AN ABLATION RATE FOR LAKE FRYXELL, VICTORIA LAND, ANTARCTICA

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Abstract. The average yearly net ablation rate on permanently ice-covered Lake Fryxell, Victoria Land, Antarctica, is 30 to 40 cm. This figure was calculated by a novel method utilizing a record of ablation which is incorporated in the ice cover of the lake. These values are higher than those measured on Ross Island 80 km. to the east; the difference in ablation rates for the two areas is attributed to the prevalence of katabatic winds in the climate of Taylor Valley. The Lake Fryxell ablation figure is applied to nearby Canada and Commonwealth Glaciers in the calculation of their ice budgets.

Résumé. *La vitesse d'ablation du Lake Fryxell, Victoria Land, Antarctique.* La valeur moyenne annuelle de l'ablation nette de la glace permanente qui recouvre le Lake Fryxell, Victoria Land, Antarctique, est de 30 à 40 cm. Cette valeur a été calculée par une nouvelle méthode utilisant l'enrégistrement de l'ablation qui est incorporé dans la glace du lac. Ces valeurs sont plus fortes que celles mesurées sur Ross Island 80 km à l'est; la différence de valeurs d'ablation pour les deux régions est attribuée à la prédominance des vents catabatiques dans le climat de Taylor Valley. La valeur de l'ablation du Lake Fryxell est appliquée aux proches du Canada et Commonwealth Glaciers pour le calcul de leur bilan.

Zusammenfassung. *Eisablation am Lake Fryxell, Victoria Land, Antarktika.* Die mittlere jährliche Nettoablation auf dem ständig eisbedeckten Lake Fryxell in Victoria Land, Antarktika, beträgt 30 bis 40 cm. Diese Zahl wurde mit einer neuartigen Methode bestimmt, die ein in die Eisdecke des Sees eingelassenes Ablationsmessgerät benutzt. Sie ist höher als die Werte, die 80 km weiter östlich auf der Ross Island gemessen wurden. Der Unterschied in der Ablationsgeschwindigkeit zwischen den beiden Gebieten wird auf das Vorherrschen katabatischer Winde im Klima des Taylor Valley zurückgeführt. Der Ablationswert des Lake Fryxell wird zur Berechnung des Eishaushaltes der benachbarten Canada und Commonwealth Glaciers verwendet.

Introduction

Lake Fryxell (lat. 77° 37′ S., long. 163° 7′ E.) is a permanently ice-covered lake situated in lower Taylor Valley at an altitude of 22 m. No information is available for the climate of the area, but on Ross Island 80 km. to the east the mean annual temperature is approximately −17°C. with a range of approximately 45°C. (David and Priestley, 1914; Flowers, 1958), and the total solar energy of wave-length $>3\ \mu$ falling is 93,000 cal./cm.^{2}yr. (Thompson and Macdonald, 1961).

The physiographic position of Taylor Valley modifies the climate; westerly winds descending from the polar plateau are channelled by the valley, and adiabatic heating and reduction in relative humidity result. Sections of ice core obtained by drilling through the lake ice-cover were stood vertically on its surface; periodic inspection of the cross-sectional shape of these cores showed that maximum ablation occurred during periods of westerly wind.

In November 1963 the eighth Victoria University Expedition carried out a limnological investigation of Lake Fryxell. A series of ice platforms were observed, and the measured heights between successive ice platforms were interpreted to give a measure of ablation of the lake ice.

Formation and Significance of Ice Platforms

The lake ice-cover, which varies in thickness from 3·8 to 4·5 m., is being continually replaced by accretion of ice at the ice–water interface and ablation from the surface. During summer, absorption of solar energy causes the formation of water-filled interstices within the ice column. In late summer the ice column becomes permeable by interconnection of the interstices and a water table appears at depths varying between 45 and 56 cm. below the mean surface of the ice. Interstices above the water table are then drained.

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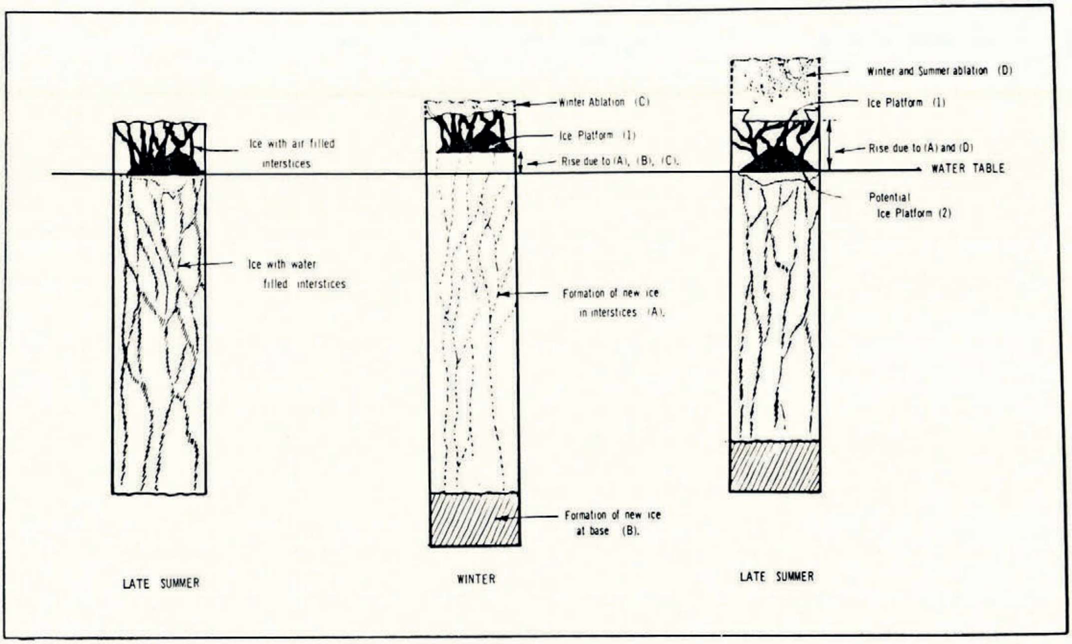

Fig. 1. Diagram showing the yearly cycle of changes within the lake ice-cover and the formation of ice platforms

Patches of wind-blown dust derived from extensive moraines surrounding the lake accumulate on the ice surface throughout the year. During summer the dust patches absorb solar energy and pass downwards to form pits similar to the dust wells described from the surface of glaciers by Charlesworth (1957, vol. 1). After a period of growth the pits intersect the level of the late summer water table.

In late summer some pits and interstices intersect the water table and during the freezing of early winter the water table in such situations is preserved as local horizontal platforms separated from the overlying ice by an air space. With subsequent surface ablation and addition of ice at the base of the column, these platforms become elevated above the level of the late summer water table and are eventually exposed at the surface (see Fig. 1). Being protected from the wind and incident radiation by the surrounding remnant sides of pits and interstices, these platforms tend to resist ablation. Three series of platforms at different heights, representing the repetition of this process in three successive yearly cycles, are preserved on Lake Fryxell; two platforms formed successively, and preserved one above the other, are illustrated in Figure 2.

If it is assumed that the thickness of the ice cover of the lake remains approximately constant from year to year, although varying cyclicly within a year, then the height difference between successive ice platforms gives a measure of ablation of the lake ice as a whole. At the end of summer the water table in the lake ice freezes. During the winter the ice as a whole rises relative to the water-level, as a result of the accretion of ice on the bottom and the ablation of ice from the surface of the ice cover. At the beginning of the summer (November 1963) the frozen water table in the surface ice of Lake Fryxell was already 19·7 cm. above the new water table (Table I). During the summer the effect of surface ablation far outweighs

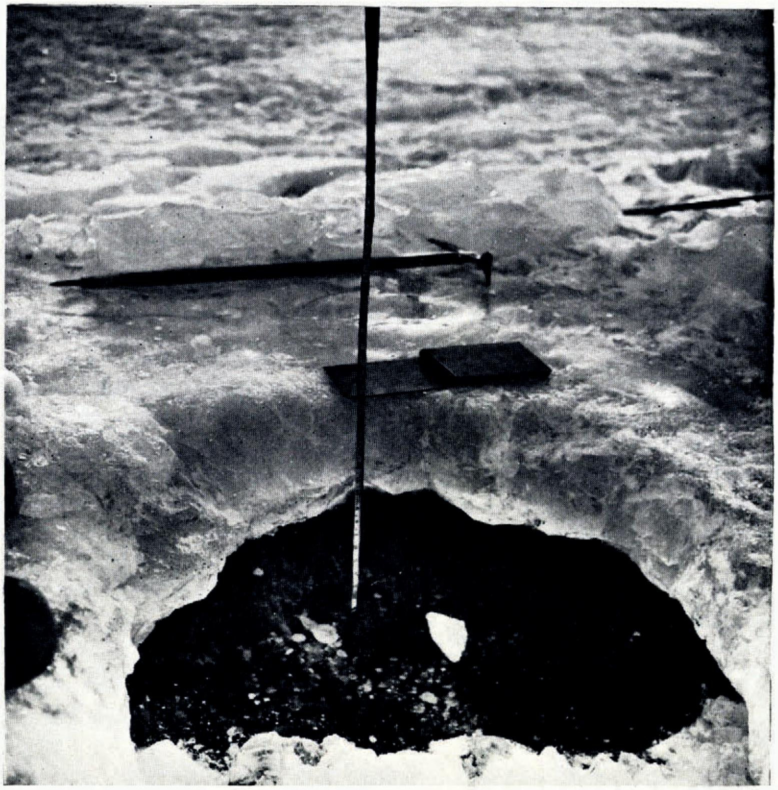

Fig. 2. Two successive ice platforms preserved one above the other. The tape measure rests on a platform of clear ice formed in 1963; the notebook and ice-axe rest on an ice platform formed in 1962

bottom melting, so that from the winter of 1962 to the winter of 1963 a total rise of 40·7 cm. had occurred. This total uplift equals the thickness of ice ablated from the surface, if it is assumed that the ice had the same thickness at the start of each winter. The assumed constancy of thickness is supported by the regularity of height differences between the three successive ice platforms and by a measurement of ice thickness in 1961–62 (Angino and others, 1962), compared with that measured in November 1963. Measured heights of the 1963 ice platforms above the water table and the height differences between the 1963, 1962 and 1961 ice platforms are given in Table I.

TABLE I

	Number of observations	*Mean value of measurements* cm.	*Standard deviation of measurements* cm.
Height of 1963 platform above water table	20	19·7	2·1
Height of 1962 platform above that of 1963 (net ablation for year 1962–63)	30	40·7	3·1
Height of 1961 platform above that for 1962 (net ablation for year 1961–62)	2	31·0	2·0

Conclusions

The results yield a mean net ablation figure of 40·7 cm. of ice for the year-long cycle terminating with the winter freeze of 1963. The mean value for the previous cycle was 31 cm. of ice. Since no precipitation figures are available for this area, gross ablation cannot be calculated, but net ablation figures are more useful for calculating glacier ice budgets. These figures are considerably higher than those given for net ablation at similar altitudes on Ross Island 80 km. to the east (David and Priestley, 1914). Estimates based on ablation measurements for most of 1903 and 1908 are given as 15·2 and 17·8 cm., respectively. The difference between ablation values for opposing sides of McMurdo Sound is attributed to the prevalence of katabatic winds in Taylor Valley.

Application to the Ice Budgets of Canada and Commonwealth Glaciers

At opposing ends of Lake Fryxell are Canada and Commonwealth Glaciers (Fig. 3); fed by firn fields situated at altitudes between 400 and 800 m. in the Asgard Range, the glaciers descend through constricted valleys to produce broad tongues on reaching the floor of Taylor Valley. The position of the snow line divides the glaciers into regions of net accumulation and net ablation. By extrapolating the net annual ablation rate measured on Lake Fryxell to the tongues of these glaciers and by assuming the tongues are neither growing nor shrinking, estimates of ice budget and rates of ice flow can be calculated. The assumed steady-state is supported by the observations of Péwé and Church (1962) and by a comparison of ice thickness at the snouts at present with those given by Taylor (1922). On Gornergletscher in Switzerland and Taku Glacier in Alaska, the increase in net ablation below the firn limit has been found to be almost proportional to the distance below the snow line (Renaud, 1952; Nielsen, 1957). If it is assumed that the same condition exists between Lake Fryxell (where an average

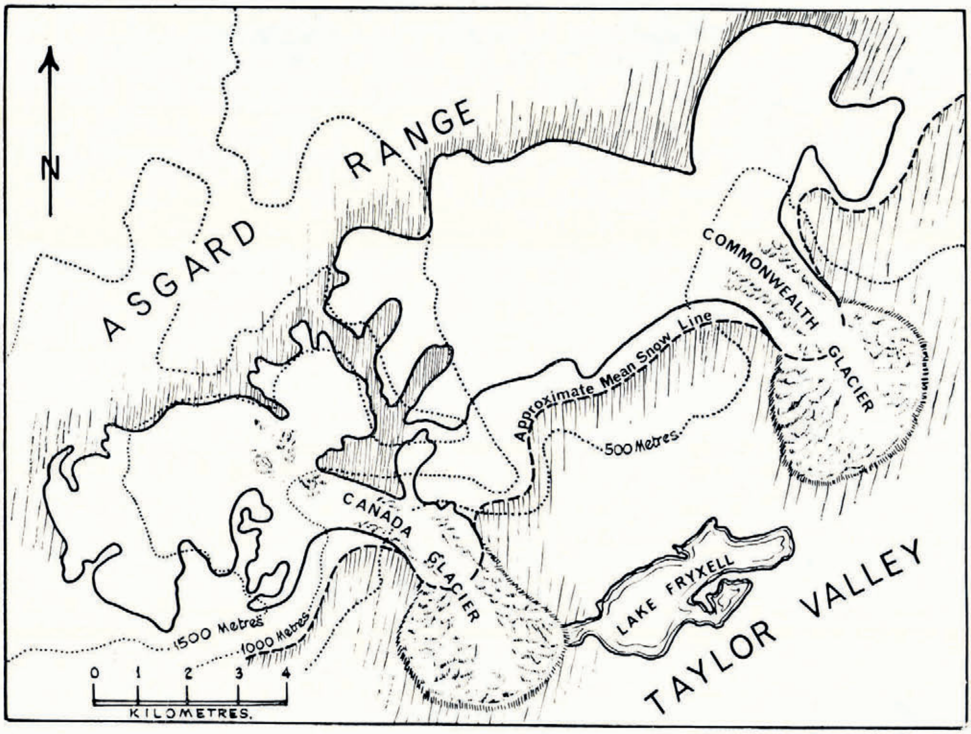

Fig. 3. Map showing the relationship of Lake Fryxell to Canada and Commonwealth Glaciers

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figure for net ablation is 36 cm.) and the snow line (where net ablation is zero), then net ablation on the snouts of Canada and Commonwealth Glaciers can be calculated by measuring the areas of the tongues between the contours at 50 m. intervals and using the interpolated ablation figures for altitudes intermediate between those of the contours.

Ice Balance for Commonwealth Glacier

If the *névé* of the glacier is defined as the area above the snow line and the tongue as that below, then the *névé* covers 46·2 km.^{2} and the tongue 7·7 km.^{2}. 0·0015 km.^{3} of ice ablate annually from the snout, so to maintain the glacier at its present size the average net ice accumulation in its *névé* is 3·3 cm. annually. The narrowest part of the valley through which the ice descends is 1·15 km. wide; assuming that the thickness of the glacier in this position is 60 m., the flow rate is approximately 21 m./yr.

Ice Balance for Canada Glacier

The area of the glacier above the snow line is 23·6 km.^{2}, while that below has an area of 6·6 km.^{2}. 0·0012 km.^{3} of ice ablate annually from the snout; to maintain the glacier at its present size, the annual average net ice accumulation in the *névé* is 5·1 cm. The most constricted part of the valley through which the glacier descends is 1·15 km. wide; assuming that the thickness of the glacier in this position is 60 m., the flow rate is approximately 17 m./yr.

The *névé* of Canada Glacier lies mainly above the 1,000 m. contour, while that of Commonwealth Glacier is mainly below (Fig. 3). This height difference explains the higher precipitation in the firn fields of Canada Glacier compared with those of Commonwealth Glacier.

It is appreciated that the values given for ablation, accumulation or ice flow of the glaciers are not necessarily exact. The purpose of the calculations is to provide estimates for approximate values for this type of alpine glacier, so common in the ice-free areas of Victoria Land, in the absence of any field measurements.

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