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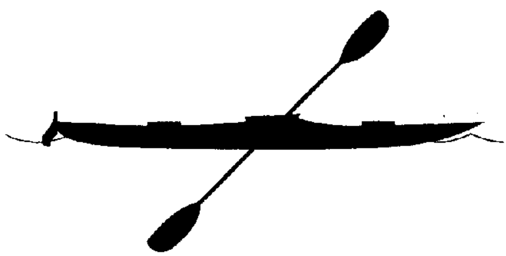
Of Rock & Ice

An Explorer's Guide to the Geology of Prince William Sound Alaska

By

Joseph Kurtak



United States Department of Agriculture
Forest Service
Bureau of Mines
United States Department of the Interior

Joseph Kurtak

"Something hidden. Go and find it. Go and look behind the ranges."

Rudyard Kipling
The Explorer
1898

Acknowledgements

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The Author

JOSEPH Kurtak is a geologist with the U.S. Bureau of Mines and an avid kayaker presently living in Anchorage, Alaska. He has spent the last 10 years travelling in, and studying, the geology of Prince William Sound.

About this Story

NESTLED in its ocean kingdom of hidden fjords, bays and isles, Alaska's Prince William Sound reveals a geography created at great depths in the earth, then scorched by fire and sculpted by ice. Here glaciers, snaking down from ice-covered massifs, meet the lushly forested and protected coastline of the north Pacific Ocean. Heart of the Chugach National Forest, the sound is a special place rich in sea life. It is a place that entices the adventurous.

While navigating through this unique environment, seafarers pondering nature's work often ask questions about its ongoing formation. Where did these rocks come from and how old are they? Did glacial ice once cover this entire area? Why are some shorelines covered with boulders, while others are sandy beaches? This booklet will answer these and other questions about the geologic story of Prince William Sound.

The Sound's Geologic Time Clock

IF we compress the 4.6 billion years of our earth's history into 12 hours on a clock face, the earliest rocks would have formed at about 2:30 or 3.8 billion years ago. The earliest life forms appeared at 4:10. Dinosaurs roamed the land at 11:25 and the first humanoids appeared only 15 seconds before 12:00.

Where does Prince William Sound fit into this time clock? Here rocks began to form somewhere around 11:50 or 80 million years ago and glaciers covered the area only 1-2 seconds before 12:00. The sound is definitely a new kid on the block in a geologic sense and is still experiencing dramatic change.

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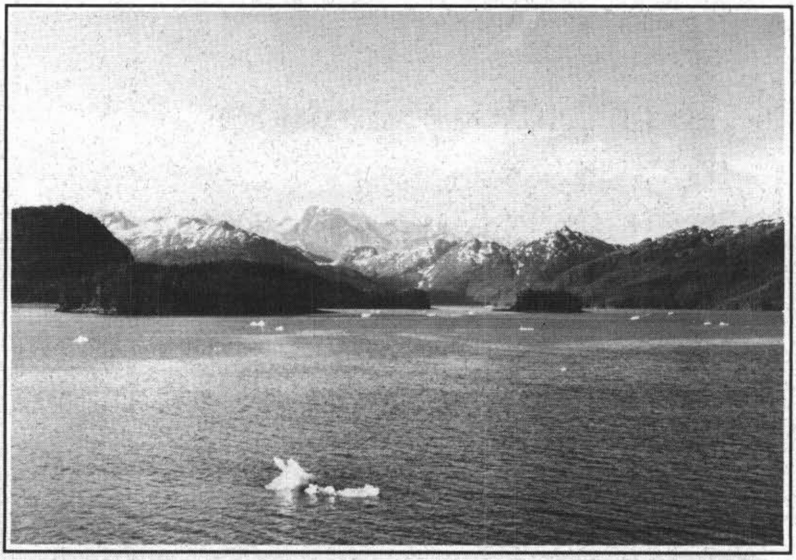


David Allen

"In favorable weather the shining water and the green slopes and snow-covered tops of the surrounding mountains com bine to make a scene that delights the eye of every observer."

Fred Moffit
U.S. Geological Survey
1954

The Geology of Prince William Sound

Plates in Collision

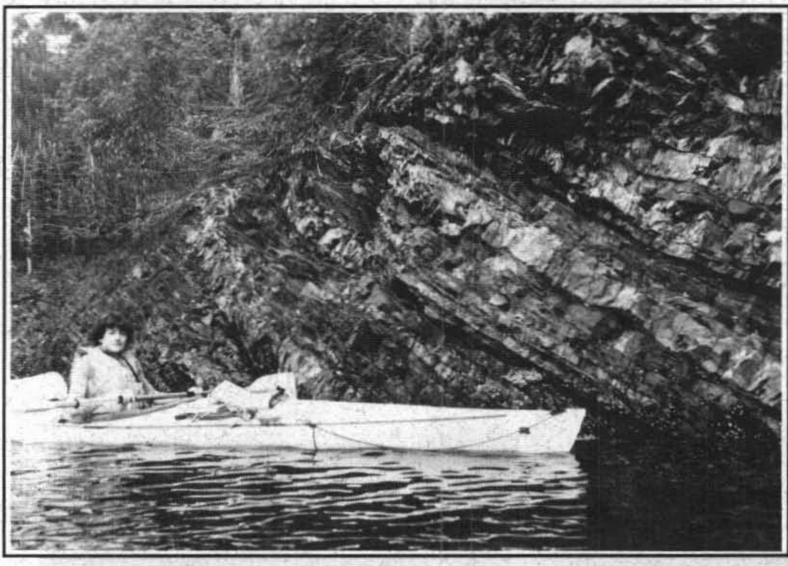
THE geologic story of Prince William Sound would be incomplete without a brief discussion of plate tectonics and continental drift. Geologists believe the earth's surface is made up of a series of interlocking plates, like the surface of a cracked hard-boiled egg. These plates are in constant motion, some slowly sliding past one another, others crashing together at the rapid rate of a few inches per year. At points of plate contact, the denser oceanic plates have a tendency to dive under the less dense continental plates (subduction). Prince William Sound lies at the boundary of the North American and Pacific plates. As it gradually moves north, the Pacific plate slides under the North American plate. This has been happening for millions of years.

About 65 million years ago, sand and muddy sediments were scraped off the edge of the Pacific plate during subduction and dumped onto the continental margin. Geologists call these nomadic masses of sediment "terranes." With time, these sediments were compacted and cemented into rock and then warped and uplifted to become the ancestral Chugach Mountains north of Prince William Sound. This package of rocks has been appropriately labelled the "Chugach Terrane" and the formation within it called the "Valdez Group" after the town of Valdez.

About 42 million years ago, this ancient Chugach highland began to erode and fine sediments accumulated in the trench which borders the continental margin of Alaska. This trench, formed by the subducting Pacific plate, acts as a kind of geologic garbage dump catching sediments eroding off the continent. Fine sediment particles, drifting out to sea, slowly settled to the ocean bottom forming large submarine deltas. These sedimentary layers of sandstone and mudstone reached depths of more than a mile.

A similar process continues today. For example, the Copper River, east of the sound, carries more than 40,000 tons of sediment per day and deposits it in a huge underwater ocean delta beyond the river's mouth.

As time passed, the weight of this great mass of material caused high pressures and temperatures which slowly baked (metamorphosed) these sediments to form slate. Following uplift, weathering has caused these rocks to form friendly shingle beaches such as those found on the southern end of Culross Island. These slates were used to make scraping and cutting tools by the Chugach Eskimo, residents of the sound for thousands of years.



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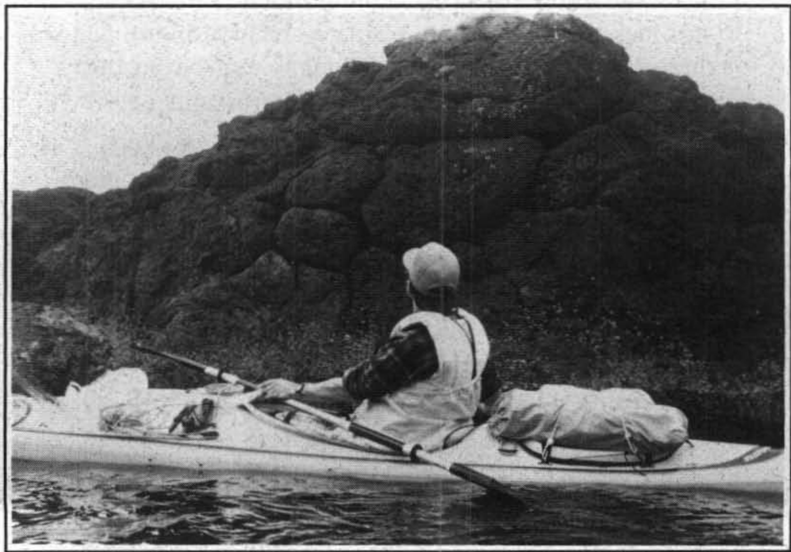
Sandstone and slate sedimentary layers in Eshamy Bay.



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Basalt pillows near Crafton Island.

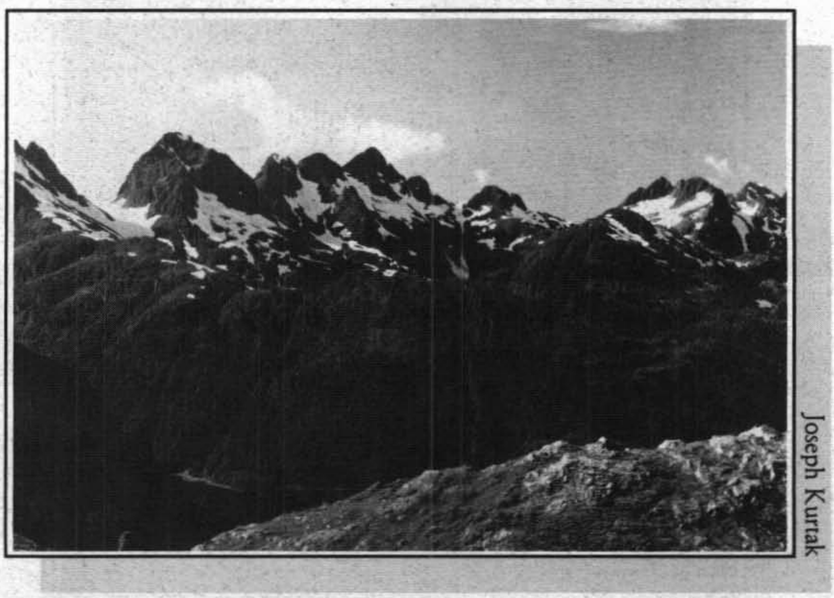
ENTER THE FIRE GODS

WHILE vast amounts of sediments were being dumped into the huge trench formed during subduction of the Pacific plate, other events were occurring at depths of 20 miles or more beneath this plate. Here the plate was heating up due to friction with its surroundings as it slid under the North American plate. Temperatures of 1,000°F caused plate material to melt into molten rock called magma. This magma, being less dense that the surrounding crustal rocks, began a slow ascent to the surface like bubbles rising in an inverted bottle of liquid shampoo. The magma pooled in a high pressure chamber near the surface and then worked its way up along weaknesses in the earth's crust to erupt as lava flows. These flows spewed out onto the sea floor and cooled to form volcanic rocks called basalts. The magma quickly cooled as it contacted sea water, forming closely packed elliptical masses called pillow lava. These basalt pillows vary in diameter from a few inches to as much as 13 feet. They do not make a soft place to rest one's head at night. Masses of these pillows can be seen in numerous places in the sound, especially on Knight and Crafton islands.

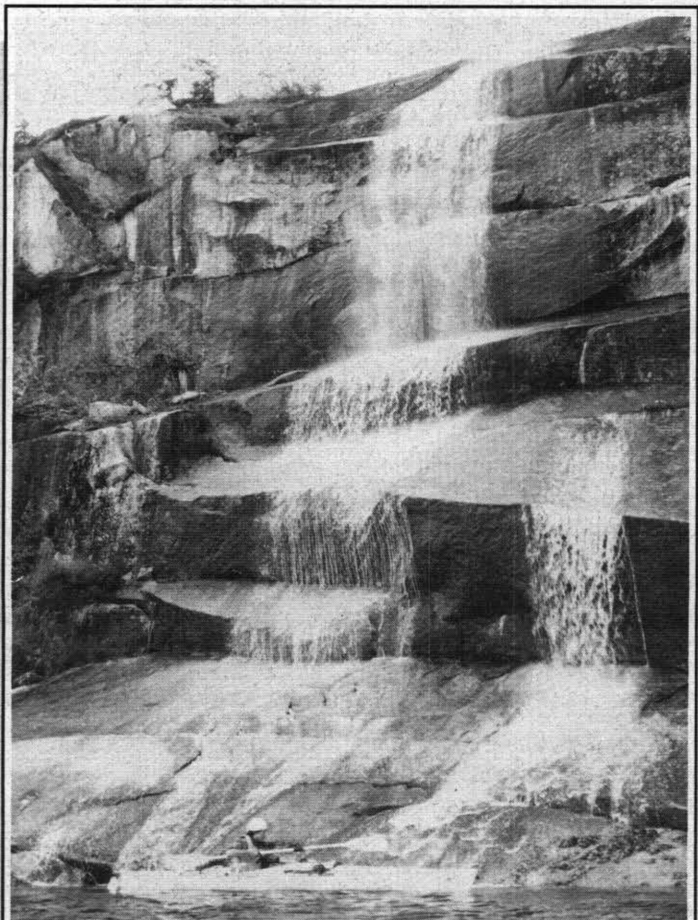
Basalts of Prince William Sound are hard and very resistant to weathering. They constitute many of the boulder beaches in the sound. Basalts also make up some of the more rugged terrain such as the cleaver-like peaks of the Three Giants on central Knight Island. Basalts were used by the Chugach Eskimo for stone hammers and digging tools.

This package of intermixed volcanics and sediments was in for a rough ride as the Pacific plate on which they rested pushed them onto the continental margin during subduction, buckling and folding them while doing so. To illustrate this, push one end of your living room rug toward someone standing on the other end of the rug. What happens? Lots of folds! Excellent examples of this type of folding are exposed along the west shoreline of Latouche Island. These rocks make up the Prince William Terrane and have been named the "Orca Group" by geologists.

In some areas, copper- and iron-rich brines spewed from sea floor vents along with the volcanics. As the brines cooled, metals precipitated among the basalts and neighboring sediments. The first miners of these metals were the Chugach Eskimo. They used copper ore (chalcopyrite) as an ingredient in dyes, and the iron-rich mineral pyrite as a striker for making sparks to produce fire. Soft native copper was pounded into spear points. In 1897, Natives showed prospectors the source of their copper on Latouche Island. This site was later developed as the Beatson Mine, producing six million pounds of copper before it closed in 1930.



Rugged peaks composed of basalt at the head of Drier Bay on Knight Island.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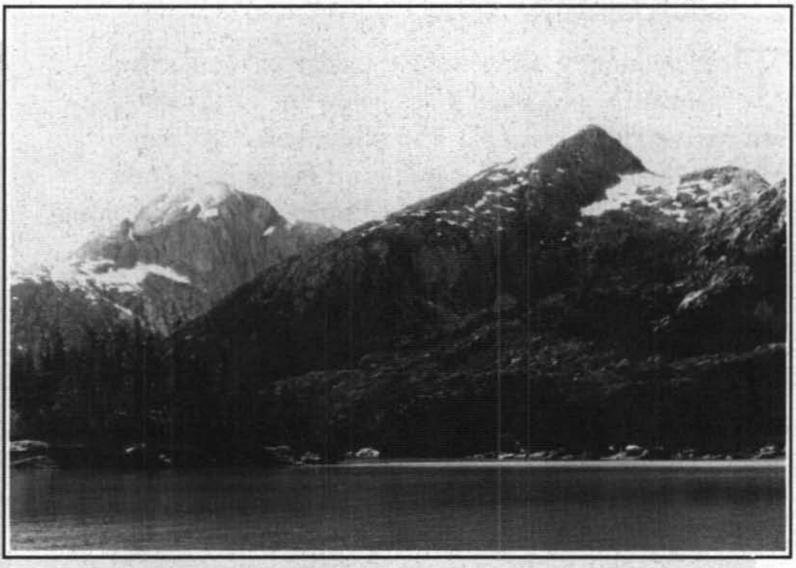
Blocky granite outcrops in Derrickson Bay.

Enter the Granites

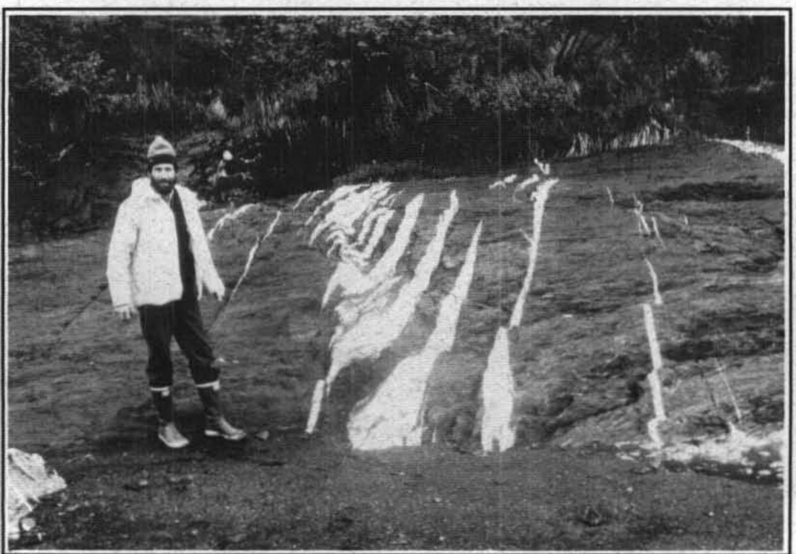
THE melting of rocks along the edge of the Pacific plate as they plunged miles below the earth's surface was not yet over. From 30-35 million years ago, more magma slowly worked its way toward the surface of the ocean floor, melting and engulfing surrounding rocks along the way. This magma pulse was different from that which produced the pillow basalts. It stopped its ascent short of the surface and during a cooling process that took millions of years, crystallized into granite. This slow cooling, along with a composition different from the basalt magmas, resulted in the development of large mineral crystals including quartz, feldspar and biotite, which give granite its sparkled appearance. Later these crystalline rocks were exposed at the surface as the overlying rocks eroded away. Some of the finest scenery and exploring in the sound lies within these granite areas, such as those in Deepwater Bay, where one can paddle beneath Yosemite-like walls. Weathering of the granite also produced some of the few white sand beaches in the sound, good for wiggling one's toes in on a warm sunny day.

During cooling and crystallizing stages, the granites released hot silica-rich fluids containing such metals as gold, silver and zinc. Under high pressure the fluids shot off from the main cooling granite into fractures within the overlying rocks. As the fluids cooled in these openings, they crystallized to form milky-white quartz veins, trapping the metals within. Millions of years later, the search for this elusive yellow metal would lure prospectors into the sound. Gold discoveries were made and mines developed in the early 1900s in such places as Port Wells and Culross Island. These abandoned mines are important remnants of the sound's history and their associated paraphernalia is interesting to explore. Use caution when exploring old mine workings as they can be dangerous.



Joseph Kurtak

Granites make for great background scenery in Deepwater Bay.

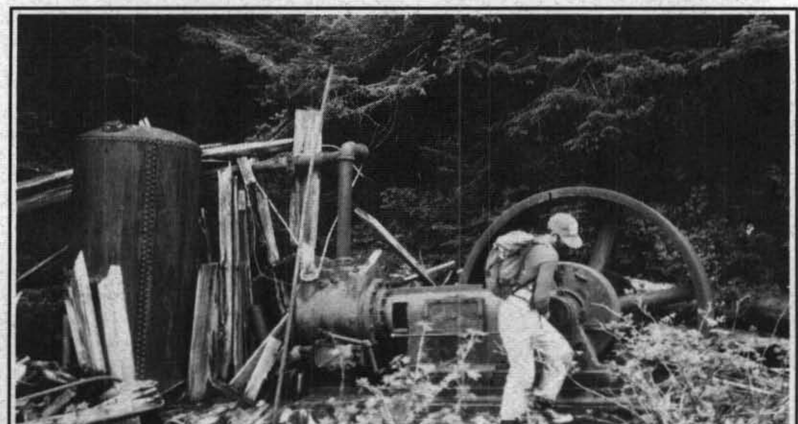


Kevin Killilea

Quartz veins in Barry Arm.

From six to 30 million years ago, compressive forces were still at work on the sedimentary rocks which, by this time, had become well consolidated and brittle. Instead of bending into folds, large blocks of rock would break, or fault, with individual blocks sliding past each other. The rocks in the western sound are weakest parallel to their sedimentary layers which have been tilted so that they are oriented in a northeast-southwest direction. Thus, when breaks happened, they tended to occur along this orientation. Weathering along weakened zones that were crushed during faulting, eroded depressions in the bedrock surface. These depressions provided basins for the development of glaciers, which further scoured them out, resulting in features such as Blackstone and Kings bays.

All of this compressive force on the rocks forced them to go only one way—up! The present land masses of Prince William Sound thus began to emerge from their birthplace deep under the sea.



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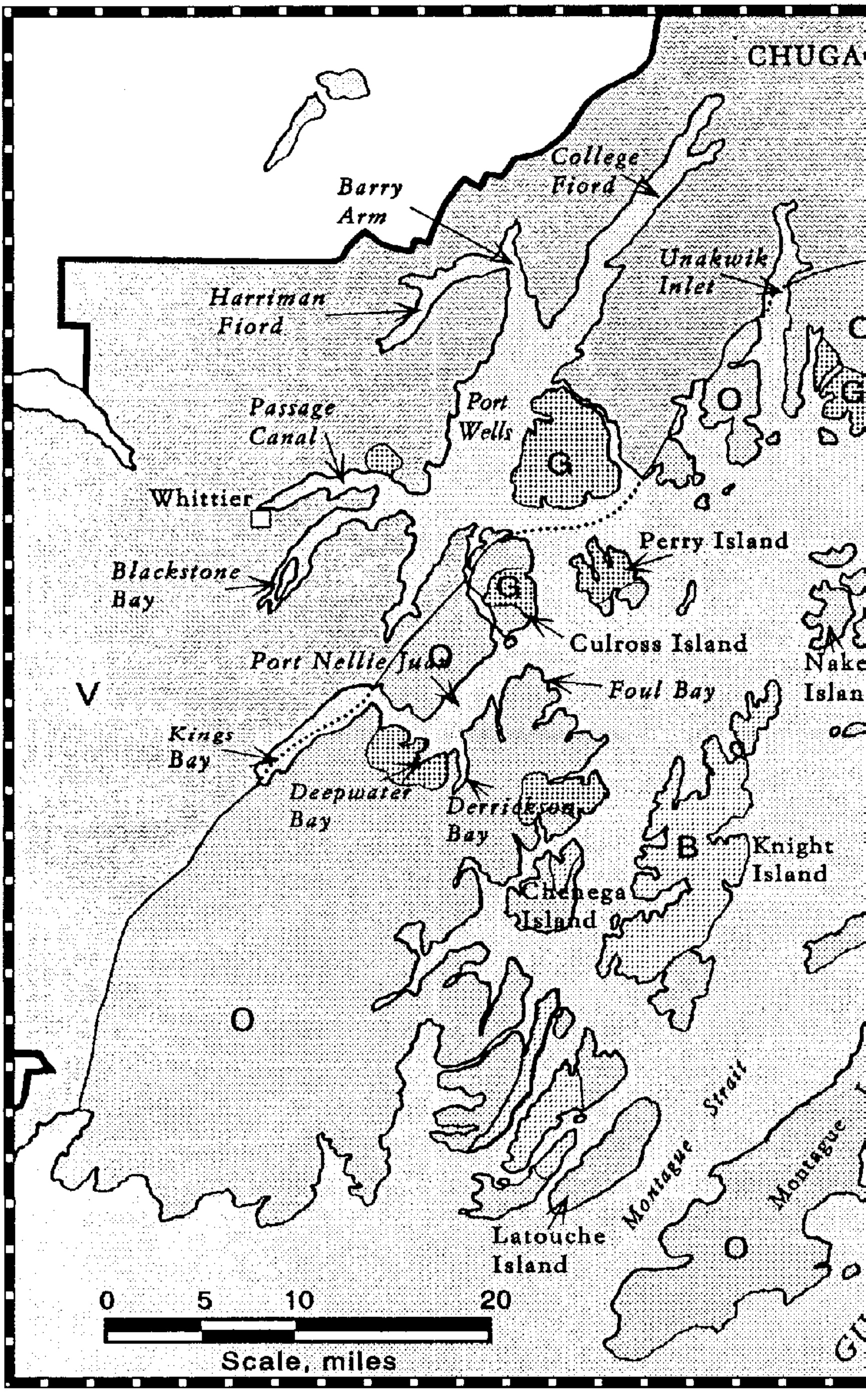
Exploring old mine machinery in Port Wells.


CHUGA
College
Fiord
Barry
Arm
Unakwik
Inlet
Harriman
Fiord
Port
Wells
Passage
Canal
Whittier
Blackstone
Bay
Perry Island
Culross Island
Port Nellie Juan
Foul Bay
Kings
Bay
Deepwater
Bay
Derrickson
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Island
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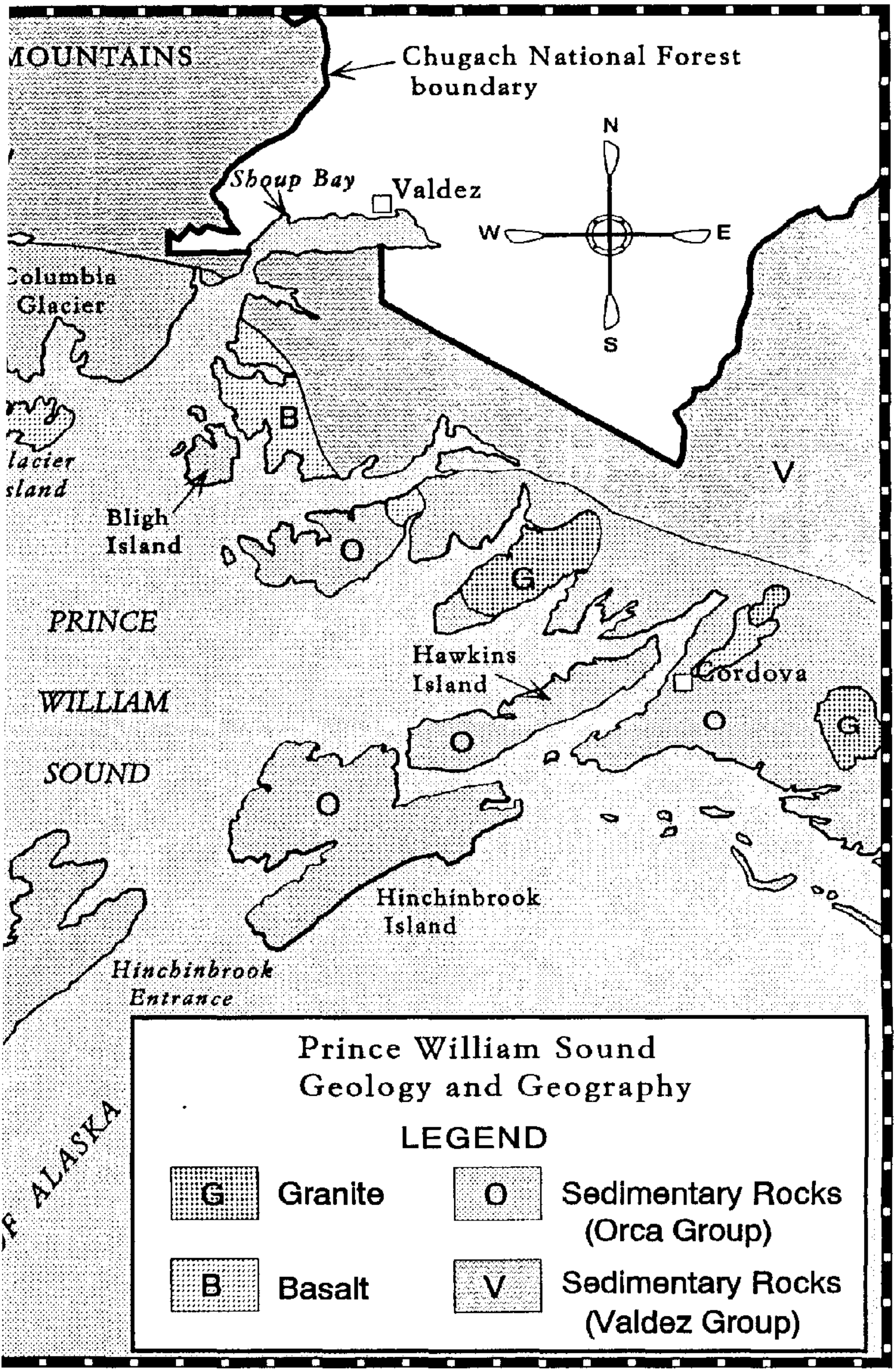
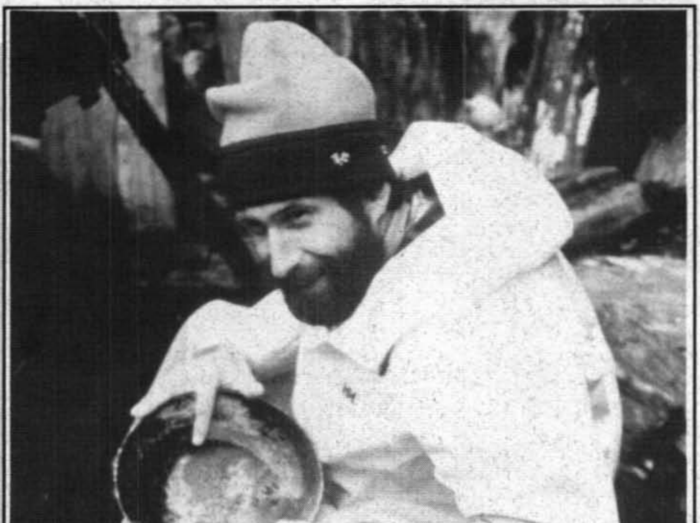


MOUNTAINS
Chugach National Forest boundary
N
S
W
E
Shoup Bay
Valdez
Columbia Glacier
Glacier Island
Bligh Island
B
O
G
V
PRINCE
WILLIAM
SOUND
Hawkins Island
Cordova
O
G
O
O
Hinchinbrook Island
Hinchinbrook Entrance
ALASKA
Prince William Sound
Geology and Geography
LEGEND
G Granite
O Sedimentary Rocks (Orca Group)
B Basalt
V Sedimentary Rocks (Valdez Group)



Kevin Killilea

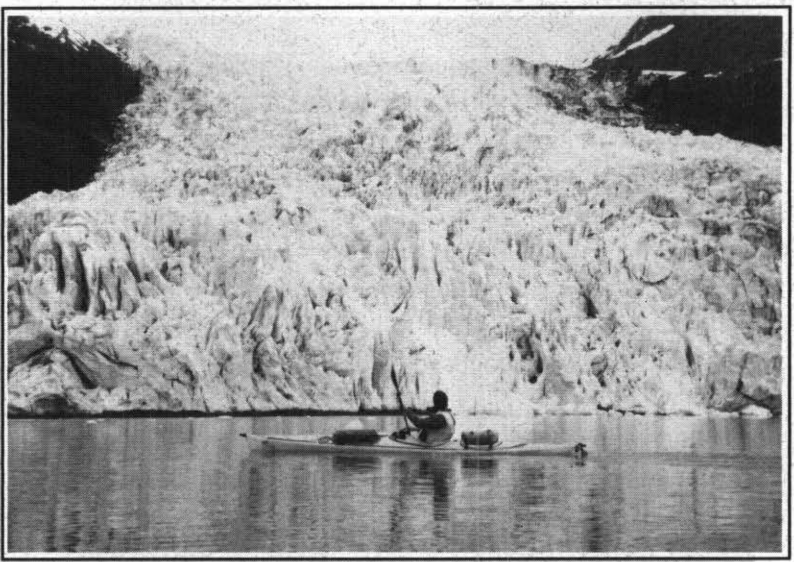
The camp skillet does double duty as a gold pan and rewards the author.

The Ice Comes

THE landscape that made up Prince William Sound approximately six million years ago is obscured in the mists of geologic time. Some geologists theorize that extensive erosion during this time may have reduced the area to a lowland only slightly above sea level. Others believe that it was somewhat mountainous, though not as rugged as today's landscape. Whatever it looked like, the stage was being set for a major event in the sculpting of the sound. Beginning about 40 million years ago, the world's climate began to cool. Snow and ice began to accumulate at higher elevations. As the earth continued to cool, the ice migrated to lower areas—through valleys previously formed by faulting and erosion.

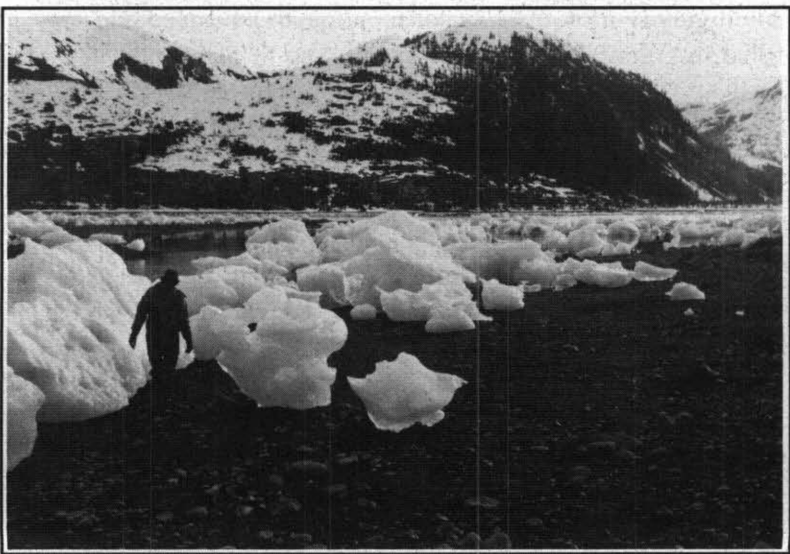
Approximately two million years ago, snow was accumulating in the high country faster than it could melt. The great weight of snow caused it to compress itself into ice. Then gravity took over. Giant ice tongues advanced and filled intermountain areas. Eventually, up to 30% of the earth's surface was covered with a mammoth ice sheet. The ice thickness varied. An estimated ice depth on Knight Island of approximately 2,400 feet combined with a present sea floor depth of another 2,400 feet would have made the total thickness of ice 4,800 feet. All the water stored as ice caused the sea level around the world to drop as much as 400 feet. The great weight of the ice may have depressed the earth's surface as much as 480 feet in parts of the sound. The current high peaks of Knight Island would have stuck out of the giant ice sheet. Soundings indicate that the ice sheet flowed out to sea along channels it carved through Montague Strait and Hinchinbrook Entrance. The main channels were fed by smaller streams of ice coming from fjords such as Port Wells and Port Nellie Juan. Both of these areas are noted for their tidewater glaciers, mere remnants of once large ice masses.

Trisha Herminghaus



Wellesley Glacier meets the sea in College Fiord.

Joseph Kurtak



Extreme tide variations in the sound can take your kayak out to sea or beach icebergs like these in Derrickson Bay.

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The grinding action of the ice smoothed off, rounded, and, in some places, polished the bedrock as it ground its way like a giant bulldozer. In some places, ice, mixed with rock fragments, ground grooves (glacial striations) in the bedrock. Striations are exposed in many places, with good examples near Barry Glacier in Harriman Fjord. The extent to which the bedrock was carved was dependent on rock hardness. The basalts resisted the grinding action, thus producing the rugged terrain of Knight Island, while the flaky slates were easy victims resulting in more rounded Perry and Naked islands. This glacial bulldozer also produced the U-shaped valleys characteristic of the sound's fjords.

A gradual warming trend beginning 12,000 years ago forced the ice to retreat, reducing the once large sheet to a series of smaller high valley glaciers. By 10-11,000 years ago, shorelines in the sound were probably ice-free and the first signs of plant life were appearing.

The beginnings of the emergence of spruce/hemlock forests 2,000 years ago, indicated the start of a major warming trend. The Chugach Eskimo may have arrived in the sound during this period of glacial retreat. The Natives found protected waters, abundant sea life and security from enemies. The melting ice also caused a significant rise in sea level and, linked with the bouncing back of the now unburdened bedrock (isostatic rebound), caused considerable fluctuation in shoreline levels. Evidence of older, wave-cut terraces, now elevated above the present high tide line, can be seen in numerous places, especially in the western sound. These perched beaches provide excellent, well-drained campsites safe from the effects of extreme high tides.

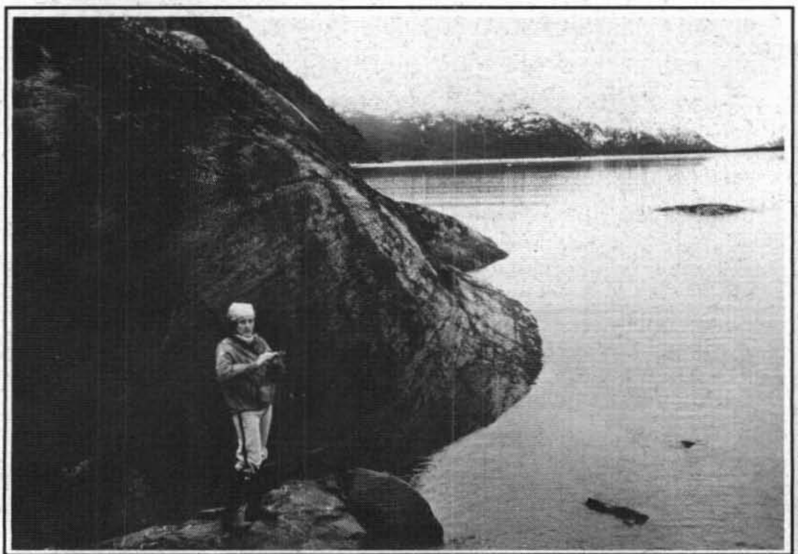
The sound is still experiencing a warming trend. Many of the once large glaciers have been reduced to small ice fields seen high above the water line in cirques beneath the peaks. Columbia Glacier has retreated more than two miles since 1981. Even during this general warming period, there are a few glaciers that are advancing. One of these is the Meares Glacier at the head of Unakwik Inlet, parts of which have advanced more than 700 feet since 1979.

The glaciers are continuing their dozer action, though on a much smaller scale than before. Freeze/thaw action at a glacier's source dumps rock debris on top of the ice. This overburden is either carried along by the glacial conveyer belt or overridden and ground into a fine rock dust (glacial flour) beneath it. This dust is carried out from under the glacier by streams and clouds sea water a silty green color. Seafarers, observing this water color, can bet that a glacier is coming up around the bend.

Rock debris carried on the surface of the glacial conveyer is often dumped off the end of the melting glacier front to build a crescent-shaped mound called a terminal moraine. As the glacier retreats, the moraine is left behind as evidence of a previous advance. As an example, the Nellie Juan and Shoup glaciers have left terminal moraines more than a mile beyond their present ice fronts. Many times these moraines provide well-drained campsites and good locations from which to safely observe active glaciers. In some fjords, moraines are submarine and can be detected by checking water depths on navigational charts. Unakwik Inlet contains a classic example of a submarine moraine.

The tidewater glacial environment is one of the special features of Prince William Sound. The small size and shallow draft of kayaks make them perfect for intimate experiences with these ice behemoths. It is an awe-inspiring sight to see blocks of ice the size of office buildings peal off the face of a glacier with a thundering crack and plunge into the water with a cannon-like explosion! Hidden beneath tidewater, great freshwater streams flow out from under the melting glacial ice and mix with the salty sound water. Having a lower specific gravity, the fresh water wells up to the surface, bringing with it an abundance of nutrients from the bottom, attracting many members of nature's food chain. This glacial delicatessen serves fish and other sea life. These critters in turn attract gulls which build precarious nests on the near-vertical fjord walls. The fish and abundant bottom life attract sea mammals including whales, seals and otters.

Camping in a spot like this, observing nature's wonders, instills in us a primordial feeling as we watch the birth of a landscape as it emerges from the earth's icy womb.



Joseph Kurtak

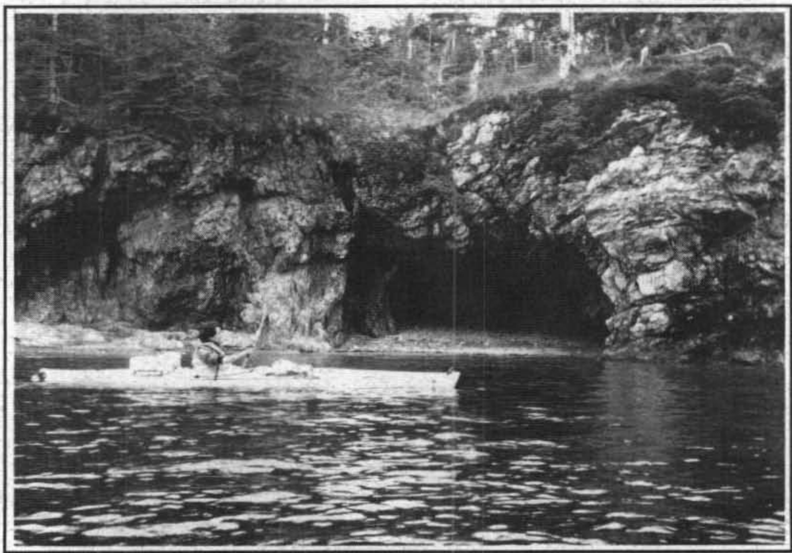
Glacially-carved bedrock in Barry Arm.

Watch that Ice!

A few words of caution are appropriate while glacier watching. When making a moraine camp near an actively calving glacier, be sure to get your boats and tents well above the high tide line. Waves generated by falling ice can flood camps and, from the author's own experience, wash boats out to sea. Also do not linger at put-in and take-out sites. A wave can hit with almost no warning, giving you an unexpected bath. Keep a safe distance between your boat and the glacier front while observing falling ice. Also, keep an eye out for icebergs. They often have a bluish color since the dense crystal structure (with very little pore space) reflects blue light wavelengths and absorbs others. These ice chunks can flip over quickly, exposing the other four-fifths of their mass concealed below the surface. Nearby boats could easily be swamped or tip over. Currents can be very unpredictable near glaciers. What initially looks like an open channel through floating ice, can quickly disappear as the ice closes in around you and your boat.

The Unrelenting Sea

POUNDING sea waves along the sound's rocky coastline are continuously breaking down the bedrock. The debris, along with stream and glacial gravels, moves along the shore by wind and tidal currents. Where no beaches exist, shoreline currents are very strong or deep water comes close to land. Wave action is not so strong near sheltered islands as it is on islands exposed to the full brunt of the sea. Along sheltered islands, deposits of sand and gravel build up just off points of land, in protected coves and between islands where the waves have piled them up or tidal currents have lost their carrying power. The beaches of Crafton Island, like those of Main and Foul bays are good examples of protected beaches with excellent campsites.



Joseph Kurtak

A sea cave gouged out by wave action pounding against faulted basalts on Crafton Island.

The Earth Doesn't Sleep

THROUGHOUT its geologic history, Prince William Sound has been moving and shaking with few pauses and still the beat goes on. The Pacific plate continues to grind into and under the North American plate making the ground shake in the process. Chugach Eskimo legends, hundreds of years old, tell of subterranean demons who shook the ground. The town of Valdez in the northeast corner of the sound has experienced 70 major earthquakes since records were begun in 1898.

On the afternoon of Good Friday, March 27, 1964, violent forces were triggered miles beneath the waters of Unakwik Inlet in the northern sound. At 5:36 p.m., the earth began to shake. It shook for four minutes, spreading devastation over a 110,000 square-mile area. A broad tilting effect caused the land to uplift as much as 38 feet in some areas of southeastern Prince William Sound. Subsidence in the northwest dropped land surfaces an average of 2.5 feet, flooding beaches and killing vegetation. Systematic horizontal shifts of 64 feet occurred in a seaward direction. The quake registered between 8.4 and 8.6 on the Richter scale, making it the most violent ever recorded in the North America.

Local submarine landslides caused by the violent shaking, created destructive sea waves which devastated tidewater communities in the sound. Waves towered as high as 70 feet above tide level on Chenega Island, destroying all but one house and drowning 23 inhabitants. Tsunamis (seismic sea waves) flooded communities as far away as northern California, 2,700 miles south.

Now, years later, evidence of this catastrophic event can still be seen. Trees killed by flooding stand below Billings Glacier near Whittier. Wave scars can be recognized by snapped off trees near shoreline in such places as Kings Bay and Passage Canal. Two hundred feet from shore near

Mink Island in Port Nellie Juan, a barge lies up-side-down where it was thrown by a violent wave. On Knight Island, remnants of barnacles, left high and dry by 6.5 feet of uplift, can still be observed.

Numerous small quakes rattle the sound each year. These may be beneficial as they may relieve the stress build-up a little at a time rather than saving it up for one big jolt.


Joseph Kurtak

A protected cove in Bettles Bay makes a friendly landfall.

Today and Looking Ahead

THIS brings us to the present time. Though the sound may seem fairly calm on the surface, many of the geologic processes described here continue. As you float along drinking in the remarkable beauty and wonder of this paradise, remember the processes at work both around and beneath you. Sediment, still being deposited in layers on the sea bottom, will slowly harden into rock and eventually exposed at the surface due to uplift. When the ground shakes, you are reminded that the earth's mobile plates are still sliding past each other somewhere beneath your boat. Glaciers still chew up rock and send it to the sea as they carve out their niches in the sound's beautiful fjords.

And the battle of opposing forces, of building and destroying, rages. Sometimes quietly, sometimes explosively, these forces continue to shape the ever-changing and ever-intriguing Prince William Sound of Alaska.

Recommended Reading

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Notes