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TITLE

DENSITY STRATIFIED LAKES IN NORTHERN ELLESMERE ISLAND

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(Reprinted from Nature, Vol. 225, No. 5227, pp. 55–56, January 3, 1970)

Density Stratified Lakes in Northern Ellesmere Island

The discovery of density stratification in Lake Tuborg, northern Ellesmere Island (lat. 80° 50′ N, long. 79° W)[1], alerted us to the possibility that other lakes in the area might show the same phenomenon, provided they were near enough to sea level to allow the trapping of seawater either through advance of a glacier or through postglacial rise of land. Lake Tuborg is an example of a lake that has been cut off from a fiord (Greely Fiord) by glacier advance; the radiocarbon age of the old seawater near the bottom of the lake indicates that this occurred about 3,000 yr ago[2].

In May 1969 our airborne party, based on Ward Hunt Island, investigated seven lakes near the north coast of Ellesmere Island at elevations ranging from 2·5 to 53 m above sea level. The locations of these unnamed lakes, provisionally labelled from A to G, and the streams that drain them for two months in the summer are shown in Fig. 1. Like Saelsøen in north-east Greenland[3], all the lakes are situated at the heads of fiords or arms of fiords, and are the result of glacial over-deepening followed by postglacial uplift, which would allow seawater to be trapped behind rock or moraine steps in the fiord bottom. Elevations of the lakes were determined by the Wallace and Tiernan surveying altimeter to an accuracy of ±0·3 m. At the time of our visit the lakes were covered by from 1 to 2 m of freshwater ice, which in three cases was of one winter's growth and in the remaining cases of more than one winter's growth as shown by the candled ice surface beneath the snow. Temperature and salinity measurements were made near the centre of each lake with Knudsen bottles, reversing thermometers and an automatic salinity–temperature–depth recorder, the cable of which was lowered through a hole of 0·2 m diameter in the ice made by a power auger. Table 1 summarizes relevant data on the lakes.

The results of temperature and salinity measurements in lakes A, B and C are plotted in Fig. 2. The lakes are seen to be virtually fresh in the upper 5 to 10 m, but below this depth there is a gradual rise in salinity towards the bottom. In the case of lakes A and C, the salinity reaches values of 32 and 30 parts per thousand at the bottom, which compare closely with values at similar depths in nearby fiords connected with the Arctic Ocean. We may infer from this that the saline water in the lakes is in fact old seawater, and conclude that inflowing fresh-water from spring run-off has completely replaced the seawater at the surface and diluted it for a further 30 to 40 m by a process of diffusion. The remarkable temperature distribution might lead us to expect that the lakes would be unstable, but calculated values of density for

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DENSITY STRATIFIED LAKES IN NORTHERN ELLESMERE ISLAND

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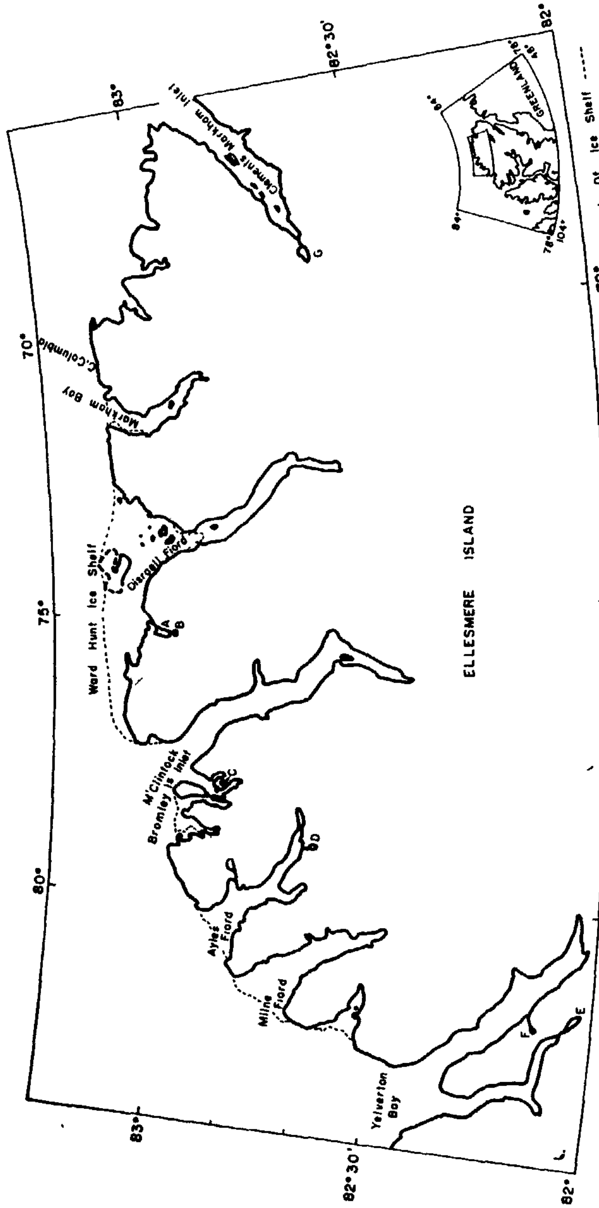

Fig. 1. Map of northern Ellesmere Island to show lakes A–G.

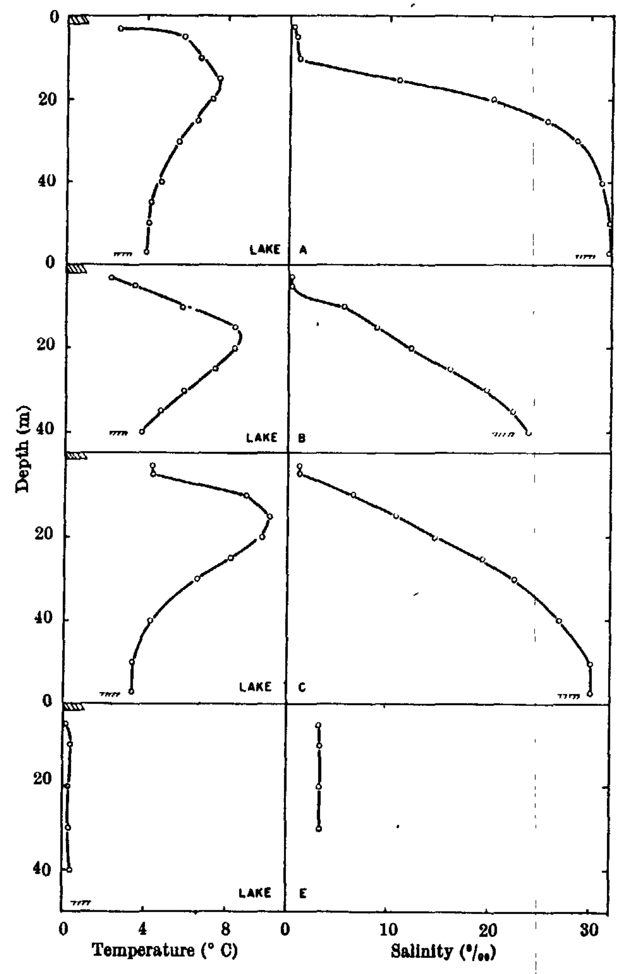

Fig. 2. Salinity and temperature versus depth for lakes A, B, C and E.

various depths show the lakes to be highly stable. In fact, the stability is controlled almost entirely by the salinity, with the temperature playing only a minor part. The most probable cause of the warm layer in these lakes is the trapping of solar radiation beneath a permanent ice cover, as Shirtcliffe and Benseman have convincingly shown to be the case in Lake Bonney, Antarctica[4]. The temperature profiles in Lake Bonney and in our three lakes are similar, with maxima occurring at depths of 10 to 15 m; in the case of lake C the maximum temperature is as high as +10·1° C. Solar heating has also been put forward as a possible explanation for the high temperature of the stratified bottom waters of Lake Vanda, Antarctica[5], and for the layer of relatively warm water lying between depths of 25 and 50 m in Tanquary

Table 1. DATA ON DENSITY STRATIFIED LAKES

	Lake A	B	C	D	E	F	G
Lake area (km²)	4·9	0·9	0 8	13	4·9	1·5	7·0
Basin area (km²)	36	5·2	4 7	54	585	23	23
Elevation (m)	3·3	23	2 3	50	3·0	53	
Depth (m)	57	40	57	33·5	47·5	33	41 5
Ice thickness (m)	2·0 (candled)	2·0 (candled)	1 6 (candled)	1·03 (winter)	1 7 (winter)	1·62 (winter)	1·5 (candled)
Temperature inversion	Yes	Yes	Yes	No	No	No	No
Salinity gradient	Yes	Yes	Yes	No	No	No	No
Stability	High	High	High	Low	Low	Low	Low

Fiord, northern Ellesmere Island[6]. But the thermal profiles in these last two situations are quite dissimilar from those in lakes A, B and C.

In lakes D, F and G the water is essentially fresh with the temperature increasing with depth from zero beneath the ice to about +4° C at the bottom. If seawater were ever present in these lakes, it has long since been flushed out by meltwater run-off. In lake E, however, the water is almost isohaline and isothermal with a salinity of 3·2 parts per thousand and a temperature of −0·8° C (Fig. 2). Because the lake has very nearly neutral stability, very little energy would be required to mix inflowing water throughout the entire depth of the lake. It seems that lake E has reached a stage in which inflowing freshwater has mixed completely with ancient seawater.

While all the lakes seem from single soundings to be of comparable depth, they show considerable ranges in lake area, basin area and elevation above sea level (Table 1). This is true even of the strongly stratified lakes A, B and C; in particular we note that lake B lies as high as 23 m above sea level. There is evidence from the north coast of Ellesmere Island that the land has risen by at least 75 m in postglacial time and by about 40 m in the past 7,200 yr (ref. 7), so that stratified lakes at higher levels than 23 m may be expected. Radiochemical analysis of the relict seawater in the lakes may provide a means of assessing the rate of land emergence over the past few thousand years. For this purpose one of us (J. E. M.) collected seawater samples from lakes A, B and C for radiocarbon ageing of the bicarbonate content. The north coast of Ellesmere Island is unique in Arctic Canada in being fringed by an ice shelf which has existed for not more than 3,000 yr (ref. 8), perhaps for a much shorter period[9]. There is thus special interest in obtaining rates of uplift in order to show what effect this had on the development of the ice shelf and on its periodic grounding to form ice rises.

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