depth, will be resurveyed during February and again in August 1951, for plotting a vertical velocity profile for the intervening periods of time. This information will then be compared with surface movement records obtained during these same periods by theodolite sights and will be useful in calculation of the volume transfer of ice to lower elevations by englacial as well as surficial glacier flow. The depth of the Taku glacier at the drilling site is approximately 900 ft. (274 m.) as determined by the expedition's geophysical crew during the summer of 1949.* The technique described above, in regard to method employed for obtaining englacial rates of flow, though new in some phases of its implementation, is actually a modification of the principle applied by Dr. Max Perutz in direct measurement of the velocity distribution in a vertical profile through the Jungfraufirn, Swiss Alps, in 1948 and 1949.†

Temperature recording with spaced thermistors (consisting of alloyed semi-conductors which have a 4·4 per cent negative change in electrical resistance per degree Centigrade change in temperature; measurements can be made to 1/100° C. by means of a specially designed Wheatstone Bridge), were installed in the upper Taku Glacier for precision measurement of englacial temperatures along one of the vertical drill profiles. These cables were supplied by the U.S. Geological Survey and are similar to the type being used in connection with permafrost studies by the Geological Survey at Point Barrow, Alaska. One 200 ft. (61 m.) string of thermistors was sealed into a drill hole and will permit a party visiting the ice field in mid-winter to record the depth of penetration of the winter cold wave beneath the glacier surface and may serve as a check on theoretical calculations of the pressure melting temperature of temperate glacier ice at depths considerably below the level of penetration of negative winter temperatures. Attached to a light weight frame tower erected on the surface of the upper Taku Glacier is another 35 ft. (10·7 m.) cable of thermistors by means of which it will be possible during the 1951 winter operation to record the amount and extent of sub-freezing temperature penetration in the 1950–51 layer of winter snow.

A full report of the results of these investigations will be published next autumn. This will incorporate data from the 6-month increment of time between August 1950 and February 1951, obtained by the winter party to the Taku Glacier, and will include records obtained next August by members of the fourth summer season of the Juneau Ice Field Research Project.

American Geographical Society,
New York
19 *January* 1951

MAYNARD M. MILLER

CORRESPONDENCE

The Editor,
The Journal of Glaciology

SIR,

The Formation of Forbes's Bands

Professor Haefeli's note on the ogives of the Arolla Glacier (*Journal of Glaciology*, Vol. 1, No. 9, 1951, p. 498) interested me particularly. Haefeli is correct when he says that the number of such bands is a measure of the number of years for flow of ice over the interval. I checked that on the Mer de Glace last summer; a specially large boulder, which I had noted in 1912, and in 1950, had travelled just 38 bands in 38 years.

Haefeli and Streiff-Becker's idea that these bands are pressure waves, whose wave length is controlled by seasonal variations in the flow of the glacier, is very interesting. But seasonal variations in flow can only apply to the surface shell of the glacier—the 10 m. shell which alone is penetrated by

* Poulter, Thomas C., Allen, C. F. *and* Miller, Stephen W. *Seismic Measurements on the Taku Glacier*. Stanford Research Institute, Stanford, California, 1949.

† Perutz, M. F. Direct Measurement of the Velocity Distribution in a Vertical Profile through a Glacier. *Journal of Glaciology*, Vol. 1, No. 7, 1950, p. 382–83.

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each winter's cold wave. With surface ablation of 2 m. or more per annum, the bands at the lower end of his Fig. 1, 30 waves removed, must be in ice which was 60 m. under the surface at their point of origin—a depth far below any penetration of winter cold.

In 1948 on the Arolla and Trift Glaciers (and in 1950 on the Mer de Glace) I verified that the difference in whiteness of the two parts of each band is due to the white band being bubbly ice, the dark band clear ice—densities about 0·85 and 0·91 respectively, rather than to surface dirt. It seems hard to imagine any process by which rhythmic surface compressions could convert clear ice into bubbly ice at the surface; even more difficult 60 m. or more below the surface.

As Henri Bader suggested in the preceding issue of the Journal, I am strongly convinced that bubbly ice is the normal product of firnification of cold snow, with no melt water present. If melt water is present, clear ice results. For instance, the lane of white bubbly ice on the Gorner Glacier can be traced to that cold, arctic, north-facing slope, up against the Silbersattel of Monte Rosa—the one and only large area of Arctic-like accumulation at an altitude of well over 4000 m. in the Alps. That Gorner white bubbly lane is a longitudinal lane.

To introduce transverse dikes of bubbly ice into glaciers such as the Arolla or the Mer de Glace and, at that, dikes of bubbly ice that should penetrate down 100 m. beneath the surface, is one unique test which any explanation of Forbes's bands must meet (along with others).

Then, too, if nothing more is needed than pressure of a nearby steep ice fall, reacting on a flat glacier whose surface offers rhythmic seasonal fluctuations in its viscosity, as on the Mer de Glace, Arolla and Trift (in the Gothardgebiet), why are there no vestiges of ogives on the Leschaux, below the Talêfre ice fall? On the Saleinaz? On the Z'mutt, beneath the Stockje Gletscher ice fall? On the Gorner, beneath the ice fall coming down from the Jägerhorn area? On the Morteratsch beneath its own ice fall—or beneath the Pers Gletscher ice fall?

25 *West* 43*rd Street,*
New York 18,
N.Y.
4 *April* 1951

JOEL E. FISHER

SIR,

Mr. Fisher's very interesting observations on the Arolla Glacier, the Trift Glacier and the Mer de Glace, contending that the white bands of the "ogives" consist of ice containing air and that the dark bands consist of clear ice, are undoubtedly an important contribution to the problem of ogive formation. These views must certainly be considered when attempting a solution. Whether the pressure wave hypothesis can be reconciled with Fisher's basic observations only the future can show. Nevertheless the following reasons make it appear quite probable.

The causes of the sudden increases in speed in the summer, as may be observed at the Mt. Collon Glacier, are, in my opinion, not due to the changes in viscosity of the surface ice layers since shallow sections of the glacier are influenced by the annual temperature variations—as Fisher rightly observes. The sudden increase in speed seems much more likely to be due to the melt water which on reaching the glacier bed gives a sudden added impulse to the ice by various influences. Measurement of the speed in the tunnel of the Mt. Collon Glacier yielded very small values in winter (for instance 3 cm. a day). Calculations according to Somigliana indicated that during the winter the glacier does not slide upon its bottom layer in the lower, flat reaches of the tongue. This result has since been confirmed by observations in the lower tunnel of the Mt. Collon Glacier and by further investigations in other glaciers. The sudden increase in speed at the surface of the Mt. Collon Glacier in July, which is a multiple of the winter speed, can therefore only be explained by the additional impulse caused by gliding upon the glacier bed. This implies, however, that extensive variations in pressure must occur which will influence the entire cross section of the glacier with varying intensities in different places and at different times. This might cause the effect of the pressure waves to penetrate deeply into the glacier, even causing change in the lowest ice layers which only come to the surface at the end of the glacier.

A glacier phenomenon can never be due to one single cause, many influences are usually brought to bear. It seems to me that more research will be necessary before we can answer the question

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