USDA
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# Sculptures in GRANITE

Forest Service Alaska Region R10-RG-243 May 2019

*Cover photo. A waterfall flows over gneiss. Misty Fjords is comprised primarily of granite, but gneiss and meta sediments are also present.*
*Forest Service photo by Jim Baichtal.*

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Jim Nieland

This is scenery.
There are glaciers, mountains, and fjords elsewhere, but nowhere else on Earth is there such abundance and magnificence of mountain, fjord, and glacier scenery. For thousands of miles the coast is a continuous panorama.

John Burroughs, John Muir, et al.
Alaska—*The Harriman Expedition*
1899

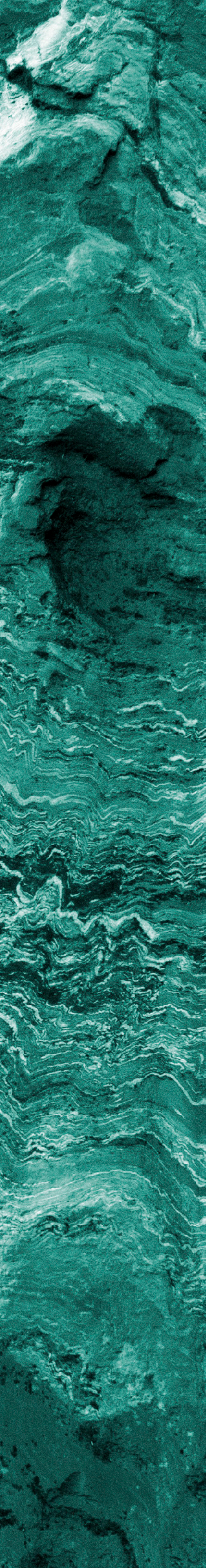
Misty Fjords National Monument was established in 1978 by presidential proclamation. The Alaska National Interest Lands Conservation Act of 1980 designated almost all of the monument as Wilderness. The monument protects cultural, ecological, geological, historic, prehistoric, scientific, recreational, and wilderness values.

Quite literally, the very foundation of this special place is its bedrock geology, its geomorphic landforms, and their continuing changes. Some changes we can see, others happen deep beneath the monument's surface. The wildlife, hemlock and spruce forests, and abundant fish of the surrounding sea are greatly affected by these geologic shifts.

This is the story of the land we call Misty Fjords—how it has come to be what it is today, and what it might be tomorrow. We welcome you to a place of inspiring beauty and adventure—a place where time, glaciers, and water etch fantastic landscapes into

*Sculptures in*

**GRANITE**



# Sculptures in GRANITE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*Note: **Bold** italicized words colored green in the text are listed and defined in the glossary beginning on page 34.*

# Roll 'em

Rock is history. Each outcrop you pass, each stone you pick up, even the shape of the land itself, has a story to tell. The excitement of geology is in piecing together small stories from the land and assembling them like still frames in a movie. Get enough of them together in sequence, and the landscape comes into motion before your mind's eye, revealing its true nature as a vital portion of a living planet.

Geologists have been sleuthing around Misty Fjords for years, gathering material for this movie. There is much to figure out yet, but a basic story line is emerging. Here is a preview:

**SCENE 1** Keep your eye on the old continental margin as bits and pieces of extinct continents once adrift in the Pacific collide with early Southeast Alaska.

**SCENE 2** Stand back as we bury these bits and pieces exposing them to tremendous heat and pressure, inject them with granite, and lift up the coast range and erode it.

**SCENE 3** Watch for repeated glacial advances which shape the land to its present form.

# Scene 1: Assembling the bits and pieces

The west coast of North America has been difficult to decipher. One look at a geologic map of Misty will show how complex and seemingly chaotic the rock patterns are. It was all very confusing. Then about 50 years ago, a new theory—called the ***crustal plate theory*** (plate tectonics)—suggested a new way of looking at the earth's surface.

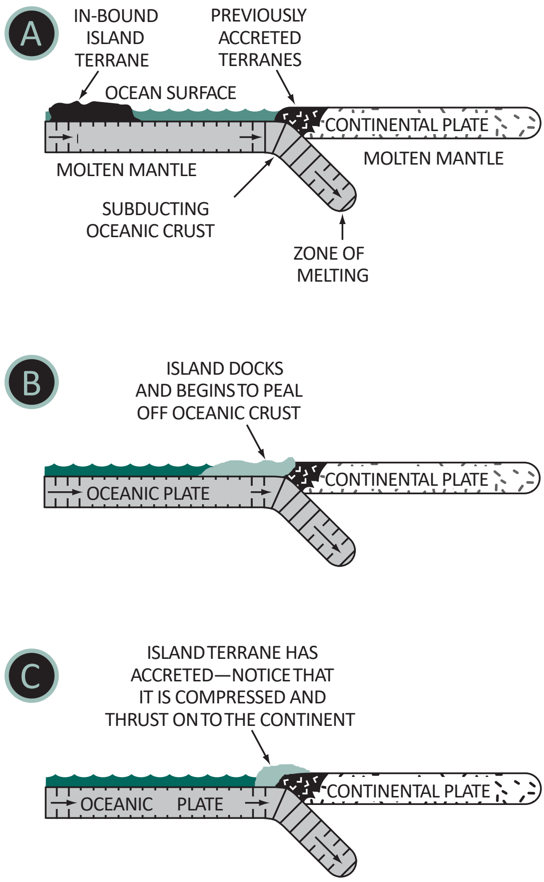
According to this theory, the earth's crust consists of discrete plates adrift relative to each other on currents in the underlying semi-liquid mantle. Where plates meet there is great geologic activity, generating the lion's share of the world's mountain ranges, oceanic trenches, volcanoes and earthquakes. Many of these boundaries are at the edges of continents.

Several things can happen where two plates meet. If the plates are converging, rocks of one may plunge under the other, ride up and over, or be compressed and folded into a thick mass. Plates may diverge, creating a void into which the mantle wells up to form new crustal material. Or plates may chafe past each other. Sometimes smaller blocks of crust break off and get battered along plate edges until they settle down and get welded into place. When geologists applied crustal plate theory to the west coast of North America, a story emerged. It goes something like this:

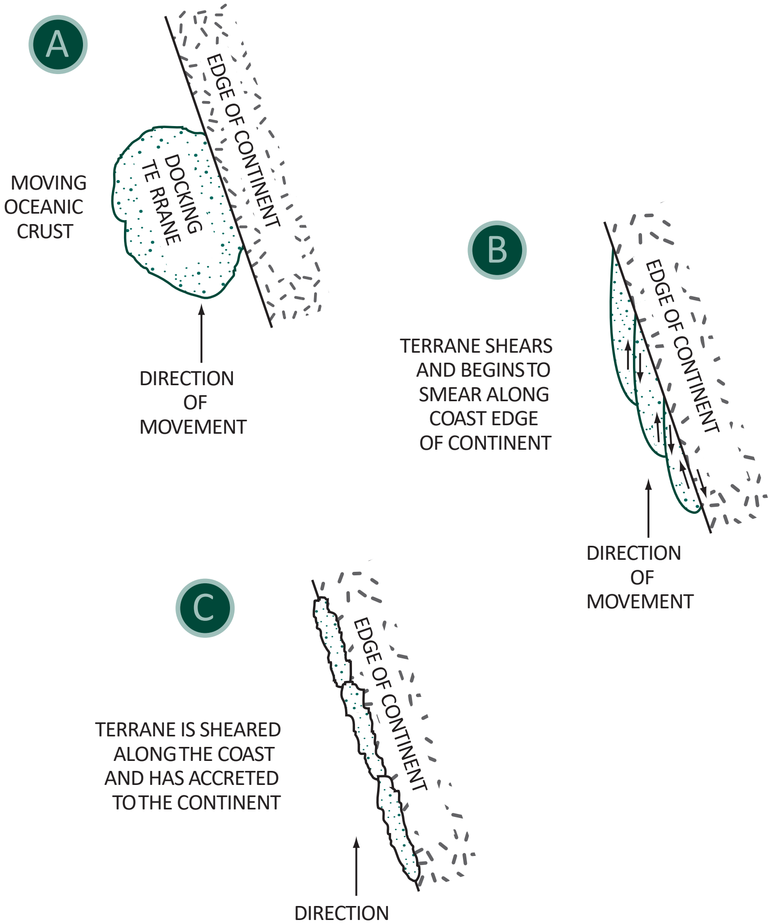
During the Age of Dinosaurs, North America began to rift apart from Europe, giving birth to the Atlantic Ocean. Since then the Atlantic rift has widened, pushing the North American crustal plate slowly westward away from Europe and overriding the Pacific plate. Meanwhile, the Pacific plate has been gradually rotating in a counterclockwise direction. Some thicker pieces of the Pacific plate have occasionally refused to be overridden. Instead they get shattered and smeared along the plate edge, sometimes welding on to become a part of North America. Other pieces (***terranes*** in geologist-speak) have come along and welded onto the outboard edge of the earlier ones. At our latitude, this accretionary process has been going on for perhaps 170 million years. It is going on right now.

That's the basic picture as geologists now understand it. Misty lies about midway in the accretionary jumble between the North American and Pacific crustal plates. It is made up of at least three crustal fragments smeared in a northwest-south-east direction—the Taku, the Coastal Mountain Batholith Complex, and the Stikine Terranes. Other terranes separate it from *bona fide* North America to the east and the Pacific to the west.

## Docking Terranes



## Shearing terranes



## Misty's early history—through a glass dimly

So how do the particular rock formations we see in the national monument today fit into this big picture? The best place to start looking is along the Monument's gateway, Behm Canal. This waterway is a groove eroded into a deep shatter zone in the earth's crust that separates two quite different rock regimes commonly interpreted to be separate terranes—the Coastal Mountain Batholith on the mainland side and the Taku on Revillagigedo Island. (The seam is still open to great depth and conducting molten rock with some very interesting effects that we'll come back to).

The southwestern shore of Behm Canal between Pt. Alava and Smeaton Island gives you a good look at a variety of Taku rock units. They are among the terrane's oldest rocks, and thus give the best indication of its early existence. They are mostly ***greenstone, marble and schist***—derivatives of what seems to have been former volcanic islands with their associated limestone reefs and muddy sediments. Considerable alteration by heat and pressure has garbled most clues they once held to the terrane's former nature, but some fossils have survived to indicate that the reefs and sediments were still forming about 210 million years ago.

Just across Behm Canal, the black ***amphibolites*** of Winstanley Island and light gray ***gneisses*** along the mouth of Rudyerd Bay are probably the oldest rocks of the Coastal Mountain Batholith Complex, but they have been so strongly altered that we may never know much of their early history. Their mineralogy suggests previous existence as volcanics and marine ***sediments***.

# Geology of Misty Fjords National Monument


## Legend

**Igneous Rock**
(once molten, formed at depth)
granite, granodiorite, diorite,
tonalite, gabbro, etc.

**Igneous Rock**
(once molten, formed at surface)
basalt, rhyolite, tuff, obsidian, etc.

**Sedimentary and Volcanic Rock**
(stratified; less altered by heat and pressure)
limestone, sandstone, shale, and conglomerate interbedded with andesite and basalt.

**Metamorphic Rock**
(strongly altered by heat and pressure) phyllite, schist, gneiss, marble, hornfelds, etc.

***NAME OF TERRANE***

**Terrane Boundary**

**Misty Fjords National Monument Boundary**

**United States/Canada Border**

### The Quartz Hill Mine

In 1974, U.S. Borax Corporation found extensive molybdenite deposits at Quartz Hill. Further exploration identified one of the largest molybdenum deposits in the world. Molybdenum is an element used to harden steel. With the creation of Misty Fjords National Monument, the Quartz Hill area was set aside as a non-wilderness area to allow for mineral development within the monument. Currently the world market price for molybdenum is too low to allow for production from the now patented claims which are currently owned and operated by Cominco American.


Map prepared by Jim Baichtal and Cass Klee, Thorne Bay Ranger District, Ketchikan Area, Tongass National Forest, USDA Forest Service.

# Scene 2: A tale of heat and pressure

The really clear events written in the rocks of Misty Fjords begin about 120 million years ago during the onset of their collision with North America and with other terranes barging into them from the west. Intermittently for the next 60 million years or so—and to some degree right up to the present—these collisions have unleashed forces that could be relieved only by the folding and faulting of rock ***strata***. Like a clayball pressed between your hands, the rocks have been forced upward as highlands and downward into the earth's mantle as they were squeezed sideways.

Consider the fate of rocks in these circumstances. Those forced upward were intensely eroded and exited the scene in pieces. Those forced downward encountered extreme levels of heat and pressure that changed their mineral composition and grew new crystals until they became so different that they merited different names. Volcanic ***basalt*** changed to its ***metamorphic*** equivalent, ***greenstone***; ***sedimentary limestone*** and ***shale*** to ***metamorphic marble*** and ***schist***; and so on. These are the rock types we mentioned before, outcropping along the Revilla side of lower Behm Canal. Especially intense conditions in the Coastal Mountain Batholith Complex, however, brought rocks close to their melting point where they metamorphosed further into dense, compact rocks such as the Rudyerd Bay gneiss and Behm Canal amphibolite.

Accompanying these metamorphic events was the main feature of Misty's geologic drama—emplacement of vast bodies of granite and related rock. Rocks chafing past each other and forced downward to great depth near the base of the crustal plates became hot enough to melt. This hot ***magma*** was less dense than surrounding solid rock, and so migrated upward along deep fracture zones, melting out vast chambers in the rock several miles below the surface. There the magma lost its upward impetus as it slowly cooled, eventually magma lost its upward impetus as it slowly cooled, solidifying to form the coarse-crystalled granites and related rocks that today dominate the Coastal Mountain Batholith terrane.

These generally very hard, light gray rocks form most fjord walls and uplands east and north of Behm Canal. One major granite body is found in the Taku terrane at the northwestern corner of Behm Canal.

As time went on, the deep reservoirs that had supplied the granitic magma neared depletion. Like a wine vat allowed to settle, the remaining dregs had different chemistry than the upper fluids. When these last dregs were finally injected upward to cool and solidify, they tended to form dark-mineraled ***gabbro*** instead of the gray granite.

The last magmas (buried deep under the surface and injected into place about 23 million years ago) were of this sort. One of these west of Winstanley Lake is only a mile wide on the surface, but has been shown by magnetic measurements to widen and extend to great depth. Since that time, there have been minor episodes of magma injection into small cracks. These have formed ribbon-like ***dikes*** of generally dark, fine-grained rocks that cut across formations of nearly all ages illustrating their relative youth.

## Recent (?) geologic events

The word "recent" to geologists is in the context of geologic time—a time frame which spans hundreds of millions of years. Therefore, geologists consider volcanic activity in the last 400,000 years within Misty as "recent."

Episodes of activity have brought magma right to the surface, leaving puddles of dark volcanic basalt that straddle central Behm Canal and occupy an upper tributary of the Unuk River. The Behm Canal basalts include the 400,000-year-old flows that form the columnaded barrier between Punchbowl Cove and Punchowl Lake. They also include flows and cinder cones at Princess Bay which are probably only 13,000 to 15,000 years old. The upper Unuk (Blue River) flows are the youngest of all, occurring as recently as the last 130 years. The two flows are approximately 380 and 130 years old, respectively.

## Have a soda

Strongly carbonated or “soda” springs can be found on the eastern side of Revillagigedo Island, opposite New Eddystone Rock. In 1915, a 1-inch pipe driven into the spring flowed at four gallons a minute. Water from this spring was said to have been bottled and sold locally for a short time as “Eddystone Water.” The iron content probably stained the bottles and inhibited its extensive sale.

## Tough on boots

Canadian party surveying the Alaska/Canadian boundary camping on the lava fork of the Blue River (1909). The survey party under Leland reported the following:

*Prior to this season the Blue River valley was almost unexplored. The lower part of the valley for a distance of about six miles above the Unuk was known to be filled with volcanic lava of comparatively recent origin, and it was the difficulty of travelling over this lava that pre-vented men's prospecting in the valley. It was considered impossible for men to carry supplies enough to maintain themselves for an extended trip over the lava. The surface is exceedingly rough, as may be gathered from the photographs, and aside from the slowness of travel in consequence, there is great difficulty owing to the wearing out of boots from the cutting action of the lava fragments. It is almost incredible that one or two days travel over the lava will make it necessary to repair a new pair of heavy boots. They are literally scratched to pieces. Also, the roughness of the chunks of lava prevents their slipping into stable positions and they roll under a man's feet and cause many falls, so that men's hands are often seriously cut.*

## Between the docking and the Ice

Except for the recent volcanics, all the great happenings recorded in Misty's rocks during the last 120 million years occurred deep in the crust. Now the blanket of rocks several miles thick that must once have overlaid the granites and metamorphics is gone—uplifted and eroded away. Evidence from adjacent Canada suggests that prior to 10 million years ago, the Misty area may have been relatively low country. If so, the only remnant from this ancient landscape is the Unuk River, which managed to hold its old grade as the mountains have risen around it. However that may be, we have had mountains in the Misty area for at least the last 10 million years. In the early days of these mountains, well before the Ice Ages, Misty's landscape would have been a maze of water-carved upland valleys and ridges probably not unlike parts of the southern Rockies today. But unfortunately, eroding landscapes are very poor record keepers, and so we can only make an educated guess about this. The glaciers have scoured away any record of the past landscape.

Chip Porter


*Aerial photo of Blue Lake an the Blue River lava flow today. The view is looking down the lava flow filling the valley floor towards the Unuk River. The "X" marks the approximate location of the 1909 boundary surveyor's camp.*

# Scene 3: Enter the ice

Meanwhile, as the coast range rose up and eroded, the earth's climate was cooling. When you put increasingly cold together with increasingly higher mountains and moisture-laden storm tracks off the Pacific, you get ice! Not far up the coast, there is evidence of major glacial activity by 7 million years ago—the earliest in North America. Glaciers in Misty were probably not far behind.

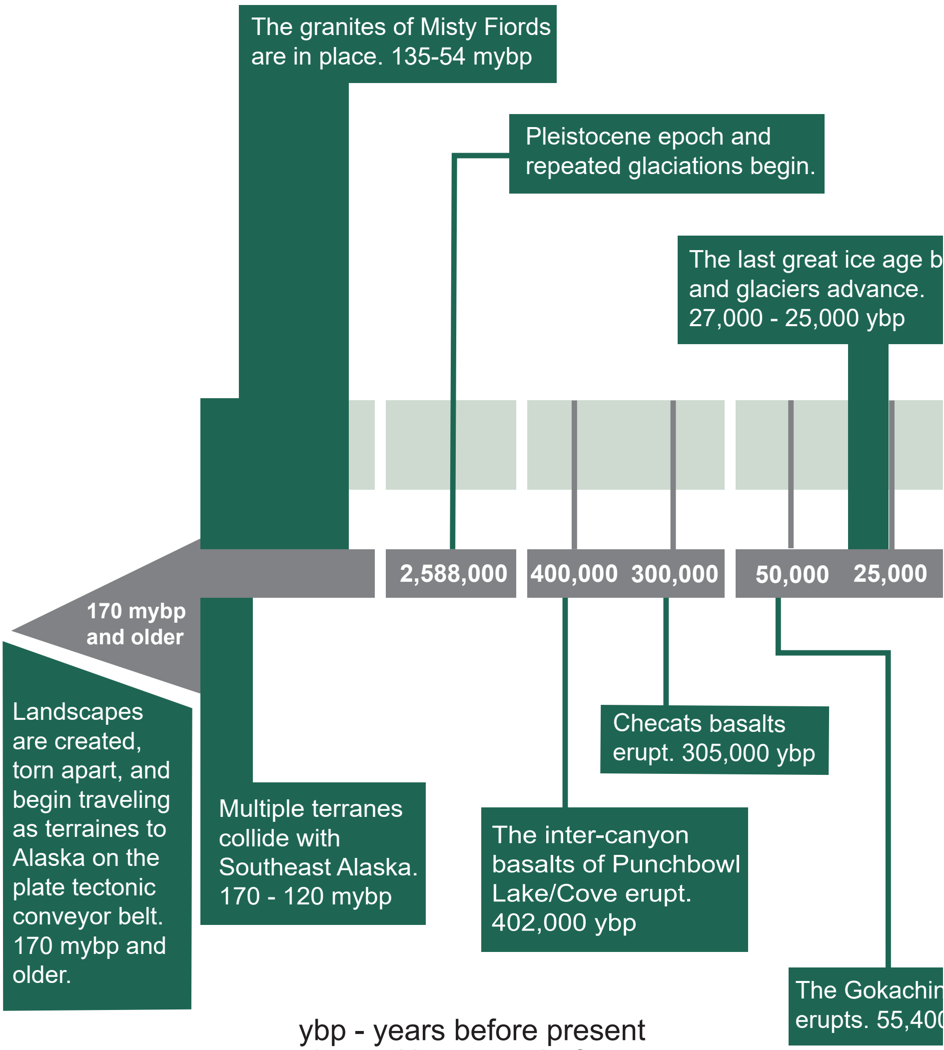
The first small glaciers would have formed in upper elevation watersheds, scouring and plucking away rock to begin transforming V-shaped river valleys into U-shaped ones. At their heads, these glaciers ate into the ridges steepening and sharpening their crests.

As climatic conditions chilled further, more snow fell each year and less melted. Well-fed glaciers extended into the lowlands and coalesced with neighbors in the main valleys to form deeper ice masses with greater erosive power. Where stream valleys had formed following faults and geologic boundaries, ice exploited these weaknesses with a vengeance, lowering the valley floors and etching cliffs into the valley walls.

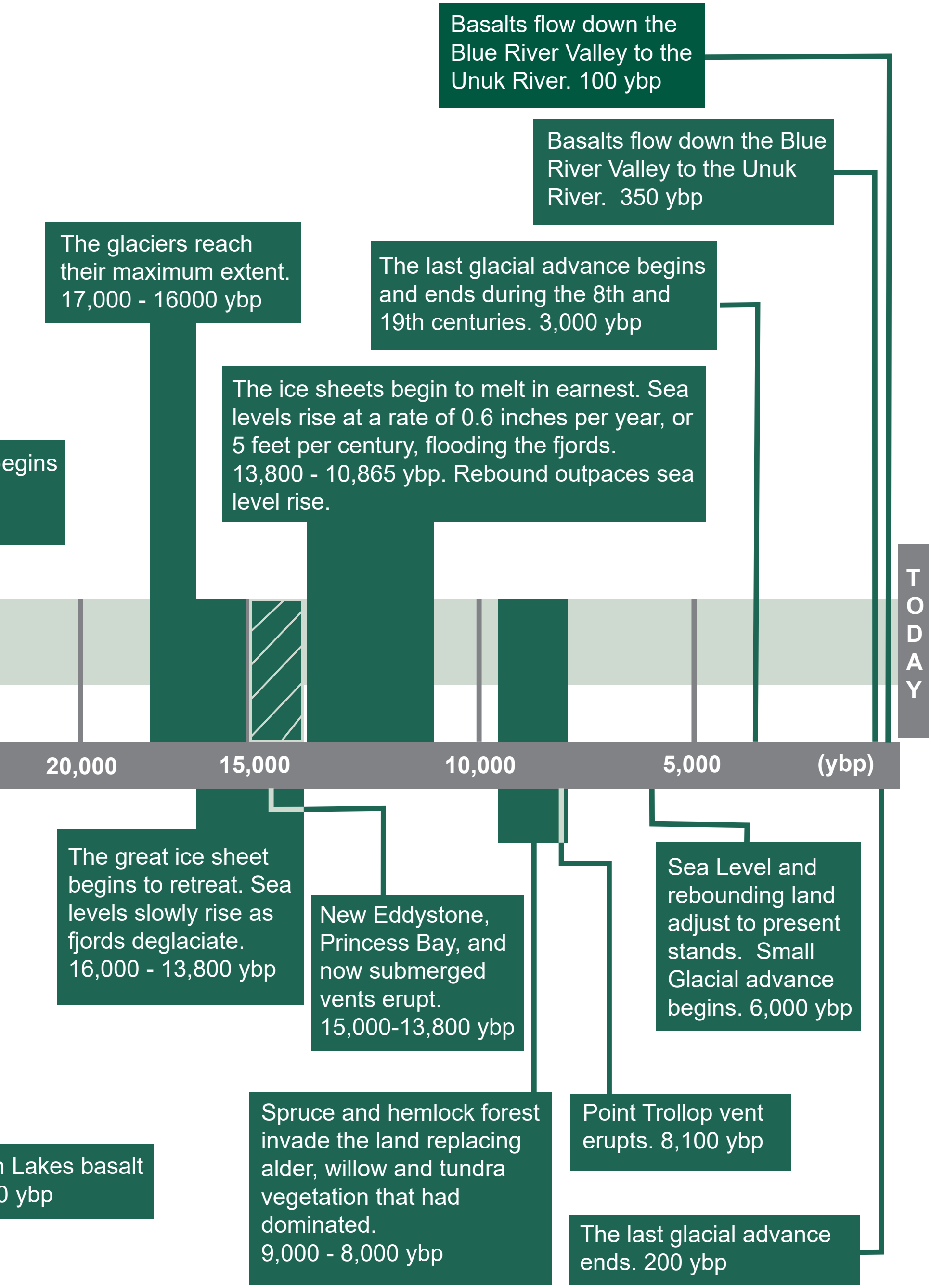
Finally the climate became so severe that ice extended far to the west. In the Misty area, it rose like a great frozen tide to inundate virtually the entire landscape, leaving only the highest peaks and ridges exposed. Then the climate cycled into a milder mode and the ice retreated, to return again when conditions allowed.

Since then, the ice has come and gone dozens of times. Each cycle has brought times of alpine and valley glaciation, during which discrete tongues of ice scoured troughs into the lowlands. The most severe ice ages climaxed in a great ice sheet with more regional effects. The most recent and perhaps most severe of these peaked 17,000 to 23,000 thousand years ago, when a vast ice plateau covered all but the tallest peaks, sloping from elevations over 6,000 feet near the present-day Canadian border to a bit less than 4,000 feet at Misty's western margin. In those days, ice extended from well west of Misty all the way across the continent to Cape Cod.

# Geologic Time Line for Misty Fjords National Monument

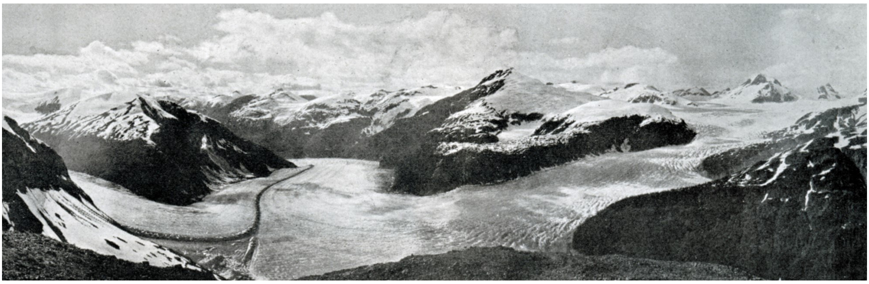



ybp - years before present
mybp - milion years before present


Basalts flow down the Blue River Valley to the Unuk River. 100 ybp
Basalts flow down the Blue River Valley to the Unuk River. 350 ybp
The glaciers reach their maximum extent. 17,000 - 16000 ybp
The last glacial advance begins and ends during the 8th and 19th centuries. 3,000 ybp
The ice sheets begin to melt in earnest. Sea levels rise at a rate of 0.6 inches per year, or 5 feet per century, flooding the fjords. 13,800 - 10,865 ybp. Rebound outpaces sea level rise.
TODAY
20,000
15,000
10,000
5,000
(ybp)
The great ice sheet begins to retreat. Sea levels slowly rise as fjords deglaciate. 16,000 - 13,800 ybp
New Eddystone, Princess Bay, and now submerged vents erupt. 15,000-13,800 ybp
Sea Level and rebounding land adjust to present stands. Small Glacial advance begins. 6,000 ybp
Lakes basalt
ybp
Spruce and hemlock forest invade the land replacing alder, willow and tundra vegetation that had dominated. 9,000 - 8,000 ybp
Point Trollop vent erupts. 8,100 ybp
The last glacial advance ends. 200 ybp

## Chickamin Valley-then and now

*Chickamin Valley. Photogaphed by A.F. Buddington, 1925.*

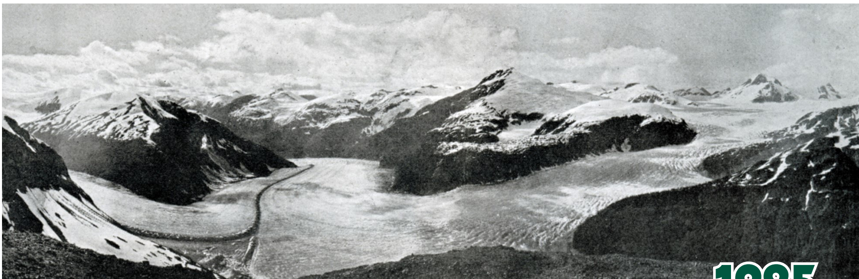


*Chickamin Valley. Photographed by Brooke Kubby, Alex Lyles, and Jim Baichtal, September 26, 2018.*

The Chickamin Glacier connected with the Through, Greenpoint, and Hummel glaciers in 1925. Now they have receded up their valleys and no longer connect with the Chickamin Glacier.

Although this glacier still occupies much of the valley, it is not nearly as thick as it was in 1925. Much more of the steep valley walls are exposed today. The ice has thinned by as much as 350 feet and the terminus has pulled back over four miles.

The terminus of the glacier has moved up the valley over four miles as the glacier has receded, revealing the valley floor and much more of the valley walls.



1925

Chip Porter

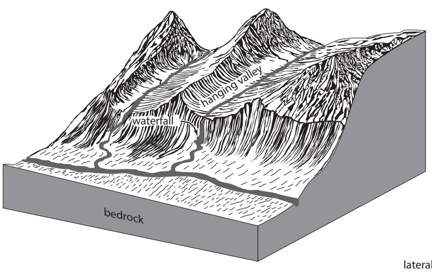
2010

2018

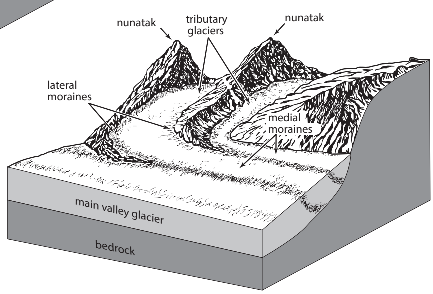
## How glaciers shape the land before glaciation and alpine glaciers

As the climate cools, alpine glaciers flow out of upland valleys. Debris plucked from the landscape and frozen to the ice's foot acts like a giant sheet of sandpaper, eventually eroding bowl-shaped cirques at the valley heads and U-shaped valleys along the path of the glaciers.

Extending down-valley, these small ice tongues coalesce to form valley glaciers. The thicker the ice in these glaciers, the greater their erosive ability (like you when bearing down harder on a sheet of sandpaper). After many episodes of erosion, the greatest of these glaciers erode their valleys so deeply that later, when they recede, the sea follows the ice into the valleys forming fjords. The side valleys often are left "hanging," their watercourses descending abruptly as waterfalls.



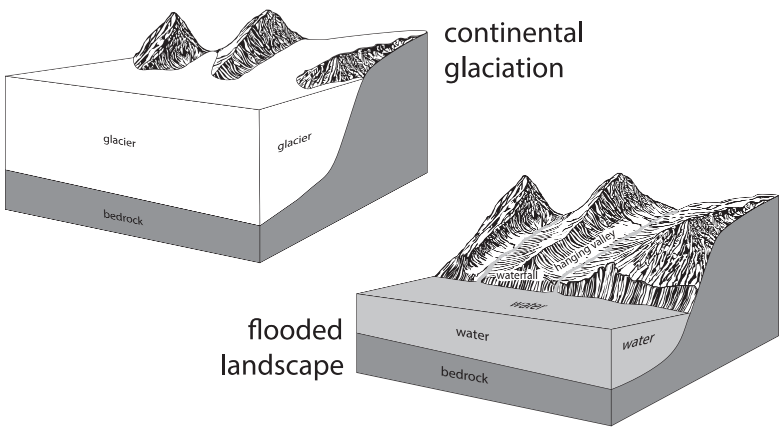

unglaciated landscape




glaciated landscape

## Continental glaciation and today's landscape

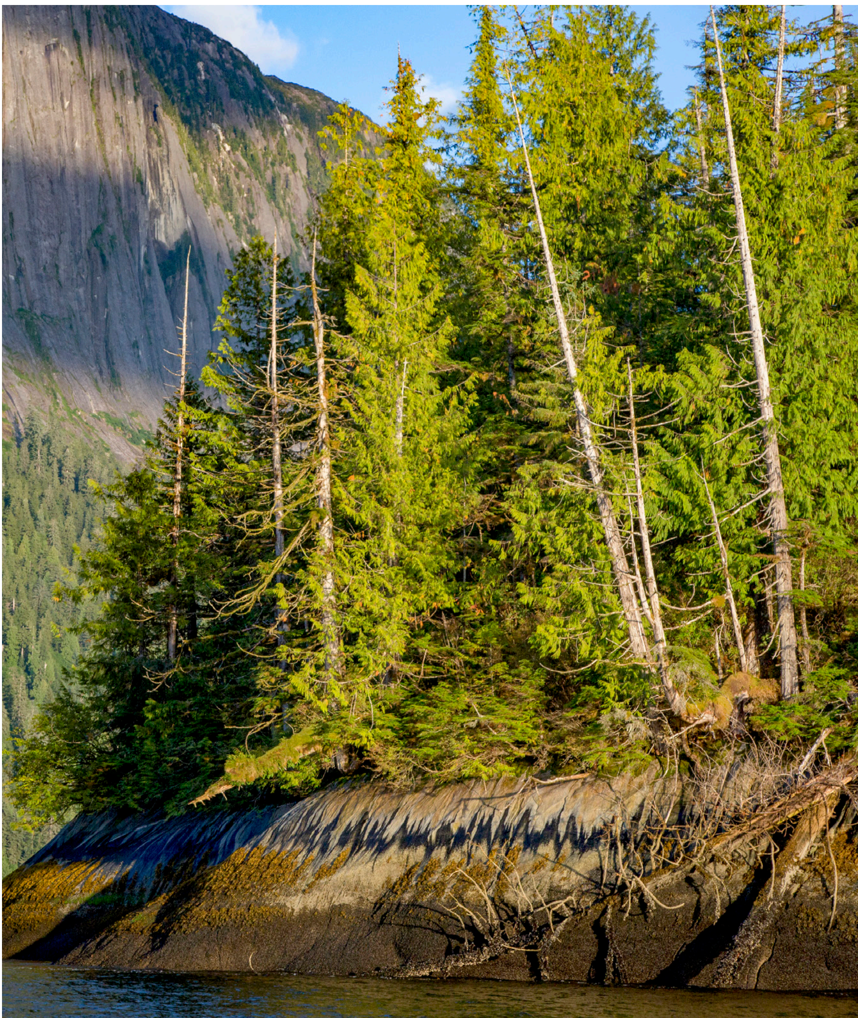
Alpine glaciers slowly enlarge their cirques, which eat into the uplands sharpening the peaks and ridges that lie above them. Then as glaciers expand, their surfaces rise. Eventually, the rising surfaces spill out of the fjords and valleys, coalescing into vast moving plateaus of ice. This abrasive blanket mutes all sharp upland features it overrides and plucks at the base of the heights that rise above it. In the Misty area, only a few peaks and ridges above 4,000-6,000 feet in elevation were high enough to escape the last great ice advance.



## The white stripe

The natural color of the gneisses and granites between Checats Cove and Rudyerd Bay is a silver-gray, but you seldom get to see that color because of the carpet of living things on them. In the lower and middle intertidal zone, a solid carpet of barnacles, mussels, and rock weed covers the rock. Just above these bands, a coating of tar-like black lichen continues the carpet of life to just below the high tide limit. It is only in a narrow, irregular belt in the splash zone—a sort of no-man's-land where conditions are too terrestrial for the black lichen, but too wave-washed for the forest, that the rock can show its true color.

Chip Porter



# The modern landscape emerges

About 17,000 years ago the most recent great deglaciation began. Ice retreated from the fjords and the sea flooded in behind it. Worldwide, sea levels were considerably lower due to the vast amount of water tied up in the glaciers, but Misty's landscape was so depressed by its recent load of ice that sea level in the deglaciating fjords was several hundred feet higher than it is today. Freeing the fjords of ice had an effect similar to pulling the plug in your bathtub—ice poured from the uplands, draining away the ice sheet in relatively short order. Only the alpine glaciers were left.

*View looks towards Behm Canal across Manzoni Lake. Photo shows typical vegetation pattern on the granites within the Coastal Mountain Batholith Complex.*

A brief downturn in the global climate about 12,800 to 11,500 years ago may have resulted in some glacial advance. Most recently, the Little Ice Age, which began about 3,000 years ago, brought glaciers down their valleys a mile or so beyond their present snouts, where they have left small end ***moraines*** and erased forests a short way up their valley walls. Vegetation on the moraines suggest that this advance ended by roughly 225 years ago.

The landscape that emerged from the ice bore the signs of repeated and intense ice erosion. Virtually nothing but solid rock remained. The uppermost elevations bore sharp spires and knife ridges that stood above the reach of the ice sheet. Middle elevations that had been overridden were contoured into rounded hills. Deeply scoured U-shaped valleys punctuated the uplands, the deepest of which extended well below sea level as fjords. Given the lack of valley sediments and the higher sea level, the sea extended much farther into the fjord valleys than today.

How did the sea rise far above its present level? The sea did not rise higher than its present stand— the land surface was depressed by the immense weight of the glacial ice. The land began to rebound once the glaciers had retreated. However, the sea reinvaded the land faster than the earth's crust rebounded. The net result was that the sea rose covering lands that are now above sea level. Eventually, the rebounding land caught up with the invading sea. About 6,000 years ago, the shoreline had adjusted to its present position and the landscape took on its present character.

The landscape of today is still dominated by glacial features. Small rock slides have provided rubble piles here and there. Running water has incised a few minor ravines, but most valley wall streams still run across almost unaltered glacial surfaces. The sea has taken small bites out of rocky shorelines, especially along central Behm Canal where crumbly volcanic rocks run into substantial wave action. The resulting debris has collected as gravel beaches in sheltered places. Only rivers like the Unuk and Chickamin, that drain Misty's remnant glaciers, have managed to appreciably alter the monument's landscapes. The abundant glacial debris that these rivers carry has progressively filled fjord heads, in some cases for miles. This debris has been graded into valley floors across which the rivers meander today.

## Landforms and forests

In many places east of Behm Canal, the general steepness of the country, the lack of sediments, and the slow rate at which granitic rocks break down has resulted in a very thin and tenuous carpet of forest vegetation. Any soil that does manage to form is always in danger of sliding off the slopes; any tree daring to grow tall risks being pried off its perch by wind or avalanche. Lush forest growth is mostly confined to small areas of sediments in lowlands that have been built since deglaciation by rivers or avalanches.

Chip Porter

*Punchbowl Cove in the Behm Canal.*

## Cliffs, joints, and the layers of the onion

Flowing ice is more resistant to changing its direction than water. So glaciers tend to straighten river-cut valleys, truncating ridges that stick out in their path. Glaciers also erode their valleys deeper and wider at the base. The result is steeper valley walls. Certain types of rock are strong enough to hold a tall vertical face, forming cliffs.

A wonderful example occurs in Punchbowl Cove. The spectacular gray cliff on the cove's north side are made of granite, a once-molten rock that solidified under great pressure. Relief of that pressure as erosion brought it to the surface resulted in expansion of the rock. In some types of granite, this expansion results in a regular series of cracks, or joints. If the joints stand vertically (especially if they run into the rock at right angles to the valley) the rock can stand very tall. If the joints are parallel to the cliff face or slope, large curved sheets or slabs of granite may break loose or exfoliate from the outcrop. Much like peeling off the layers of an onion, the landscape weathers into domes or odd shapes. A great example is the "owl's face" in the rock at the narrows of upper Rudyerd Bay.

Chip Porter

*The owl's face in Rudyerd Bay is a good example of exfoliation.*

The blackish cliffs at the head of Punchbowl Cove are composed of basalt, a formerly molten rock that can form strong, pillar-like columns as it cools. If a glacier plucking at its base manages to topple a column, another vertical one just behind it maintains the vertical face.

Colonial birds often choose cliffs for nest sites to protect themselves from land predators, but by the luck of the draw, very few of Misty's cliffs have a jointing pattern that produces appropriate ledges, and so there are few bird colonies here. For the same reason, there are very few ledges in the intertidal zone on which seals can haul out.

Jim Nieland

*The bird rookery in Rudyerd Bay. The jointing pattern in the fjord walls has provided small ledges, overhangs, and fractures for birds to nest on. Their droppings fertilize the cliff face encouraging the growth of vegetations such as mosses.*

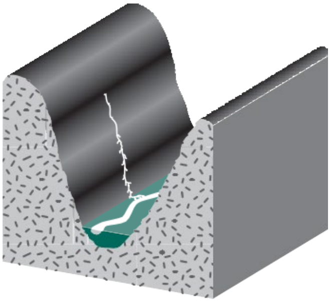
Chip Porter

In a few valleys, glaciers have provided abundant sediments that were graded by rivers into nearly level plains. The Unuk, Chickamin, Wilson, Blossom, Keta and Marten river valleys are examples. These streams are gentle enough for fish to ascend and provide good spawning beds. Their tributaries are typically stabilized and enriched by lush river bank forests. Almost all of Misty's important salmon streams are found in such places.

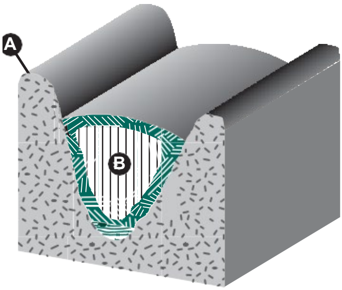
Chip Porter

Travelers passing the upper portals of Rudyerd Bay enter the bay head, which is terminated abruptly in two directions by two rivers and two flats. Why the abrupt change in topography? The beach is made mostly of gravel, while the surrounding steep shores are mostly glacially scoured bedrock. The gravel beach also merges landward into the river valleys without much change in gradient. That's because it *is* part of the river valleys. It represents the most recent material laid down as the rivers slowly build seaward. Unravelling this process, the flat valleys behind the beaches have also been progressively built by the rivers, as they brought sediments out of the mountains in the millennia since the ice. So as a final exercise, imagine these flat areas gone, and you have a picture of the topography at the end of the Ice Age. Rudyerd Bay was quite a bit longer then (and made longer still by a higher sea level due to depression of the land by its recent load of ice).

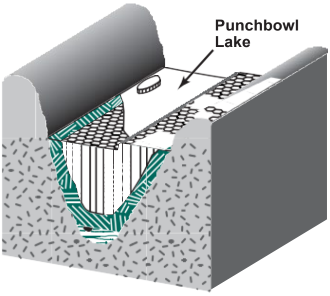
The Punchbowl basalts not only add to the spectacular Rudyerd Bay scenery, they also give two rare glimpses of the area's landscapes 400,000 year ago, the time that radiometric dating tells us the magma solidified at the surface. Notice first that the basalt cliffs at the cove head extend below sea level. Since the basin has to predate the magma injected into it, this means that Punchbowl fjord must have already been pretty well formed by the time of the eruption. Extrapolating from this, much of the glacial sculpting in the Misty area was done prior to this date. Punchbowl Lake contains a second, related lesson. The basalts plugged up the fjord head, forcing the glacier to spread sideways, creating a broader basin. This suggests that ice erosion has been able to do some fairly major landscape modification since 400,000 years ago, too. Very recent basaltic flows damming the Blue River (a tributary of the upper Unuk) give a feel for what the punchbowl basalts may have looked like before they were worked over by the ice.



*Sometime over 400,000 years ago a river/ glacial valley existed. Most likely, a stream flowed across the valley floor.*




*From a nearby vent, basalt flowed in filling the valley, burying the old valley floor and walls. The outer surfaces of the flow cooled quickly, creating a chilled margin "A". The center of the flow cooled more slowly, shrinking as it cooled, forming large columns "B".*




*Subsequent glaciation scoured off the chilled margin and sheared the columns off parallel to the basal cleavage. (See photo on page 28.) The landscape seen today is the result.*

*This photograph shows columnar jointing of the basalt on the face of the island depicted in the lower drawing above.*

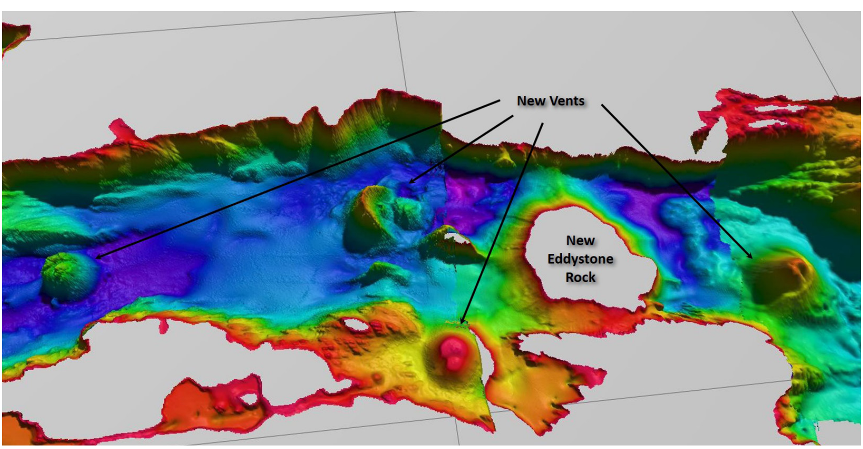
### New Eddystone Rock

This prominent landmark and the small islands around it are remnants of a volcanic system extruded onto the Behm Canal area about at the end of the last ice age. The volcanic core's age is approximately 15,000 to 13,800 years old. The rock itself is a plug of hardened lava occupying a former volcanic vent through which the magma poured. There is no way that New Eddystone Rock could have stood up to ice erosion in its present form. New Eddystone Rock was never eroded or scoured by Pleistocene ice. The landscape was depressed by the weight of the ice and soon began to rebound after deglaciation. It was this deformation of the earth's crust, the crust's flexure, that opened the conduit that created the New Eddystone volcano and several others in the adjacent area. As the land surface rose, wave action over the millennia tore away the mantle of the volcano, finally leaving only the resistant core and a broad pedestal of fringing underwater shallows that show on a marine chart. Therefore, wave action, combined with uplift after deglaciation, has left the 237-foot-tall landmark intact today.

Jim Nieland

## Volcanoes beneath Behm Canal

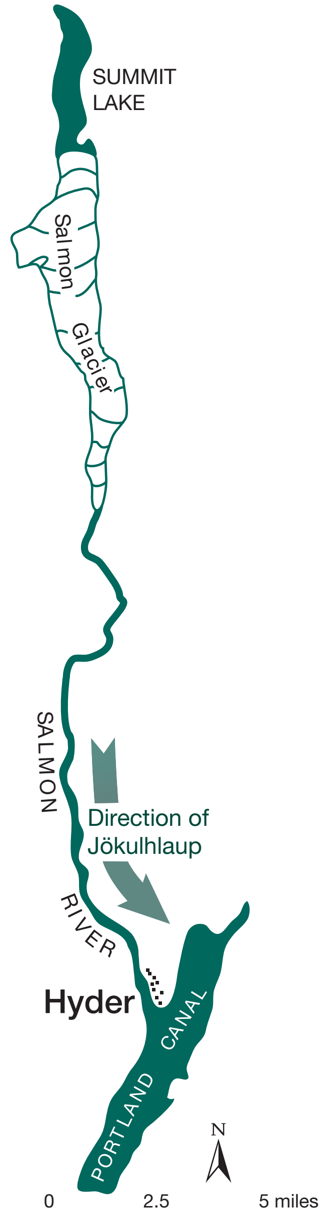
For years New Eddystone Rock has been recognized by geologists as a volcanic plug rising from the depths of Behm Canal. Some older lava flows were known to the west and northeast of the landmark. Geologic mapping by the US Geological Service (USGS) and US Forest Service (USFS) in 2008 and 2009 identified several postglacial cinder cones and lava flows on either side of Behm Canal. The National Ocean and Atmospheric Administration (NOAA) conducted multibeam surveys from 2009 through 2013 in Behm Canal and Rudyerd Bay. These were published online in 2013. A USFS Geologist downloaded these bathymetric surveys and immediately noticed three unknown vents, one a perfect cinder cone, the top of which is 150 feet beneath the waves. The following year NOAA reported another cinder cone north of New Eddystone. All of these vents likely erupted between 15,000 and 13,800 years ago. Two of the vents are "dome" shaped and likely erupted subglacially, the others are unweathered cinder cones. It is believed that the retreat of the glaciers caused the land to rapidly rebound, flexing the earths crust. This flexure opened up the conduits that brought magma to the surface creating the four vents on land and the five vents in Behm Canal. Of the five, only New Eddystone is now above the waves. The eruptions that created these cinder cones started when sea level was approximately 600 feet lower than today, suggested by terraces on the cinder cone flanks.



## Hyder and a Jökulhlaup

Hyder, Alaska, was founded in 1900 under the name Portland City. This name was changed to Hyder in 1915 when a post office was established. The town has its roots in the hopes of finding rich mineral deposits associated with those found to the east in Canada. Though deposits of great wealth were never discovered on the United States side of the line, Hyder became important to mineral development in Canada as an ice-free port and supply center. Hyder is one of only three Southeast Alaska communities (the other two are Haines and Skagway) that can be reached by road, but only through the Canadian highway system. Today Hyder is the gateway to Salmon Glacier and the Fish Creek Bear Viewing Area.

Summit Lake, formed behind the ice of the Salmon Glacier in British Columbia, Canada, yearly sends flood waters rushing down the Salmon River towards Hyder. (See map on page 7.) The lake level rises behind the ice dam until the pressure clears a path beneath the ice. The floods occur between August and November and are 5–10 days in duration as the lake drains. The Icelandic term for such glacial floods is ***Jökulhlaup***, pronounced YUCK-a-lup).




*(See map on pages 6–7 for Hyder location)*

## Misty Fjords and past Peoples

The geologic and glacial history of Misty Fjords is intimately intertwined with the human occupation of the area. Rugged terrain caused by uplift and recent glaciation limited the resources available to hunter-gatherer populations throughout the Holocene. While human occupation of the outer islands dates back approximately 10,000 years, the earliest known human use of the Behm and Portland Canal areas occurred less than 2,500 years ago. However, by the time of European exploration in the 18th century, it is probable that some 2,000 people, including the coastal dwelling Tlingit and the Tsetsaut Athabaskans living primarily in the interior, occupied what is now Misty Fjords. It is reported that George Vancouver, who explored the area in 1793, stopped to have lunch on New Eddystone Rock. After the purchase of Alaska from Russia, in 1867, Euro-Americans came to the area to fish, trap, harvest timber, and explore the mountainous terrain for mineral deposits. Evidence of the historic and prehistoric past can be seen in the remains of canneries and mines, stone fish traps, rock art, collapsed cabins, Civilian Conservation Corps constructed shelters, and trails used by earlier inhabitants of the area.

Illustration by Marilyn Jesmain originally used in the Forest Service publication *Passages: An Archaeology Timeline of Southeast Alaska.*

# Glossary

***Alpine Glaciers.*** Glaciers in mountainous areas.

***Amphibolite.*** A metamorphic rock containing mostly amphibole and plagioclase feldspar.

***Basalt.*** An extrusive igneous rock which is fine grained, mafic, and made of ferromagnesium minerals and calcium-rich plagioclase feld-spar.

***Cirques.*** A steep-sided, amphitheater-like hollow carved into a mountain at the head of a glacial valley.

***Columnar Basalt.*** A basalt divided into prismatic columns by cracks produced by thermal contraction while cooling.

***Crustal Plate Theory (Plate Tectonics).*** The theory and study of plate formation, movement, interactions, and destruction. A theory that the earth's surface is divided into a few large, thick plates that are slowly moving and changing in size. Intense geologic activity occurs at the plate boundaries.

***Dikes.*** A roughly planar body of vertical intrusive igneous rock that cuts across bedding or foliation within the surrounding rock.

***Exfoliation.*** Stripping of concentric rock slabs from the outer surface of a rock mass—like peeling the layers of an onion.

***Fjords.*** A former glacial valley with steep walls and a U-shaped profile, now occupied by the sea.

***Gabbro.*** A black, course-grained, intrusive igneous rock, composed of calcic feldspars and pyroxene. The intrusive equivalent of basalt.

***Gneiss.*** A course-grained metamorphic rock that shows compositional banding and parallel alignment of minerals.

***Granite.*** A coarse-grained, intrusive igneous rock composed of quartz, orthoclase feldspar, sodium-rich plagioclase feldspar, and micas.

***Greenstone.*** A term applied to any altered or metamorphosed basic igneous rock such as basalt and gabbro, that owes its green color to the presence of chlorite, actinolite, or epidote.

***Hanging Valleys.*** A former glacial tributary valley that enters a larger glacial valley above its base, high up on the valley wall.

***Joint.*** A fracture or crack in bedrock along which essentially no displacement has occurred.

***Jökulhlaup*** (pronounced "Yuck-a-lup"). An Icelandic term for a glacier outburst flood—a sudden, often annual, release of meltwater from a glacier-dammed lake.

***Limestone.*** A sedimentary rock composed mainly of calcium carbonate (calcite).

***Magma.*** Molten rock material which forms igneous rocks after cooling.

***Marble.*** The metamorphosed equivalent of limestone or other carbonate rock.

***Metamorphic.*** A rock whose original mineralogy, texture, or composition has been changed due to the effects of pressure, temperature, or the gain or loss of chemical components.

***Moraine.*** A glacial deposit or till (sand and gravel) left at the margin or terminus of an ice sheet or glacier.

***Schist.*** A metamorphic rock characterized by coarse-grained minerals oriented approximately parallel.

***Sedimentary.*** A rock formed by the accumulation and cementation of mineral grains transported by wind, water, or ice to the site of deposition or by chemical precipitation at the depositional site.

***Strata.*** A sequence of rock which reflects the geologic history of the region.

***Terrane.*** A fault-bounded geologic entity characterized by a distinctive stratigraphic sequence and/or a structural history differing markedly from those of an adjoining neighbor.

***Valley Glaciers.*** A glacier that is smaller than a continental glacier or icecap, and that flows mainly along well-defined valleys, many with tributaries.

***Volcanic.*** A term applied to rocks which have originated as the result of some type of volcanic eruption, either of lavas or pyroclastic materials scattered or ejected by volcanic explosions.

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