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OBSERVATIONS ON THE LEVEL OF A SELF-DRAINING LAKE ON THE CASEMENT GLACIER, ALASKA*

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ABSTRACT. A small ice-dammed glacial lake beside the Casement Glacier in south-eastern Alaska was observed to drain in two separate pulses during the summer of 1965. The initial discharge appears to have resulted when the ice lobe damming the lake was floated by the increasing depth of water. There is no good explanation for the second rapid discharge but it may have been due to the sudden opening of crevasses.

RÉSUMÉ. *Observations sur le niveau d'un lac se drainant lui-même au bord du glacier Casement, Alaska.* Un petit lac formé par une digue de glace sur le bord du glacier Casement dans le sud-est de l'Alaska fut observé se vidant en deux temps distincts durant l'été 1965. Le première baisse semble avoir eu lieu lorsque le lobe de glace qui barrait le lac commença à flotter à cause de la profondeur de l'eau. Nous n'avons aucune explication probable pour la deuxième baisse rapide mais il se peut qu'elle ait été produite par le développement subit de crevasses dans le glacier.

ZUSAMMENFASSUNG. *Beobachtungen über den Stand eines selbstabfliessenden Sees am Casement Glacier, Alaska.* An einem kleinen, vom Eis aufgestauten Gletschersee neben dem Casement Glacier in Südost-Alaska wurden im Laufe des Sommers 1965 zwei getrennte Entleerungen beobachtet. Der erste Abfluss scheint erfolgt zu sein, als der Eiswall, der den See aufstaute, durch die grössere Wassertiefe zum Schwimmen gebracht wurde. Für den zweiten, plötzlichen Abfluss gibt es keine eindeutige Erklärung, doch kann er durch die plötzliche Öffnung von Spalten verursacht worden sein.

DURING the summer of 1965 observations were made on the water level of a self-draining lake at the side of the Casement Glacier (Fig. 1), 130 km. north-west of Juneau in the Glacier Bay National Monument, Alaska.

The western margin of the Casement Glacier blocks the mouth of a small ice-free tributary valley, so that a large volume of water can collect there. When first observed on 22 June, the lake was full (Fig. 2), the water level being only a few meters below the lowest point of the retaining ice wall. When next observed, at noon on 8 July, the water was still at much the same level. However, by noon the following day the level had fallen 36 m., discharging about $6 \cdot 88 \times 10^6$ m.^{3} of water. Detailed observations were not made in the next 20 days, but a deep horizontal notch in the retaining glacier wall suggests that during this time the water level remained relatively constant.

On 29 July the level fell slowly (Fig. 2), 37 cm. in 24 hr. Over the next 6 days the level continued to fall at a slow but steadily increasing rate. During the night of 4–5 August the lake began to drain at an extremely rapid and ever-increasing rate, so that in the 70 or so hours to 7 p.m. on 7 August the level fell $21 \cdot 5$ m. and approximately $1 \cdot 49 \times 10^6$ m.^{3} of water were discharged. This almost emptied the lake and left many large icebergs perched on the steep valley walls. Stream-gauge records of the melt-water stream issuing from the terminus of the glacier show no evidence of either discharge. It appears that the volume discharged from the lake is so small compared to the total volume of melt water at the terminus that its effect on the stream level is negligible.

During the next 18 days the level fluctuated slightly with a net drop of $4 \cdot 3$ m. On sunny days the level fell only slowly and at times the lake began to fill. On overcast days the level fell slightly. The connection between the weather and the water level suggests that the discharge through the sub-glacial channels was relatively constant while the inflow, as melt water, varied. When the final measurement was made on 25 August, the level was still falling, about 53 cm. in 24 hr.

Aerial photographs taken by Mr. C. Janda (U.S. National Park Service, Gustavus, Alaska) on 8 November show the water level only about 7 m. below the 8 July maximum (Fig. 1).

The filling and emptying of this particular lake probably occurs at least once a year. The initial discharge in July occurred when the glacier lobe damming the lake was floated by the increasing depth of water, and the water flowed out under the glacier. (Floatation of the ice barrier as a drainage mechanism for ice-dammed lakes was suggested by Thorarinsson (1939).) To float the glacier front the water has to inundate the lower 89 per cent of the retaining ice cliff to overcome the mass of the ice, plus a further indefinite percentage to overcome the cohesion of the ice to the bedrock. With the Casement Glacier Lake the water rose to cover 94 per cent of the ice cliff. Once the discharge began the

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Fig. 1. The Casement Glacier self-draining lake partially filled on 8 November 1965. Photograph from the air looking approximately north-west with the retaining ice lobe in the foreground. (Photograph by C. Janda)

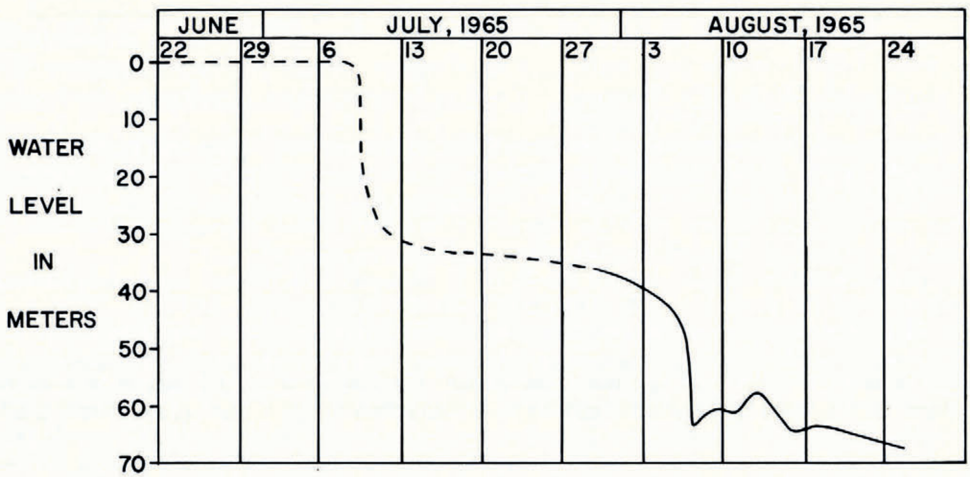

Fig. 2. Variations in the water level of the Casement Glacier self-draining lake during the summer of 1965. The level is given in meters below the 8 July maximum

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flowing water cut a channel in the ice which remained open, even when the lake could no longer float the glacier. However, eventually the depth of water and the flow decreased to a point where the channel could no longer be maintained. The actual mechanism involved in closing the channel is unknown.

Glen (1954) suggested that catastrophic emptying of an ice-dammed lake could result from an enlarging process due to water pressure. However, since the lake under study discharged in two separate pulses, this mechanism seems unlikely. The total depth of the lake is about 70 m., and as the two discharges involved even smaller depths of water, it is unlikely that the pressure differences between the ice and water would be sufficient to initiate the tunneling process. Further, if the pressure differences were sufficient, it is difficult to understand why the lake did not drain before filling to the level at which floatation could take place.

So far there is no good explanation for the rapid discharge of 5–7 August. However, since the lake occurs immediately above a large ice fall, it is possible that the discharge resulted from the sudden opening of one or more crevasses. The discharge stopped quite suddenly when the level reached a point 69 m. below the level of the glacier surface. This level may represent the local lower depth limit for open crevasses. Similarity of the rate of fall before and after the rapid discharge indicates that the subglacial drainage remained unchanged.

Again after the second rapid discharge, the lake level was largely controlled by the inflow of melt water, so that on sunny days the level remained stationary or rose, while on cloudy days it fell. The discharge carried by the subglacial channels appears to have remained relatively constant, both before and after the second rapid discharge. Drainage into the lake from the surrounding hills was negligible over this period (8–25 August), so that an estimate may be made of the subglacial discharge rate from the observed ratio of the ablation rates of the glacier on sunny and cloudy days (3·2 : 1) and the corresponding rates of change of lake volume. The volume of flow is approximately 84,000 $m.^3$ day^{-1}. Knowing the drainage rate and the ablation rate on a sunny day (14·0 cm. of ice), the minimum area draining into the lake is calculated to be about 1·25 $km.^2$.

Some time after the final measurement was taken on 25 August, the sub-glacial channels closed. The mechanism involved may be due in part to the motion of the glacier. Whether the lake drained over the winter or remained partially full until the spring thaw before draining again is not known.

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