Recent Glacier Survey

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THE movements of the glaciers of the European Alps are a perennial source of interest, which has increased of late years, more or less in proportion to the large increase in the number of climbers, skiers, summer holiday-makers and winter-sports visitors. During the same time there has been an immense improvement in the organisation of the systematic study of glacier motion, by the formation of national and international glacier commissions. The Governments of Switzerland, France and Italy in particular have now regular officials of the State engaged in effecting definite observations, surveys and measurements, and reports are issued at stated intervals, of both scientific and general interest. For example, the fifty-fourth annual report, for the year 1933, of "Les Variations périodiques des Glaciers des Alpes Suisses", edited by Prof. P. L. Mercanton, chairman of the Commission Suisse des Glaciers and professor of geophysics at Lausanne, has recently been issued. The observations were made by cantonal forestry officials. Also the Département des Eaux et Forêts of the French Ministry of Agriculture has just issued a voluminous report on the work carried out during 1920-30 on the glaciers of Savoy, Dauphiny and the Tarantaise, under the direction of M. P. Mougin, inspecteur général des eaux et forêts*. One is sorry to learn that M. Mougin has now retired from the post which he has so long and ably filled. In a very kindly letter to the writer, he has given further details of the work, bringing it up to 1933, and thus rendering it comparable with that of Prof. Mercanton, as regards the glaciers of the Mont Blanc chain. The Italian glacier surveys are likewise carried out by specially trained departmental officers of Piedmont and Lombardy.

This glacier research is not merely of scientific, geographic, geodesic and geophysical importance, but has also been the means of preventing the recurrence of those terrible calamities, generally due to the formation and bursting of lakes and water-pockets in the glaciers, which so frequently in the past have appalled the world and brought destruction to whole villages and districts in the Alps; for example, those of 1818, 1898 and 1892, due to lakes and immense pockets in the glaciers of Giétroz, Crête Seche and Tête Rousse. Indeed, I was myself a spectator immediately afterwards in the last instance, and well remember the terrible havoc, and the immense gap in the glacier de Bionnassay, where the torrent from the Tête

Rousse had torn a great portion of the glacier away. The scene at the village of Bionay and at what had been the Baths of St. Gervais, where a hundred and fifty persons had been killed or drowned, was very harrowing. Thanks to these researches, however, siphoning trenches and other suitable means are now constructed and provided in time to obviate such disasters completely, the imprisoned water being released automatically, when the crisis comes, harmlessly and effectually.

It may also not be out of place to mention that careful research is now being carried out concerning snow and ice avalanches, their nature and causes, and not only the best means of avoiding them but also of foreseeing them. On this subject, an admirable article, beautifully illustrated by actual photographs, is contributed by Mr. Gerald Seligman to the 1934 issue of the "British Ski Year-Book".

The usual geodesic and theodolitic methods of glacier survey have now been supplemented by determinations of the annual change in the bulk of the ice and snow, by the regular reading of immense vertical scales, nivometers, engraved on upwards-projecting rocks. These nivometers have during these last two years been read and photographed from aeroplanes, Prof. Mercanton having had the advantage of being taken up by some of the most skilful of the Swiss pilots. Fig. 1 is a reproduction of an aerophotograph taken near the nivometer of the Glacier d'Orny, by Prof. Mercanton, piloted on this occasion by M. Champod. It shows the Saleinaz, d'Orny and Trient group of peaks and glaciers at the north end of the Mont Blanc chain. Efforts have also been made to ascertain the inner movements in the depths of glaciers. For example, Prof. Mercanton and his staff have sunk a considerable number of 75 mm. shells in the Rhone and Great Aletsch Glaciers, each having an identity piece sealed within it, and a sequence number deeply engraved on its outside: the initial position of each was accurately recorded, with reference to fixed marks on adjacent rocks.

Moreover, actual measurements of the daily movements of the extremities (snouts) of glaciers have been made with the aid of the ingenious little instrument devised by Prof. Mercanton—the cryocinometer. These latter measurements, and the new depth-sounding work (determining the thickness of a glacier) by the seismographic method, are particularly interesting. In these latter determinations the length of path of a seismic wave produced by an explosion between surface and rock-bed, is ascertained with the aid

* Ministère de l'Agriculture: Direction des Eaux et du Génie rural. *Études glaciologiques, 1920-1930.* Par P. Mougin. Tome 7. Pp. vii+306+76 plates. (Paris: Imprimerie Nationale, 1933.)

of a modified form of earthquake seismometer. The many attempts which have been made to employ depth-sounding hydrophones, ultrasones and piezo-electric apparatus have not met with success, and it was a happy thought of Dr. Mothes to adapt the earthquake seismometer to the problem. A photographic recorder for the vertical component and a microphonic attachment are the chief modifications necessary. The time taken by the explosion wave to pass through the thickness of the glacier and to be echoed back to the surface is determined, both the longitudinal waves and the transverse vibrations being recorded; and from the previously determined velocity of the

The preponderating phenomenon is thus that of retreat; that is, the position of the extremity of the snout of the glacier has retrogressed higher up the glacier valley, the total length of the glacier being reduced. As regards the amounts of retreat in the cases of the more famous glaciers they are:—The Rhone glacier 9 m., Fiesch 11 m., Aletsch 3 m., Allalin 10 m., Fee 7 m., Gorner 11 m., Arolla 10 m., Trient 16 m., Oberaar 31 m., Unteraar 54 m., Rosenlauri 12 m., Upper Grindelwald 12 m., Eiger 3 m., Blümlisalp 6 m., Morteratsch 4 m., Forno 40 m., and Palü 39 metres.

Of the better-known glaciers which have advanced, the amounts were only 4 m., 1 m., and 2 m.

FIG. 1. The Saleinaz, d'Orny, Trient group, Mont Blanc massif, from the air.

waves the thickness of the ice can be immediately calculated. Dr. Mothes first employed this method on the Hintereisferner, and in 1929 on the Great Aletsch glacier, near the Concordia hut, where a depth of no less than 700 m. was found, greatly exceeding the 200 m. found by the late M. Joseph Vallot on the Mer de Glace.

Passing now to the main results of the latest surveys, the following table gives them for the last eight years (1926–33), for one hundred Swiss glaciers.

Year	Growing (advancing)	Stationary	Decreasing (in retreat)
1926	52	8	40
1927	22	7	71
1928	14	5	81
1929	11	12	77
1930	8	12	80
1931	22	12	66
1932	13	7	80
1933	15	4	81

respectively for the Ferpèche, Moming, and Lower Grindelwald glaciers.

It is important to note that the average temperature for the quarter July–September, 1933 (most effective in reducing the glacier length) was 1.3° C. above the mean summer average, confirming the view of M. Billwiller that the summer temperature is the principal factor in determining the question of advance or retreat.

The retreat of the Rhone Glacier has caused the disappearance of its beautiful ice-cave, from which issues the infant Rhone. Two lobes were left at the snout, and cryocinometer measurements were made, at their terminations, of the actual forward and downward movement of the ice, on September 4 and 5, 1933; the amounts were 8 cm. and 13.5 cm.

a day. In the previous year, similar determinations gave 2.25 and 11.5 cm., so that the actual downward movement of the ice has accelerated, although more of the glacier has melted away, causing the retrogression in position of the glacier end. There is here afforded a good illustration of the clear distinction, that must ever be remembered, between (a) the 'advance' or 'retreat' of the position of the snout terminus (determining the length of the glacier), as given in the table, and due to the balance between precipitation and fusion, and (b) the ever-persisting downward motion of the ice itself along its natural downward sloping valley, due to the now well-known causes to which ice owes its viscosity and plastic flow, and which is ever being urged by pressure from above.

The outstanding retreat of 54 m. by the Unteraar glacier is largely owing to the enlargement of the

and an advance of 14 m. in 1928. After this, in 1929 it receded for 51 m., and again in 1930 still more, for 108 m. In both 1931 and 1932, however, it retreated for no less than 120 m., the maximum observed for ice fusion in the case of this glacier since observations were made by the Department. In 1933 it had slowed down to a retreat of 75 m.

Similar fluctuations have been observed with the Glacier d'Argentière. In 1920 the mass of this glacier had increased so much that opposite the Pavillon de Lognan the ice was flush with the top of the moraine, and there were further advances that year and 1921 of 40 m. In 1922 and 1923 the amount of advance had diminished to only 3 metres; in 1924 it retreated 2 metres, but 1925 brought a slight advance of 6 metres. In 1926 it was distinctly in retreat ($6\frac{3}{4}$ m.), and a particularly beautiful ice-cave was formed at the snout, from

FIG. 2 The Grimsel Lake and Unteraar Glacier.

Grimsel lake, now three and a half miles long, for the provision of immense electric power stations at Handeck, Boden, and Innertkirchen. The end of the glacier is now formed by ice-cliffs bathed by the waters of the lake, and as this has occurred now for three summers it has resulted in excessive fusion of ice and the breaking away of icebergs, as at the Märjelen See by the side of the Aletsch glacier. The cavernous portal of the Aar has moved backwards 70 m., and during 1933 alone nearly a million cubic metres of ice have disappeared. Fig. 2 shows reproductions of photographs taken in 1933 by Prof. Mercanton, showing the remarkable change which has occurred here.

Turning now to the more important Savoy glaciers, the position of the end of the Glacier du Tour had advanced 356 m. in the year 1920, but it then receded 8 m. in 1921, 45 m. in 1922, 66.67 m. in 1923 and 1924, but only 19 m. in 1925. But in 1926 it advanced again, to the extent of 31 m. Then came fluctuations, a retreat of 33 m. in 1927

which issued the River Arve. The retrogression continued during 1927 (9 m.) and increased to 14 m. in 1928 and 35 m. in 1929, a very fine cavern forming again the portal of the Arve. In 1930 the retreat had diminished to 26 m.; by 1932 it had again increased to 55 m., but in 1933 the retrogression was only 5 m.

The Mer de Glace showed even more remarkable fluctuations of advance and retreat, partly owing to its very awkward gorge of exit. In 1920-21 it retreated 25 m., but in 1923 it advanced 132 m., nearly filling the gorge. In 1924 it advanced a further 47 m., but in 1925 suffered a catastrophic fall and receded 52 m. In 1926 it was again coming forward, and had advanced 95 m. since the preceding July. In 1927 it was curiously stationary. In 1928 and 1929 it advanced 96 m. and 8 m. respectively, since which, from 1930 until 1933, it remained stationary.

The Glacier des Bossons had so increased in the year 1920 as to fill up the ravine to the level of

the moraines, below the lower Châlet, and in the next year it advanced still more. But in June that year a great heat wave commenced, and so much fusion occurred, with disintegration of the snout, that great masses of broken ice were carried away by the people of St. Gervais and Sallanches. With the exception of a slight advance in 1928, much fusion continued to occur up to 1930; in 1931 the retrogression occurred for 26 m., but in 1932 for only 8 m. In 1933, however, it retreated no less than 95 m., a fact very evident when I visited it that year. Its twin neighbour, the Glacier de Taconnaz, bifurcating from the Bossons at the celebrated Jonction below the Grande Mulets, receded 22 m. in 1931, and 22 m. again in 1932. The Bionnassay Glacier also showed slight retrogression during 1932 (14 m.). But no measurements were made, for reasons of economy, of either of these glaciers in 1933.

Space forbids detailing the observations on the glaciers of Dauphiny, the Tarantaise, the Isère

and the Maurienne, but from the foregoing account concerning the better-known glaciers it will be clear that, on the whole, the glaciers of the main Alpine chains appear to be at present in a period of retreat. The fluctuations, however, have been so great during the last decade and a half, that it is not possible to assign any specific time limits to the period, or assert the occurrence of an alternation of such cycles of advance and retreat of definite duration. What does appear more and more clearly from these researches is that the average summer temperature affects the length of a glacier far more than any other factor, and if this can be shown to vary in clear-cut cycles, then the advance and retreat of glaciers may be found to occur more or less periodically, correspondingly. The figures now available, from more perfect and accurate measurement than has ever before been attempted, certainly do not admit of such broad and sweeping generalisations as have from time to time been put forward.

Boussingault and Agricultural Science

THE year 1934 may well be considered by agricultural chemists as the centenary of the foundation of modern agricultural chemistry. Much work on growing plants had been done before 1834, but it was probably in that year that Boussingault began on a field scale the experiments which led to methods of present-day agricultural science.

Jean Baptiste Boussingault was born in 1802 and took his degree at the School of Mines at St. Etienne. In 1822 he went as a mining engineer to South America, where he spent some years, including six years' service with the armies of Bolivar. During this time, he published several papers on mining and other problems. On his return to France he was elected professor of chemistry in the Faculty of Science at Lyons. In 1833 he married Mdlle. Le Bel and became co-proprietor with his brother-in-law of a farm at Bechelbronn in the Bas-Rhin. It seems more than probable, therefore, that the year 1834 saw the beginnings of the field experiments which he set up in connexion with his work on agricultural chemistry.

De Saussure had, some thirty years previously, grown plants in measured quantities of air and had studied the gaseous exchanges during growth. He had shown that the part played by the soil in plant nutrition was small in amount, but of enormous importance to growth. The constituents of plant ash, he found, varied with the nature of the soil and with the state of development of the plants themselves. His work did not receive the

support it deserved, and for long afterwards it was held by many that the carbon in plant tissues was derived from the humus of the soil in which the plants had grown.

Boussingault reintroduced the methods of de Saussure and applied them to crops grown under field conditions. He grew different crops in rotation and measured carefully the amounts of fertiliser added to the plots and the yield of crop obtained. In this way he was able, at the end of the rotation, to draw up an account of the materials taken in by the plant and the amount of mineral material retained in the soil. He found that more dry matter was obtained from the plants grown in a rotation than was given in the fertiliser in the first instance, and that large amounts of carbon and of oxygen must have been obtained from another source—the atmosphere. On the other hand, much less nitrogen was recovered in the crop than had been applied in the fertiliser treatment, and a considerable proportion of nitrogen must have been retained in the soil. He suggested, therefore, that crops should be grown which gave the greatest increase in dry matter over the amount contained originally in the manures. He found, for example, that rotations which included leguminous plants or successive crops of leguminous plants, such as clovers and lucerne, gave a higher nitrogen content in the harvested crop than could be accounted for in the nitrogen given in the manure.

Boussingault pointed out that atmospheric nitrogen could enter directly into the composition