CORRESPONDENCE

The Editor,

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SIR,

Chamonix Glaciers

At the symposium held at Chamonix from 16 to 25 September 1958 very important theoretical and practical papers were read on the physics of ice movement. Those of J. F. Nye and of J. W. Glen, and the comments on them contributed by R. Haefeli and others, gave a deep insight into the rheology of ice. From S. Steinemann's researches it was established that there is no great difference between the movement of a temperate and a cold glacier. Matters connected with the ice crystal and the physics of ice were adequately handled. It was possible to obtain a good insight into the excellent work done in polar regions during the International Geophysical Year.

The researches on ogives, and also on the waves caused by increased accumulation in the firn basins of glaciers, were of particular interest. Glacier waves flow with velocities several times greater than the glacier itself. It was good that the symposium was held at Chamonix since the magnificent Mont Blanc group enabled us to find impressive evidence of many of the phenomena discussed during the symposium.

The excellent map, *Carte du Mont Blanc* 1: 10,000, made from air photogrammetry at the Institut Geographique National in Paris proved a valuable contribution to the work of the symposium. This very accurate map, based on carefully surveyed contour lines, shows the state of the Mont Blanc glaciers in 1952 in great detail. This helped us to make an interesting comparison with the state of the Glacier des Bossons in 1958, particularly in regard to its speed of flow and its glacier waves. This glacier comes down from the Aiguille du Midi as an impressive and much crevassed ice stream terminating in the main valley close to Chamonix.

During intervals in the lectures at the symposium, we made terrestial photogrammetric surveys from two points on the Aiguille du Midi on 20 September; these were repeated three days later. A second survey was made near the end of the tongue, and this was repeated two days later. These surveys show clearly that the tongue of this glacier is in a state of advance.

The survey from the Aiguille du Midi also provided a check on the 1: 10,000 map in regard to the rock margins at the sides of the glacier. On the glacier itself at an elevation of 2,900 m. a decrease in height of 8 m. since 1952 was found. This decrease became less lower down and was nil at 2,400 m. The ice speeds were found by parallax measurements on a stereocomparator at 50 points between the same altitudes—2,900 and 2,400 m. The mean velocity was found to be 2·5 m. with a maximum of 4·1 m. during the period of measurement; this is equivalent to a mean speed of 310 m./year with a maximum of 500 m./year.

The result of a survey of the tongue near the Chalet des Bossons at an altitude of 1,350 m. indicated a mean speed 60 m./year with a maximum of 80 m./year. Owing to changes in the terrain at this point, due to buildings erected and demolished since the 1: 10,000 map was made, it was impossible to fix the position of the theodolite with great accuracy. Nevertheless the photogrammetric results showed that an advance of the snout of 350-400 m. had taken place since 1952. This seems to have happened quite recently; it is still going on although it appears to be coming to an end. The velocities mentioned above were determined from a cross-profile just above the former snout.

The advance of the tongue may have been caused by increased accumulation in the firn region in the years 1953-56. Such accumulations amounting to 5-10 m. had been measured by us on glaciers in the eastern Alps. Accumulations of this nature are probably the cause of a glacier wave. As the velocity of the Glacier des Bossons is very considerable (300-500 m./year) and the slope very steep (1 in 1·7, *i.e.* 32°) the wave must have reached the end of the glacier in 3 years (that is to say, now); this is on the assumption that it travelled three times faster than the glacier itself, the horizontal distance from firn to snout being about 1-2 km. It is of some interest that one has also found a wave on the near-by Mer de Glace, but in this case it had not yet reached the end of the tongue as this glacier moves more slowly on a less steep bed. The tongue of the Mer de Glace is still retreating.

The facts and measurements described above seem to explain the actual advance of the Glacier des Bossons with a reasonably high degree of probability. They may also serve as a practical example of the glacier waves treated theoretically at the symposium.

The behaviour of the two glaciers, the Glacier des Bossons and the Mer de Glace, situated as they are fairly close together, is also very instructive in another respect. It shows that these two glaciers react

in quite a different manner to a relatively small difference in weather conditions. The cause is obviously the difference in their inclinations. This raises the further question of how climatic changes influence glaciers and also in what manner climatic fluctuations and changes can be known or calculated from the behaviour of glaciers. The problems involved by such questions could well be the subject for the next symposium for the Commission on Snow and Ice, which is to be held between the Congress of the I.U.G.G. at Helsinki, and that to be held three years later. It was resolved at Chamonix that such a symposium should also be held triennially in the year preceding the I.U.G.G. Congress.

This may be a suitable occasion to say something about the influence of climate on glaciers and the evaluation of suitable figures denoting as clearly as possible the effect of these influences. This effect is closely connected with the movement of the ice and the slope of the glacier as shown above. It is also connected with the time which the ice needs to come down from the firn regions to the lower parts of the tongue, *i.e.* the length of the glacier. If this time is long the effects of short climatic fluctuation of perhaps one or two years are superimposed upon the effects of longer climatic periods; for instance, the 35-year period of Brückner or the period which is indicated by the retreat of glaciers since 1850 until the present day.

In order to find out, and to distinguish the individual influences, it seems desirable to investigate short and rather steep, as well as longer, flatter glaciers. In my view the best method for an investigation of this nature is the volumetric method briefly described in the *Journal of Glaciology*, Vol. 2, No. 15, 1954, p. 308, and fully detailed in the *Zeitschrift für Gletscherkunde und Glazialgeologie*, Bd. 2, Ht. 2, 1953, p. 189-239. From repeated geodetic measurements over the whole glacier surface, the ablation and the accumulation surplus is obtained for single zones and also for the whole glacier. This deficit or surplus expressed as metres of water is the decisive figure, and can be brought into relationship with the meteorological data of the period. With the aid of the volumetric method investigations were made on several glaciers of the eastern Alps for the periods 1850-90, 1890-1920, and particularly for the period 1920-50. It was possible to obtain quite reliable figures for these periods. More detailed observations for shorter periods of one or a few years have also been systematically undertaken in the eastern Alps since 1950. The treatment of shorter periods, especially those of one year, raises certain problems, for instance in regard to obtaining results of sufficient accuracy. On the other hand data of glacier fluctuation during a single year provide better possibilities for tying these up with the meteorological data of the same year. The experiences, results and problems connected with glacier fluctuation and climate during these shorter periods will be dealt with in a future publication.

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