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The Mount Edgecumbe Volcanic Field
A Geologic History

The Author

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Purpose

This booklet is a compilation of technical information collected from many hours of research done on the Mount Edgecumbe Volcanic Field. It is presented here for the reader who has an interest–but not necessarily a background–in geology. The booklet includes information that will help hikers understand significant features of the Mount Edgecumbe Trail from the east shore of Kruzof Island to the summit of Mount Edgecumbe.

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Alaska Region National Forests

Introduction

Mount Edgecumbe, a beautifully symmetric cone on southern Kruzof Island (Fig. 1A), is one of southeastern Alaska's striking landmarks. The volcanic origin of the mountain has been long recognized: it is referred to even in Tlingit legends as a smoking volcano.[1] Russian explorers and settlers referred to the volcano by several names, including St. Lazarus[2] (a name now given to a small island off the southern coast of Kruzof Island). The mountain was given its present name in 1778 by Captain James Cook. In 1803, Urey Lisianski climbed the volcano and deduced that, because ash and pumice on the mountain appeared so weathered, the volcano must have been inactive for some time.[3]

Mount Edgecumbe is actually one of several volcanoes on southern Kruzof Island (1B). Volcanic activity started about 600,000 years ago when basalt began to erupt quietly from ground cracks scattered across the island. By about 400,000 years ago, other types of magma as well as basalt had begun to erupt. Eruptions eventually concentrated in a narrow zone that extends from the southwestern tip of the island to the northeast and passes beneath

1(A). The symmetric cone of Mount Edgecumbe, viewed from the east. The high point on the summit rim is 3,201 ft (970 m).

1(B). Southern Kruzof Island viewed to the northeast. Cone-shaped Mount Edgecumbe, which when snow-covered bears a striking resemblance to Japan's Mount Fuji, is at the lower left. Aligned to the northeast are, in succession, the crater and domes of Crater Ridge, a small unnamed scoria cone, the Shell Mountain scoria cone, the partly eroded remains of an old cone to the right of Shell Mountain, a young lava flow that erupted from Shell Mountain and flowed northward, and another unnamed scoria cone.

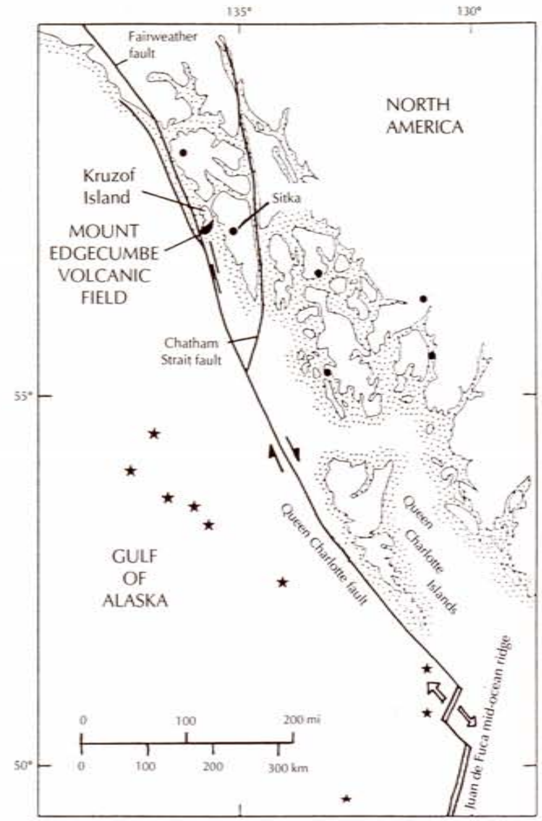
the site of Mount Edgecumbe. By 30,000 years ago, construction of Mount Edgecumbe itself was well underway. Crater Ridge, the cluster of peaks immediately northeast of Mount Edgecumbe, was formed about 20,000 years ago by five lava domes that grew over a period of years.

Southern Kruzof Island had a series of major explosive eruptions about 12,000 to 14,000 years ago, just after glaciers had retreated from the region. Ash deposits resulting from these eruptions can be seen today in streambanks and roadcuts in Sitka and as far as Cape Fairweather, 150 miles (240 km) to the north. The last known eruptions on Kruzof Island were two minor ash eruptions 5,000 to 6,000 years ago. Volcanoes are categorized by the length of time since their last activity. "Active" volcanoes have erupted during historic time or within the past 2,000 years, and "extinct" volcanoes have been inactive for at least 10,000 years, so Mount Edgecumbe and its neighboring vents are considered "dormant." There is presently no evidence that another eruption on southern Kruzof Island is imminent, but other dormant volcanoes have awakened after thousands of years of inactivity and Mount Edgecumbe could do so again as well.

Mount Edgecumbe and the other vents in the Mount Edgecumbe volcanic field are today part of the Tongass National Forest, which is administered by the United States Department of Agriculture Forest Service. This booklet summarizes the volcano's geologic history and presents a guide to the hiking trail leading to the summit of Mount Edgecumbe. The geologic terms used are marked by *italics* the first time they occur, and definitions are given in a glossary at the end of the booklet.

Regional Setting: What Has Caused the Volcanic Activity?

Mount Edgecumbe is on southern Kruzof Island, 15 miles (24 km) west of Sitka (Fig. 2). The island is part of the North American *plate*. The boundary between the North American and Pacific plates is the Queen Charlotte-Fairweather *transform fault*, which is only 10 miles (16 km) offshore to the

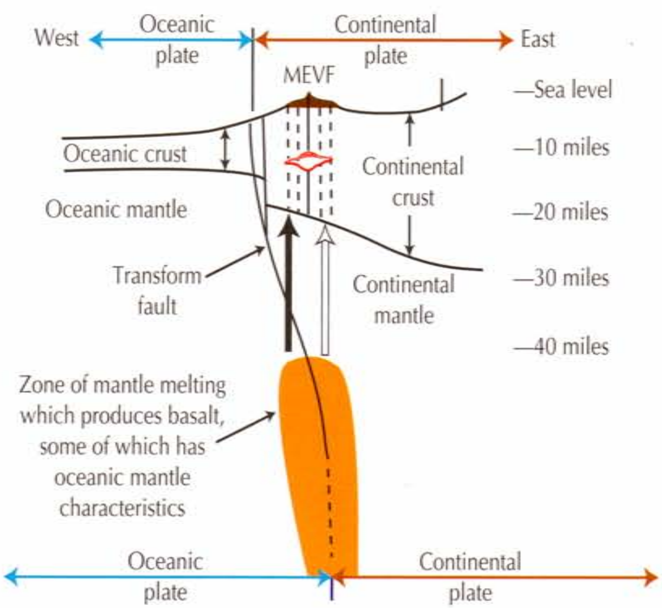


2. Map of southeastern Alaska showing the Mount Edgecumbe volcanic field on southern Kruzof Island (black). Other, small volcanic fields in the region that have been active in the past 2 million years are indicated by dots (on land) and by stars (submarine seamounts). The Queen Charlotte-Fairweather transform fault (heavy lines) is the boundary between the North American and Pacific plates. The Pacific plate is moving northward past Kruzof Island (solid arrows) in response to spreading away from the Juan de Fuca ridge (open arrows) where new ocean crust is forming.

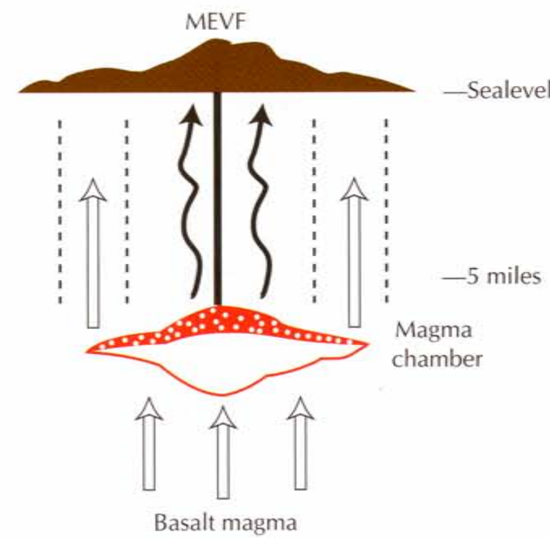
west. Movement of the Pacific plate northward causes earthquakes on this boundary. One of the larger earthquakes to have been felt in Sitka was a magnitude 7.2 in 1972. This earthquake was located along the Queen Charlotte-Fairweather transform fault about 30 miles (48 km) south of Sitka.[4]

Volcanoes are rare along transform faults worldwide, and geologically young volcanoes are uncommon in southeastern Alaska (Fig. 2). To volcanologists, then, the Mount Edgecumbe volcanic field (MEVF) is unusual for its geologically recent eruptions so near to the Queen Charlotte-Fairweather transform fault. Geophysical surveys of the seafloor near the Queen Charlotte Islands, 200 miles (320 km) south of Kruzof Island,[5] show that the Queen Charlotte-Fairweather fault dips eastward beneath the earth's surface. Although similar surveys have not been done near Mount Edgecumbe, it is likely that the fault continues to dip eastward beneath Kruzof Island. *Basalt* on southwestern Kruzof Island has chemical characteristics of oceanic basalt, while basalt from the northeastern part of the MEVF has characteristics of continental basalt. This means that MEVF basalt comes from a zone in the earth's *mantle* that may include both Pacific oceanic plate and North American continental plate. Such a zone may straddle the transform fault at depth where it dips beneath Kruzof Island (Fig. 3A). So while it is not known why the volcanic field formed at this particular place along the transform fault, it is likely that MEVF basalt formed because movement on the transform fault caused melting of some of the mantle.

Hypothetical views of the subsurface beneath southern Kruzof Island, along an east-west section.



3(A). The Queen Charlotte-Fairweather transform fault probably dips east beneath Kruzof Island; the exact locations of the fault and the base of continental crust beneath Kruzof Island are uncertain. Basalt magma forms by melting of the mantle beneath Kruzof Island and rises (large vertical arrows) to erupt in the Mount Edgecumbe volcanic field (MEVF). Basalt that erupts in the southwestern part of the MEVF has chemical characteristics of oceanic mantle, so this basalt (solid arrow) may have originated in the oceanic plate on the west side of the transform fault. Basalt that erupts in the northeastern part of the MEVF has characteristics of continental mantle (open arrows). The red area below MEVF in the middle of the continental crust is a crustal magma chamber where crustal rocks partly melt to form silicic magmas.The transform fault splits into multiple strands see (fig. 2), not a single fault, as indicated by the fork in the diagram above. The splitting signifies a poorly understood complexity in the contact between the plates near Kruzof Island, which may some how be responsible for the volcanism on the island.



3(B). A close view of the MEVF magma chamber, which is probably 5 to 10 miles (8 to 16 km) below the surface of the earth in the continental crust. In the chamber, silicic magma (dots) overlies basalt (open area). The magma chamber is thickest on a major crustal fracture (solid vertical line) because heating by basalt has been concentrated on this fracture. On and near the fracture, silicic magma has risen (wavy arrows) to erupt at the MEVF but basalt is blocked from rising further by the thick magma chamber. At the margins of the MEVF where the magma chamber is thin, some basalt has been able to rise (open arrows) along small fractures (dashed lines; see, for example, the fissure vent in Fig. 6) to erupt even after the magma chamber grew to its present size.

Stage One: Early Basalt Eruptions of the Mount Edgecumbe Volcanic Field

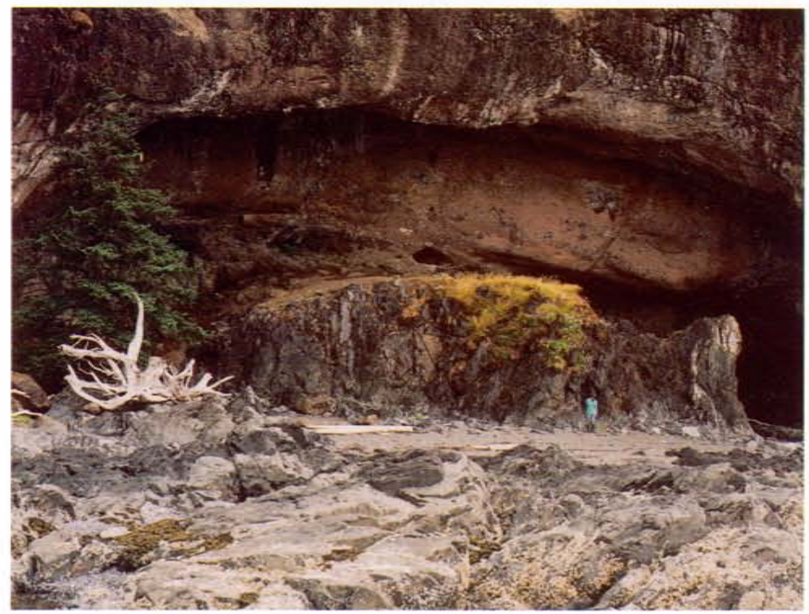
The oldest volcanic rocks in the Mount Edgecumbe volcanic field (MEVF) erupted from fissures (cracks) in sedimentary and igneous rocks that comprise the older part of Kruzof Island.[6] The oldest rocks are basalt, which is the same type of *lava* that erupts in the Hawaiian Islands. MEVF basalt flows have smooth, ropy tops that indicate the fluid nature and rapid flow typical of this type of lava (Fig. 4). Basalt flows are easy to see along the

4(A). The surface of a basalt flow that can be seen on the beach on the southeastern coast of Kruzof Island. The top of the flow was mounded while the lava was still hot due to pressure of fluid lava within the chilled crust. The pattern of six-sided fractures in the crust, called "columnar jointing," is characteristic of shrinkage caused by cooling of the lava from the outer surface inward.

4(B). A lava tunnel forms a cave in the seacliff 1 mile (1.6 km) east of Cape Edgecumbe. A tunnel results when the fluid interior of a lava flow drains away, leaving the chilled roof and sides.

beach from Mud Point south to the Army camp. The first eruptions occurred in part on the seafloor, as shown by *breccia*—deposits of broken pieces of lava—that contain shells of small ocean organisms (Fig. 5). Marine breccia

5(A). Volcanic breccia can be seen in the seacliffs near Port Krestof. The dark block is basalt, similar to nearby lava flows that erupted during the earliest volcanic activity at the Mount Edgecumbe volcanic field. The shells of small marine organisms can be found in the mud and sand between the lava blocks. The breccia is formed mainly of pieces of lava broken from flows that erupted on the seafloor.



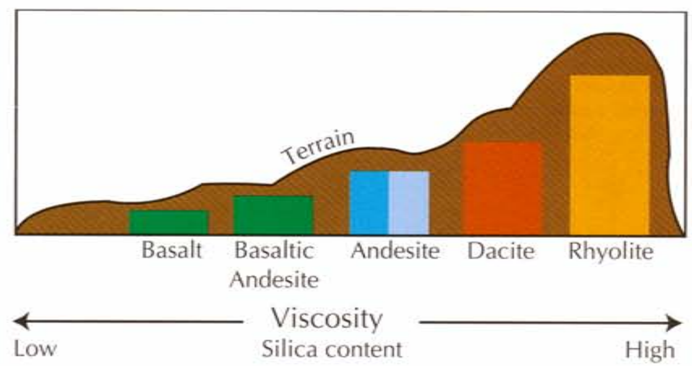
5(B). The volcanic breccia was deposited on a surface eroded in the underlying Sitka Graywacke (note the person for scale). The arch is the result of erosion today by waves and weathering, which is concentrated at the contact between the hard graywacke and the less resistant breccia.

can be seen in sea cliffs between Kamenoi Point and Mountain Point. A partly eroded *cone* that consists of basalt flows and breccia marks a former vent just west of the head of Mud Bay. Most early basalt flows, however, erupted from many fissures across southern Kruzof Island. The only evidence that remains of such fissure vents are *dikes* like one visible in the sea cliff north of Crab Bay (Fig. 6A).

6(A). Fissure vent on the eastern shore of Kruzof Island is marked by a vertical slab of chilled basaltic lava called a dike. The dike formed when lava was squeezed up to fill a fracture. Here, the fracture cuts older lava flows and breccia, which are now eroded below the top of the dike. Elsewhere on Kruzof Island, dikes also fill fractures in Sitka Graywacke.

Stage Two: Different Lavas Erupted Near the Center of the Volcanic Field

After basalt had erupted for a time, other kinds of lava that have a higher *silica* content than basalt began to erupt along with the basalt (Fig. 6B). Eruptions began to concentrate in a central zone that extends northeast from Cape Edgecumbe to Mud Bay. For example, the low, forested mound 1 mile (1.6 km) southeast of Shell Mountain (Fig. 7A) is the eroded remains of a cone-shaped vent built of *andesitic* lava flows. *Basaltic andesite* lava erupted from near the tree-covered hills southwest of Mount Edgecumbe, and andesitic *domes* formed west of Shoals Point (Fig. 8A) and at St. Lazaria Island.



6(B). Various types of lavas that have erupted from the MEVF showing the least viscous to the most viscous and how viscosity, effects topography. Colors found in the bars in this chart represent the same lavas indicated in Figure 7A, 7B, and 7C.

The higher the silica content of lava, the higher its *viscosity* (stiffness). The effect of viscosity on lava behavior can be seen by comparing a steep-sided, andesitic lava flow (Fig. 8A) with a thin basaltic lava flow of lower relief (Fig. 8B). It is lava viscosity, then, that helps to explain major landforms of southern Kruzof Island. The low ground of limited relief along the coast from Mud Bay south to Shoals Point and west nearly to Sitka Point (see Fig. 7B.) is underlain by thin, flat-lying lava flows of low-viscosity basalt or basaltic andesite. Higher ground inland from this coastal strip, having relief to 150 ft (50 m), is underlain by more silicic, viscous lava flows of andesite.

Basaltic eruptions began about 600,000 years ago and continued to at least 140,000 years ago, making basalt the dominant type of lava erupted during the first 500,000 years of activity at the MEVF (Fig. 7C).

8(A). An andesitic dome on the coast 1.5 miles (2.4 km) west of Shoals Point. Note the massive interior and a chilled outer "rind" that consists of columnar jointed lava (compare with Fig. 5A). The dome formed by upwelling of lava immediately above a vent; the lava was so viscous that it could not flow away from the vent.

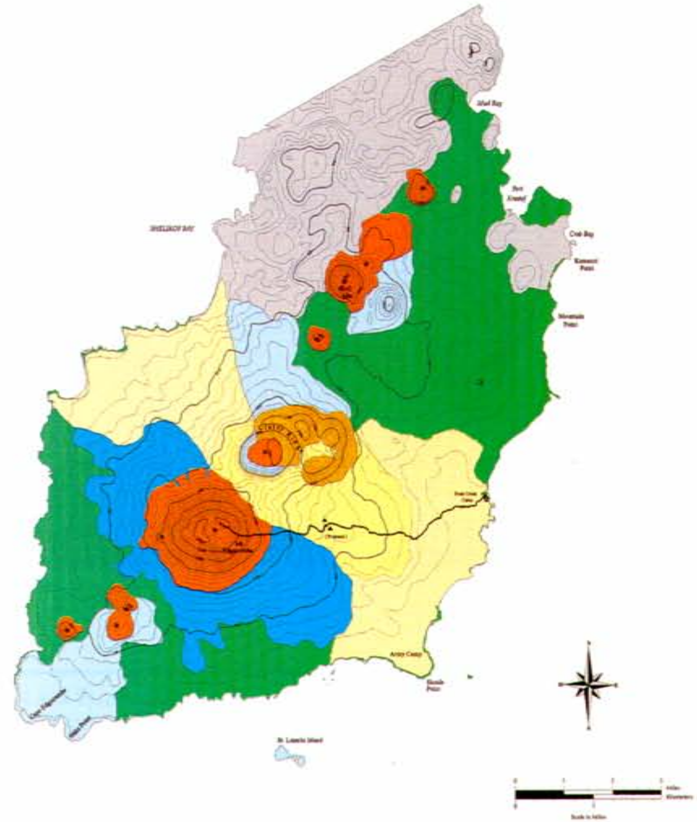
8(B). The surface of a chilled basalt flow about 6 feet (2M) wide on the beach south of Fred's Creek, on the east side of Kruzof Island. In contrast to the viscous andesitic lava in Fig. 8A, the basaltic lava was highly mobile and made long, thin flows.

Silicic lava flows that are less than 100,000 years old are found at Sitka Point and Cape Edgecumbe, around the base of Mount Edgecumbe, and near Crater Ridge. Some older silicic lavas may be buried beneath these young lavas, but the important fact in the history of the MEVF is that silicic lavas had begun to construct the higher ground at the center of southern Kruzof Island by about 100,000 years ago. Andesitic lava flows on the flanks of Mount Edgecumbe are between 20,000 and 40,000 years old; the interior of the Mount Edgecumbe cone undoubtedly contains older lava flows.

Among the most silicic lavas at the MEVF are the domes of Crater Ridge. These *rhyolitic* lavas were so viscous due to their high silica content that they could not flow at all and instead mounded up over their vents (Fig. 9). The domes are each about 20,000 years old, indicating that the most silica-rich lava at the MEVF appeared late in the geologic lifespan of the field. Based on observations of actively growing domes elsewhere, each of the Crater Ridge domes probably required years to decades to grow to its present size.

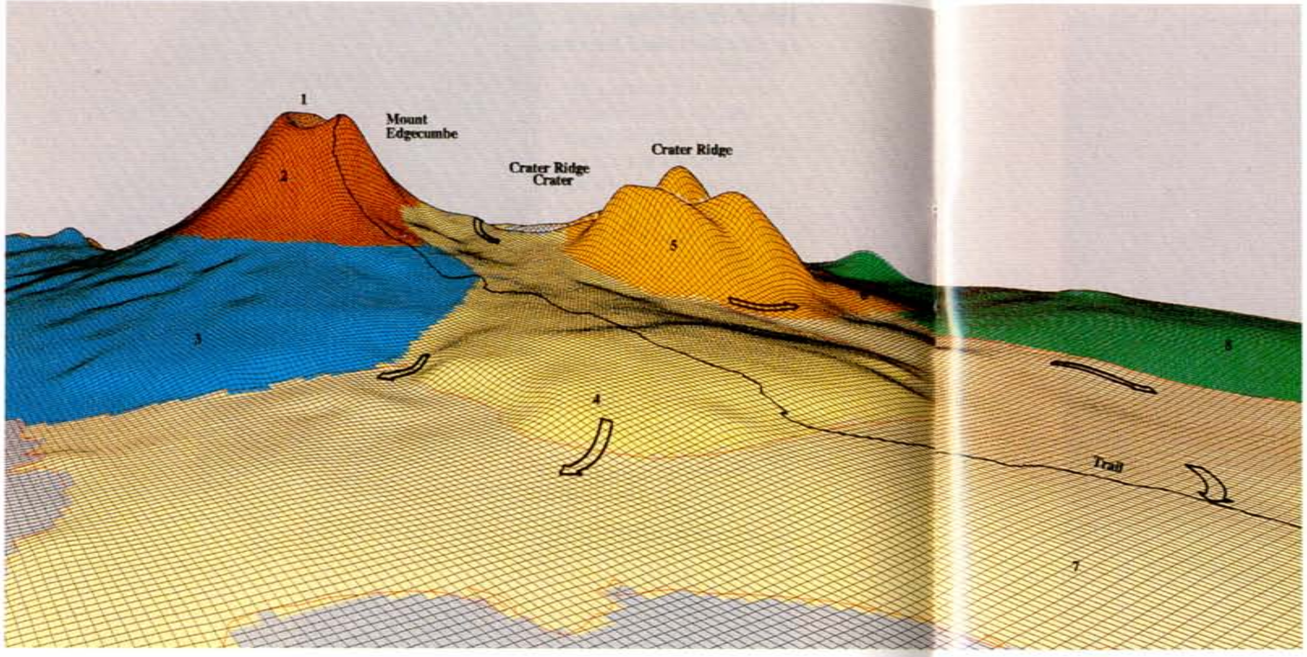
What is on Top

Surface Rocks and Deposits.



7(A). Geologic map of the Mount Edgecumbe volcanic field, southern Kruzof Island, Alaska. Unit symbols are:

- *pre-volcanic bedrock (Sitka Graywacke and Kruzof Island pluton)*
- *lava flows of basaltic or basaltic andesite composition; typically low and flat-lying due to low viscosity*
- *andesitic lava flows, typically steep-sided and having hummocky surfaces due to high viscosity; erupted from vents other than Mount Edgecumbe*
- *andesitic lava flows erupted from Mount Edgecumbe*
- *rhyolitic domes of Crater Ridge; there are four nearly complete domes and the remains of a fifth, which was largely destroyed during formation of Crater Ridge crater*
- *ash, pumice, and scoria erupted from vents identified by * symbol during major series of explosive eruptions 12,000 to 14,000 years ago; airfall deposits are thickest on Mount Edgecumbe and on cones to the northeast and southwest; also includes an andesitic lava flow on the northeast side of Shell Mountain cone and a dacitic lava flow on the floor of Crater Ridge crater*
- *rhyolitic pyroclastic-flow deposits erupted from Crater Ridge crater 12,000 to 13,000 years ago; up to 300 ft (90 m) thick in the southwest wall of Crater Ridge crater, more typically 30 to 50 ft (10 to 15 m) thick where they cover andesitic or basaltic lava flows (bright yellow) or low-lying, basaltic lava flows near the coast (dull yellow)*



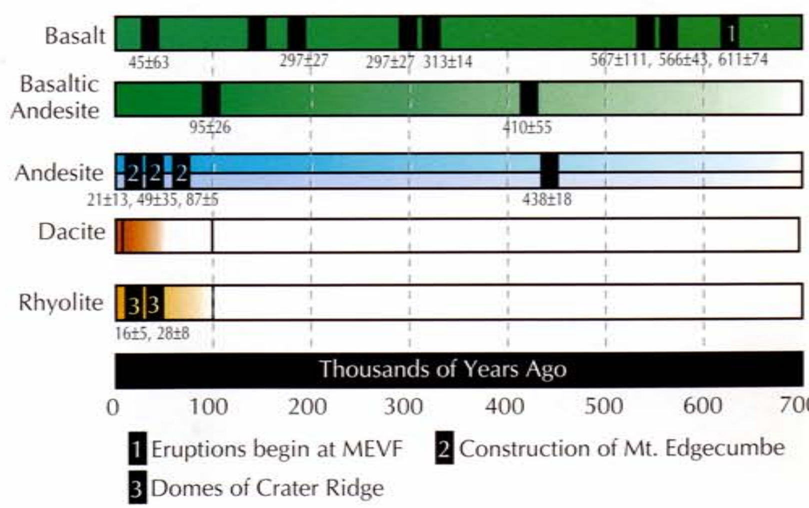
7(B). A digital elevation model (DEM) emphasizing the geomorphic features along the hiking trail to the summit of Mount Edgecumbe. The relations between terrain (physiography) and underlying geology (color shading) are well illustrated by this type of image.

What is Underneath

Explanation of Physiographic Units

1. Summit crater of Mount Edgecumbe, formed about 12,500 years ago during major explosive eruption of dacitic pumice.
2. Volcanic cone of Mount Edgecumbe; constructed of andestic lava flows, now heavily covered by andesitic and dacitic pumice and ash erupted by Mount Edgecumbe.
3. Andesitic lava flows erupted by Mount Edgecumbe, thinly covered by *airfall* pumice and ash.
4. Andesitic lava flows erupted by Mount Edgecumbe, heavily covered by air fall ash and pumice and by pyroclastic-flow deposits erupted by Crater Ridge crater. Arrows indicate paths followed by pyroclastic flows after their explosive eruptions from Crater Ridge crater.
5. Rhyolitic domes of Crater Ridge; 3 of 4 remaining domes are visable as rounded peaks.
6. Andesitic lava flows erupted by Crater Ridge before the rhyolitic domes formed; these lava flows were shielded by the rhyolitic domes from the pyroclastic flows erupted at Crater Ridge crater
7. Low-lying, basalt lava flows erupted from local fissure vents scattered across southern Kruzof Island early in the history of the volcanic field; now, are buried by pyroclastic-flow deposits and by airfall ash and pumice deposits.
8. Basalt lava flows like those in unit 7, but less deeply buried and only by airfall ash and pumice deposits;

Ages of Lava Types of the MEVF

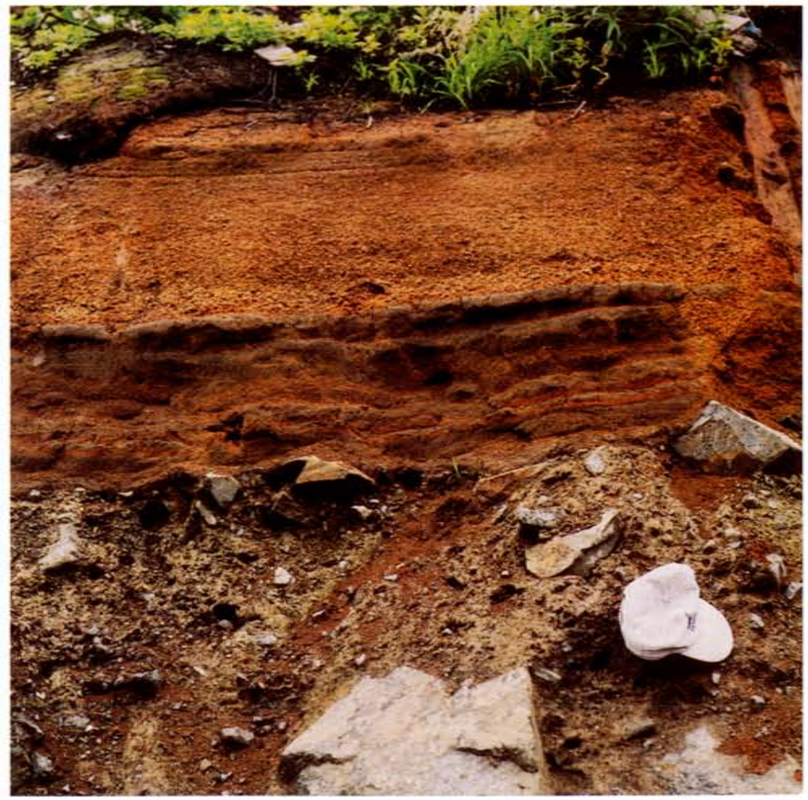


7(C). A summary of the ages of the different lava types of the MEVF; blocks are potassium-argon ages of specific samples. The "±" attached to each potassium-argon age is a measure of the uncertainty due to imprecision in analyses of potassium and argon; for example, "189±51" means that there is a 67% probability that the actual age of the sample is within 51,000 years of 189,000 years old.

9. A view to the northeast from the summit of Mount Edgecumbe, showing the rhyolitic domes of Crater Ridge. The rhyolitic magma was so viscous as it extruded from the ground that it formed steep-sided domes rather than flows. Also, the gas content of the magma was low, or else the magma would have erupted explosively to make ash and pumice. Three complete domes—the three conical peaks—can be seen; part of a fourth is out of view to the left. The tree-covered ridge that extends toward Mount Edgecumbe from the conical peaks is the remains of the fifth dome, which was largely destroyed in the explosive eruptions that made Crater Ridge crater. The dark mound next to the person in the foreground is an andesitic plug of Mount Edgecumbe.

Stage Three: More Recent Explosive Eruptions of Ash and Pumice

Volcanic *ash* beds are easily seen in roadcuts and streambanks in Sitka and elsewhere in the region. These deposits formed during a series of explosive eruptions at the MEVF between about 12,000 and 14,000 years ago.[7] The deposits are about 36 inches (1 m) thick in Sitka, but are more than 100 ft (30 m) thick near their source vents on southern Kruzof Island (Fig. 10 A&B) The beds are dark grey or red at the bottom, brownish yellow in the middle, and light yellow or light grey at the top. The colors reflect the different compositions of the *magma*s that were erupted by different vents. Generally, the darker colors indicate a lower silica content.



10(A). Ash and pumice deposits produced by a series of explosive eruptions at the Mount Edgecumbe volcanic field between about 12,000 and 14,000 years ago. In Sitka, the deposits are a total of about 36 inches (1m) thick. The bottom layers are dark gray and red, basaltic andesite scoria, those in the middle are gray-brown andesitic scoria, and those at the top are pale gray or yellow, rhyolitic ash and pumice. The deposits rest directly on glacial till (boulders), with no intervening soil.

10(B). The ash and pumice deposits near their source vents on Kruzof Island are locally up to 100 ft (30 m) thick! Here, most of the quarry wall is dark grey-brown, basaltic andesite ash erupted from a nearby scoria cone. Yellow-orange layers at the top of the bank are rhyolitic pumice, the same as the pale yellow deposits in Fig. 10(A).

The explosive eruptions began soon after retreat of glaciers from the region about 14,000 years ago.[8] The oldest layers of volcanic ash in a pond on northern Baranof Island are just above the base of pond sediments that rest on glacial till. By tracing ash deposits in the direction that they become thicker and coarser, it has been found that this basaltic andesite ash came from small *scoria* cones at the northeastern and southwestern ends of the MEVF. The mixture of dark grey and red fragments in these basaltic andesite deposits resulted from alteration of some of the magma shortly before eruption, perhaps by groundwater that entered the magma beneath the volcano. The grey fragments are fresh lava, whereas the red fragments—which are otherwise identical to the grey fragments—contain more water. The red color is due to oxidized iron, similar to rust.

As eruptions of basaltic andesite ash ended, eruptions of brown andesitic ash began at Shell Mountain, at a scoria cone 5 miles (8 km) northeast of Crater Ridge, and at Mount Edgecumbe itself. The andesitic vent on Mount Edgecumbe is marked today by a small, dark gray *plug* visible in the northwestern wall of the summit crater (Fig. 11). In addition to ash clouds, Mount Edgecumbe produced small avalanches of hot andesitic blocks that tumbled down the northern side of the volcano. While andesitic eruptions were occurring at Mount Edgecumbe, rhyolitic ash and *pumice* began to erupt at Crater Ridge. Deposits of some of the andesitic avalanches cover rhyolitic pumice layers between the two volcanoes, indicating (1) that both andesitic and rhyolitic eruptions occurred multiple times, and (2) that some andesitic eruptions occurred at about the same time as some rhyolitic eruptions.

Rhyolitic eruptions from Crater Ridge became increasingly violent, breaking off pieces of old rhyolitic dome and blowing them skyward with ash and pumice (Fig. 12). In addition to airborne ash, rhyolitic *pyroclastic flows* were produced. These fast-moving masses of expanding magmatic gas, hot ash, pumice, and pieces of cold rhyolitic dome swept to the sea both to the east and west of the low saddle between Crater Ridge and Mount Edgecumbe (Fig. 7A). The flows were, however, blocked from passing to the north by Crater Ridge and to the southwest by Mount Edgecumbe. This means that

11. The summit of Mount Edgecumbe, viewed from the south; the crater and domes of Crater Ridge are in the background. A dark plug in the northwestern wall of the summit crater marks the source vent of andesitic eruptions by Mount Edgecumbe between about 13,000 and 14,000 years ago. The crater itself was the source of a major explosive eruption of dacitic ash and pumice that occurred after the end of the andesitic eruptions, between about 12,600 and 13,000 years ago. Halfway up the northern wall of the crater is the contact between dark gray, andesitic airfall pumice and overlying, red-gray dacitic pumice. The pumice compressed and fused to a solid mass of glass under its own weight, due to its high temperature and low viscosity where it fell close to the vent (compare with uncompressed pumice in Fig. 13).

the flows formed during low-energy eruptions and/or as horizontal wind blasts from the base of rising eruption columns and were unable to surmount these topographic barriers.

The amount of rhyolitic dome material in deposits of rhyolitic airfall and pyroclastic flows is roughly equal to the volume of the Crater Ridge crater, indicating that the crater formed as the rhyolitic eruptions blew apart a dome.[9] Not all craters form by such "excavation." Crater Lake—a famous volcanic crater in Oregon—formed when the former summit of the volcano collapsed downward as a result of the sudden eruption of a large volume of magma from beneath the volcano. One reason that there was no such collapse at the MEVF may be that the subsurface magma chamber is deeper than that beneath Crater Lake volcano.

One last, remarkable eruption occurred at Mount Edgecumbe, late in the sequence of rhyolitic eruptions at Crater Ridge. The andesitic eruptions at Mount Edgecumbe had ended with emplacement of a plug. A sudden, violent eruption of *dacitic* pumice occurred alongside the plug, producing the present summit crater and making an airfall deposit of pumice that is 30 feet (9 m) thick 4 miles (6.4 km) to the northwest at Shelikof Bay (Fig. 13 A&B).

12. Deposits of airfall pumice and ash at a site 1 mile (1.6 km) northwest of Crater Ridge. The pumice is vesicular rhyolitic magma that erupted from Crater Ridge crater. The dark blocks are solid rhyolitic glass (obsidian), formerly a dome that occupied the site of the crater and which was caught up in the explosive eruptions of the pumice. Note how the layers of ash and pumice were deformed by the force of the falling block. The dome itself was not the source of the eruption, because blocks of obsidian like these, where studied at nearby sites, were deposited cold while the pumice blocks—the magma that actually caused the eruption—were deposited hot.

Clearly this was a major eruption. What is remarkable, is that no dacitic pumice or ash was deposited only 10 miles (16 km) north of the Shelikof Bay site, nor anywhere in the region to the east of this site including on the Crater Ridge domes! Instead, only rhyolitic ash deposits are found east of a line that extends north from Mount Edgecumbe. This phenomenon can be explained if a rhyolitic eruption at Crater Ridge occurred at precisely the same time as the dacitic eruption at Mount Edgecumbe. Little mixing of the ash clouds would have occurred near the vent, where the clouds were dense and vigorously expanding. As the clouds moved northward, dacitic ash was confined to the west of the rhyolitic ash cloud. The dacitic ash cloud would eventually have mixed with the rhyolitic ash cloud, and indeed, a single deposit of mixed, dacitic and rhyolitic ash occurs at sites 200 miles (320 km) to the north, between Lituya Bay and Yakutat.

Deposits of rhyolitic or dacitic ash occur in peat deposits away from Kruzof Island. Radiocarbon dates of the peat indicate that the ash deposits are between about 12,500 and 13,300 years old.* The interpretation of this

13(A). Thick deposit of dacitic airfall pumice at Shelikof Bay, 4 miles (6.4 km) north-northwest of the source at Mount Edgecumbe. Dacitic pumice extends from below the base of the cliff to the prominent yellow band near the top of the bank. Dacitic pumice is overlain by a dark grey, rhyolitic pyroclastic-flow deposit. Even this far from the vent, the deposit is still more than 30 ft (9 m) thick.

range of ages is that the many rhyolitic eruptions occurred over an interval of about 800 years. The simultaneous dacitic and rhyolitic eruptions occurred near the end of this period.

All ash deposits found more than 30 miles (48 km) from Kruzof Island are at least 11,900 years old, which means that the major eruptions ended by this time. Evidence for eruptive activity after this time is found on Kruzof Island at Shelikof Bay where a tree 10,200 years old was rooted in pyroclastic flows and buried by a volcanic mudflow. The tree was not in a streamchannel, so it is likely that the mudflow that buried the tree was triggered by eruptive activity and was not simply a flood. Such an eruption was probably a minor event during the gradual cessation of activity after the large, dacitic-rhyolitic eruptions.

**Radiocarbon ages are typically reported in the scientific literature as "radiocarbon years before present (yr BP)." Radiocarbon years are not identical to calendar years and must be converted; a radiocarbon age of 10,000 years, for example, is equivalent to about 12,000 calendar years. All ages in this brochure that are based on radiocarbon dating have been converted to calendar years. Readers who refer to the original references listed in the endnotes should be aware of the difference.*

13(B). A close view of the dacitic pumice, which is angular due to its transport in an ash cloud rather than by tumbling in an ash flow. Here, the pumice blocks were cool enough when they fell that they did not compress and fuse, unlike those at the summit of Mount Edgecumbe.

Two thin deposits of ash occur above, and separate from, the main sequence of ash deposits on Kruzof Island and the nearby parts of Baranof and Chichagof Islands. In many places only one deposit occurs, probably because the two eruptions closely followed one another and the deposits have become mixed. The deposits consist of rhyolitic pumice, like rhyolitic pumice of the main sequence, and small pieces of *Sitka Graywacke*. A layer of graywacke and pumice up to 3 inches (7.5 cm) thick is on the floor of Crater Ridge crater, which is a possible source of the young ash deposits. Radiocarbon dates of peat above and below these ash deposits indicate that the two eruptions occurred closely together between 5,000 and 6,000 years ago. Because there are 4,700 years between the last eruption of the main sequence (10,200 years old) and these young, minor eruptions (about 5,500 years old), the young eruptions are probably separate eruptive activity unrelated to the older sequence of eruptions.

Significance of the Ash Eruptions

The major ash eruptions of the Mount Edgecumbe volcanic field (MEVF) are notable to volcanologists for several reasons: (1) many types of magma were erupted in a geologically short span of time; (2) the eruptive activity moved from vents at opposite ends of the MEVF, to Crater Ridge and Mount Edgecumbe in the center of the field; and (3) the ash vents align northeasterly, along the center of southern Kruzof Island (see Figs. 1A and 7).

Most of the ash vents had erupted lava flows of the same composition as the ash a short time before the ash eruptions. For example, rhyolitic ash was erupted from the Crater Ridge rhyolitic domes, and scoria cones that erupted basaltic andesite ash had earlier extruded basaltic andesite lava flows. All of the magma types involved in the ash eruptions existed in the subsurface in a pool or magma chamber, at the beginning of the explosive eruptions.

The ash eruptions show that these different magmas were not distributed uniformly in the magma chamber beneath Kruzof Island. Basaltic andesite magma is beneath the opposite ends of the MEVF, and rhyolite—the most silicic magma—is beneath the center of the field. Some of the rhyolite in the center of the magma chamber erupted quietly as domes shortly before the main explosive eruptions. Chemical and isotopic studies show that MEVF basalt formed in the mantle[10] and that the silicic magmas are a mixture of basalt and partly melted crustal rocks.[11,12] The basaltic andesite is mostly basalt and a small amount of crustal melt, while the rhyolite is mostly crustal melt and a small amount of basalt.

The progression of the ash eruptions, from low-silica magma at the beginning to high-silica magma at the end, is due to the *viscos*ity of the different magmas: low-silica basaltic andesite magma could rise to the surface much faster (230 times faster by some calculations) than viscous rhyolitic magma.[13]

The subsurface beneath southern Kruzof Island may look something like Figure 3. Some magma may be spread throughout a large volume of solid rock, but most of the magma is concentrated in a magma chamber because, in laboratory experiments, silicic magma is too viscous to be easily removed from rock. Beneath the northern and southern ends of the MEVF, basalt is overlain by basaltic andesite or andesite. Only minor crustal melting and mixing with basalt have occurred there. The most *silica*-rich magma, and the greatest amount of crustal melting, are beneath the center of the volcanic field, where the rise of basalt and heat from the mantle is concentrated along the major fracture. There is no direct evidence for the depth at which this melting and mixing occur. Indirect evidence from mineral compositions suggests that it is between 5 and 10 miles (8 and 16 km). The heat required to melt crustal rocks is provided by basalt, which rises from the mantle at temperatures in excess of 1150° C. Crustal rocks at depths of 5-10 miles begin to melt at about 700° C, so basalt can melt a lot of crustal rocks. Small pieces of partly melted Sitka Graywacke and *Kruzof Island pluton* have been found in basaltic andesite and andesitic lavas which supports this hypothesized process of mixing and melting. Other, unknown rock types deeper in the crust may also be involved in melting and mixing with the basalt.

The alignment of the ash vents in the center of southern Kruzof Island is thought to mark a major fracture in the Earth's crust. A fracture would provide a path for magma to preferentially follow to the surface. The 50-degree angle between the inferred fracture and the adjacent Fairweather-Queen Charlotte transform fault (Fig. 2) has been duplicated in laboratory experiments to model transform faulting. The fracture is the result of pressure in the edge of the continental plate, caused by friction on the nearby transform fault. What is not understood is, why has magma not erupted from fractures elsewhere along the Queen Charlotte-Fairweather fault?

14(A&B). Basalt lava flowed over boulders of a light-colored granitic rock (the Kruzof Island pluton; see glossary) on the beach near the mouth of Fred's Creek. The boulders had been transported to the site by glaciers; if, as is likely, the boulders were deposited during the last ice advance and not during an earlier ice advance, then the basalt is no more than about 14,000 years old. Young basalt like this could have triggered the main explosive eruptions by adding heat to the base of the silicic magma chamber.

What triggered the explosive eruptions? It is not known for certain. One possibility is unweighting of the crust beneath Kruzof Island by deglaciation. Such a trigger has been proposed to account for explosive eruptions at an Italian volcano, where crustal unloading was caused by a fall of sea level.[14] Another possibility is that newly risen basalt suddenly heated the base of the magma chamber, driving the more silicic magmas upwards to eruption. This possibility is suggested by an occurrence of basalt lava that flowed over boulders on the beach near the mouth of Fred's Creek (Fig. 14). Attempts to date this basalt by the potassium-argon method failed due to the low argon content of the basalt. Low argon could result from several causes, including that the lava is geologically very young. The boulders were deposited by glaciers, most likely during the last major glaciation. Because the last glaciation ended just before the onset of the explosive eruptions, this means that the basalt flow is probably about the same age as the explosive eruptions.

How the Geology of Mount Edgecumbe Influences Its Vegetation

Following is a brief summary of the main types of vegetation to be seen along the Mount Edgecumbe trail and elsewhere on southern Kruzof Island.[15,16]

Compared to development of the volcanic field on a geologic time scale, plant community development is very rapid. Plant colonization and community development on a new surface, such as an ash deposit or lava flow, is called primary succession. This process has been much studied on bare surfaces left by glaciers in southeastern Alaska. Typically early colonizers include plants such as willows, fireweed, horsetail, alder, lichens, and mosses. These plants help build up the soil by trapping wind and water-borne sediments, adding organic material to the substrate, and, in some cases, fixing atmospheric nitrogen and thereby enriching the soil. These plants may become established very quickly after a surface is exposed, depending on factors such as seed availability, type of surface, moisture, temperature, etc.[17,18]

Typically, these pioneer plants are replaced by willow and alder shrubland with occasional cottonwood or spruce trees. Spruce and hemlock forest with a diverse understory of shrubs and herbs begin to develop. Eventually, conifers dominate on most sites, unless the site is frequently disturbed (for example by floods), poorly drained, or at high elevation. The conifer forest may persist indefinitely on many sites, while, on others, forest may gradually be replaced by wet soils and muskeg vegetation. Spruce forest may develop on bare ground in as little as 100 years.

Succession on lava flows and ash deposits can be expected to follow a similar pattern, with mosses, lichens, and herbs arriving first, followed by shrubs and trees. Where the lava has flowed over relatively level ground, drainage is typically impaired, and muskeg vegetation may develop. On steeper, more well-drained sites, conifers are likely.

Through their effect on soil drainage, the volcanic rocks and ash deposits of southern Kruzof Island influence vegetation patterns. This influence can be seen from Sitka as a radial pattern of vegetation on the flanks of Mount Edgecumbe: dark green forest stringers on low ridges and along gullies, and tawny muskeg in between. Soils on steeper topography—the low ridges—and along the edges of gullies are better drained, which favors forest vegetation. The lava flows between the gullies and ridges underlie poorly drained soils, which support nonforested peatland (see Fig. 1B). Such a pattern of mixed forest and peatland is characteristic of the volcanic portion of Kruzof Island. In contrast, the northern part of the island—and better drained, steeper slopes in the southern island such as Crater Ridge—support more productive, western hemlock forest types.

The Mount Edgecumbe Trail

The trail from Fred's Creek to the top of Mount Edgecumbe is 7 miles (11.2 km) in length, and involves an elevation gain of 3,189 ft (966 m). Much of the lower trail is over wet muskeg, whereas the trail above treeline to the summit of the volcano is steep and rocky. Thus, footwear should provide both ankle support and moisture protection.

At the Fred's Creek trailhead, the influence of volcanic deposits on vegetation is not dominant, and the vegetation is similar to coastal forest elsewhere in the Sitka area. Sandy soils that occur in a narrow shoreline fringe formed from marine deposition followed by centuries of weathering. This type of well drained, mineral soil (without much accumulated organic material) favors Sitka spruce growth. Thus, a tall spruce forest occurs on the approximately 100-yard-wide (91 m) fringe. Trees in this forest are often widely spaced, and the vegetation under the trees is not well developed.

As the trail moves inland, the terrain slopes gently because it is underlain by flat-lying, basaltic lava flows that are covered by ash and pumice (Fig. 15A). The sandy deposits are left behind, and the volcanic deposits dominate the substrate. Drainage is impeded and tree heights decrease. Organic material builds up on the soil surface, favoring growth of western hemlock over spruce. The coastal spruce forest gives way to a western hemlock and mixed conifer forest. The tree canopy typically covers 60 percent of the sky, so this is referred to as open forest. Trees in this forest grow relatively slowly, and are referred to as scrub or low productivity forests. The overstory is a mix of western and mountain hemlock, yellow cedar, Sitka spruce, and occasional shorepine. Rusty menziesia and tall blueberry are the most common shrubs. Understory herbs typically include fern-leaf goldthread, skunk cabbage, deer cabbage, bunchberry, false hellebore, sedges, and ferns. The ground cover is often moss-dominated. As drainage decreases (farther from the beach and small streams), the tree cover thins even more, and nonforested peatland becomes dominant.

Nonforested peatland, or "muskeg," is dominated by grass-like plants such as tufted clubrush, many-flowered sedge, and cottongrass, and by dwarf shrubs such as Labrador tea, crowberry, bog laurel, bog rosemary, juniper, cranberry, and low blueberry. Scattered stunted shorepine, yellow cedar, and mountain hemlock trees also occur. Herbs on the peatland include shooting star, sundew, trifoliate goldthread, deer cabbage, skunk cabbage, bog orchid, fleabane, and swamp gentian. Peat moss (Sphagnum) is common, and is one of the main ingredients in the accumulated organic layer.

At 2 miles (3.2 km), the trail encounters the first of several short, steep climbs onto andesitic lava flows erupted by Mount Edgecumbe (Fig. 15B). Here mixed conifer, open forest is favored over muskeg by the improved

15(A). The hiking trail to the summit of Mount Edgecumbe is over a gently sloping surface of low relief for the first mile. The surface is underlain by flat-lying basalt lava flows that have been blanketed by pyroclastic deposits. The hill in the background is the front of an andesitic lava flow.

15(B). At about 2 miles (3.2 km) the trail makes the first of several short, steep ascents onto andesitic lava flows erupted by Mount Edgecumbe.

drainage on these steeper slopes. The andesitic flows are deeply covered by pyroclastic-flow deposits, which accounts for the flat, gentle slopes of muskeg meadows on the andesitic flows (Fig. 16). The poorly sorted pyroclastic-flow deposits can be seen in the creekbank just above the footbridge near the shelter. The pyroclastic flows are known to have erupted from Crater Ridge when the crater formed, because dense, dark fragments of Crater Ridge dome rock are mixed with yellow rhyolitic pumice in the pyroclastic-flow deposits. (The dark grey rhyolitic domes of Crater Ridge are an exception to the rule that the darker the color of volcanic rocks, the lower their silica content. For an explanation, see "rhyolite" in the glossary.) The pyroclastic flows hugged the floors of gullies, so their deposits are restricted to lower ground both northwest and southeast of the saddle between Crater Ridge crater and the north flank of Mount Edgecumbe (see Fig. 7A). Likewise, wet soil communities hug the gully floors, while forest communities parallel the streams and steeper ridges.

At the shelter, midway from the coast to the summit of Mount Edgecumbe, the trail encounters the steep front of another andesitic flow (Fig. 16). About 1.2 miles (1.9 km) above the shelter, the trail begins to ascend the lower

16. A muskeg meadow near the midway shelter, typical of much of the trail below the base of Mount Edgecumbe. The muskeg is underlain by pyroclastic flows and airfall deposits, which increase in thickness from about 15 ft (5 m) at the coast, to 66 ft (20 m) at the base of Mount Edgecumbe. The deposits of ash and pumice bury and subdue the hummocky surfaces of andesitic lava flows; the front of such a flow underlies the hill in the background.

slopes of Mount Edgecumbe proper. The steeper, well drained slopes allow better tree growth. Forests along the lower cone are nearly as productive as those along the beach. Western hemlock dominates the forest canopy and the shrubs are dominated by blueberry and rusty menziesia.

Lava flows from Mount Edgecumbe near the foot of the cone overlie the lava flows that extend further down the trail and so are younger than the lower flows. The potassium-argon age of one flow on the flanks of Mount Edgecumbe is 36,000 years.

Mount Edgecumbe consists of andesitic lava flows that are interlayered with blocks and ash, so the volcano is called a "composite cone." The deposits on the flanks of Mount Edgecumbe are mainly red-orange, dacitic airfall pumice and ash that lie on dark grey or brown andesitic airfall pumice and ash (Figs. 19A and 19B). Both the dacitic and the andesitic deposits were erupted by Mount Edgecumbe during its most recent activity 12,000 to 14,000 years ago. Close up views of both Mount Edgecumbe and the Crater Ridge domes are

17(A). The domes of Crater Ridge as seen from the middle part of the hiking trail.

17(B). Mount Edgecumbe trail climbs the left edge of the broad ridge in the center of the photo.

18(A). During clear weather views on the trail from the flanks of Mt. Edgecumbe are breath taking. View to the west of Sitka Sound and Baranof Island; the City of Sitka is near the shore of Baranof Island to the right of center. The small islands and a low coastal strip on Baranof Island are underlain by the Sitka Graywacke. The dark, craggy ridges to the left (north) of Sitka are underlain by the Kelp Bay Group of volcanic and sedimentary rocks, whereas the lighter ridges and peaks to the right (south) of Sitka are underlain by granitic rocks that intruded the Sitka Greywacke and Kelp Bay Group about 50 million years ago. The valleys were carved by glaciers during several glacial stages, the most recent between about 14,000 and 25,000 years ago.

18(B). St. Lazaria Island off the south shore of Kruzof Island. The island consists of massive andesitic lava, some of which has domical structures (like that shown in Fig. 8A) suggesting that the island is the site of a volcanic vent.

19(A). View from below of the lower flanks of Mount Edgecumbe. The outer part of the cone consists of thick deposits of airfall pumice and ash, which are visible as reddish grey layers in the left bank of the gully. The layers dip downslope because airfall deposits follow the underlying slopes, like a blanket, rather than filling them with a horizontal layer as pyroclastic-flow deposits would do.

19(B). Above timberline, vegetation is low and scattered, occurring in leeward areas protected from wind and desiccation.

possible from along the central part of the trail (Figs. 17A and 17B). Timberline, or the upper limit of tree growth, on Mount Edgecumbe occurs at about 1,800 feet (549 m). In southeast Alaska, timberline generally occurs at elevations from 2,500 to 3,000 feet due mainly to cold and wind that restrict tree survival.[18] Timberline is lower on Mount Edgecumbe due to several factors. First, the cone is isolated on an outer island and exposed to winds, which restrict accumulation of organic material for soil development and plant growth sites. The effects of wind can be seen near the summit, where plants occur primarily in protected gullies or in the shelter of boulders, and where scoured areas can be seen on the windward side of boulders. Second, the cone is very steep, which limits accumulation of weathered minerals and organic material for plants to grow in. Steep slopes are often unstable, especially in ash soils, resulting in slumps, landslides, and avalanching. Third, the materials making up the cone (pumice and ash) drain rapidly, leaving little moisture for plants. These materials are not well weathered and do not readily release phosphate, an essential nutrient, into soils for plants to use. These factors combine to limit tree growth on the upper cone.

20(A). The hiking trail ends at the summit on the northeastern side of the crater. The summit of Mount Edgecumbe consists of windswept deposits of ash and pumice and blocks of dense, fused volcanic glass.

20(B). View down the flanks of Mount Edgecumbe. The ash and pumice deposits, visible in the left bank of each gully, are susceptible to erosion unless stabilized by vegetation.

Above timberline, typical subalpine vegetation includes deer cabbage, luetkea, moss heather, dwarf blueberry, alpine blueberry, hawkweed, and buttercup. These plants are growing under marginal conditions (wind, cold, short growing season) and are, therefore, slow-growing. Repeated trampling by hikers will destroy foliage and even roots. Loss of vegetative cover opens the substrate to erosion. Shrubs and sedges tend to be hardier than herbs, but once damaged, may be less able to recover the following growing season. Twenty-five one-way passes through a subalpine herb meadow were sufficient to decrease relative vegetation cover by 50 percent in a study in the Washington Cascades.[19] Therefore, hikers are asked to spread out and walk in multiple paths above timberline. While there is a trail marked with poles and cairns above treeline, this is for use only when visibility is restricted (fog, storm, whiteout). Avoid areas where vegetation appears damaged or soil rutting has occurred. Do not pull up plants, and avoid dislodging rocks to further protect this habitat.

Although the top of the mountain appears to be devoid of vegetation, it is not. Much of the area high on the crater is blanketed by a brown crust, which is composed of tiny, intertwined liverwort plants. The plant (GYMNOMITRION APICLATUM) is of particular interest since it is only known from two other places in North America; one is in Mt. McKinley National Park, and the other is on Yakobi Island. Organic crusts such as this are an important component to Mt. Edgecumbe's ecosystem; they stabilize soil and help prevent erosion. This interesting crust is very fragile, so please make every effort not to disturb the crust's integrity.

The trail ends on the northeastern rim of the summit crater (Figs. 20A and 20B).

In the northwestern wall of the summit crater, a dark grey plug of andesite marks the vent from which andesitic airfall and pyroclastic flows were erupted (Fig. 11). The summit crater was formed after emplacement of the andesitic plug, during the dacitic eruption that was the culminating explosive eruption on Mount Edgecumbe. Dacitic ash and pumice is more than 150 ft (45 m) thick in the northern, eastern, and southern walls of the crater; in the northern wall of the vent, dacitic airfall deposits can be seen overlying andesitic airfall deposits. Ash and pumice that fell so close to the vent atop Mount Edgecumbe retained enough heat to compact under their weight and fuse to nearly solid, red-brown to dark grey glass. Fused glass can be seen, both in the airfall layers that have not yet eroded and as loose blocks around the rim of Mount Edgecumbe. On clear days, excellent views of Sitka Sound and Baranof Island are afforded from the flanks of Mount Edgecumbe (Figs. 18A and 18B).

As on all trails - Pack out what you pack in.

A Brief History of the Hiking Trail

The Mount Edgecumbe trail was initially constructed in the 1930s by the Civilian Conservation Corps (CCC), to provide recreational access to the top of the volcano. Unlike most CCC activities throughout the contiguous United States, projects in Alaska were completed by local citizens who had joined the Corps. With the onset of World War II, CCC activities stopped and the program ended in 1942.

Several examples of CCC work can be seen along the trail. The woodshed at the start of the trail near the Fred's Creek cabin is a CCC structure. The shed was built in the Adirondack style: the roof has a double pitch and the overlap of these slopes creates a vent which extends the length of the ridgepole. This design allows for warming fires to be built under the dripline of the shelter, yet smoke can escape from the vent. Several primitive sign posts marking the route of the trail remain standing in the muskeg, some partially covered by moss. Near the new midway shelter are the remains of the original, Adirondack-style CCC shelter.

Glossary of Geologic Terms

For further details, and for introductory texts in volcanology, see the additional sources following the endnotes.

airfall: refers to the origin of a volcanic rock or deposit by being erupted into the air, drifting downwind (such as an ash cloud), and eventually falling to earth. Pyroclastic deposits are formed mainly of either airfall ash or scoria, or by deposition from pryroclastic flows.

andesite: magma having between about 55 percent and 63 percent by weight SiO_2 (silicon dioxide); also refers to lava flows, scoria, ash, etc., which are the rocks and deposits formed of andesitic magma. Andesitic lava flows are typically medium to dark grey or brown, reflecting intermediate contents of iron and magnesium, and have a viscosity intermediate between that of basalt and rhyolite. See Fig. 8A.

ash: a volcanic particle the size of a sand grain, that is, about 0.0025 to 0.16 inches (0.06 to 4 mm) diameter, which consists of solidified magma. Ash is commonly produced during explosive eruptions, hence the term "ash cloud." Its name derives from mistaken reference to the ash that accompanies wood fires.

basalt: magma having between about 47 percent and 51 percent by weight SiO_2 (silicon dioxide); also refers to lava flows, scoria, etc., which are the rocks and deposits formed of basaltic magma. Basaltic lava flows are typically dark gray due to their high contents of iron and magnesium. The viscosity of basaltic lavas is low due to the low silica content, thus, basaltic lavas flow readily and spread laterally. See Fig. 8B.

basaltic andesite: magma having between about 51 percent and 55 percent by weight SiO_2 (silicon dioxide), that is, intermediate between basalt and andesite.

breccia: a rock formed of a deposit of angular fragments of older rocks and mineral grains. Volcanic breccias may be formed of airfall deposits of pumice and ash or of mudflow deposits (see Fig. 12), or may form beneath and adjacent to lava flows that have shed broken fragments of lava (see Fig. 5A).

cone: a volcano having the shape of a cone; composite cones are constructed of mixed lava flows and ash, whereas scoria cones are constructed mainly of scoria and ash.

crust: with reference to the Earth, the outermost 5 to 50 miles (8 to 80 km) of rock, which differs in composition and physical properties from the underlying mantle. Crust beneath the continents differs from that beneath the oceans, but the larger difference is between the crust and mantle.

dacite: magma having between about 63 percent and 70 percent by weight SiO_2 (silicon dioxide); also refers to lava flows, pumice, etc., which are the deposits formed of dacitic magma. Dacitic pumice or lava is typically medium to light gray or brown due to its low contents of iron and magnesium; where the iron has oxidized during or shortly after eruption, the color can be pale orange-yellow to dark red (see Fig. 13B).

dike: a mass of lava having the shape of a slab, formed when magma fills a vertical crack in older rock.

dome: a mass of lava of which the thickness (height) is about the same as the horizontal dimensions. A dome by definition marks the site of a volcanic vent, because domes form where the lava is too viscous to flow or is prevented by the surrounding rocks from flowing horizontally away from the vent. See Figs. 8A and 9.

fault: a break in rocks along which there has been relative movement of the rocks. The movement can be purely lateral (horizontal), in which case the fault is called a transform; other types of faults involve some vertical movement.

Kruzof Island pluton: granitic rocks on Kruzof Island and adjacent islands, which intruded the Sitka Graywacke between about 60 and 30 million years ago; the rocks are white to pale grey with specks of dark minerals (see Fig. 14) and are easily distinguished from the drab grey Sitka Graywacke or from lavas of the Mount Edgecumbe volcanic field; lavas and ash of the volcanic field are much younger than the pluton and the greywacke and bury these rocks over most of southern Kruzof Island; boulders of pluton and of graywacke along the southern and eastern shores of Kruzof Island were deposited on the lava flows by southflowing glaciers between about 14,000 and 25,000 years ago.

lava: magma that has erupted at or upon the ground surface; also, a rock formed of cooled, solidified magma.

magma: melted rock before it has erupted; magma typically contains dissolved gases (water, sulfur compounds, carbon dioxide, etc.) but they are not formally considered magma.

mantle: that part of the Earth between the outer crust and the core. The top of the mantle is typically buried by 5 to 10 miles (8 to 16 km) of oceanic crust and by as much as 30 to 40 miles (48 to 64 km) of crust in the continents. The crust, mantle, and core differ significantly in chemical composition; the mantle, for example, is low in silica and high in iron and magnesium relative to the crust. As a consequence of such differences, the mantle typically produces basalt magma if partly melted whereas the crust produces andesite, dacite, or rhyolite.

plate: in a geologic context, a piece of the Earth's crust and upper mantle that moves as a single fragment relative to adjacent pieces. The outer shell of the Earth is now believed to consist of seven large plates and another half-dozen smaller plates. Plates form at mid-ocean ridges by eruption of basalt, which adds new material to the plates on either side of the ridge. Plates accomodate to the addition of material by moving slowly away from the ridge. Besides oceanic ridges, plates can be bounded by transform faults, where two adjacent plates slide laterally past one another, or subduction *zones*, where one plate slides beneath another to be eventually assimilated into the mantle deep beneath the overlying plate.

plug: a mass of magma, typically cylindrical in shape; the central conduits of composite volcanoes are commonly filled by plugs (see Fig. 11).

pumice: a highly vesicular volcanic rock, essentially a rapidly chilled magmatic froth. The chilled magma is now glass, so pumice breaks easily and is highly abrasive. The vesicles that make the froth are the castings of gas bubbles, which were dissolved in the magma prior to its explosive eruption. Generally only high-silica, viscous magmas—dacite and rhyolite—form pumice, in which the vesicles are typically small and isolated by the intervening glass walls (which is why pumice floats!). Low-silica magmas, in contrast, allow for easy merging of gas bubbles and tend to make scoria.

pyroclast: literally, "hot" (pyro) and "fragment" (clast). Refers to volcanic deposits formed of hot, broken fragments; implies an explosive eruption.

pyroclastic flow (ash flow): a moving mass of incandescent magmatic fragments (ash and pumice) and hot, expanding gases. Pyroclastic flows range from small features formed by nonexplosive collapse of slowly growing domes, to large, fast-moving hurricanes of explosively erupted magma and gas. In both cases, the solid fragments concentrate at the bottom of the flow where they are channelled by irregularities in the ground surface. The hot gases form an overriding cloud, or surge, that can become detached from the basal fragments and even surmount hills and ridges. A pyroclastic surge from Mont Pelee killed 30,000 residents of St. Pierre, on the Caribbean Island of Martinique, in 1902.

rhyolite: magma having the highest content of SiO_2 (silicon dioxide; from about 70 percent to more than 77 percent by weight) and thus, the highest viscosity. As a consequence of high viscosity, low-gas rhyolitic magma makes short, steep-sided flows or domes and gas-rich rhyolitic magma can cause highly explosive eruptions because it is so difficult for the gas bubbles to escape the magma. Because of low contents of iron and magnesium and because the iron is commonly oxidized ("rust"), frothy rhyolitic pumice tends to be light yellow or orange. However, dense rhyolitic glass—called "obsidian"—can be nearly black due to the solid nature of the glass in combination with the nonoxidized state of the iron.

scoria: a fragment of vesicular lava in which the vesicles tend to be coarse and interconnected, thus, scoria does not float as does pumice. Scoria is more typical of low-silica, low-viscosity magmas (andesite or basalt) than of dacite or rhyolite.

silica: one of the most abundant elements in the Earth's crust. Combined with oxygen (SiO_2), occurs in noncrystalline form as "chert" or in crystalline form as the mineral quartz. The amount of silica dissolved in magmas (silicate melts) strongly influences melt behavior because melt viscosity directly correlates with silica content.

Sitka Graywacke: a rock unit consisting of layers of dark gray sandstone and mudstone and minor amounts of conglomerate (hardened pebbles and cobbles), which underlies much of Kruzof Island and nearby islands in the region; the rock formed between about 60 and 90 million years ago by deposition of sediments in a deep marine trench at the edge of the continental slope.

transform fault: see "fault."

vesicle: a hole in a volcanic rock that is the casting of a gas bubble, formed when the surrounding rock was molten lava.

viscosity: a material property of fluids; the greater the viscosity, the "stickier" or "stiffer" the fluid.

Endnotes

Literature sources of information provided in the brochure

1. As handed down by Herman Kitka: Sealaska Heritage Foundation, Sitka.
2. Notes on Russian America, Part I: Novo-Arkhangelsk, by K.T. Khlebnikov. Alaska History No. 43, 308 p. The Limestone Press, Kingston, Ontario and Fairbanks, Alaska, 1994. (S.G. Fedorova, compiler; Richard Pierce, editor.)
3. Voyage round the world in the years 1803, 1804, 1805, and 1806, by Urey Lisiansky. Bibliotheca Australiana #42, Da Capo Press, New York, 1968.
4. The Sitka, Alaska, earthquake of 1972—an expected visitor, by R.A. Page. U.S. Geological Survey, Earthquake Information Bulletin v. 5, pp. 4-9, 1973.
5. Queen Charlotte Islands margin, by R. Riddihough and R.D. Hyndman. In The eastern Pacific Ocean and Hawaii, E.L. Winterer, D.M. Hussong, and R.W. Decker, editors. Geological Society of America, The Geology of North America, v. N, 1989, pp. 403-411.
6. Geologic map of the Mount Edgecumbe volcanic field, Kruzof Island, southeastern Alaska, by Riehle, J.R., Brew, D.A., and Lanphere, M.A. U.S. Geological Survey Miscellaneous Investigations Map I-1983, 1989, scale 1:63,360, 1 plate.
7. The Mount Edgecumbe tephra deposits, a marker horizon in southeastern Alaska near the Pleistocene-Holocene boundary, by J.R. Riehle, D.H. Mann, D.M. Peteet, D.R. Engstrom, D.A. Brew, and C.E. Meyer. Quaternary Research, v. 37, 1992, pp. 183-202, Univ. of Washington.
8. Wisconsin and Holocene glaciation of southeast Alaska, by D.H. Mann. In Glaciation in Alaska, the geologic record, T.D. Hamilton, K.M. Reed, and R.M. Thorson, editors. Alaska Geological Society, Anchorage, 1986, pp. 237-265.
9. Pyroclastic deposits of the Mount Edgecumbe volcanic field, southeast Alaska: eruptions of a stratified magma chamber, by J.R. Riehle, D.E. Champion, D.A. Brew, and M.A. Lanphere. Journal of Volcanology and Geothermal Research, v. 53, 1992, pp. 117-143.
10. Rare earth element contents and multiple mantle sources of the transform-related Mount Edgecumbe basalts, southeastern Alaska, by J.R. Riehle, J.R. Budahn, M.A. Lanphere, and D.A. Brew. Canadian Journal of Earth Sciences, v. 31, 1994, pp. 852-864.
11. The Mount Edgecumbe volcanic field, Alaska: an example of tholeiitic and calc-alkaline volcanism, by D.G. Kosco. Journal of Geology, v. 89, 1981, pp. 459-477.
12. Geology and petrogenesis of the Edgecumbe volcanic field, SE Alaska: the interaction of basalt and sialic crust, by J.D. Myers and B.D. Marsh. Contributions to Mineralogy and Petrology, v. 77, 1981, pp. 272-287.
13. Assimilation of crustal material by basaltic magma: strontium isotopic and trace-element data from the Edgecumbe volcanic field, SE Alaska, by J.D. Myers, A.K. Sinha, and B.D. Marsh. Journal of Petrology, v. 25, 1984, pp. 1-26.

14. Mechanical models for correlation of ring-fracture eruptions at Pantelleria, Strait of Sicily, with glacial sea level drawdown, by P. C. Wallmann, G. A. Mahood, and D.D. Pollard. Bulletin of Volcanology, v. 50, p. 327-339, 1988.

15. J.R. Martin, S.J. Trull, W.W. Brady, R.A. West, and J.M. Downs, 1995, Forest Plant Association Management Guide, Chatham area, Tongass National Forest. U.S.Dept. of Agriculture, Forest Service, Alaska Region, report R10-TP-57.

16. L.A. Viereck, C.T. Dyrness, A.R. Batten, and K.J. Wenzlick, 1992. The Alaska Vegetation Classification. U.S. Dept. of Agriculture, Forest Service, Pacific NW Research Station report PNW- GTR-286.

17. Harris, A.S. and W.A. Farr. 1974. The forest ecosystem of southeast Alaska. 7. Forest ecology and timber management. USDA Forest Service GTR-PNW-25, Pacific Northwest Forest and Range Experiment Station, Portland, OR.

18. Harris, A.S. and 6 others. 1974. The forest ecosystem of southeast Alaska. 1. The setting. USDA Forest Service GTR-PNW-12, Pacific Northwest Forest and Range Experiment Station, Portland, OR.

19. Cole, D.N. and S.J. Trull. 1992. Quantifying vegetation response to recreational disturbance in the North Cascades, Washington. Northwest Sci. 66(4):229-236.

Additional Sources

Glossary of Geology, by R.L. Bates and J.A. Jackson. American Geological Institute, Falls Church VA, 751 p., 1980.

Volcanoes, by G.A. Macdonald. Prentice-Hall, Inc., Englewood Cliffs, NJ, 510 p., 1972.

Volcanology, by Howel Williams and Alexander R. McBirney. Freeman, Cooper & Co., San Francisco, CA, 397 p., 1979.