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*Throughflow water velocities in Austre Okstindbreen, Norway*

The velocity with which melt water moves through a glacier is largely determined by the internal drainage characteristics of that glacier. Measurements of throughflow times were made in August 1977 in the ablation area of Austre Okstindbreen, the main outlet glacier of the Okstindan ice cap in Norway (lat.  $66^{\circ} 02' N.$ , long.  $14^{\circ} 19' E.$ ). Instantaneous injections of fluorescein dye were made at three sites where supraglacial streams entered moulines (Fig. 1). Largely because of problems associated with dissipation of the dye trace, only one reliable result was obtained, that being from the point furthest up-glacier at site 1. Using a straight-line distance between the injection and outflow points of 1.4 km, a throughflow velocity of  $1.8 \text{ m s}^{-1}$  was calculated. Dye was injected into the moulin at 13.40 h, a time of day when throughflow velocities may be at a maximum (Behrens and others, 1975). Less reliable estimates of throughflow velocity ranged from 0.6 to  $1.9 \text{ m s}^{-1}$  for site 2, whilst the dye trace was never sighted at the outflow point after repeated injections at site 3.

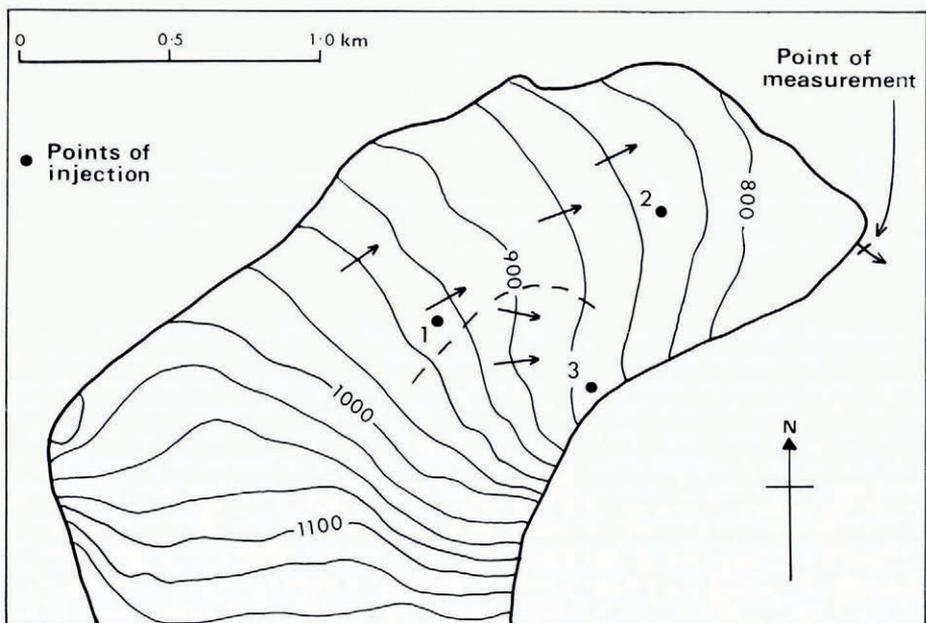


Fig. 1. Map of the lower part of Austre Okstindbreen with points of dye injection indicated. Surface contours are given in metres. The main directions of surface drainage are shown, with the dashed line indicating a major drainage divide.

The measured velocity of  $1.8 \text{ m s}^{-1}$  appears relatively high when compared with similar measurements made elsewhere. Stenborg (1969) obtained average velocity values ranging from 0.5 to  $0.7 \text{ m s}^{-1}$  over distances of up to 1.7 km from the snout of Mikkaglaciären. Behrens and others (1975) reported values for the Hintereisferner of between 0.47 and  $1.11 \text{ m s}^{-1}$  which were consistent over two summer seasons, suggesting that the internal drainage system changed little over that period; a diurnal cycle of throughflow velocities at Hintereisferner included a maximum at about 14.00 h and a minimum at 05.30 h. Krimmel and others (1973) found that, at South Cascade Glacier, the mean velocity of dye tracer injected into moulines ( $0.29 \text{ m s}^{-1}$ ) was within the velocity range of supraglacial streams ( $0.17$  to  $0.42 \text{ m s}^{-1}$ ). The high velocity value recorded at Austre Okstindbreen presumably reflects unimpeded drainage between site 1 and the glacier snout, which in turn probably implies deep penetration of the moulin and the existence of a well-defined subglacial stream. It is interesting to note that mean velocities calculated from measurements made with a current meter in several of the surface streams rarely

exceeded  $2 \text{ m s}^{-1}$ , suggesting that the drainage characteristics of surface and sub-surface melt water are similar in certain respects, the presence of flow in some form of channel being of particular importance.

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16 January 1978*

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SIR,

*Experiments on the origin of kettle-holes:  
comments on the paper by Dr J. K. Maizels*

Dr J. K. Maizels' (1977) paper on laboratory simulations of kettle-hole development was a reminder of "mini-kettle-hole" formation observed in July 1958. Figure 1 shows the small cavities in various stages of development, each related to the melting rate of partially buried ice blocks.

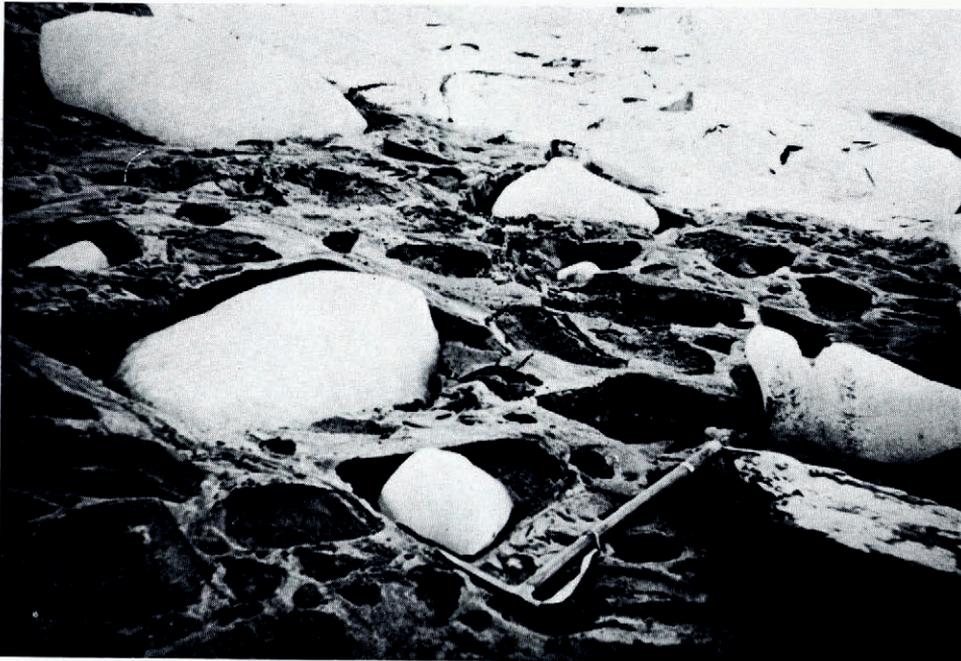


Fig. 1. "Mini-kettle-holes" formed by the ablation of ice stranded on the basin floor of Tulsequah Lake 3 days after it had drained.