GEOLOGY & GLACIERS OF TONGASS NATIONAL FOREST

Glaciers and Caves

Southeast Alaska is a young land, a land shaped by fire, ice, and water. It's part of the "ring of fire," the volcanic band that stretches around the north rim of the Pacific Ocean, although there are no volcanos active here at the moment. An excellent example of this fiery part of the Tongass's history is Mount Edgecumbe, a volcanic cone clearly visible from Sitka.

A more recent force is ice. Like much of the northern hemisphere, Southeast Alaska was covered by ice during the last ice age. Ice still covers thousands of square miles, mostly at higher elevations but extending clear to sea level in several places. The ebb and flow of glacial ice over thousands of years carved out deep U-shaped valleys. In the last 10,000 years as the ice retreated, the land it once covered has lifted, "rebounding" in the absence of the glaciers' massive weight. Melting ice raised the level of the sea, too, and it poured into the deep valleys, forming the islands and fiords that make up the landscape we see today.

Nor were glaciers the only source of water that shaped the Tongass. The abundant rainfall, flowing over organic soil and into the limestone underlying many areas, has formed karst landscapes and deep and extensive caves, many older even than the glaciers. This recently discovered and recognized karst geology is proving to be a world-class resource. Exploration and mapping of the caves is revealing their extent and also yielding evidence of their prehistoric use by animals and humans.

The geologic history of the region - young soils "growing" after retreating glaciers bared scoured rock - and the cool, wet climate have produced the Tongass of today, a land of towering trees where water could drain and stunted plants in the peat bogs that formed where water was trapped, of ice fields, bare rock, alpine meadows, and temperate rain forest.

How It All Started: Glacier Heaven - Southeast Alaska

Alaska has hosted a glacier-favoring mixture of climate and topography for the last 12.5 million years. During the Pleistocene age, when the climate was 3 to 9 degrees Fahrenheit colder than it is today, an ice sheet covered a large expanse of the earth, including the islands of southeastern Alaska. Today there are still over 100,000 glaciers in Alaska, although ice covers only 5 percent of the state. The icefields and glaciers of the Tongass National Forest are some of the few remnants of the once-vast ice sheets.

In Southeast Alaska, maritime climate and coastal mountains work together to create favorable conditions for glaciation. The icefields straddle the Coast Mountain Range on the United States-Canadian border, directly in the path of the Pacific Ocean's prevailing winds. Moist air flows toward the mountains, rises, cools, and releases snow and rain. Annual snowfall on the Juneau Icefield exceeds 100 feet, and mild Southeast summers assure that winter snow accumulation exceeds summer snowmelt at higher elevations.

As the Earth Turns - Changes Affect Glaciers

Weather and terrain are not the only factors that make glaciation possible. One widely accepted theory suggests that Pleistocene glacial and inter-glacial periods resulted from the Earth's orbital-rotational cycles. Swings in the tilt of the Earth's spin axis and the shape of the Earth's orbit interact, varying the amount of seasonal sunshine that the Earth receives in certain areas. These changes in seasonal intensity may affect ocean currents that ultimately influence the climate.

What Is a Glacier?

Glaciers -- perennial accumulations of ice, snow, sediment, rock and water -- respond to changes in temperature, snowfall, and geologic forces. Several components make up a glacial system: the ice and sediment contained in the glacier; the valleys, fiords and rock features it flows over, on, or around; and the deposits left by its retreat or advance.

New snow layers create pressure on existing layers of snow and ice. This process, firnification", changes snow to firn, a dense granular snow (like corn snow). After the first season's melt, snow becomes firn. As it is compressed further, firn becomes ice. As the snow collects over many years, an ice field forms. Ice flows down the valleys and slopes of the mountains to the lower elevations, and glaciers are born.

Anatomy of a Glacier

Glaciers form where more snow falls than melts. A glacier's **accumulation** area, located at higher elevations, accrues a wealth of snow and ice. The **ablation** area, located at lower elevations, loses ice through melting (**downwasting**) or calving. A glacier's **terminus** or face advances when more snow and ice amass than melt, and it retreats when melt exceeds accumulation. When melt equals accumulation, a glacier achieves equilibrium and its face remains stationary. Whether the glacier's face is advancing or retreating, glacial ice persistently glides down-valley.

Coerced by gravity, ice pursues the path of least resistance. Ice depth and bedrock angle influence the rate of glacial flow. Glaciers contain two zones of ice flow. The **zone of plastic flow**, ice closest to the bedrock, experiences extreme pressure from the weight of the ice above and conforms to the anomalies in the bedrock. The **zone of brittle flow**, the upper 150 feet of glacial ice, lacks this pressure and reacts inelastically to the bedrock features, forming elongated cracks called **crevasses** which fluctuate with the glacier's flow. Tubular chutes or **moulins** drain surface meltwater, and formidable spires of ice called seracs reach skyward. Ice plummets over particularly steep terrain creating ice falls. One theory suggests that differences in seasonal flow rates over an icefall create the convex bands called **ogives** at the base of the falls, which undulate down glacier. The erosive power of glacial flow changes the landscape and scrapes much of the soil and rock from the valley walls that channel its irrepressible flow.

Glaciers - Master Carvers of Landscapes

Glaciers leave an impressive footprint on the landscape, carving the rock as they retreat and leaving behind steep topography and fiords where the ice once held sway. Flooded seacoasts and rising water levels are the legacy of their retreats, as are the ecological changes on the landscapes around the glacier's edge. Glaciers also have cultural impacts, in that their activity has affected human settlement, migration, and subsistence over thousands of years.
The landscape around a glacier clearly illustrates the effects of Pleistocene and Holocene glaciation. Ice excavates the bedrock, forming bowl-shaped **cirques**, pyramidal **horns**, and a series of jagged spires called **arête ridges** that separate glacial valleys. As glaciers carve U-

shaped valleys, rocks plucked from the bedrock and frozen in the ice etch grooves and striations in the bedrock. Rocks scoured from surrounding valley walls create dark debris lines called lateral or **medial moraines** along the edges and down the center of glaciers. Pulverized rock called rock flour, ground by the glacier to a fine powder, escapes with glacial meltwater producing the murky color of glacially fed rivers and lakes. Glacial recession unmasks trimlines, slightly sloping changes in vegetation or weathered bedrock on the valley walls that indicate a glacier's height at its glacial maximum. Meltwater transports glacially eroded material to the **outwash plain**, an alluvial plain at the edge of retreating glaciers. Icebergs break away or **calve** from the faces of glaciers ending in lakes or the ocean.

Cracked pieces of rock, plucked or torn from the bedrock, are carried with other debris in and on the glacier. This debris scrapes the valley walls and floors, leaving grooves and striations. Rock debris is crushed and ground into fine grains, called rock flour.

Tidewater Glaciers

Glaciers are found in a variety of settings in Alaska and come in a variety of different types, including mountain, valley, piedmont, cirque, hanging, and tidewater glaciers. Found at the heads of fiords and inlets, tidewater glaciers flow to the seacoast. Glacier Bay alone has sixteen tidewater glaciers flowing into it. In Southeast Alaska, many of the most active glaciers calve daily when giant pieces of ice crack off the head of the glacier and fall into the sea. Tidewater glaciers that end in deep water can also calve from **under** the water, shooting huge pieces of ice like missiles up through the surface to fall back with mighty splashes. The image of slow, imperceptible glacial movement is now replaced by the sounds of the thundering ice bergs cracking and falling into the sea. The freshly-calved bergs are often a sparkling deep blue and assume fantastic shapes as they slowly drift with the currents or beach themselves on outgoing tides. All this makes tidewater glacier watching a popular tourist attraction by sea or air.

As a tidewater glacier advances, it pushes a mound of debris called a moraine shoal in front of its terminus, protecting it from deep tidal water. If climate or glacial dynamics force the glacier's terminus to retreat from its moraine shoal, the deeper water behind the shoal causes the glacier to calve, rapidly producing many icebergs and triggering its retreat. Once the glacier retreats to a stable position, calving slows, and the glacier advances again, gradually rebuilding its moraine shoal.

Why the Pretty Colors?

Year after year, snow accumulates and compacts underlying snow layers from previous years into solid ice, causing changes in volume, density and crystal structure. Glacial ice appears blue because it absorbs all colors of the visible light spectrum except blue, which it transmits. Glacial ice may also appear white because some ice is highly fractured with air pockets and indiscriminately scatters the visible light spectrum. Rocks and other debris picked up by the glacier add a brown tint to the picture.

Fabulous Glaciers

Hubbard Glacier, the largest calving glacier in North America, is advancing and threatens to turn Russell Fiord into Russell Lake, with possible major consequences to the Situk River near Yakutat.

Mendenhall Glacier is part of the 1,500-square-mile Juneau Icefield and flows to Mendenhall Lake near a Forest Service visitor center which is on the Juneau road system.

The Stikine Icefield covers 2,900 square miles along the crest of the Coastal Mountains that separate Canada and the U.S. It extends 120 miles from the Whiting River to the Stikine River and reaches saltwater with LeConte Glacier.

What Happens Next?

Perhaps inter-glacial warming trends will prevail. The icefields may continue to melt as glacial meltwater trickles among the debris, and plant and animal communities ultimately reclaim the land. Maybe the next Ice Age waits just around the corner, and the icefields will again advance. Modulating climate and astronomical forces may trigger glaciation, and the ice would once more scour the bedrock, destroying all life within its reach and forcing animal communities to find new homes.

What will happen in the centuries yet to come? The neo-glaciation that created the coastal icefields started only 3,000 years ago, a mere blink in geologic time. Also youthful by geologic standards, the Holocene's climatic warming and glacial events began in Alaska just 10,000 to 15,000 years ago, and the history of the Great Ice Age stretches back almost two million years in time. Although clues from the past illuminate today's observations, the future of glaciation provides a perplexing question for scientific research. Regardless of advance or retreat, melt or accumulation, one factor on the icefields will remain constant. Change will persevere.

Life Around the Glacier: The Big Shuffle

Each episode of glacial advance and retreat also shuffles the mix of flora and fauna. Fragile vegetation ventures into a seemingly barren wasteland. Carried by the wind, seeds and spores of pioneering plants cling tenaciously to life in the hostile environment.

Plants

As lichen and moss clothe the exposed rock, the rebirth of the temperate rainforest begins, with alder, willow, cottonwood, spruce and hemlock systematically reclaiming the land they inhabited before the most recent glacial advance. Glacial debris, poor in nutrients, depends on flowering lupine, decomposing alder leaves, and alder root nodules to fix nitrogen into the developing soil. Overshadowed by cottonwood and spruce, decaying alder adds additional fertilizer to the forest floor, while hemlock ultimately rises to close the canopy, shading out most spruce and creating an old growth stand or **climax forest**. Encompassing almost 350 years, this sequence of plant succession nurtures the development of the forest community and provides habitat for an increasing number of plant and animal species.

Animals

Barriers, created by the geography and the brief span of time since the Great Ice Age, inhibit the rapid re-establishment of animal communities in Southeast Alaska. River valleys provide primary routes into recently deglaciated areas. Several species venture rapidly into the developing landscape. Migrating songbirds, snowshoe hare and mice build homes in the young forest. Salmon establish spawning areas in lakes and streams formed by retreating glaciers, while wolf and wolverine occasionally journey onto the ice from the adjacent ridges and forest.

Many other species including Sitka black-tailed deer, black bear, goshawk and weasel wait to take residence during the middle to later stages of plant succession.

As the soil is replenished and the time since the last glacial advance continues to pass, additional species repopulate the land. Each episode of glacial advance and retreat renews the cyclic tug-of-war between ice and vegetation.

How To Enjoy The Glaciers

Flightseeing, helicopter tours, charter boats and kayaking are among the many options available to visitors wishing to see the icefields. Contact the ranger district nearest the glacier of your choice for more information and a list of available flightseeing and charter operators.

Special Message to Visitors

Visitors should maintain a safe distance from actively calving glaciers. Glaciers are very active, and huge icebergs can detach from the glacier face from above and BELOW the water surface. The icefields and glaciers of the Tongass are part of a spectacular, un-spoiled wilderness which belongs to you. Help protect them. Enjoy your visit but please take special care to preserve all aspects of the environment so future visitors may enjoy it as you have.