siderably by the nature of the ground being considered, for the state of the surface (*e.g.* unbroken, freshly fallen snow) and the light conditions can so affect the relative tones in the photographic image that an accurate placing upon it of a floating mark is impossible. To draw contours of the precision required for computations such as those of Professór Finsterwalder's, an exceptionally clear stereoscopic model is essential, and snow and ice surfaces do not necessarily give this, especially in unsuitable light conditions. It was presumably in connexion with this clearness of the stereosopic model that Professor Finsterwalder found the Multiplex method of projection unsuitable; for, theoretically, this method of optical projection is capable of giving the required accuracy, but the clearness and "solidity" of the stereoscopic model is not so good as that of the mechanical plotting machines.

Concerning the measurement of movement there are two important limiting factors; one referring to the amount of movement, the other to the number of such measurements that are possible. The first is that there must be considerable movement, certainly more than that caused by ablation. This is an obvious limitation, but one that has not always been heeded in the past.

The second factor is implied in Professor Finsterwalder's statement that in observing the amount of movement it is not necessary to mark artificially any point on the glacier itself. Without such marks the problem becomes one of identification, and the ease, or otherwise, with which this can be done will control the number of transverse sections that can be made. The writer suggests that as many transverse sections can be taken as are desired, but this will depend very much upon having even light conditions throughout the series of observations and upon the number of points that can be identified without any doubt when seen at different times and from different directions. The use of markers will obviate this difficulty, but they are useless when the amount of movement is less than that caused by ablation, and they are not easy to set up and maintain.

With very careful attention to light conditions the difficulties of identification can probably be minimized, and in any case there is more scope in this method than in the alternative method of theodolite measurement. However, there is room for research in this particular branch of the work; Professor Finsterwalder has only referred to the measurement of fairly straightforward movement in a direction at right angles to the direction of photography, but there is also the problem of the multi-directional small movements which will require simultaneous photographic exposures from three or four suitably distributed cameras, and the increased difficulty of identification from three or four directions.

Professor Finsterwalder has rendered a great service to glaciologists in stressing the photogrammetric side of his work, thereby encouraging the use of the best available methods for particular problems.

GLACIERIZED AREAS IN THE SWISS ALPS

By P. L. Mercanton

(Commission Helvétique des Glaciers—S.H.S.N.)

In 1902, J. Jegerlehner, working in Bern, published a carefully compiled memoir entitled "Die Schneegrenze in den Gletschergebieten der Schweiz." * This dealt with the distribution of the permanent snow and ice cover of our Alps based upon *l'Atlas Topographique de la Suisse*, the Siegfried Atlas, which was published about 1877 (actually from 1860 to 1890). The present *Carte Nationale de la Suisse* was brought out about 1932 (1918–44), a good half-century later. During this period our glaciers as a whole had not ceased receding except in a few cases here and

* *Gerlands Beiträge zur Geophysik*, Bd. 5, Ht. 3, 1902.

there, so that it appeared essential to look into the state of the Swiss glacierization afresh. On the initiative, therefore, of the writer, with the helpful and indispensable assistance of the Service Topographique Fédéral, the Commission Helvétique des Glaciers carried out a planimetric survey of all the ice-covered areas shown on the new map. This very detailed work was carried out with great care by Herr W. Büla.

These areas, 72 in number, were distributed over 34 sheets of the map. As the surveys were spread over many years they naturally refer to varying dates, but in the main they were carried out during a time lapse of about twelve years, namely from 1927 to 1940. In order to determine with accuracy the total variation in an area surveyed over such a prolonged period it would, of course, be necessary to take into account the exact time of the initial and the final surveys. But to obtain a comprehensive picture of the extent of the ice in Switzerland, especially in view of the long lapse of time between the making of the two maps (1877 to 1932), this degree of precision was not absolutely necessary; indeed the mere comparison of the total glacierized areas of former times and the present is, of itself, of great value to glaciology and world climatology. For this reason we have considered it opportune to give a total figure for the variation without waiting for the final details. Jegerlehner gave as his computation of the total glacierized area 1853 km.^{2}. In 1932 it stood at 1384 km.^{2}, a reduction of 469 km.^{2} (25 per cent)—a little less than the area of the Lake of Geneva, or about 3·3 per cent of the area of the whole country.

It should be noted that these computations refer to the glaciers seen as horizontal areas.

THE STABILITY OF ICE-DAMMED LAKES AND OTHER WATER-FILLED HOLES IN GLACIERS

By J. W. GLEN
(Cavendish Laboratory, Cambridge)

ABSTRACT. It is well known that an empty hole in a glacier will fill in if it is more than some 15 to 20 m. deep, due to the rapid variation of strain rate with shear stress. It is pointed out that a water-filled hole or lake will tend to enlarge itself by the same mechanism, if it is more than 150 to 200 m. deep. This phenomenon is believed to be responsible for the periodical and complete emptying of some glacier lakes, such as has been reported for the Tulsequah Lake in British Columbia, and Graenalón and Grímsvötn in Iceland.

ZUSAMMENFASSUNG. Es ist wohlbekannt, dass sich ein leeres, mehr als 15–20 m. tiefes Loch in einem Gletscher von selbst schliesst; dies ist darauf zurückzuführen, dass die Deformationsgeschwindigkeit des Eises mit der Scherspannung sehr rasch ansteigt. Es wird gezeigt, dass sich ein mit Wasser gefülltes, mehr als 150–200 m. tiefes Loch auf Grund desselben Mechanismus von selbst vergrössert. Dieses Phenomän erklärt wohl die periodische und vollständige Leerung gewisser Gletscherseen, wie z.B. des Tulsequah Lake in Britisch Kolumbien, und des Graenalón und Grimsvötn in Island.

THEORY

Recent experiments on the mechanical properties of ice [1] have shown that, whenever ice is subjected to a shear stress greater than about one bar, flow takes place at a rate which increases rapidly with the stress. An example of this is the filling up of crevasses and bore holes in glaciers; for when a vertical wall of ice is more than some 20 m. high, the ice at the surface of the wall near the bottom is subjected to a vertical compressive stress of about 2 bars in addition to atmospheric pressure, while the horizontal component of the stress in a direction perpendicular to the wall can only be atmospheric. By the usual methods of stress analysis, this implies that there must be a shear stress of about one bar on planes at 45 degrees to the horizontal, and this will cause the ice to flow and the hole to fill in. This explains why crevasses of much greater depth than 20 m. are rare in a temperate glacier.