the radiation in overcast conditions. Observations in high latitudes, summarized in Wallén[8] show that the incoming radiation during cloudy weather can be considerably greater than the above term suggests, and has a considerable seasonable variation. But in view of the variations between the various high latitude observations there seemed to be no merit in using them in this case.

The 47 cm. of energy received during the melting season is disposed of in the following ways:

(i) the formation of superimposed ice yields $16{\cdot}5 \times 0{\cdot}91 = 15$ cm. as sensible heat to the underlying ice, because equation (5) shows clearly that $\int_o^t K\frac{\partial\theta}{\partial x}dt = \int_o^X L\rho dX$.

(ii) the remainder (about 70 per cent) 32 cm. units together with the 5 cm. of rain is discharged as run-off water to the rivers and lakes surrounding the ice cap. Admittedly, a small amount of this water, which cannot be estimated, yields more heat to the ice by running into the few narrow crevasses and refreezing.

Thus a considerable proportion of the summer energy never enters the ice cap.

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REFERENCES

1. Carslaw, H. S., *and* Jaeger, J. C. *Conduction of heat in solids*. Oxford University Press, 1947.
2. Erikssen, B. E. Meteorological records and the ablation on the Fröya Glacier in relation to radiation and meteorological conditions. *Geogr. Annaler*, Årg. 24, Ht. 1–2, 1942, p. 23–50.
3. Orvig, S. The climate of the ablation period on the Barnes Ice Cap in 1950. *Geogr. Annaler*, Årg. 33, Ht. 3–4, 1951, p. 166–209.
4. Penman, H. L. Natural evaporation from open water, bare soil, and grass. *Proc. Roy. Soc. A.*, Vol. 193, 1948, p. 120–45.
5. Shaw, Napier. *Manual of Meteorology*, Vol. 2, second edition, Cambridge University Press, 1938, p. 4.
6. Sverdrup, H. U. The ablation on Isachen's Plateau and on the Fourteenth of July Glacier in relation to radiation and meteorological conditions. *Geogr. Annaler*, Årg. 17, Ht. 3–4, 1935, p. 145–66.
7. —— The eddy conductivity of the air over a smooth snow field. *Geofys. Publikasjoner*, Vol. 11, No. 7, 1936.
8. Wallén, C. C. Glacial-meteorological investigations on the Kårsa Glacier in Swedish Lappland 1942–48. *Geogr. Annaler*. Årg. 30, Ht. 3–4, 1948, p. 451–672.

MORE ABOUT ADVANCING AND RETREATING GLACIERS IN PATAGONIA

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ABSTRACT. Contrary to prevailing opinions, the glaciers of south Patagonia have normally been stationary or have advanced during the last twenty years. Exceptions can be accounted for by a lag due to a long travel through narrow passes or by the lowering of waters in the terminal lake at the foot of a rocky cliff.

RÉSUMÉ. Contrairement à l'opinion admise, les glaciers du Sud de la Patagonie ont été normalement stationnaires ou ont avancé au cours des vingt dernières années. L'on peut rendre compte des exceptions par le déphasage dû à un long parcours à travers des étranglements, ou par un abaissement des eaux dans le lac terminal, au pied d'une barre rocheuse.

THE writer was a member of the French alpine expedition which made the first ascent of Monte Fitz Roy,* lat. 40° 16′ S., on the Argentine–Chilean frontier, and stayed in that district from 25 December 1951 until 15 February 1952.

* This mountain is shown on some maps as Cerro Fitz Roy, Cerro Chaltel or Fitz Roy Peak.—*Ed.*

Several interesting observations were made on the snow and ice around this mountain which will be the subject of a further article.

In the present paper the author attempts to complete the article of Messrs. Nichols and Miller on the nearby simultaneously advancing and retreating glaciers [1] by studying several others. He tries also to select from among the numerous possible causes they have suggested, the one which is likely to be effective.

A New Advance of the Moreno Glacier

Since the reconnaissance of Nichols and Miller, the Moreno Glacier has again dammed the Canal de los Témpanos. We were informed of this fact by an eye-witness on landing at Lago Argentino. It happened at the end of September 1951. When flying back two months later, the pilots of the L.A.N. told us that the waters had risen 9 m. behind the ice dam. According to Heim [2] and the above-mentioned authors, the damming of the Canal de los Témpanos in the twentieth century, that is since the settlement of this region, has occurred during:

January 1917
January to December 1935
July 1939 to 17 February 1940
Beginning of 1941 to 21 March 1942
April to December 1948
End of September 1951 and still persisting in February 1952.

It may be noted that, while the destruction of the dam occurs on the return of warm weather, the obstruction happens at every period of the year. Yet the wastage of the glacier is due principally to melting by the tepid water of the immense lake, and consequently seems to be related to the season. But really we know nothing about the temperature of the lakes of Argentino and Viedma throughout the year, although this may be of great interest.

The upper layers are exceptionally warm; at 1 km. from the front of the Viedma Glacier * in a bay crowded by floating blocks of ice and small icebergs (Fig. 1, p. 173), the temperature of the water was about 12° C. and the ice melted quickly, allowing the crystals, which were of hazel nut size and surprisingly uniform, to be seen. The greatest part of the lakes of Argentino and Viedma lie inside the barren Pampa, where the relative dryness and great purity of the air allow a high degree of insolation. Therefore, the cold melt water certainly flows to the bottom without mixing.

Retreating Glaciers

Fig. 2, p. 171, taken from the U.S. Air Force Charts,[3] shows the south Patagonian ice field. It will be seen that the retreating Ameghino, Mayo and Upsala Glaciers are fed from snow fields through narrow passes. The firn line is about 1200 m. in this watershed.

The Ameghino Glacier issues from the snow field of the Moreno Glacier to the south through a narrow defile 18 km. from its end. The Mayo Glacier has two narrow passes at 9 and 12 km. from its snout. (If it continues to retreat it will uncover a hitherto dammed fjord which is still unexplored, and whose lower end is only 8 km. from an unexplored fjord in the Pacific Ocean.) The Upsala Glacier is fed by the Altiplano Italia, a flat ice field of an altitude of 2100 m., perhaps also by the Bertacchi Glacier, and three other narrow parallel glaciers at distances of respectively 11, 17, 25 and 30 km. from the snout. It is also probably fed through a pass 35 km. distant.

These conditions can entail a lag of twenty to fifty years between the variations of these glaciers and that of the Moreno Glacier with its simple shape. This, possibly, is the reason why they are still retreating while the Moreno advances.

* With the exception of the Viedma Glacier, referred to in the official maps as Ventisquéro Viedma, the glaciers of the region now described are not marked in official maps. For convenience "Glacier" will be used throughout this article and not "Ventisquéro."—*Ed.*

The Viedma Glacier

This glacier is similar to the Moreno in its dimensions and its "orthodox" configuration; it is essentially alpine in type, although immensely larger than the average Alpine glacier. It has diminished since the beginning of the century, its small right arm having disappeared (as reported by a local inhabitant, A. Madsen, to A. Heim). But a photograph from De Agostini [4] taken in December 1930, when compared with Fig. 1, shows that the front has been stationary or has even advanced during the last 20 years. Rocks are no longer seen under the southern part of the front, the whole breadth of the glacier reaching to Lago Viedma.

Some new local phenomenon would perhaps have counteracted this advance. Observing still confidential A.A.F. photographs of 1945, Professor Carlos Keller of the University of Chile, found a volcanic crater of 7·7 km.^{2} which was giving forth smoke in the accumulation area of the Viedma Glacier at the foot of the Mariano Moreno range. By kind permission of the Argentine Government we were enabled to fly over Monte Fitz Roy when returning, and I distinctly saw the crater of ashes among the ice, on a level with the glacier. It in no way resembled a nunatak, but was without any sign of volcanic activity. At the firn line there was an irregular brown marking which could not be explained by any moraine deposit, and is perhaps the evidence of a relatively recent eruption of ashes.

Corrie Glaciers around Monte Fitz Roy

This mountain, 3441 m. high according to my calculations, is a fantastic tower of granodiorite, which rises from 1300 to 2000 m. over corrie glaciers flowing east–west, at the margin of the Patagonian ice field the "*Hielo Continental*". The region was explored by De Agostini in 1931 and 1936, and numerous photographs are published in his book.[4]

All these glaciers end in a lake, formed by a barren moraine, except the small ones on steep slopes which cannot reach the bottom of the valley. This has often been considered a sign of very recent glacial retreat. (In the French Alps the only example is, I believe, the lake formed at the end of the Glacier des Bossons during recent years.) Now we must consider that, first, owing to the very strong and persistent west winds which produce important aeolian erosion, vegetation settles with great difficulty on barren mountains unless there is the screening effect of a forest. Secondly, these lakes are almost on the level with large neighbouring, horizontal valleys, so that fluvial erosion must be small and they cannot be drained off very quickly. The date of 1780–1880 advanced by Nichols and Miller after studying the Ameghino Glacier seems more credible than a more recent date.

At the south of Monte Fitz Roy flows the Grande Glacier (sometimes called the Fitz Roy Glacier although it does not come from the Fitz Roy). This ends in Lago Torre, from which flows the Fitz Roy River. The southern side ends at a rocky cliff 50 m. above the waters of the lake, while the north side is lower and afloat. The photographs of De Agostini in 1931, and of Heim in 1946, show no variation between these two dates. The glacier has not retreated 200 m. and decreased in height by 30 m. during these years as stated by Heim.

Between 1946 and 1952 the floating part of the glacier has retreated a little, but the level of the lake has been lowered from 12 to 15 m. by the erosion of the morainic dam by the river. The five or six rocky eminences forming part of the same cliff between the corrie of the Grande Glacier and the valley have remained unchanged since 1931.

A similar lowering of the lake could perhaps explain the recession of the Rio Blanco Glacier between 1932 (first photograph of De Agostini) and the present day. In De Agostini's photograph the glacier flowed over a cliff on the south side and plunged into the lake, covering a third of it without breaking up into seracs. To-day it only reaches the top of the cliff, from which seracs fall every two hours with terrific noise, forming four avalanche cones. From these cones blocks of white ice and firn laden with rock debris extend, more or less united, to form a little ice pack rather than a true re-formed glacier (Fig. 3, p. 173).

Fig. 2. The South Patagonian Ice Field. The stippled areas are the parts of glaciers lying below the firm line

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On 16 December 1913, as local inhabitants told De Agostini, a huge flood of water, earth and rocks washed down the Rio Blanco valley. An accumulation of rocks, still visible although invaded by vegetation, proves that it was caused by the destruction of a great dam in front of the Rio Blanco Glacier. We can assume that the glacier has been retreating since then, and has not yet reached its new equilibrium.

The next corrie glacier to the north, Piedras Blancas Glacier, so named for its white granodioritic frontal moraine, and Marconi Glacier, have the same extension as in 1936. The same can be said of the Gorra Blanca Glacier, which is not a corrie glacier but an outflow of the "*Hielo Continental*" through a broad pass between Cerro Gorra Blanca and Cordón Marconi.

Conclusion

There is then no proof of a general recession of south Patagonian glaciers during the last twenty years as in Europe. The known examples can be explained by local orographic factors. I think that hitherto authors have been influenced by the important and undeniable recession of glaciers in the Andes near Santiago and Mendoza, and the consequent production of many important "stone rivers," but the climatic conditions of Pantagonia are quite different, and no extrapolation through 2000 km. can supply the missing records.

A pilot who has flown over Patagonia for the last twenty years has assured the writer that the climate has become less cold but wetter and cloudier during that time. With the invasion of settlers and sheep there were many huge fires which destroyed an important part of the primeval woods. This may make for dryness, but the influence of the relatively near and almost unknown Antarctic Continent should prevail.

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REFERENCES

1. Nichols, R. L., *and* Miller, M. M. The Moreno Glacier, Lago Argentino, Patagonia. *Journal of Glaciology*, Vol. 2, No. 11, 1952, p. 41–46.
2. Heim, Arnold. *Informe sobre un estudio glaciológico en el Parque Nacional "Los Glaciares."* Argentina. Ministerio de Oras Públicas de la Nación, Administración General de Parques Nacionales y Turismo, 1946.
3. A. A. F. Preliminary Base, Scale 1/250,000. Washington Aeronautical Chart Service. (From trimetrogon photographs taken in 1945.)
4. Agostini, A. M. De, *Andes Patagónicas*. Buenos Aires, *Ed.* Kraft, 1945.

MARINE AND LACUSTRINE ICE-PUSHED RIDGES

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Marine ice-pushed mounds and ridges * formed by sea ice, growlers and bergs are common on the Arctic beaches. Crescentic ice-pushed ridges are found on both modern and elevated beaches at Slidre Fiord, Ellesmere Island, N. W. T. The material in the ridges is derived from the scars which are associated with them. The slope which faces the scar is flat, due in part to the fact that it may have been overridden by the ice, whereas the other slope of the ridge is steep. The ridges are a few feet in height and several feet long. One ridge was found which is more than 20 ft. (6 m.) above sea level and many scores of feet from the strand line. It may have been formed when the sea level was higher, or during the present sea level by ice thrust above and beyond the highest tide line. Ice-pushed ridges and crescents were not seen on the elevated beaches at Resolute Bay,

* These features have been variously described as "ice ramparts", "ice-shove ridges" and "ice-push ridges"; the name used here is, in our view, more descriptive and euphonious.—*Ed.*