 550.
	July 6th & 16th	Water level was moderately high on the 6th and perceptibly higher by the 16th.	Air-photos: 503 C–Ø, no 35596; 503 E–V, no's 36018 & 36019.
1948	July 23rd	The lake drained probably shortly prior to this date. A conspicuous deposit of rock flour marks the highest water level. Large numbers of icebergs occur near the lake margins and around the outlet.	Air-photos: 504 C1–S, no 8240.
	Aug. 25th	The rock flour deposit was by now much less conspicuous, and many of the icebergs had melted (plate 2).	Air-photos: 504 C2–S, no 6577.
1958	Aug. 1st	The lake had drained previous to this date; a few stranded icebergs were present on the lake bed (fig. 4b).	Air-photos: 203 P, no's 62–64; 203 Q, no 48.

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1960	Aug. 16th	No lake, but a few stranded icebergs present on the lake bed.	GGU helicopter photos: no 1134 (Midternæs).
1964	July 2nd	Water level fairly high (fig. 4c).	Air-photos: 272 Æ, no 342.
1965	Aug. 19th	Lake bed empty.	Writer's observations.
1966	July 7th to 22nd	Water level rose steadily until July 19th when the highest level was reached, but this was still several metres below the highest terrace (fig. 5a). A several hundred metre long section of glacier on the east side of the front had broken off into the lake on the 19th. At 09.30 on the 20th the lake level had dropped 1 m from its maximum, by 16.30 about 3 m and at 20.00 about 6–8 m. Between midnight and 01.30 on the 21st continuous calving at the ice dame was heard, but fog prevented observations until 03.00 when the empty lake bed became visible (fig. 5b). Numerous icebergs were left stranded at the lake margins and especially at the glacier front (fig. 4d; cf. plate 2). Intermittent calving of the glacier continued during the 21st and 22nd.	Writer's observations.
1967	Aug. 4th	A few stranded icebergs were present on the empty lake bed.	Writer's observations.

Tordensø

Year	Date	Observations	Source
1942	July 24th	Rather distant photographs indicate that Tordensø was at a moderate level.	Air-photos: B39L, no's 140 & 141.
1946	Aug. 6th	Lake at a very high level with several large sections of the floating termination of the west glacier broken away into the lake.	Air-photos: 6P173–M16L, no 661.
1947	April 20th & 21st	Lake at a very low level. Large numbers of stranded icebergs rest on a 2 km stretch of lake bed at the east end. Two large separated sections of the west glacier rest partly aground in the relatively shallow west end of the lake, their relative positions being as on the 1946 photographs. The drop in water level compared to August 1946 was estimated at 130 to 140 m.	Air-photos: 6P173–M6R, no's 556 & 557; 6P173R–M8R, no's 51–55.

Year	Date	Observations	Source
	July 6th & 16th	Photographs of both dates indicate a discernable rise in water level since April.	Air-photos: 503 C–Ø, no's 35594 & 35595; 503 E–V, no's 36021 & 36022.
1948	July 23rd & 25th	Lake level very high.	Air-photos: 503 B1–Ø, no 26068; 504 C1–S, no 8237.
	Aug. 25th	Water level very low, about the same as April 1947, and the lake apparently in the process of emptying. Several sections of the west glacier have broken away and rest aground in the shallow lake. Deposits of rock flour clearly mark the old water level (plate 3). At the south side of the front of Sioralik Bræ 15 km west of Tordensø a large volume of water issues from the glacier where normally an insignificant stream is found (plate 4); this water almost certainly stems from Tordensø. It enters the fjord Sioralik, and discolours the surface of Sioralik and part of Sermiligârssuk for 25 km.	Air-photos: 504 B1–N, no 8162; 504 B2–N, no's 6598, 6605 & 6615.
1958	Aug. 1st & 2nd	Photographs of the 1st show the lake at a very high level, probably close to the maximum (fig. 6b), and a second run on the 2nd shows that a raft of ice 1000 m by 500 m had become detached from the west glacier and drifted eastward since the 1st (fig. 6c).	Air-photos: 203 N, no 118; 203 O, no 87; 203 P, no 72; 203 N1, no 170.
1960	Aug. 16th	Tordensø was at a fairly high level.	GGU helicopter photos: no 1285 (Midternæs).
1964	July 2nd	Water level moderately high, the west glacier termination being partly afloat and in rather broken condition (fig. 6d).	Air-photos: 272 Æ, no 345; 272 Z, no 306.
	Aug. 21st	Water level not far short of its maximum.	Writer's observations.
1965	Aug. 8th	Tordensø had drained and the water level was the lowest recorded, estimated at 160 m below maximum level. Stranded icebergs rested aground at the east end of the lake bed in jumbled masses, and at the sides to within a few metres of the highest water mark.	Writer's observations.
1966	July 25th	Lake at a fairly high level.	Writer's observations.
	Aug. 20th	Discernably higher water level. A large and several small sections of the west glacier had, since July 25th, become detached and drifted eastwards.	Writer's observations.
1967	Aug. 2nd	Tordensø at a high level with sections of the west glacier separated and afloat.	Writer's observations.
	Aug. 12th	The lake was at an extremely low level, and had evidently drained since the 2nd.	Photos: K. Raunsgaard Pedersen.