National Park Service
U.S. Department of the Interior

Gates of the Arctic National Park and Preserve

Glacier Chronologies in the Southern Brooks Range

Photo credit: Simon Pendleton

Ice once spread across this valley in Gates of the Arctic National Park and Preserve. Features such as the moraine boulders (note person for scale) can be used to date when glaciers deposited these rocks.

Glaciers move, and through valleys they move like rivers.

—John Tyndall, 1911

Rising from within the southern Brooks Range in Gates of the Arctic National Park and Preserve (see map on reverse), the granite rocks of the Arrigetch Peaks tower to heights of ~7,200 feet (~2,200 meters) above sea level. Hikers might find it hard to believe that ice once covered the valleys between the peaks.

Today in the valleys of the Arrigetch, there are no mighty rivers of ice. Only a few scattered glaciers remain in the high peaks. However, there are telltale signs of past glacial activity. Glaciers carved sheer rock ridges (*arêtes*), scoured grooves into bedrock, and deposited *moraines* (piles of sediment and boulders) at their sides and ends. These boulders and bedrock hold the key to deciphering the chronology of ice movement following the last glacial maximum (~20,000 years ago).

During the summer of 2012, Simon Pendleton, then a graduate student at State University of New York at Buffalo, ventured into the remote landscape of the Arrigetch to explore such questions as (1) When did the glaciers retreat after the glacial maximum? and (2) When did the remnant glaciers advance and retreat in the last few thousand years?

Glaciers and climate

Glaciers at high latitudes may be particularly sensitive to changes in climate. While small climate fluctuations at lower latitudes may not affect glaciers greatly, such changes in the Arrigetch had a more pronounced effect on its glaciers. Through a better understanding of past glacier response to climate change in the Arrigetch, Pendleton hopes to provide a scientific window into current changes that Arctic environments are undergoing.

Tools for studying glacier dynamics

In the past, researchers have used lichen size and growth rate to calculate the age of lichens that are growing on moraine boulders (and thus to date when the moraine was deposited by glacial advance).

Recently, researchers have begun applying a more sophisticated dating method to improve the chronologies of glacial activity. The technique of *cosmogenic nuclide exposure dating* is based on the fact that when rocks (bedrock or boulders) are freshly exposed, bombardment by cosmic rays will alter certain elements into radioactive isotopes (e.g., Oxygen into Beryllium-10) at a known rate. The amount of ^{10}Be in a rock sample can be used to calculate the length of time the rock surface has been exposed.

The timing of glacier *retreat* from a valley location is determined from the exposure time of rock samples collected from (1) bedrock surfaces scoured by glaciers and exposed as the ice retreated up valley and (2) boulders that were exposed when they dropped on bedrock as glaciers melted. For dating glacial *advances*, rock samples are taken from large

Photo credit: Kathryn Ladig

Pendleton gained park permission to collect rock samples. Here he samples an erratic perched on bedrock to date the retreat of glaciers.

Photo credit: Kathryn Ladig

To date when a recent glacier advance happened, Simon prepares to sample a boulder atop a moraine.

Photo credit: Simon Pendleton

Lichen diameter can be used to calculate when rocks were exposed after recent glaciers deposited moraines.

boulders deposited and exposed by glaciers on top of their lateral and end moraines. The time of exposure is used to date the period of glacial advance that created the moraine.

Field studies in the Arrigetch

Pendleton selected several valleys in the Arrigetch Peaks for his study of glacier chronology.

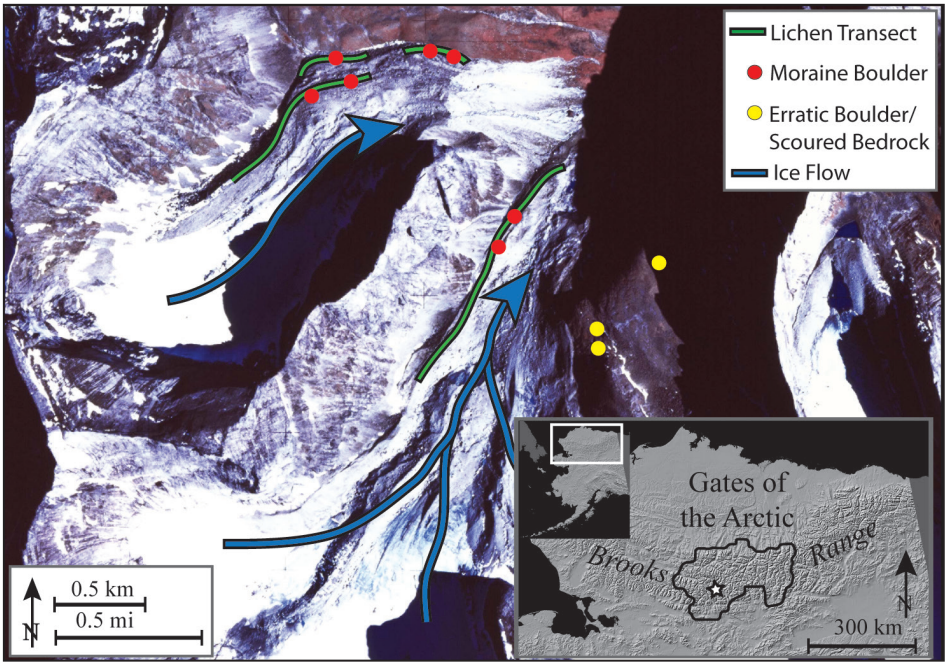
Rock samples for exposure dating. For dating glacial retreat, Pendleton collected two rock samples from glacial erratic boulders (see upper photo at left) and one sample from glacially-striated bedrock. For dating glacier advances, he also sampled seven rock samples from boulders on the top of moraines (see middle photo at left). The samples were analyzed on an Accelerator Mass Spectrometer with funding from the National Science Foundation and a Murie Science and Learning Center Research Fellowship.

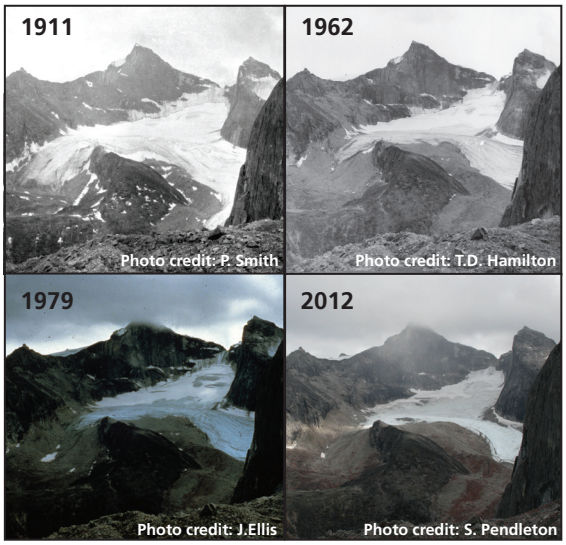
Lichen measurements. To provide additional ages for rock exposure after glaciers deposited moraines during recent advances, Pendleton established transects along prominent moraine crests (green lines on map below). He measured the diameter of the largest *Rhizocarpum geographicum* lichen on moraine boulder surfaces (see photos at left).

Results

Bedrock and erratic boulder samples that were dated from the Arrigetch River valley indicate that glaciers had retreated to their modern limits by ~16,000 years ago (see map). The moraine boulders sampled in the Arrigetch Peaks show that, following deglaciation, the remaining glaciers advanced downvalley three times about 3,800, 2,500, and 1,000 years ago. The diameters of lichens ranged from 2.3 to 5.4 inches (58 to 138 mm) and suggest dates of glacier advance ranging from 1,500 to 4,000 years ago, similar to the ^{10}Be findings.

In the Arrigetch (see star), glaciers moved in the direction of the blue arrows, scouring bedrock and leaving erratic boulders as they melted and retreated ~1.2 miles or 2 km (rocks were sampled at yellow dots). As the glaciers (white) advanced more recently, they deposited moraine boulders (sampled at red dots).





Repeat photography shows gradual retreat of ice about 1/3 mile (0.5 km) in the Arrigetch Peaks in the last century.

Repeat photography

Repeat photography is an important tool for recording glacial change in the past century. The Arrigetch—where Pendleton conducted his research—is the same locale where others had taken photographs in order to document glacier change. Photos of two nearby valley sites were taken initially in 1911 (P. Smith) and again in 1962 (T.D. Hamilton) and 1979 (J. Ellis). Pendleton repeated the shots in 2012. This 101-year photo series from the Arrigetch Peaks show a steady retreat of ice up the valley.

The future of ice in Gates of the Arctic

The glaciers in the Brooks Range are experiencing unprecedented warming. If the warming and other aspects of climate change continue, glaciers will continue to shrink and retreat. Information about the chronology of past glacier activity (from Pendleton's work with lichens, surface exposure dating, and repeat photography) will better equip geologists to project the changes yet to come for ice in the high Arctic. Perhaps future hikers in Gates of the Arctic will marvel that glaciers ever *existed* in the Arrigetch in recent times—and that glaciers once *covered* the Arrigetch valleys 15,000 years ago.

For more information

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