The Geophysical Institute QUARTERLY

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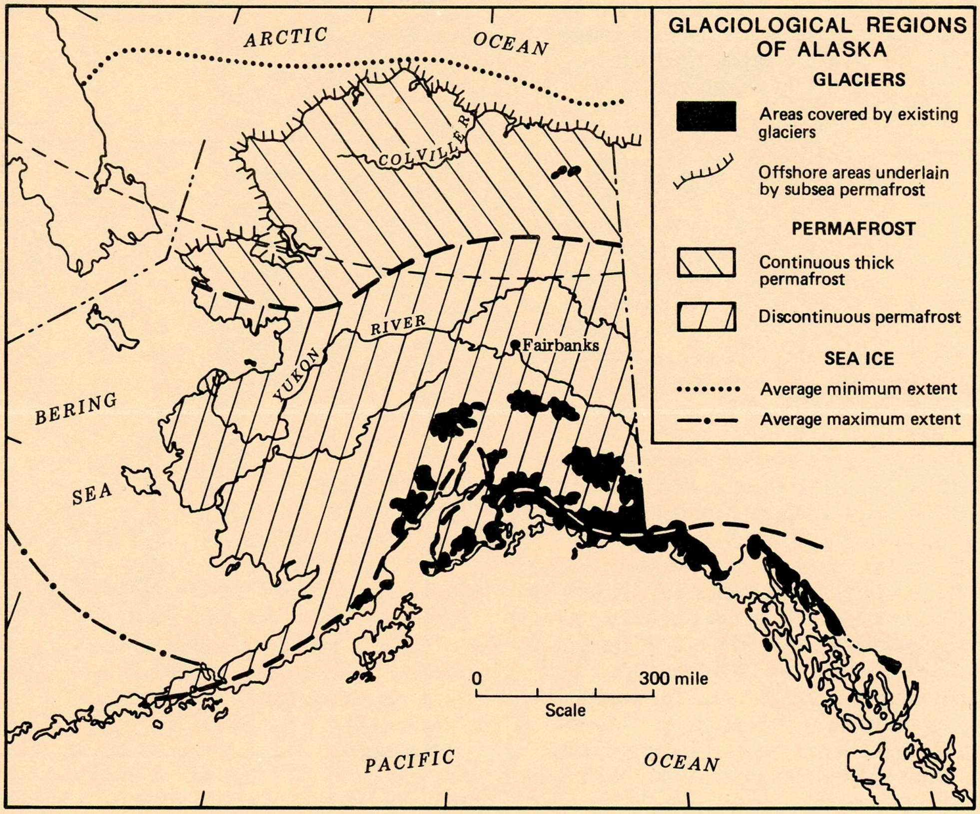
SNOW, ICE, AND PERMAFROST



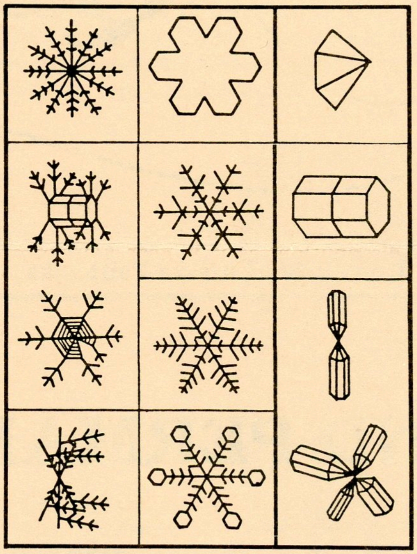
ICE, IN ITS VARIOUS FORMS, affects almost every facet of life at high latitudes. Sea ice covers the waters of the Beaufort, Chukchi, and Bering seas for up to ten months of each year. Alaska has more glaciers than any other region outside of Antarctica, Greenland, and the high Canadian Arctic. Rivers and lakes may be ice covered for as much as nine months of the year; and a seasonal snow cover blankets the area. Permafrost underlies approximately three-fourths of the state and most of the continental shelf under the Beaufort Sea. For snow, ice, and permafrost research, Alaska offers a vast and magnificent natural laboratory to scientists of the Geophysical Institute who can study both fundamental and practical problems.

This issue of the *Quarterly* will define and explain some of the terms and the processes associated with the various ice forms in Alaska. It is specifically addressed to high school students and college undergraduates who are interested in glaciology and may even contemplate pursuing a career in this field.

Editors

ICE CRYSTALS

Water freezes at 0°C (32°F). In the atmosphere, tiny water droplets and water vapor may freeze into delicate crystals such as those shown in the figure. A Japanese scientist, Dr. Ukichiro Nakaya, has spent almost all of his professional life studying and classifying these crystals, of which there are hundreds of different forms. When snow crystals fall on the ground, a very low-density (light-weight) snow cover results, after which the crystals grow in size and the snow becomes denser. During spring in the interior of Alaska, so-called depth hoar often can be found at the bottom of the snow pack. This depth hoar consists of large platelike crystals, up to 1 cm (3/8 inch) in size, that collapse easily. On the wind-swept Arctic Slope and on mountain tops the snow is often compacted into hard, dense layers that are not crushed even by heavy loads.



From *Snow Crystals* by U. Nakaya, Harvard University Press, 1954.

GLACIER FLOW

In mountainous areas of the colder parts of the world, more snow falls than can melt in one season. As the snow is compacted by successive layers of newly fallen snow, its density increases and the snow finally turns into ice with a density of 0.9 (the density of water is 1.0). The ice behaves like a plastic material and begins to flow downslope under the force of its own weight. As the glacier flows, it collects boulders and stones and then deposits them in formations called moraines. The molasses-like flow of ice and the rock bands of the moraines can be seen clearly in the photograph of the Barnard Glacier in the St. Elias Mountains on the border between Alaska and the Yukon. When the ice moves over rock ledges and slopes, it is caused to crack open, forming crevasses as large as several meters (tens of feet) wide and tens of meters deep.

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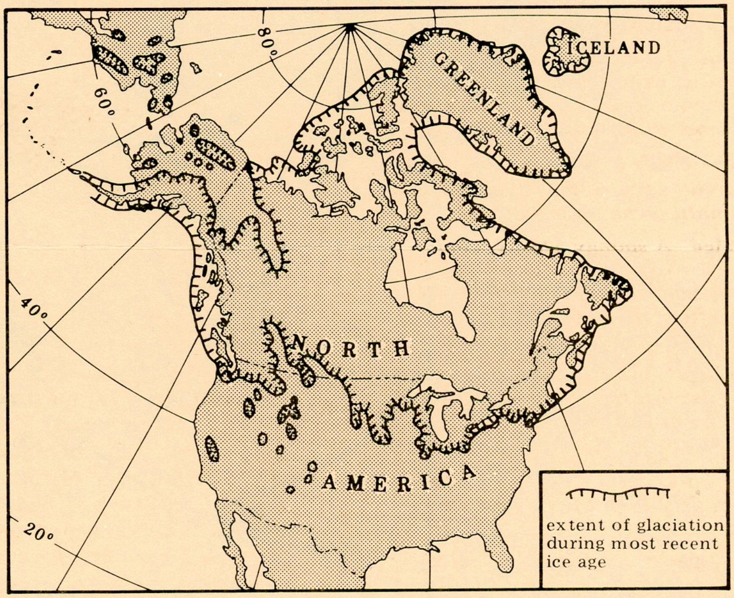
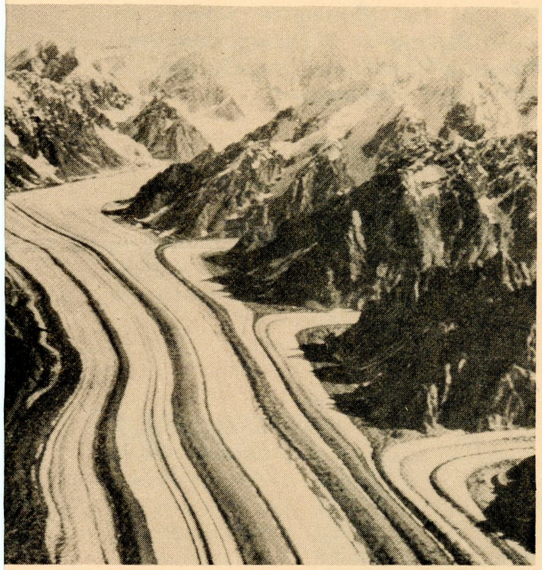
ICE SHEETS AND ICE AGES

Ice sheets are ice masses of very large dimensions. Only two exist on the earth at present, in Greenland and in Antarctica; the latter covers an area larger than the U.S. with ice over 3.2 kilometers (2 miles) thick. In the earth's history, however, there have been ice ages during which much larger parts of the earth's surface were covered by ice. The causes of these ice ages are still poorly understood, but they probably involved less energy reaching the earth's surface in the form of sunlight. About 30,000 years ago, large ice sheets covered both North America and Europe. (Interior Alaska was not glaciated.) As shown on the map, the ice extended south of the Great Lakes region of the contiguous United States. The sea level was much lower then, since much of the ocean water was locked up in the giant ice sheets. Asia was connected to North America through the Bering Land Bridge, making it possible for humans to migrate from Asia to what is now Alaska and eventually through Central America to South America. Most of this ice is now gone from North America, with the exception of inland alpine glaciers, ice caps in the coastal ranges along the Gulf of Alaska, and glaciers on the islands of the Canadian Archipelago; but future ice ages are entirely possible.





aciers by R. P. Sharp, University of Oregon Books, 1960.

SOME TERMS ON ICE

Ablation *Processes by which snow and ice are lost from glaciers, floating ice, or snow cover. These include melting, evaporation, and wind erosion.*

Fast ice *Sea ice that is attached (made fast) to the coast and does not move much until break-up in summer.*

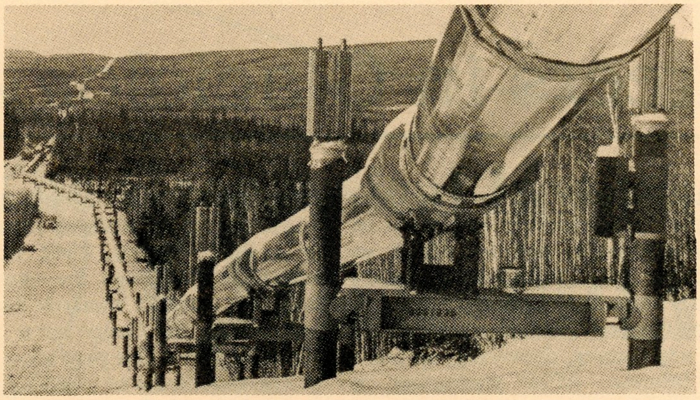
Frazil ice *A spongy, slushy, cinder-like mass of frazil crystals. Frazil crystals, small coin-shaped discs, are formed from the freezing of super-cooled turbulent water.*

Glaciology *The study of snow and ice. In its more restricted form it refers to studies of glaciers only.*

Pack ice *Sea ice that usually consists of broken-up large and small floes of ice that drift with the currents and winds.*

Surging glacier *A glacier that alternates between surges (brief periods of rapid flow) and stagnation.*

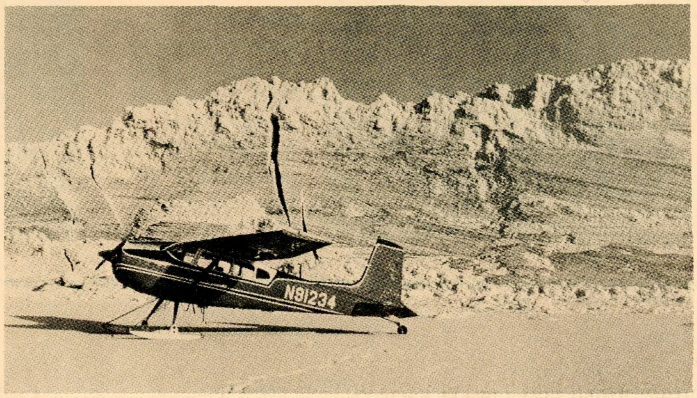
Thermokarst *Topography with holes caused by local melting of ground ice (permafrost) and subsequent settling of the ground.*



Alyeska photo.

FROZEN GROUND AND PERMAFROST

Water also freezes in the ground. When ground temperatures stay below freezing year-round, permafrost is formed. Permafrost does not necessarily have to be ice, but can be any material, including dry soil, rock, or even rusting tin cans buried in the ground. Permafrost is called *discontinuous* when it is patchy in its distribution, as it is near Fairbanks. North of the Brooks Range permafrost is *continuous*, in other words the entire area has permafrost, which is up to 600 meters (1800 ft) thick near Prudhoe Bay. Only when there is ice in the ground, usually in the form of ice lenses and ice wedges, does permafrost cause problems to man-made structures such as roads and buildings. When these ice masses melt, for example beneath a poorly insulated house, the ground may collapse and with it any structure. The trans-Alaska pipeline was constructed above the permafrost to prevent the warm oil from melting it and causing the pipeline to sag and break. Geophysicists are now studying various methods to detect these permafrost ice masses quickly and cheaply from the surface.



B. Points photo.

SEA ICE

Sea ice is quite a different substance from freshwater ice. It includes salt and brine and freezes at about -1.8°C (29°F) into small crystals. Accumulations of these crystals bump together and solidify into round pancake-like floes that may reach several feet in thickness. When strong winds blow, the ice may be pushed together to form fantastic pressure ridges, such as the 15-m (50-ft) high ridge near Barrow shown in the photograph. These ridges could cause problems if they move and collide with the platforms used in oil exploration off the coasts of Alaska. Icebergs, consisting of freshwater ice broken off from glaciers rather than sea-water ice, cause similar problems.

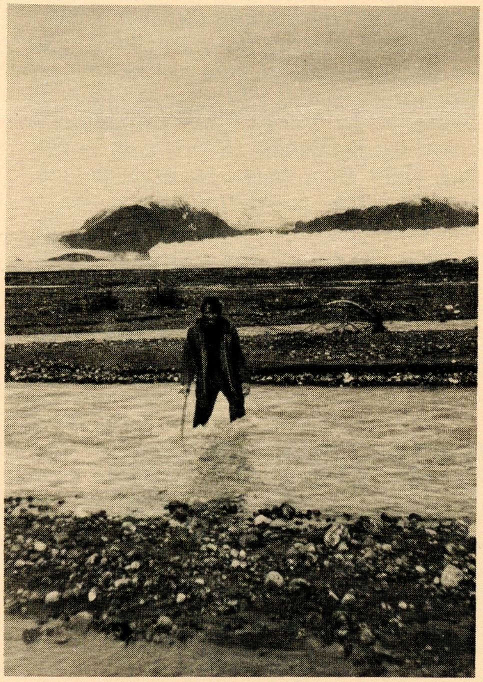
In addition to the dangers of sea ice there are some advantages. Sea ice can provide a stable surface for scientists and oil-seeking prospectors on which to work. In fact, the Arctic Ocean is the only ocean that has had permanent scientific stations established on it, and the only ocean that has been crossed by humans on foot!

The sea ice of the Arctic is continuously in motion, moving sometimes as much as several tens of miles per day. Eventually most of the ice passes out of the Arctic between Greenland and Spitsbergen and melts in the North Atlantic.

Careers in Glaciology

The study of snow and ice is an exact science that is particularly important in Alaska where snow and ice affect so much of our lives. To become a glaciologist it is necessary to study physics, as well as meteorology, oceanography, geology, and engineering, depending on one's specific interest. After graduating, a student can take graduate-level courses in glaciology at the University of Alaska-Fairbanks while working toward an M.S. or a Ph.D. degree. Field work and research in glaciology are carried out by students through research assistantships, awarded by the Geophysical Institute. As the pictures on this page show, field work in the mountains of Alaska (left) and on the ice caps of Antarctica (right) and Greenland can be both exciting and fun.

Job opportunities for glaciologists exist with the petroleum industry, government agencies such as the U.S. Army Cold Regions Research and Engineering Laboratory, the U.S. Geological Survey, the Alaska Department of Natural Resources-Division of Geological and Geophysical Surveys, and elsewhere.



Geophysical Institute Professor Will Harrison spent several seasons studying the surging Variegated Glacier in southeastern Alaska. He is shown here traveling to a study site.

Yuji Kodama, graduate student at the Geophysical Institute, is pictured near the D-57 automatic weather station in Antarctica. The tail section of this downed U.S. aircraft is the only part visible after years of snow-drifting.

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