Translation 58

MAY, 1959

Exploration of "Inland Ice"

Greenland and Antarctica

Die Erforschung der "Inlandeise" Grönland; Antarktis

by Fritz Loewe

Umschau 1956, Heft 4, p. 110-113

Translated from the German
by Katherine Martinoff,
USA SIPRE Bibliography Project,
Library of Congress

U. S. ARMY SNOW ICE AND PERMAFROST
RESEARCH ESTABLISHMENT
Corps of Engineers
Wilmette, Illinois

EXPLORATION OF "INLAND ICE"

by
Fritz Loewe

Great progress has been made during the past few decades in the study of ice caps. After occasional explorations and crossings, the first attempt at a systematic investigation of an ice cap was made by the German Greenland Expedition Alfred Wegener from 1929-1931 (1). The early loss of the leader of the expedition interrupted the extensive research program. The "Expeditions Polaires Francaises" under the leadership of Paul-Emile Victor resumed the investigations of the Greenland Ice Cap 20 years later with a more extensive program and the aid of modern technical equipment (1).

The exploration of the many times larger Antarctic inland ice has progressed more slowly due to more difficult conditions. No permanent station has yet been established on the Antarctic inland ice. The most extensive scientific exploration program was carried out by the Norwegian-British-Swedish expedition to Queen Maud Land (10°W) from 1950-1952 (2). However, the work was hampered because the base station was located on a floating ice shelf 150 km from the inland ice.

Extent of ice caps

The Greenland Ice Cap has been crossed by different parties by sled, motor sled, and airplane, and its surface has been determined as 1.75 million km^2. The interior of the larger Antarctic inland ice, on the other hand, has been entered and flown over only at individual points. Only once has an airplane crossed it. Its outline is known, thanks to American aerial photographs (3). It covers an area of 12 million km^2. Most of the latest expeditions to the Antarctic, the German "Schwabenland-Expedition" of 1939 for instance (4), discovered new mountain peaks and ridges in its interior. It is almost certain that no ice-free land surfaces exist in the unexplored areas; most of the surface is covered by an unbroken cover of ice.

Elevation of ice caps

The elevation of the Greenland Ice Cap at most points is known due to the evenness of its surface. The majority of the height data are based on barometric measurements which may show errors of a few percent. However, they are supported by trigonometric determinations for a line running from the west coast almost to the east coast. The elevation of the French winter station, Eismitte II, in Greenland's interior (70°55′N., 40°38′W.) has been assessed at 2994 ± 1 m. The mean elevation of the ice cap, according to all measurements, is 2100 m. An area of 230,000 km^2, i.e., about 3 times the size of Bavaria, exceeds the height of Zugspitze; the maximum elevation is 3300 m. (5).

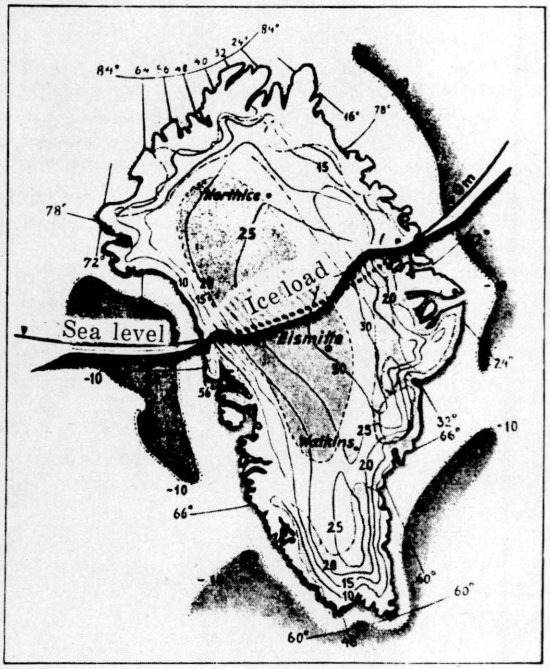
Little information is available on the elevation of the Antarctic inland ice, though indirect determinations indicate with a high degree of certainty that it corresponds to that of Greenland, in spite of its greater area.

Ice-cap elevations, as measured in Greenland, agree with values assumed for the ice sheets covering Europe and America during the ice ages (6). Nature takes care that the ice caps "do not grow into the sky." The higher their surface, the lower is the temperature of the level they reach, the smaller the water vapor content of the air, the thinner the cloud layer, and the less the snowfall. The discharge velocity of the ice, on the other hand, increases with increasing elevation and glacier steepness. An equilibrium height for ice accumulation and drainage is thus reached, which is assumed to lie not much over 3000 m elevation.

Ice thicknesses up to 3 kilometers

The mean elevation of the Greenland and Antarctic ice caps are disproportionate in comparison with the mean elevation of other continents. The question is whether it is due to the excessive ele-

Sled tracks in powdery snow in the interior of the ice cap. Here the snow cover slopes up to Eismitte. At right: a drum which served as route marker.



Elevation of the ice cap and the underlying rock of the Greenland Ice Cap.

Through the representation of Greenland provided by the contour lines, a section is cut through the middle, and the position of the section line corresponds to the drawn sea level line 0 m. Notice how the bedrock rises, then in the middle of the continent sinks below 0 m under the great load of ice, then rises again and finally drops to the sea. The huge ice dome rises over the bedrock.

vation of the continental shelf, as in Tibet, for instance, or to the thickness of the ice cover over a bedrock of normal elevation.

This question was recently solved for the Greenland Ice Cap. After the pioneer work of the Wegener expedition, the ice thickness in Greenland has been determined at many points by French investigators (7) during the past few years. The methods of measurement were similar to soundings at sea. A shock is produced on the snow surface and is reflected by the bedrock. The time between the explosion and the return of the shock wave to the surface gives the measure of the ice thickness when the wave propagation velocity is known.

According to these measurements, the ice thickness in the center of the Greenland Ice Cap exceeds 3000 m in many places. The mean thickness is 1500 m. (5) If the ice cap should melt, the level of all seas would rise 6.5 m. Thus, the bedrock of the interior lies below sea level at many places (see illustration). We find here an analogy to the glaciation of Europe and America during the ice ages, i.e., when the present high level land near the Baltic Sea and Hudson Bay lay under sea level.

Whether similar conditions prevail in the Antarctic cannot yet be ascertained. Only the Queen Maud Land expedition has made a number of thickness measurements of land ice (2, 7). Thickness values obtained from measurements 350-450 km inland exceed 2000 m and correspond to those in Greenland. Two measurements made by the French expedition to Adelie Land showed much smaller thicknesses. Our knowledge is too fragmentary to allow any definite conclusions as to the general thickness of Antarctic ice.

Measurements made in Greenland and the Antarctic have had another positive result: they confirmed thickness values determined indirectly for the diluvial ice sheet (6).

Depression of the bedrock by ice layers?

Observations that the bedrock in Greenland is below sea level under the thickest parts of the ice cap raises the question whether this is due to the load of the ice. After all, an additional load of 2-3 km of ice lies on the bedrock, which corresponds to a 1-km thick rock layer. The thought of an "immersion equilibrium" is brought about by the bowl-shaped form of the bedrock under the ice; the bedrock lies deepest where the ice is the thickest. Gravity measurements made by the Wegener expedition and by French expeditions indicate that such depression of the bedrock has taken place. This confirms the opinion that the rise of the land in the North Baltic Sea area and in the region of Hudson Bay (up to 1 m a century) represents an upward motion to return to a new equilibrium, caused by the disappearance of the diluvial ice sheet.

Are the ice masses increasing?

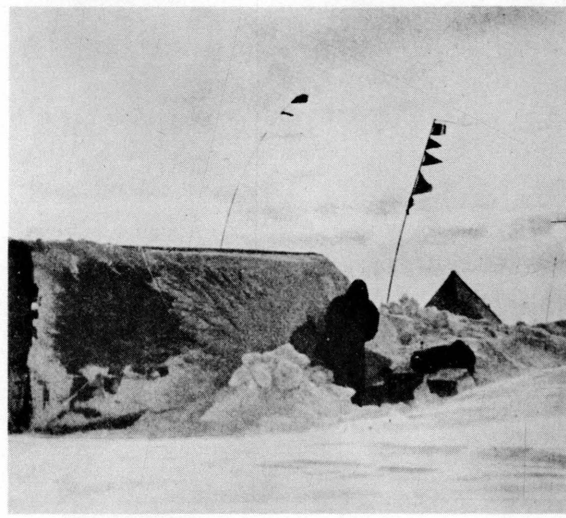
Temperatures near the ice surface are low. The annual mean in the center of Greenland is −30C, while in the center of the Antarctic Continent it is below −40C according to available snow temperature data. These temperatures are much lower than over surrounding seas at similar elevations. The ice caps thus are sources of air cooling. The intense cold results from the fact that most of Greenland and of the Antarctic is covered throughout the year by the purest new snow. Pure snow reflects 5/6 to 7/8 of the solar and sky radiation, while snow-free ground reflects only 1/8. Thus, snow absorbs only 1/5 of the heat absorbed by a snow-free surface under similar conditions. This explains the low temperature of the snow surface. The cold is transferred to the air which in turn contributes to the conservation and growth of the snow cover. We are faced here with the process of self-reinforcement, so common in nature. At the same time, the ice caps continuously lose heat by outgoing radiation. The radiation balance of these ice surfaces is negative for the greater part of the day. Unless continuous heat loss by radiation is compensated for, the ice caps will become increasingly colder. The compensation takes place in Greenland through the heat of sublimation which is supplied to the air during the formation of snow, and in the Antarctic by the cooling of warmer air which flows over the edge of the inland ice.

The ice mass increases due to snowfall or, to a lesser degree, to hoarfrost formation at the cold snow surface. It decreases, on the other hand, as a result of melt-water runoff, evaporation, wind action, and iceberg formation. Which is the predominant factor? We cannot solve this question yet, but we know from measurements in Greenland that melting and evaporation are overbalanced by accumulation. This is even more true for the Antarctic where melting is very moderate. The amount of iceberg formation is too little known to determine whether it compensates for the excess or whether it leads to a mass loss.

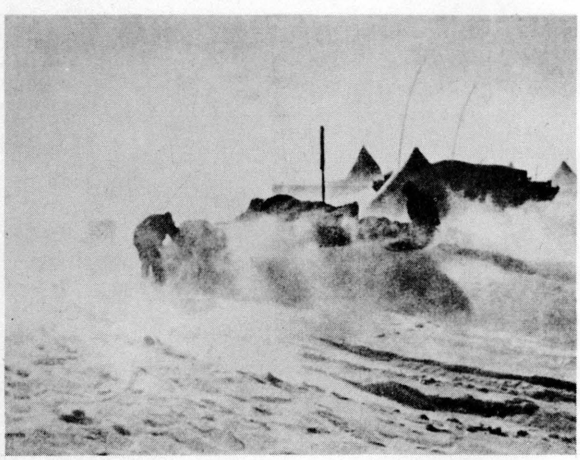
Blowing snow

Transport by wind plays a special role in the mass change of ice caps. It is the greatest enemy of the investigator who can see only a few meters in the thick blowing snow, whose face soon becomes covered with an ice crust, and whose tent disappears under rapidly forming snow drifts. Blowing snow begins at wind speeds of 6-8m/sec. in the form of a light veil over the surface. With stronger winds, it increases rapidly in height and density, and in a full fledged storm, transforms the polar world into a gray, roaring hell.

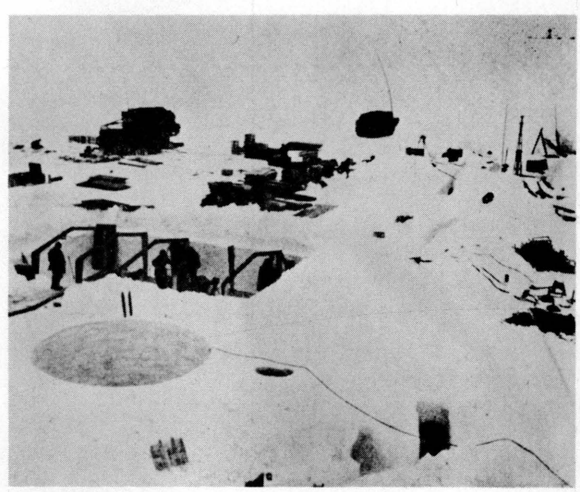
The question of how much blowing snow is transported has been answered in different ways. Investigations on the subject have been undertaken recently in Adelie Land, in the area of the Antarctic near 140°E. Here, in the "native country of snowstorms," (8) wind conditions prevail which are not known in most parts of the Antarctic and Greenland ice caps. The velocity of the winds, which flow to the coast along the slope of the ice cap, averages 70 km/hr. Only about 30 days, mostly in summer, are free of windstorms. Wind speeds of 150 km/hr. are common in winter. Hourly means of almost 200 km have been recorded. Blowing snow can be so dense that visibility is reduced to 1-2 m; three paces from the house leave a man alone in a roaring, breathtaking, stupendous chaos.



Camp prepared by members of the French Greenland Expedition.



Blowing snow on the ice cap.

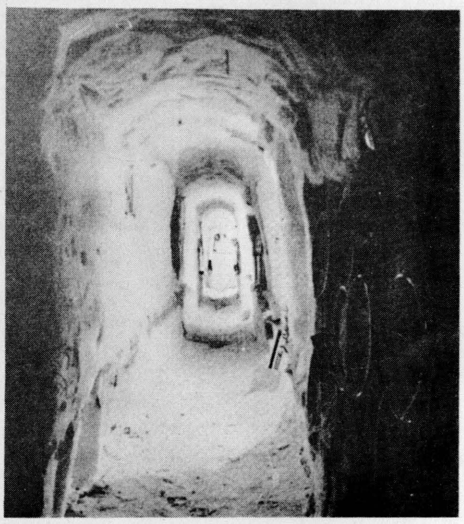


Eismitte: this winter station lies essentially underground.

Measurements of snow transported by blowing showed that during a hurricane, at least 250,000 tons of snow pass over the coastline in a 1-km wide front during 1 day. (To transport this amount to the coast by railroad would take fully loaded freight trains on tracks arranged parallel in a 1-km wide line running every 25 minutes.) At least 20 million tons of snow a year are transported by winds over every kilometer of coast line. For this reason blowing snow in this part of the Antarctic is more important than melting and iceberg formation. This, however, is not true for other parts of the Antarctic and for Greenland, where such storms are much rarer.

Further research during the "geophysical year"

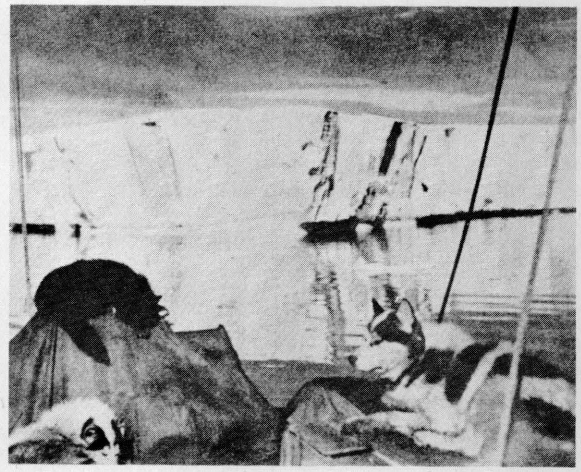
We are at this time in a period of intensified ice cap research. Since the end of the war, French, British, Swedish, Australian, and U. S. scientists have worked on the ice caps of the north and south. As a continuation of the "Polar Years" of 1882/83 and 1932/33, a "Geophysical Year" will



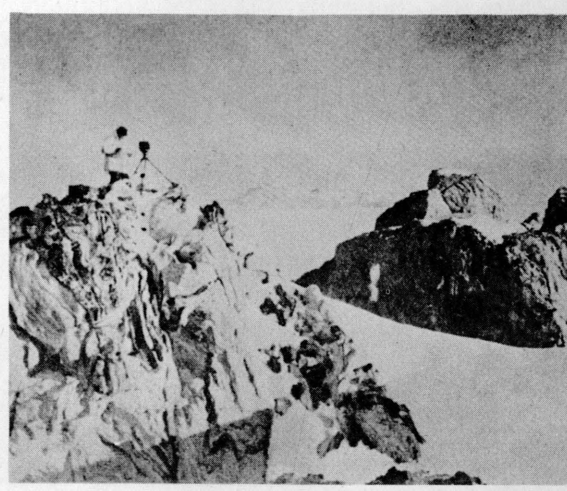
Passageway of the station after a year. The passages had to be repaired and cleared of snow again. On the left wall can be seen layers of snow which had to be cleared away to give the passage sufficient height again.

be held in 1957/58, in which observations will be made simultaneously all over the world according to a uniform program. Emphasis will be placed on investigations in high latitudes, especially the Southern Hemisphere. Various plans exist for the establishment of winter stations in the center of the Antarctic inland ice. After a number of winters spent in Greenland, enough experience was gained on the equipment required and on how to accomplish the task. Because of the exceptionally low temperatures (monthly mean below —50C) more difficulties will be met by the Antarctic winter stations than by those in Greenland. Newly developed geophysical methods will give us a better understanding of conditions on ice caps, the unfriendliest of all large areas of the earth.

While the central part of the Antarctic is presumably covered by a thick layer of ice, high mountains have been discovered in its marginal areas, through the valleys of which large glaciers move slowly to the coast.



Landing of the Antartic Expedition Crown Princess Martha Kyst, which was a joint enterprise of Norwegians, English, and Swedish. They worked principally in Queen Maud Land.



On the way to the interior of the Antarctic. (Both photos: Norsk Polarinstitut, Oslo).

REFERENCES

(1) Wegener, K., et. al. (1933-40) Wissenschaftliche Ergebnisse der Deutschen Grönland Expedition Alfred Wegener (Scientific results of the German Greenland Expedition Alfred Wegener). Liepzig: F. A. Brockhaus, Bd. I-VII.

Wegener, E. (1932) Alfred Wegeners letzte Grönlandfahrt (Alfred Wegener's last Greenland Journey). Liepzig: F. A. Brockhaus.

Georgi, J. (1933) Im Eis vergraben (Buried in the ice). Munich: Paul Müller.

Expeditions Polaires Francaises (1949) Rapports Preliminaires, and Resultats Scientifiques (Preliminary reports and scientific results). Paris.

Bouché, M. (1952) Groenland, Station Centrale. Paris: Grasset.

(2) Schytt, V. (1953) Der Erde, vol. 5, p. 179.

(3) Byrd, R. E. (1947) National Geographic Magazine, vol. 42, p. 429.

(4) Ritscher, A. (1942) D. Deutsche Antarktische Exp. 1938-39 (German Antarctic Expedition, 1938-39). Liepzig: Koehler and Amelang.

Herrmann, E. (1941) Deutsche Forscher im Südpolarmeer (German investigator in the South Polar Sea). Berlin. Safari-Verlag.

(5) Bauer, A. and Holtzscherer, J. J. (1954) Contribution a la Connaissance de l'inlandeis du Groenland (Contribution to the knowledge of the inland ice of Greenland), Expeditions Polaires Francaises, N. III 2; N.II 3. Paris.

(6) von Klebelsberg, R. (1948) Handbuch der Gletscherkunde und Glazialgeologie (Handbook of Glaciology and Glacial Geology). Vienna: Springer.

(7) Holtzscherer, J. J. and Robin, G. de Q. (1954) Depth of polar ice caps, Geographic Journal, vol. 120, p. 193-202.

(8) Mawson, D. (1914) Leben und Tod am Südpol. Leipzig: Brockhaus. (English title: The home of the blizzard).