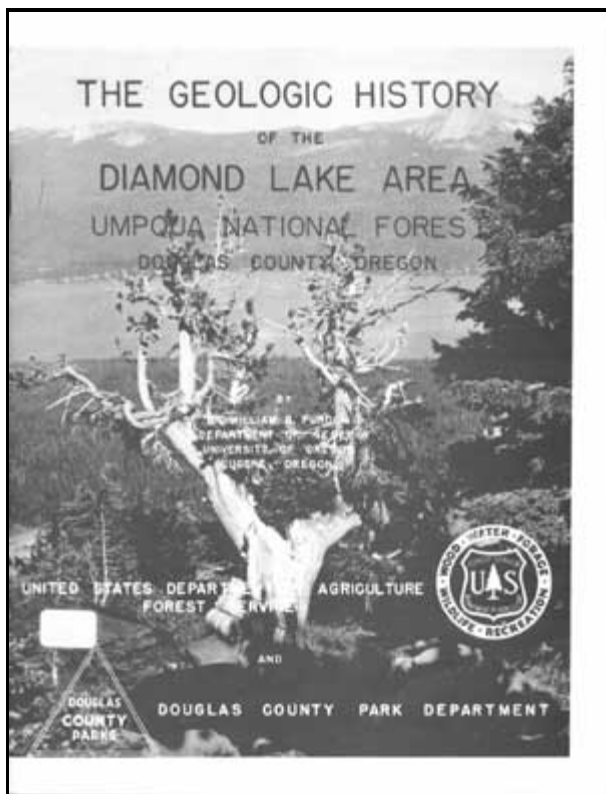


The Geologic History of the Diamond Lake Area



THE GEOLOGIC HISTORY OF THE DIAMOND LAKE AREA

Umpqua National Forest
Douglas County Oregon

By

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196?

United States Department of Agriculture
Forest Service

and

Douglas County Park Department

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The Geologic History of the Diamond Lake Area



FOREWORD

UMPQUA NATIONAL FOREST

Through centuries, our Diamond Lake Area has jealously guarded a rich, geologic story—a story of rugged, rock-bound beauty, of cataclysmic creative forces, of charred and buried forests. The serenity of Diamond Lake, herself, has made me often wonder what secrets she holds.

For a number of years it has been my desire to see this story interpreted to the public. This dream came to fruition this past summer as Dr. Purdom, Assistant Professor of Geology, University of Oregon, was engaged to study the area's geologic formation. The report of his finding is contained in these pages.

This report represents a forward step in the relatively new National Forest Visitor Information Service program—a program designed to bring added enjoyment to the Forest visitor through interpretation of our Forest's wonders.

With sincere appreciation to Dr. Purdom, we present this report, anticipating that it will add to the enjoyment of those whose interest reaches into the geologic eras of the past and how that past has sculptured the face of the present.

We welcome the interest and participation of the Douglas County Park Department in the publication of this study.

Forest Supervisor
Umpqua National Forest

DOUGLAS COUNTY PARK DEPARTMENT

Diamond Lake, the gateway to the eastern entrance to Douglas County, holds for its customers bounteous recreation and natural beauty unspoiled by man.

Mt. Thielsen, with its rugged beauty towering above the scenic blue waters of Diamond Lake, is the highest point in Douglas County. Water from this high-cascade area is the starting point for the North Umpqua River, which meanders to the Pacific Ocean by way of rapids, famed fishing holes, parks, waysides and Salmon Harbor.

On certain occasions during the summer, holiday recreationists in the Diamond Lake area find themselves in the midst of the largest concentration of people in Douglas County. With better means of transportation, man's shorter work week, and increasing population, demands on this not-so-long-ago remote area have become ever increasing. This area provides

maximum opportunity for people of all age groups to use their steadily increasing leisure time in a constructive and creative manner.

Douglas County appreciates this opportunity to work with the U. S. Forest Service.



Park Superintendent
Douglas County Park Department

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INTRODUCTION

This report is divided into three principal sections. The first, "Principles of Volcanic Activity", is designed to provide the layman with the background necessary to understand the geologic evolution of volcanic terrain such as the Diamond Lake area embraces. The growth and characteristics of volcanoes are described in non-technical jargon, and a minimum of technical geologic terms is introduced.

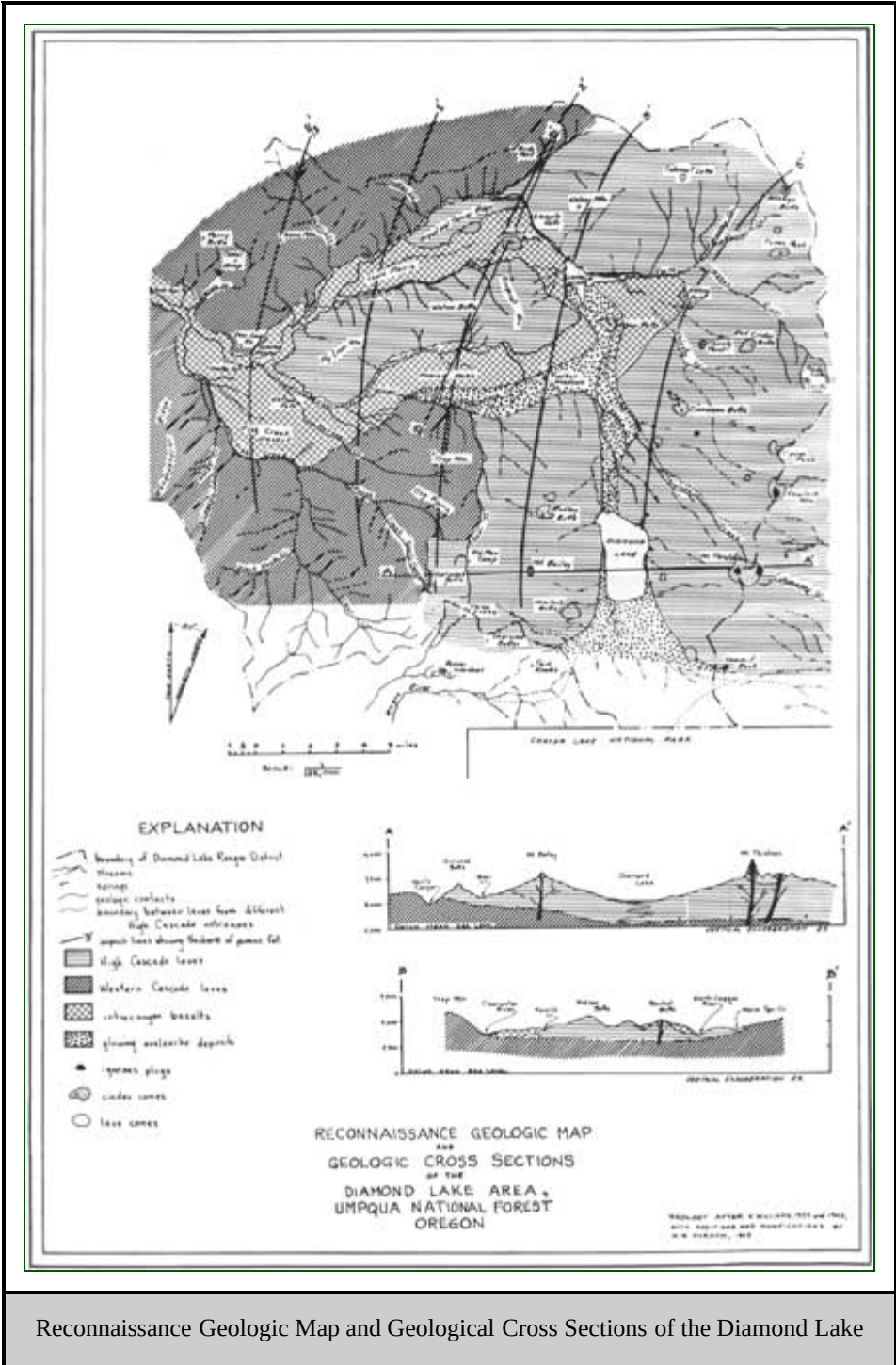
The second section of the report is "General Geologic Setting of the Cascade Region". This section describes the evolution of the Cascade Region, in general, and is presented merely to provide a broad geologic framework within which the Diamond Lake area may be placed. Also, a brief discussion of geologic time is included, and the terminology applied to the various divisions of geologic time have been introduced. This section may be understood by those possessing very little geologic knowledge, and by persons with no geologic training whatever, beyond an understanding of the material presented in the first section.



The third section of the report describes the geologic evolution of the Diamond Lake area. For purposes of this report, the phrase "Diamond Lake area" refers to the Diamond Lake Ranger District of the Umpqua National Forest. The geologic map (see in side back cover)

covers approximately this area. The geology of areas outside this district is discussed where geological phenomena in those areas influence the geological development within the Diamond Lake area or, conversely, where the influence of geologic phenomena within the Diamond Lake area is felt in other areas. This section, dealing with the geologic history of the Diamond Lake area, is designed to be understood with no more geologic knowledge than that available in the first two sections. Anyone with a modicum of geologic training will be able to read the third section without digesting the previous two, though he might find the second section of general interest in the way of background material.

The geology of the Diamond Lake area has not yet been thoroughly mapped or investigated. The brief period the author spent in the area (mid-June to mid-September 1963) revealed the numerous technical problems that await resolution. However, it is hoped the information contained in the report will provoke a greater appreciation of the area by the reader.



Area, Umpqua National Forest, Oregon. *(click on image for a PDF version)*

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ACKNOWLEDGMENTS

The impetus for the project to map and describe the geology of the Diamond Lake area must be credited to Vondis E. Miller, Supervisor of the Umpqua National Forest. In the spring of 1963 Mr. Miller contacted Lloyd W. Staples, Head of the Department of Geology, University of Oregon, and the author subsequently was engaged for the project through Dr. Staples.

While working in the Diamond Lake area the author received the cooperation of George E. Reynolds and Donald R. Darling, U. S. Forest Service employees stationed at Diamond Lake during the summer months. These individuals afforded the writer every courtesy and in large measure helped to make the field season an efficient and pleasant one.

Richard Brown and C. Hans Nelson, of the Crater Lake Naturalist's office, provided the author access to the publications available in the Crater Lake National Park Library. The assistance of these individuals is gratefully acknowledged.

Acknowledgment also is due Donald J. Tandy and Richard Platt, District Ranger and Assistant District Ranger, respectively, of the Diamond Lake Ranger District.

The author's chore has been largely one of compilation of scattered bits of geologic information. He can claim little originality for the contents of the report. Information provided by the publications of Howel Williams particularly should be acknowledged. The descriptions contained in his papers titled "The Ancient Volcanoes of Oregon" and "Mt. Thielsen: A Dissected Cascade Volcano" were especially useful. Much of the material contained in those papers appears in altered form in this report. The various publications which were used by the author appear in the bibliography.

The geologic map included in this report (see inside back cover) is based on two maps published by Howel Williams, and contains additions and modifications by the author.

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PRINCIPLES OF VOLCANIC ACTIVITY

ORIGIN OF VOLCANOES

The most basic questions concerning geology are often the most difficult for the geologist to answer. Any answer to the question "What is the ultimate cause and source of volcanoes?" is largely conjectural; however, there are several plausible answers which may be in harmony with what is known from seismic and gravity studies. These studies tell us the earth is solid to depths far below those at which volcanoes must originate. Certain types of seismic waves (the so-called "s—waves" or "shear waves") are known to pass through solids, but not liquids. Recording of these waves indicates the earth's crust is solid to a depth of 1,800 miles below the surface. The s—waves are not transmitted through the core of the earth, which is assumed to be liquid.

Data from numerous deep oil wells and mines indicate the earth is hotter at its interior than at its surface. This increase in temperature with depth, or geothermal gradient as it is called, carries from place to place on the globe, but generally varies between 30°C and 50°C per mile. The rate of increase must diminish at depths below those for which data are available, or preposterous temperatures must be assumed at the core of the earth.

According to these figures the temperature of the rocks which are 40 miles below the earth's surface would be in excess of 1200° a temperature at which virtually all rocks will melt in the laboratory. However, as seismic data indicate, the rocks at that depth are rigid or solid because of the tremendous pressure of the overlying shell of rock material. It is a fact of physical chemistry that when a solid is put under pressure its melting point is raised.

The existence of the geothermal gradient, among other information, has given rise to a theory held in good esteem by many geologists. The theory assumes the earth formed as a molten ball, and has been cooling since its creation. The earth's surface presumably has cooled and its still-hot interior is cooling still, shrinking the globe as it does so. As the interior shrinks, the solid crust wrinkles and cracks like the skin on a drying apple. Hence the theory provides an explanation for the unrest in the earth's crust as evidenced by earthquakes and volcanic activity.

Volcanoes and earthquake activity generally are confined to narrow belts or mountain ranges, often crudely parallel to the margins of continents. One such belt includes the Andes Mountains of South America, the Cascades, the Aleutians, and volcanic chains in Japan and the East Indies. This long and sinuous chain has been called the "circle of fire", as it rims a good portion of the Pacific Ocean.

If fractures in the earth's crust, however produced, extend to a depth of 40 miles or so they would release the pressure on the rocks at that depth. These rocks, already above their melting point but held rigid by pressure, would fuse or melt and begin creeping up the fracture. A source of volcanism is thus created.

Another possible mechanism whereby rocks in the earth's crust may become molten is by the generation of very high temperatures by radioactive decay. As uranium and thorium decay to produce lead, they give off large quantities of heat. Molten rock produced in this fashion also would tend to rise toward the earth's surface. The molten rock is properly called magma.

Magma is a molten, silicate-melt paste, generated within the earth's crust. Lava, though used synonymously by the layman, is properly reserved for magma which has been erupted at the earth's surface. Lava also refers to rock which has solidified on the earth's surface from a molten silicate melt.

The magma produced beneath the earth's surface tends to make its way upward. This liquid is lighter than the enclosing solid material and tends to rise as it is squeezed by the surrounding solid rocks. Also, the molten rock contains gases which, once released from solution, tend to expand and propel the liquid mass in the direction of least resistance—upward or along a fracture. The magma may rise directly to the earth's surface but commonly it rises to within a few thousand feet of the surface and begins to spread laterally. Here the magma accumulates in a magma chamber. This magma chamber is the stewing pot which furnishes the molten material that will build volcanoes.

VOLCANIC MATERIALS

The geologic evidence at hand indicates the material which is fused at great depths beneath the earth's surface is basalt. Basaltic magma, therefore, is the fluid from which all volcanic materials ultimately are derived. Basaltic magma consists of a pasty melt, rich in silica, alumina, magnesium, iron, calcium, sodium, potassium, and water vapor. Often this basaltic magma rises directly from the depths where it was created and spills out on the earth's surface in widespreading, fluid sheets. Such material does not halt temporarily in a magma chamber where subsequent changes might produce very different kinds of magma. The material that rises directly from its place of origin, then, most nearly represents the "mother" magma from which all other types of volcanic materials are derived. This material, as previously stated, is basalt. More specifically, such basalts often contain small crystals of the mineral olivine and are termed olivine-basalts.

It has often been observed that a given volcano will erupt one kind of lava initially, and a very different material at a later time. Also, it is not uncommon for neighboring volcanoes to erupt different kinds of lavas at the same time. The explanation of these phenomena lies in the changes the magma undergoes in the magma chamber.

As the magma begins to cool, crystals begin to grow in the liquid. Those minerals which are stable at higher temperatures form first: olivine, pyroxene, and calcic plagioclase feldspar. These crystals are heavier than the liquid in which they are growing, and slowly settle toward the bottom of the magma chamber. They leave behind a liquid relatively richer in sodium, potassium, and silica. Also solidifying are those portions of the magma adjacent to the cooler walls of the magma chamber. As the magma freezes, the gases it contains are excluded from the crystals, hence are enriched in the remaining liquid. The light gases thus produced, and the remaining liquid portion of the magma, rise to the top of the magma chamber. Geologists call this process differentiation. The result of differentiation is a more-or-less horizontal layering of the gases, liquids, and crystals in the magma chamber.

As the gases accumulate at the top of the magma chamber their pressure increases, and may fracture the rock from the chamber to the surface. The fractures may tap any portion of the chamber—the top, sides, or bottom—and may, therefore, release any type of material the chamber contains. The foregoing discussion of differentiation explains why rapidly spaced eruptions usually consist of olivine basalt, the "original" magma. The magma chamber is

continually refurnished with fresh olivine basalt from below, which does not have time to differentiate before being expelled at the surface. Conversely, widely spaced eruptions commonly consist of siliceous lavas, the products of differentiation. The outpouring of siliceous lavas often is followed by eruptions of more basaltic, crystalline lavas as the bottom layer of differentiated material follows the more silicic from the chamber.

As Howel Williams has written, crystallization and differentiation are the major causes of diversity in volcanoes. The differences in the liquid products of volcanoes are not wholly dependent upon chemical composition. Differences in temperature and gas content also affect the nature of the fluid issue of volcanoes.

Other things being equal, the higher the temperature, the more fluid the lavas; and the higher the gas content, the more fluid the lavas. Basalts which rise directly from the depths of the earth and which have not been subjected to differentiation retain their gas content and high temperature. Upon reaching the surface, they spread in fluid sheets like thick, muddy water. The temperatures of such lavas are commonly 1000°C to 1200°C Upon solidifying they form smooth, ropy and corrugated forms to which the name "pahoehoe" has been given. Often the crusts of lava flows are jagged, clinkery and splintery. Such lava is called "aa".

The more silicic differentiates of the magma chamber generally have cooled to temperatures between 600°C and 850°C and have been separated from much of their gas content. These lavas are extruded as viscous, pasty masses which flow with extreme sluggishness.

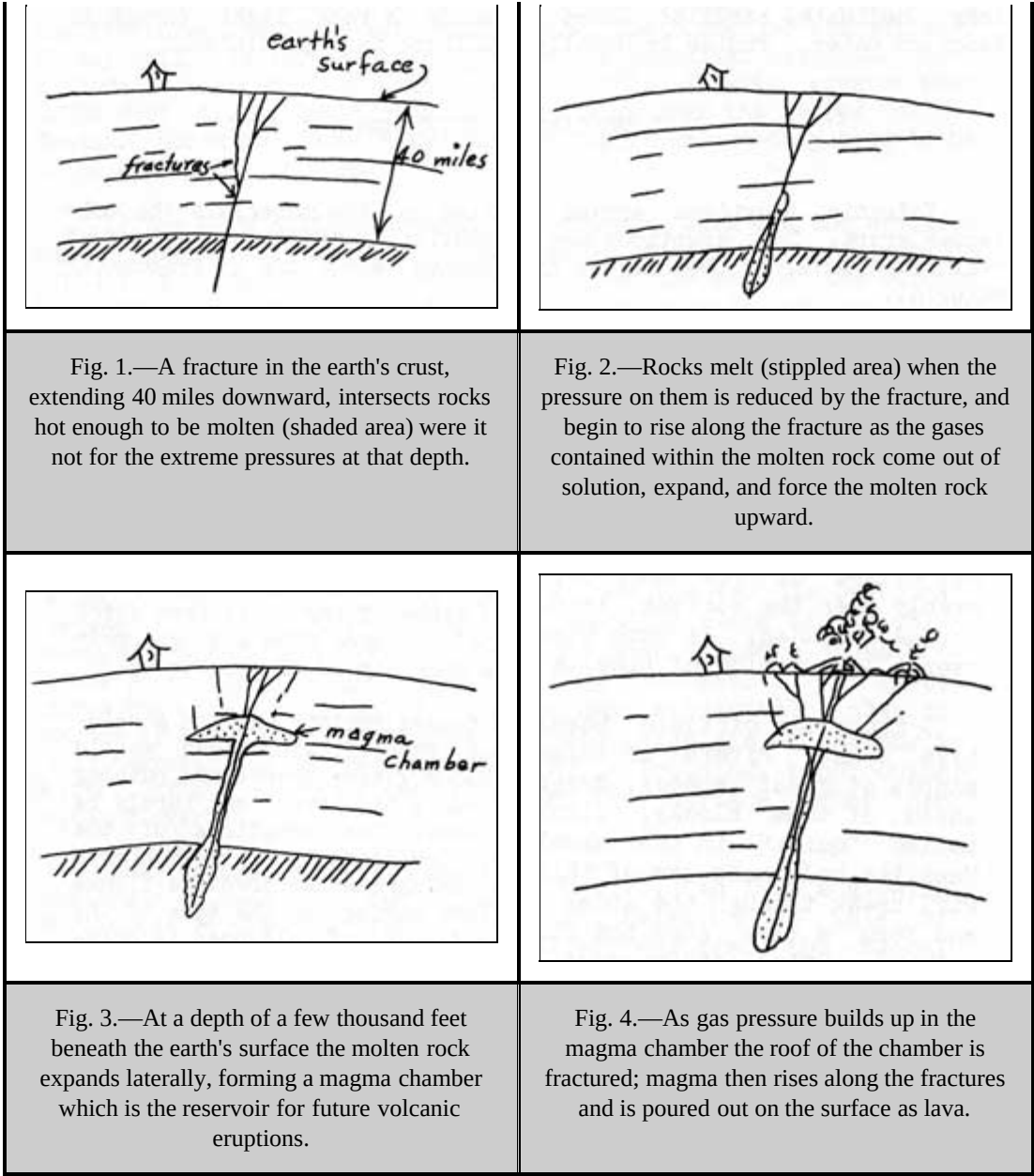
All of the products of volcanic activity, of course, are not liquid. In a magma chamber wherein differentiation has produced a separate gaseous phase near the top of the chamber, fractures tapping that portion of the chamber allow the gas to escape with rapidity and in huge volumes. Measurements of gas exhalation in the Valley of 10,000 Smokes near Mt. Katmai, Alaska, in 1912 revealed 6 million gallons of steam per second, 1-1/4 million tons of hydrochloric acid per year, and 200,000 tons of hydrofluoric acid per year were given off by the cooling pumice flows after extrusion. The relative proportions of these gases are not unique. Of the gases given off by volcanoes most is water vapor (usually 80 to 95 percent of the total gases exhaled) with carbon dioxide the next most abundant, followed quantitatively by sulfur dioxide. Minor amounts of carbon monoxide, hydrochloric acid and hydrofluoric acid gases—hydrogen, hydrocarbons, ammonium chloride, and other—are common.

Some solid material also is ejected by volcanoes. The fragments range in size from blocks weighing hundreds of tons to dust particles fine enough to be carried around the globe by winds. Some of this material consists of pasty, liquid clots which cool in the air as they are blown from the throat of the volcano. Other fragments are solid particles of the volcano which are torn loose, carried upward, and ejected forcefully by the lava and gases rushing up the conduit of the volcano.

If the fragments blown from the volcano are smaller than pea-size they are called volcanic dust and ashes. If they are pea-size to walnut-size they are called lapilli (or cinders, if basaltic in composition). If larger than walnut-size they are called blocks, if solid when blown out, or bombs, if thrown out in a liquid state. Volcanic bombs tend to be elongated or spindle-shaped with slightly twisted ends. They attain this shape when hurling through the air while still a pasty liquid.

FORMATION OF VOLCANOS





Occasionally a frothy or bubbly material, called pumice, is ejected from a volcano. The bubbles often are drawn out into long, delicate, parallel tubes forming a rock light enough to float on water. Pumice is usually silicic in composition.

VOLCANIC ERUPTIONS

Volcanic eruptions are as varied as the materials the volcanoes erupt. The eruptions may consist of quiet outpourings of very fluid lava, or they may be explosive ejections of fragmental material.

In the foregoing discussion it was stated that olivine basalt, rising directly from its point of fusion to be spilled out on the earth's surface, does not have the necessary time to differentiate, and therefore retains much of its gases in solution. These gases impart great fluidity to the molten rock, and basalt flows often spread in thin sheets across the earth's surface covering tens or even hundreds of thousands of square miles. It is often difficult to determine the point at which such rocks were extruded because their fluidity will not allow a steep volcano to accumulate around the vent. In many areas the basalt apparently has welled up from numerous, closely spaced fractures and spread evenly over the surface, leaving no

trace of the vents from which it was extruded. If such basalts are extruded from a single vent over a long period of time, a gentle dome may be formed.

Eruptions of fluid basalt are termed "quiet" only in a relative sense. Rivers of incandescent rock, flowing down gentle slopes at great speeds, dragging along glassy crusts and pushing ahead of them blocky, clinkery chunks of lava, can hardly be called "quiet" in the absolute sense. The eruptions of the Hawaiian volcanoes are of this type. Occasionally the molten rock will break through the sides of the volcanoes far down the flanks and form a flow atop the older flows making up the base of the volcano. Often the rupture in the flanks of volcanoes is occasioned by the cooling and solidification of material in the vent. A plug thus formed may temporarily seal the vent. As pressure builds up, it may overcome the strength of the flanks of the volcano; molten rock then bursts from the sides below the summit. Or the plug may be disintegrated and blown out, allowing the lava to flow again out the central vent.

If the lava is allowed to differentiate in the magma chamber there is a separation of the gaseous material from the more siliceous and less siliceous magma fractions. As the gas pressure increases, new fractures develop in the roof of the magma chamber and the various types of material can escape. As explained in the previous section of this report, the siliceous material is more viscous than the undifferentiated basaltic magma. It rises along the fractures and flows sluggishly down the flanks of the volcano. It may chill to form a dense, glassy rock called obsidian. Such a flow is Llao Rock at Crater Lake. This flow is greater than 1,000 feet thick, but flowed only a mile down the slopes of Mt. Mazama. Obsidian flows never cover large areas—they tend to be thick and stubby in form.

If the more siliceous magma is charged with gas the eruption may be explosive. As such material is ejected the gas expands rapidly, blowing clots of pasty magma from the vent of the volcano high into the air. Those clots falling outside the crater may solidify while in the air or shortly after striking the ground.

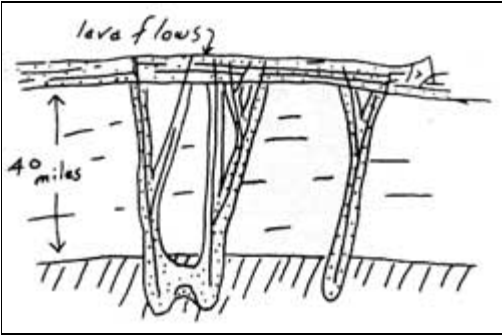
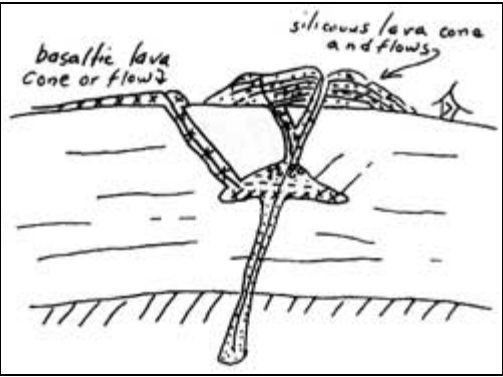
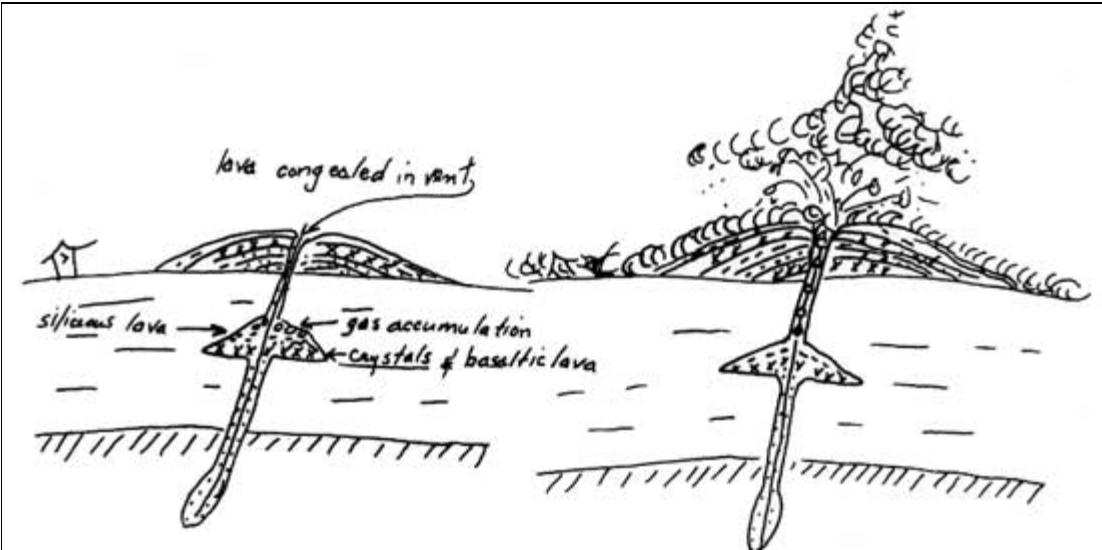
Some eruptions consist almost entirely of gas. As the gas escapes through the fractures it may tear loose fragments of older, solidified lava and hurl them high into the air.

Pumice eruptions tend to be extremely explosive. Eruptions of pumice during recorded history have produced detonations heard thousands of miles away. The coarse material may fall as ash, as the finer particles are wafted around the globe by the prevailing winds. If the quantity of pumice material is great enough, the spewing column of gas and pumice rising from the vent is overcome by gravity, and the boiling mass rushes down the slope of the volcano. This type of incandescent flow has been called a "nuee ardente", or "glowing avalanche". The high content of hot gases gives the mass high mobility. The flows may attain velocities in excess of 100 m.p.h. The pumice lumps discharge gas at extremely high temperatures and pressure, producing a frothing, mushrooming effect. The flow rolls and floats over the surface rather than sliding over it.

Such eruptions are extremely destructive. In 1902 a glowing avalanche flowed down the slopes of Mt. Pelee on the isle of Martinique in the West Indies, and swiftly engulfed the coastal town of St. Pierre. Only two of the city's 28,000 inhabitants—one a condemned murderer locked in a dungeon—escaped a searing death.

To summarize, gas is the propelling force in volcanic eruptions. If the gas content of the lava is high, the resulting flows are fluid and quiet. If the gas content is low, the flows are more viscous. If the gas in a magma chamber has segregated, gaseous eruptions may result. If the gas is associated with silicous magma, pumice eruptions may result.

TYPES OF VOLCANIC ERUPTION

 A cross-sectional diagram showing the Earth's crust with several vertical fractures. At the top, horizontal lines represent 'lava flows'. The fractures extend downwards, with a vertical double-headed arrow on the left indicating a depth of '40 miles'. At the base of the fractures, there are irregular shapes representing magma reservoirs.	 A cross-sectional diagram of a volcano showing a central magma chamber. The chamber is divided into two parts: a lower, darker portion labeled 'basaltic lava cone or flow' and an upper, lighter portion labeled 'siliceous lava cone and flows'. Fractures are shown extending from the surface down into the chamber, tapping into both the upper and lower portions.
Fig. 5.—Fractures reaching deep into the earth's crust allow the rocks at great depths to melt. The basalt, fused at great depths, rushes up the fracture zones and is extruded as a gas-charged, highly mobile sheet of basaltic lava. These rocks are often called "fissure" basalts or "plateau" basalts.	Fig. 6.—If the magma spreads to form a magma chamber, differentiation may occur, and pressure builds up as the gas in the magma accumulates in the top of the chamber. Fractures develop in the roof of the chamber. Those fractures tapping the upper portion of the magma chamber erupt siliceous lavas, gas, and pumice. Those tapping the lower portions erupt more basaltic lavas containing small crystals.
 A cross-sectional diagram of a volcano showing a magma chamber. The chamber is filled with 'gas accumulation' and 'crystals of basaltic lava'. The top of the chamber is labeled 'lava congealed in vent'. A fracture extends from the surface down into the chamber, tapping into the gas accumulation. The diagram shows the process of gas pressure building up and the vent being plugged by solidified lava.	
Fig. 7.—Gas pressure builds up in top of magma chamber as vent is plugged by solidified lava.	Fig. 8.—As volcano explodes, plug in vent is disintegrated and blown out by rapidly expanding gas. Gas and frothy siliceous lava are ejected as pumice, at first rising high into the air. As the volume of pumice ejected increases, its upward impetus is overcome by gravity and the mass rushes down the slopes of the volcano, producing a glowing avalanche.

VOLCANIC SHAPES

The different shapes volcanic rocks assume are primarily the result of their differences in composition. As already explained, fluid olivine basalts rising directly from the point of their fusion will spread rapidly and evenly. Very fluid lava behaves much like any other fluid and seeks a lower level. If canyons are available near the point of such an eruption the lava flows down them and may be confined by the canyon walls. Such rocks are called intracanyon basalts. They partially fill the canyon to form flat floors between the rugged canyon walls. If

such rocks are extruded in relatively flat areas they spread into thin sheets covering vast areas.

Eruptions of basaltic lavas from a central vent produce volcanoes with low, broad profiles, like an inverted dish. This shape is assumed because the fluid lavas flow rapidly from the vent and the height of the volcano grows slowly as its diameter grows rapidly. The Hawaiian volcanoes Kilauea and Mauna Loa are of this type. These volcanoes are called shield volcanoes.

The other extreme in volcanic forms is the cinder cone. This type consists entirely of clinkery ash, cinders, bombs, and blocks of lava. All the material making up a cinder cone is fragmental, and the angle of repose for irregular and jagged fragments is greater than that attained by a congealing fluid lava. The cinder cones, then, have steeper sides than shield volcanoes, and the slope of their sides increases toward the summit. In profile, the very top of the cinder cone may appear flattened due to the conical depression at its top. Examples of well-studied cinder cones are Parícutin in Mexico, and Wizard Island, which protrudes from Crater Lake. The flanks of Newberry Crater in central Oregon are liberally sprinkled with about 200 small cinder cones.

More common than either true shield volcanoes or cinder cones are composite volcanoes. These are composed of alternating layers of cinders and lava flows, and in profile their slopes rise at an angle between those of shield volcanoes and cinder cones. Composite volcanoes are comparatively common because of the workings of the molten rock in the magma chamber. As the material in the chamber differentiates, gas pressure builds up, the volcano erupts, and the chamber emits first the uppermost gas and siliceous lavas, then the more basaltic lavas. As the magma chamber is emptied it is refurnished from below and more basaltic lava is erupted. When the pressure is released by these eruptions, the lava in the vent of the volcano may congeal, plug the vent, and allow the new basaltic magma in the chamber to differentiate again. This cycle may repeat itself many times, with eruptions of more siliceous fragmental ejecta alternating with eruptions of fluid basaltic lava. Numerous examples of composite cones are to be found in the High Cascades—Mt. Hood, Mt. Shasta, and Mt. Rainier are among them.

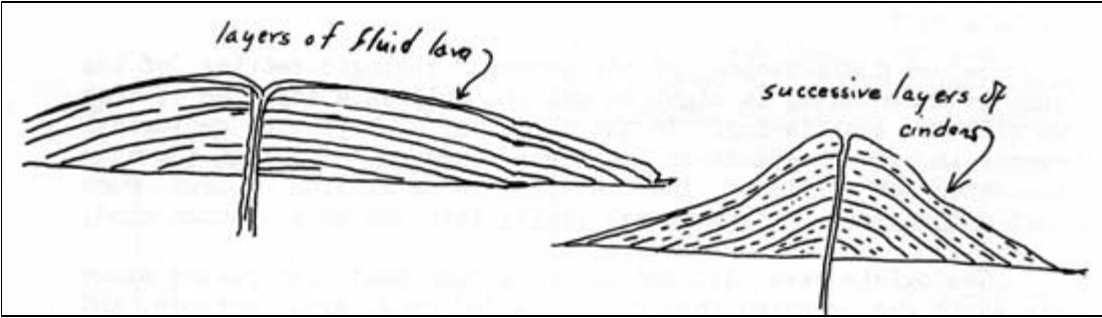
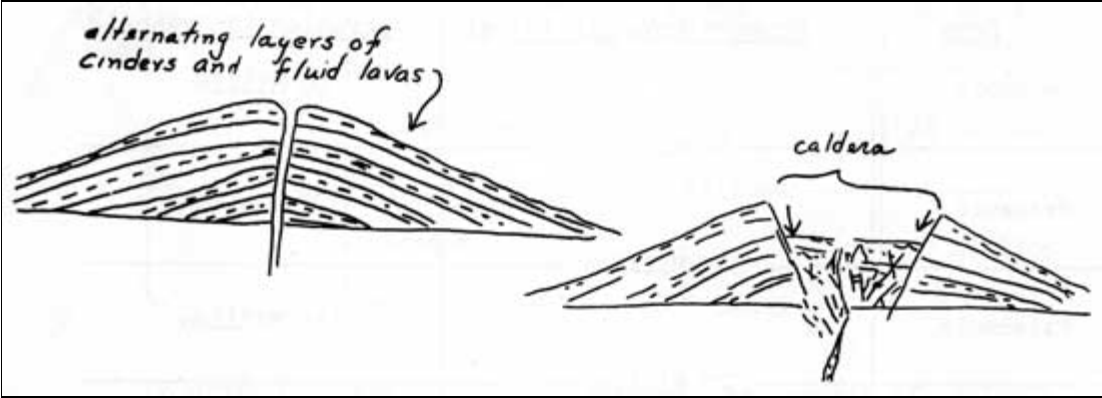
As the material in the conduit of a volcano is forced upward and blown out the vent, a certain erosive effect ensues. The gas and lava rushing from the vent are blown out with great energy, and fragments of older lava flows are torn loose and ejected also. The result is a crater, or conical depression in the top of the volcano. These depressions are seldom more than a mile across and usually are littered with volcanic fragments, bombs, blocks, etc., which were not blown beyond the rim of the crater and rolled back down into the depression.

Some volcanic peaks contain circular or conical depressions many miles in diameter. Often the interior rim of the depression is a steep escarpment extending entirely around the depression. Such depressions are called calderas, and result from collapse of the volcanic peak (including the crater) into a void created by the eruption of lavas and evacuation of the magma chamber. At the well-known "Fire Pit" in the summit of Kilauea, the walls often collapse when lava pours from fractures on the slopes of the volcano far beneath the summit. The caldera in which Crater Lake was formed is another example of a depression formed in this manner.

Eruptions of volcanic ash or fine pumice are carried by the wind and dropped to produce a blanket-like deposit. Such material covers the ground evenly, like a layer of fresh snow. Eruptions from Mt. Mazama about 6,600 years ago produced a blanket of pumice which diminishes in thickness away from the volcano, but retains a depth of 6 inches as far as 70 miles away.

Glowing avalanche deposits, because they move across the surface of the ground and are controlled by topography, assume shapes not unlike those of fluid basalts, if the terrain is relatively level—or intracanyon basalts, assuming there are canyons of sufficient depth and width to retain the material.

TYPICAL VOLCANIC FORMS

	
Fig. 9.—Cross-section of volcano (Hawaiian type) showing low, broad profile.	Fig. 10.— Cross-section of steep-sided cinder cone volcano, such as Paricutin and Wizard Island.
	
Fig. 11.—Cross-section of composite cone. Note funnel-shaped crater at the summit.	Fig. 12.—Collapsed volcano (such as Mt. Mazama), showing large caldera formed as top of the mountain falls into void created by evacuation of lavas below.

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The Geologic History of the Diamond Lake Area



GENERAL GEOLOGIC SETTING OF THE CASCADE REGION

Before a discussion of the general geologic setting of the area is undertaken, it might be well to delineate the span of time we will be considering. In the minds of most people, geological events involve thousands or millions of years. But just how many thousands or millions? And how long is a million years? Such vast quantities of time are not easily fathomed by the human mind.

Geologists have divided all the time that has passed since the earth was created into units called eons, eras, periods, and epochs, among others. The divisions separating these units are based on pronounced changes in life on earth as revealed in rocks of the earth's crust. A simplified listing of these units appears below.

<u>Eras</u>	<u>Age of Boundary Between Eras (in years)</u>	<u>Approximate Duration (in years)</u>
Cenozoic		60 Million
	60 Million	
Mesozoic		125 Million
	185 Million	
Paleozoic		335 Million
	520 Million	
Precambrian		4 Billion ?
	4-1/2 Billion ?	

Each of the geologic eras has been further subdivided. Of interest to the student of Cascade geology is the Cenozoic Era and its subdivisions. It is divided as follows:

<u>Era</u>	<u>Period</u>	<u>Subdivision</u>	<u>Age of Boundaries Between Subdivisions (in Years)</u>	<u>Approximate Duration of Each Subdivision (in Years)</u>
Cenozoic	Quaternary	Recent		10,000
			10,000	
		Pleistocene		1 Million
			1 Million	
		Pliocene		11 Million
			12 Million	
		Miocene		16 Million

	Tertiary		28 Million	
		Oligocene		12 Million
			40 Million	
		Eocene		20 Million
			60 Million	

In order to impress upon the reader the concept of geologic time, let us assume the 4-1/2 billion years that have passed since the earth was formed may be compressed into one calendar year. We would find that Precambrian time, which would have begun with the formation of the earth on January 1, would extend until November 6. By this time the only forms of life on earth were simple organisms similar to algae. The Paleozoic Era would continue from November 6 to December 13. During this time fishes, reptiles, amphibians, and numerous plants evolved. The Mesozoic Era, dominated by the dinosaurs and other large animals, would extend from December 13 to December 25. The Cenozoic Era (which includes the Tertiary and Quaternary) would extend from December 25 to midnight December 31. The quaternary, spanning the last 1 million years, would comprise only the last 2-1/2 hours in our compressed year. Modern man, who has been on earth only some 25,000 years, would appear at 11:57 p.m., December 31. Mt. Mazama, which collapsed only 6,600 years ago to produce the caldera Crater Lake now occupies, would erupt just 45 seconds before the stroke of midnight.

The oldest rocks exposed in the Cascade Region were formed during the Eocene Epoch, and are therefore 60 million years old or younger. The older rocks lying beneath those exposed in the Cascade Range are assumed to be marine sedimentary rocks of Mesozoic age. These rocks are believed to have been formed by precipitation from sea water in a broad depression between the Klamath, the Blue, and the Sierra Nevada Mountains. At the close of the Mesozoic, some 60 million years ago, widespread upheavals in the earth's crust caused the seas to retreat from the area and volcanic activity began in the Cascade Region. Evidence of this activity is preserved in the Umpqua Formation to the west of the Cascades. This formation, which is Eocene in age and sedimentary in nature, contains beds of tuffaceous material furnished by explosive volcanic activity in the Cascade Region.

The Cascade Region is divided, physiographically, into the Western Cascades and the High Cascades. Volcanic activity began in the Western Cascades at the close of the Mesozoic Era, or the beginning of the Eocene Period. Thousands of feet of volcanic rocks piled up and flowed east and west to interfinger with different types of rock in those areas. The landscape appeared in those times as a low, rolling plain, dotted with volcanoes of various sizes, cinder cones, and broad sheets of lava. For approximately 48 million years the volcanic outpourings continued, and in some areas the accumulation of lava and ashes reached almost 10,000 feet in thickness by the close of the Miocene Period. By this time a broad plateau of volcanic rocks had been built, but there was no mountain range such as the High Cascades comprise today. The moisture-laden winds from the Pacific Ocean swept eastward across the plateau to lose their water in central and eastern Oregon. During this time many lakes existed in the John Day country. The fossilized remains of the fauna and flora of the Miocene age are preserved in the ash and flood deposits in that area. Meanwhile, in eastern Oregon and Washington, copious sheets of fluid lava spread over the country. These "plateau basalts" eventually covered more than 200,000 square miles.

At the close of the Miocene Period, about 12 million years ago, a disturbance in the earth's crust uplifted, bent, and tilted the thick sequence of rocks making up the Cascade plateau. This was the origin of the present Cascade Mountains. The Western Cascade rocks were tipped so that they dipped toward the east or northeast. The slope of the beds decreased

toward the east and approached the horizontal in the vicinity of what are now the High Cascades. The Western Cascades also were intruded by a north-south chain of molten igneous masses. These did not pour out on the surface as lava, but came to rest and cooled far below the surface. Hence they are coarse-grained igneous rocks, unlike the fine-grained lavas that enclose them.

Also associated with the crustal disturbance at the close of the Miocene was a large, north-south fracture which opened along the east edge of the Cascades. Actually, the fracture probably consisted of numerous parallel cracks of shorter lengths which overlapped to form a fracture zone along the margin of the Cascades. Apparently the rocks on the east side of the fissure dropped down some 1,000 to 2,000 feet below those on the west side. Although younger lavas obscure the fissure, the older lavas beneath them crop out at lower elevations to the east of the younger lavas.

This change in the form of the Cascade area did not happen within the span of a few years. Most geologic changes occur slowly, and the uplift and faulting of the Cascade Region at the close of the Miocene period undoubtedly took place over a span of a few million years.

From the fractures produced by the crustal disturbance at the close of the Miocene Period, lava began to erupt. Throughout the next 10 million years a chain of high cones built themselves along the crest of the Cascade Range. Their eruptions were not violent at first, but rather quiet outpourings of fluid basaltic lava (olivine basalt and basaltic andesite). High Cascade peaks such as Union Peak, Mt. Thielsen, and Pig Iron Mountain grew in this fashion throughout the Pliocene Period, which ended about one million years ago. Toward the close of the Pliocene Period the shapes of some of the typical shield volcanoes were modified by the development of cinder cones atop their summits. The fragmental material was generally more silicic than the basalt making up the broad bases of the volcanoes. Other volcanoes, however, have continued to erupt basaltic material even up to the present. In other words, basaltic shield volcanoes and more silicic cinder cones were forming at the same time, and often in the same general area.

While the Cascade peaks were being built during the Pliocene Period, the older volcanic rocks of the Western Cascades were either overlapped by younger High Cascades lavas or subjected to severe erosion. On the plateau to the east of the Cascades, basaltic lavas erupted throughout the Pliocene Period. As the Pliocene Period drew to a close the Cascade Range appeared as a high plateau surmounted by broad, basaltic shield cones. During the close of the Pliocene and throughout the Pleistocene Period, a series of large cinder cones, more silicic than basaltic in composition, grew atop the basaltic shield cones. These cinder cones were arranged along the north-south crest of the Cascades and include such peaks as Mt. Mazama, Mt. Shasta, Mt. Baker, Mt. Rainier, and Mt. Hood. Some of these peaks continued to grow even into the present century. Mt. Lassen erupted as late as 1917.

The Pleistocene has been called the Great Ice Age, for during that span of about one million years, four great advances of glaciers and ice sheets crept across the continent from the north. Glaciers first form on mountain tops where snowfall is heaviest due to heavier precipitation and cooler temperatures. As the snows pile up, the layers on the bottom are compacted to granular ice which flows downhill very slowly under the weight of overlying snow. Thus, glaciers flow down the flanks of the mountains, down existing drainages, and eventually, if the quantity of ice and snow is sufficient, may emerge to cover broad expanses of land.

Glaciers have a very erosive effect on mountain peaks. Loose rock is frozen into the bottom of the glacier and dragged across the solid bedrock. Both surfaces are literally ground to rock flour, the source of glacial clay deposits. Large blocks of bedrock may freeze to the glacier and be torn loose as the glacier plucks at the mountain slopes, producing large, scooped-out

hollows called cirques.

The Cascade peaks that ceased to grow at the close of the Pliocene Period—Mt. Thielsen, Howlock Mtn., and Union Peak among them—were deeply dissected by glacial erosion during the Pleistocene. Their flanks presently exhibit hollow cirques and occasionally their hard, resistant plugs protrude above the cirques as matterhorns. Those High Cascade peaks that continued to grow throughout the Pleistocene, including Mt. Mazama, Mt. Rainier, Mt. Hood, and others, fought the destructive force of glaciation by adding new material to their slopes through eruptions from their summits or flanks. Many of them continued to grow in elevation and bulk despite the ravages of glaciation. Several rock outcrops within the caldera of Mt. Mazama (Crater Lake) reveal scratched and polished slabs of rock produced by glaciers as they dragged boulders over the bedrock. Therefore, the degree to which the Cascade volcanoes retained their conical forms is a function of their age relative to that of the age of glaciation.

Several examples of volcanism in the Cascades postdate the glacial age, which ended about 10,000 years ago. These include Belknap Crater, Trout Creek Butte, and the latest eruptions of Mt. Mazama. The lava flows along the highway at McKenzie Pass are less than 1,000 years old. The rocks are untouched by glaciation.

In his book "Crater Lake: The Story of its Origin", Howel Williams has tabulated in chronological order, the geologic events in the Cascade Region. His chart, with minor modifications, follows:

Period	Epoch	Events	Approx. Duration in Years	Years Ago
Quaternary	Recent	Post-glacial time. Concluding activity is destruction of Mt. Mazama. Formation of Crater Lake. Flows erupt in McKenzie Pass. Man appears in this region.	10,000	10,000
	Pleistocene	Great Ice Age. Main period of growth of High Cascade peaks such as Mt. Mazama, Mt. Hood, Mt. Shasta, and Mt. Rainier.	1 Million	1 Million
Tertiary	Pliocene	Building of older High Cascade peaks, such as Mt. Thielsen, Union Peak, Howlock Mtn., and Mt. Bailey. Climate becomes still cooler. Modern forests cover the lands.	11 Million	12 Million
	Miocene and Oligocene	Widespread volcanic activity over most of Oregon. Extensive fissure lavas in eastern Oregon in Oligocene and Middle Miocene time. Upheaval of Cascade range at close of Miocene. Climate becomes cooler. Redwood forests predominate.	28 Million	40 Million
	Eocene	Earth movements drive out seas, and volcanic activity begins, at the opening of the epoch. Tropical forests cover plains and temperate forests cover the hills.	20 Million	60 Million
Cretaceous		Broadly shallow, tropical seas cover most of Oregon during the latter part of the Cretaceous Period. No volcanic activity.	70 Million	

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The Geologic History of the Diamond Lake Area



GEOLOGIC HISTORY OF THE DIAMOND LAKE AREA

GENERAL DEVELOPMENT OF THE HIGH CASCADES

The oldest rocks exposed in the Diamond Lake area represent the Eocene, Oligocene, and Miocene Epochs. Therefore, they range from about 60 million to 12 million years in age. These rocks are exposed several miles to the west and northwest of Diamond Lake. More specifically, they make up Trap Mountain, Beartrap Meadows, Black Rock, Rhododendron Ridge, and the intervening canyons and hills to the west of Diamond Lake; and Birds Point, Potter Mountain, Thorn Mountain, Perry Butte, and the intervening country to the northwest of Diamond Lake. These lavas extend many miles to the west of the Diamond Lake area and make up the Western Cascades.

A glance at a topographic map of the Diamond Lake area reveals a decided change in the configuration of the land surface across the boundary between the Western Cascades and the High Cascades. The High Cascades consist of altered conical forms of obvious volcanic origin in various stages of erosion, whereas the Western Cascades consist of an area of irregular ridges and canyons which have been aptly described as a "sea" of peaks and ridges. These ridges and canyons bear no relationship to the original volcanic forms; that is, what is now a topographically high ridge initially might have been a low area between surrounding volcanic peaks. Conversely, what originally might have been a high volcanic peak now might be a deeply eroded canyon. The reason for the marked difference between High Cascade and Western Cascade topography is the greater length of time which has ensued since the formation of the rocks making up the Western Cascades. Erosion has proceeded to wear down these rocks from the instant they were poured out on the surface. During the past 60 million to 12 million years the original volcanic forms have been destroyed, and a more-or-less random network of streams now drains the area. The resulting topographic pattern is termed "mature".

The general nature and composition of the igneous rocks making up the Western Cascades have been described in an earlier section of this report. Suffice it to say here that these rocks, compared with the lavas of the High Cascades, present a more weathered appearance. They are more limonite-stained, more thoroughly altered mineralogically, and contain intrusions of coarser-grained igneous rocks that are absent in the lavas of the High Cascades.

As explained earlier, the Western Cascade lavas underlie the High Cascade lavas in the Diamond Lake area. They simply are overlapped and obscured by the younger High Cascade lavas which, having risen through fractures in the Western Cascade lavas, proceeded to bury the older rocks with fresh flows of molten lava.

The crustal disturbance at the close of the Miocene Epoch, some 12 million years ago, folded and fractured the Western Cascade lava platform. A series of north-south fractures developed along the eastern margin of the Cascade plateau and lava began to well up at various points along these fractures and build new volcanoes. The spacing of the new volcanoes indicates

the fracturing of the old lavas did not occur as a single fissure. Mt. Bailey and Mt. Thielsen, for example, which are both High Cascade volcanoes, lie on an east-west line. Viewed in a broader perspective, these two peaks form a portion of a mountain chain that is only a few miles wide, but several hundred miles long. Mt. Bailey and Mt. Thielsen probably grew along separate, but parallel, north-south fractures. Three miles to the north of Mt. Thielsen lie Howlock Mtn. and Tipsoo Peak. Two miles north of Mt. Bailey lie Rodley Butte and another, smaller cinder cone. The north-south lineation of the volcanoes thus is revealed on a small scale with in the larger framework of the Cascade Range.

The fractures in the Diamond Lake area reached deep enough into the earth's crust to tap rocks hot enough to melt if they were not under such great pressure. The fractures reduced this pressure and the rock fused, then began to work its way upward along the fractures. The first eruptions of this lava began at Pig Iron Mountain and Watson Butte, the oldest High Cascade volcanoes in the Diamond Lake area.

The relative ages of the High Cascade volcanoes are established on the basis of the degree to which they have been eroded and glaciated, and where possible to observe, the relationship of their lava flows. The mountain mass consisting of Pig Iron Mountain, Watson Butte and Elephant Mountain is entirely surrounded by the younger intracanyon basalt which obscures the contacts between lavas of those volcanoes and any others. However, the degree of erosion of those mountains suggests they are the oldest of the High Cascade volcanoes. It would be difficult to determine, from topographic form alone, whether or not these masses were volcanoes. However, examination of the rocks reveals a vent existed near the summit of Pig Iron Mountain; hence the mass is included in the High Cascades rather than the older Western Cascades. The High Cascades, which are less than 12 million years old, have retained a more-or-less conical shape despite subsequent erosion.

An interesting feature is exposed on Forest Service Road No. 264.1 about 2-1/2 miles northeast of Toketee Reservoir. This site is on the northern edge of the Pig Iron Mountain—Watson Butte mass, near the junction of Loafer Creek and the North Umpqua River. At this point the road cut exposes a tree trunk whose outer shell is petrified and whose center is carbonized. The trunk measures 3 to 4 feet in diameter and is about 8 feet high. The root system extends another 6 feet below the base of the trunk and appears to be naturally emplaced in a weathered "tuff". Tuff is a rock composed of fragments of volcanic rock. The trunk itself is surrounded by a pale green lava flow containing white feldspar crystals. The rock layer above the truncated tree is an other tuff bed. Scattered through the lava layer surrounding the trunk are carbonized limbs up to 1 foot in diameter and smaller fragments. The majority of these are scattered down-flow from the trunk. The sequence of events leading to the preservation of such a feature must have been as follows: The tree initially was



growing on a thin soil zone covering a layer of tuff. Its roots pierced cracks in the rock to a depth of 6 feet or more below the

Petrified — carbonized tree trunk near Loafer Creek.

surface. The tree then was engulfed by a lava flow which caused it to break about 8 feet above the ground. Limbs and twigs fell into the flow and were swept down hill by it. The flow was hot enough to sear and carbonize the entire trunk and those limbs that were engulfed by the flow. The tuff bed below the flow was baked and the roots piercing the tuff also were carbonized. The mass cooled and was later covered by another tuff layer. The tree and branches at this time probably were carbonized completely.

Later, silica-bearing solutions worked their way up the contact between the carbonized wood and the lava and began replacing the carbonized wood with silica. This process continued until only the central core of the tree remained carbonized. The result is a petrified silica sheath surrounding the carbonized core. The wood texture is well preserved in both the carbonized and silicified portions of the tree. The lava rock immediately adjacent to the silicified trunk contains minute flecks of pyrite, an iron sulfide mineral. Pyrite commonly forms in the presence of carbon, which reduces the ubiquitous iron to the sulfide form. This is an indication that the outer portion of the tree (now silicified) originally was carbonized, as the center is still.

The limbs and branches which are engulfed entirely by lava are carbonized, not silicified. These fragments are not silicified because they are not in contact with the more porous tuff beds, as is the main trunk. Mineralizing solutions were provided access to the main trunk through the porous tuff beds into which the root system of the tree extended.

It is believed the tuffs and lava encasing the tree are associated with lavas and tuffs of the Pig Iron Mountain and Watson Butte volcanoes, as they are totally unlike the dense, grey, olivine basalts which make up the intracanyon flows. This means the tree is between 12 million and 1 million years old—probably closer to the former.

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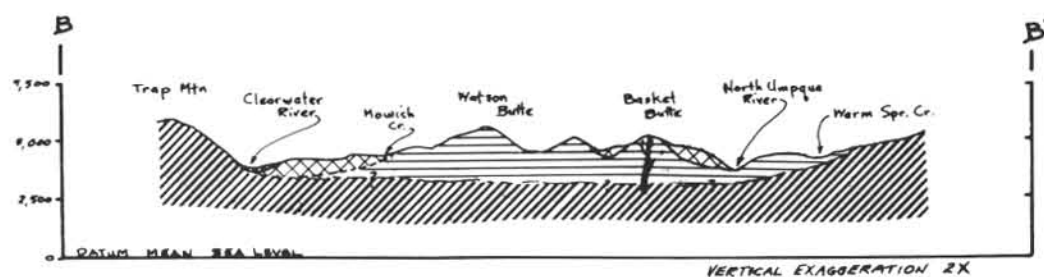
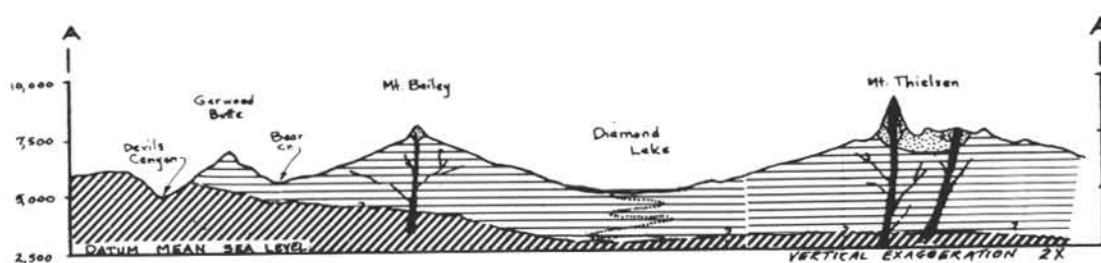


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CRATER LAKE NATIONAL PARK

EXPLANATION

- boundary of Diamond Lake Ranger District
- streams
- springs
- geologic contacts
- boundary between lavas from different High Cascade volcanoes
- isopach lines showing thickness of pumice fall
- High Cascade lavas
- Western Cascade lavas
- intracanyon basalts
- glowing avalanche deposits
- igneous plugs
- cinder cones
- lava cones



RECONNAISSANCE GEOLOGIC MAP AND GEOLOGIC CROSS SECTIONS OF THE DIAMOND LAKE AREA, UMPUQUA NATIONAL FOREST OREGON

GEOLOGY AFTER H. WILLIAMS, 1933 and 1942,
WITH ADDITIONS AND MODIFICATIONS BY
W. B. PURDOM, 1963

The Geologic History of the Diamond Lake Area



GEOLOGIC HISTORY OF THE DIAMOND LAKE AREA *(continued)*

GROWTH OF MT. THIELSEN AND MT. BAILEY

It probably was shortly after the disturbances at the close of the Miocene, and just after the initiation of volcanic activity at Pig Iron Mountain, that Mt. Bailey, Mt. Thielsen, Howlock Mountain, and the other High Cascade peaks in the Diamond Lake area began to erupt. The lavas and eruptive history of Mt. Bailey, Mt. Thielsen, and Howlock Mountain are very similar, and are representative of the other High Cascade peaks in the area. These volcanoes will be discussed in some detail, and occasional references will be made to other peaks in the Diamond Lake area.

The bulk of Mt. Thielsen, Mt. Bailey and Howlock Mountain consists of pyroxene basalt. There is a small amount of olivine in the basalt but the amount of the mineral pyroxene exceeds that of olivine in virtually all samples. Pyroxene is a mineral group containing several members. On the lower slopes of Mt. Thielsen the lavas contain mostly hypersthene pyroxene; on the upper slopes, augite is the predominant pyroxene. Changes in color and texture of the lavas on the lower and upper slopes are also noticeable. The lavas of the upper slopes are more vesicular—that is, they contain more voids, or holes—which indicates they originally contained a greater amount of gas than did the lavas of the lower slopes. Also, the lavas of the upper slopes are darker in color due to the higher content of magnetite in the glassy matrix of the lavas.

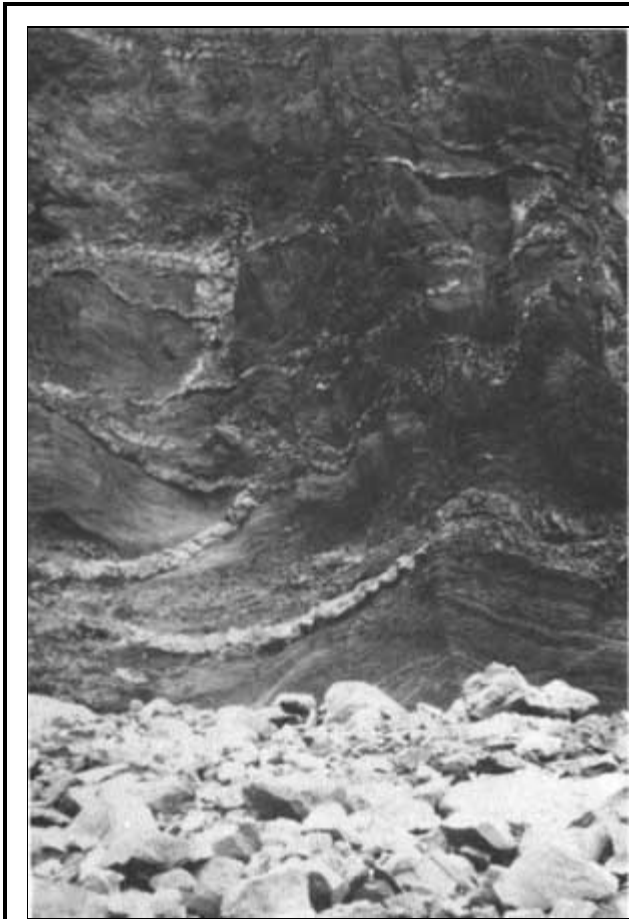
All the lavas described above were extruded over a period of 10 million years or so. As stated, the initial eruptions probably began shortly after the close of the Miocene, some 12 million years ago, and continued to erupt until about 1 million years ago. These lavas were very fluid and flowed rapidly away from the point of their extrusion, building a broad, shield-type volcano. The flows were extruded from the central vent, and probably also from fissures in the sides of the volcano. The flows making up Mt. Thielsen extended for miles away from the summit—the east-west diameter of the volcano is about 10 miles.

Within two miles due north of the summit the flows interfinger with those of Howlock Mountain. The longest flows from Mt. Thielsen and Howlock Mountain are in a northwesterly direction from their summits; flows from Mt. Thielsen extend over 7 miles in that direction.

During the approximately 10 million years Mt. Thielsen was active, hundreds of flows issued from its summit and flanks. Most of the flows exposed on the upper slopes are between 5 and 10 feet thick, and slope outward from the summit at about 5°. When its full growth was attained, the lava cone of Mt. Thielsen stood between 6,000 and 7,000 feet above the old Cascade platform which, itself, was 3,000 to 4,000 feet above sea level. Hence, Mt. Thielsen rose ultimately to a height of 10,000 or more feet above sea level.

Near the end of the eruptive history of Mt. Thielsen the nature of material issuing from its

summit changed. The volcano became explosive and began throwing out fragments of solid rock, cinders, and pasty clots of magma. The crater at the summit measured about 1-1/2 miles in diameter and was several hundred feet deep. This crater was filled with cindery, fragmental material which eventually overlapped the limits of the crater. The cinder cone consists of yellow, grey, and brown tuffs containing numerous angular blocks of old lava which were torn loose from the throat of the volcano at depth and blown out the vent with the fresh cinders and lava. The cinder cone itself contains many tabular sheets of igneous rock which resulted from the injection and cooling of magma in the cinder beds. As explosive forces ripped through the cinder cone, numerous fractures developed in these beds. Molten lava from depth was forced into these fractures and congealed there, forming dikes. Most of these dikes are about 6 feet wide. Some of the lava squeezed through the fractures and flowed down the flanks of the cinder cone to form thin basalt flows.



Dikes in exposed cross-section of cinder beds on Mt. Thielsen.

The explosions which built the cinder cone alternated with periods of quiet inactivity during which gas pressure mounted in the magma chamber. The magma in the conduit above the magma chamber cooled and solidified during these periods of inactivity, only to be shattered and blown out when increasing gas pressure from below overcame the solidity of the plug of frozen lava in the throat of the volcano.

During the last stages of volcanic activity the magma in the conduit of Mt. Thielsen solidified partially or completely to form a plug. The pressure from below was great enough to force this plug upward as a solid or semi-solid mass, but did not fracture it or blow it from the conduit. As the plug rose through the cinder cone it dragged the adjacent cinder beds upward so they sloped steeply away from the plug. In some places the cinder beds are so deformed that they are vertical or slightly overturned next to the plug.

Another plug developed simultaneously and is exposed about one-half mile to the east of the one just described. The cinder beds adjacent to it dip sharply, like those surrounding the main plug. The cinder

cone atop Mt. Thielsen, therefore, was built around two closely spaced vents, both within the limits of the crater.

The plugs themselves consist of more-or-less vertical cylinders of dark grey to light grey lava. The outer margins of the plug are fine grained and dark colored, due to their more rapid cooling. The texture and color grade inward to a coarser grained and lighter grey lava in the central portion of the plug. This portion cooled more slowly; therefore, the crystals had time to grow larger and the gas contained in solution exsolved, producing a vesicular texture in the interior portion of the plug.

Also near the close of Mt. Thielsen's eruptive history, and perhaps even later than the

building of the cinder cone at its summit, two parasitic cinder cones developed near the base of the volcano. These are located to the south and southwest of the summit, and consist of fragmental lava, cinders, and scoria. The surfaces of these cones are now heavily timbered, making exposures of the rock scarce.

Summit Rock, an intrusive plug very similar to the plugs at the summit of Mt. Thielsen, lies at the base of Mt. Thielsen about 3-1/2 miles south of its crest. The dense lava making up this plug is suitable for use as road metal, and currently is quarried for that purpose. This rock is of interest to the mineral collector because it contains labradorite and pigeonite in the ground mass; also, small crystals of hematite, hypersthene, acmite, albite, apatite, cristobalite, and tridymite appear as incrustations lining small fractures and vesicles in the rock. Cristobalite and tridymite also are found in the plugs at the summit of Mt. Thielsen. The summit crater measures about a mile in diameter and contains an intrusive plug. The rock making up the plug is essentially identical to that making up the plugs on Mt. Thielsen. The diameter of the Howlock volcano is about the same as that of the Mt. Thielsen volcano, but the cone is about 1,000 feet lower. Like those of the Mt. Thielsen volcano, the longest Howlock lava flows merge with those from Mt. Thielsen along Thielsen Creek.

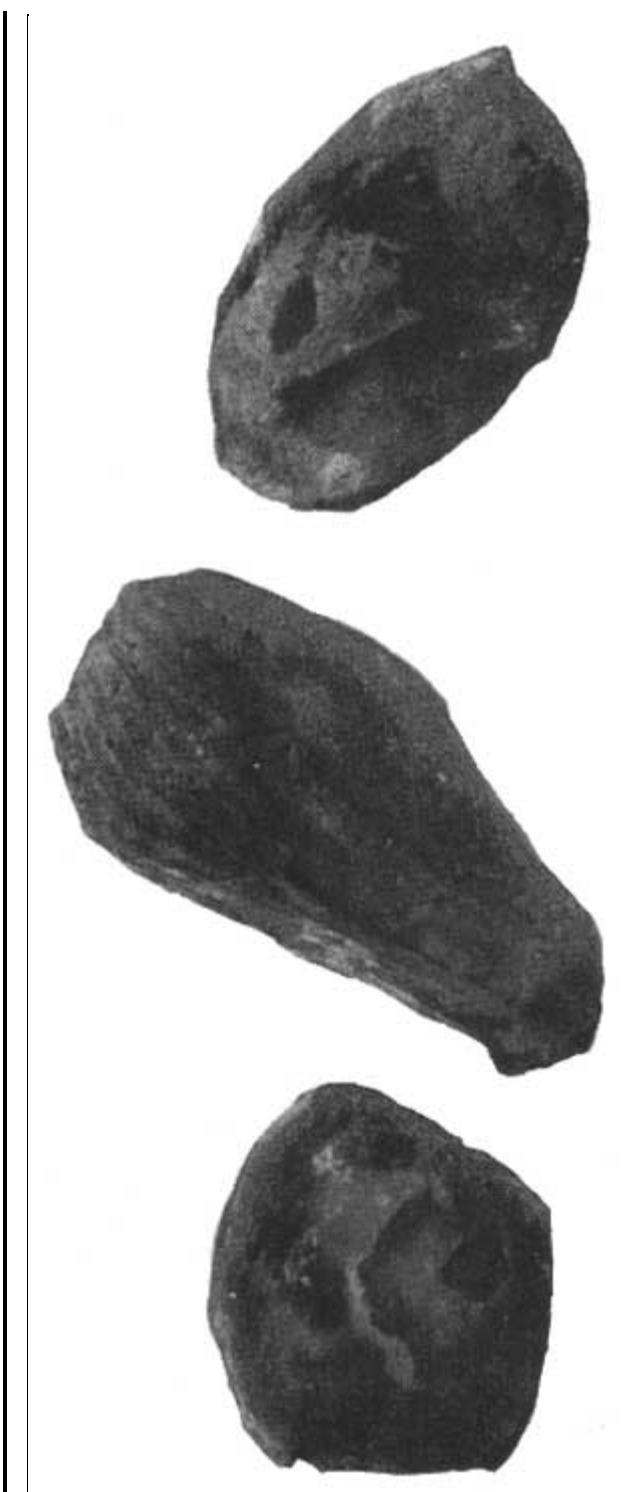


Cinder beds exposed in rock pit on Kelsay Point.

Several cinder cones are scattered over the slopes of Howlock Mountain. Tipsoo Peak, Red Cinder Butte, and Cinnamon Butte are the largest of these. Tipsoo Peak and Cinnamon Butte are breached cones. A portion of their flanks was blown out, giving an arcuate or crescentric form to the cones.

Cinnamon Butte, Kelsay Point, and other cinder cones in the Diamond Lake area are littered with volcanic bombs and fragments of bombs. These range in size from a few inches to a few feet across, and display fine grained rinds and bubbly, vesicular interiors.

The cinder beds at Kelsay Point have been well exposed by a quarrying operation. The beds at the summit of the cone dip northerly, indicating the vent lay somewhere to the south of the present summit. The cinder beds display well developed layering of coarser and finer fragments, and contain volcanic bombs and blocks up to several feet across. (The large, reddish bomb displayed on the porch of the Information Center at Diamond Lake was taken from the Kelsay Point cinder cone.)



Volcanic bombs taken from Cinnamon Butte.

The variance in the size of the cinders and fragments in given layers reflects the variation in intensity of the eruptions that blasted the material from the vent.

The Mt. Bailey volcano was built contemporaneously with Mt. Thielsen and Howlock Mountain. The lava flows from Mt. Bailey and Mt. Thielsen interfinger beneath Diamond Lake. The flows from Mt. Bailey extend some 6 or 7 miles northward from its summit, and there they are overlain by the younger, glowing-avalanche deposits which obscure the contact between the Mt. Bailey lavas and the intracanyon basalt flows. To the west and northwest of Mt. Bailey the lavas overlap the older Western Cascade lavas. About 2 miles to the south of the summit of Mt. Bailey, the Bailey lava flows merge with those of Twin Knobs and Sherwood Butte. These hills form a portion of a deeply dissected, basaltic lava cone. The flows making up Mt. Bailey are very similar to those making up Mt. Thielsen in that the later lavas are darker in color and more vesicular than the earlier flows. Mt. Bailey also is capped by a cinder cone, though it is much smaller than the one capping Mt. Thielsen. The cinder cone atop Mt. Bailey neither contains dikes, which are numerous in the Mt. Thielsen cone, nor does it contain a central plug, of which Mt.

Thielsen has two. At the south end of the main ridge crest leading to Mt. Bailey's summit is a small, subsidiary crater. The crater is well preserved, and evidently was formed near the cessation of volcanic activity. From the lip of the crater to its bottom is a vertical distance of 50 to 100 feet. The crater apparently contains some snow the year round.

When the Bailey volcano had attained its full height, it stood perhaps 1,000 or 2,000 feet lower than Mt. Thielsen. Like Mt. Thielsen, Mt. Bailey grew over a period of several million years and became inactive about one million years ago.





Arête divides two glacial cirques high on slopes of Mt. Thielsen.

About 3 miles down the north slope of Mt. Bailey are two parasitic cinder cones. The larger of these, Rodley Butte, has the typical crescentric shape of a breached cinder cone. Two and one-half miles southeast of the summit, near the base of Mt. Bailey, lies Hemlock Butte—a parasitic lava cone. The material extruded at this point was fluid, rather than fragmental, and resulted in a small volcano perched on the lower slopes of Mt. Bailey.

Kelsay Mountain is another High Cascade volcano that grew in the Diamond Lake area during the Pliocene Period. Numerous cinder cones also grew during this period, and these include Red Cinder Butte, Thirsty Point, Tenas Peak, and Windigo Butte.

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The Geologic History of the Diamond Lake Area



GEOLOGIC HISTORY OF THE DIAMOND LAKE AREA *(continued)*

THE ERUPTION OF MT. MAZAMA

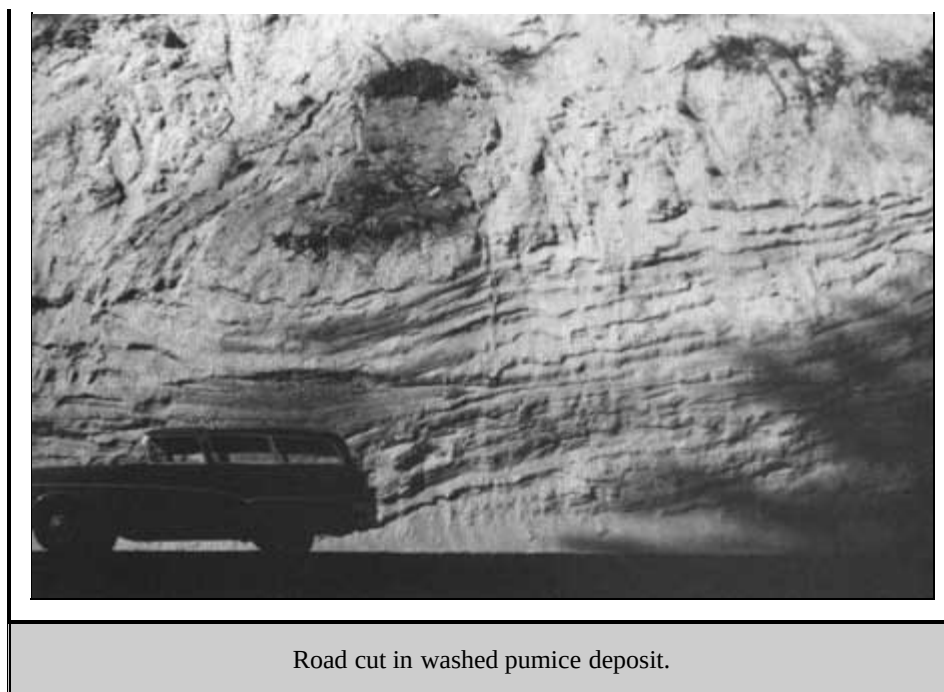
From the close of the Pleistocene, some 10,000 years ago, to the present, the geologic history of the Diamond Lake area has been dominated by Mt. Mazama. Mt. Mazama is the name given to the vanished mountain peak whose collapse created the caldera now occupied by Crater Lake some 15 miles to the south of Diamond Lake. The major growth of Mt. Mazama was accomplished during the Pleistocene; and the volcano remained active until a few thousand years ago. After the ice receded, Mt. Mazama's smoking summit stood an estimated 12,000 to 14,000 feet above sea level.

A few thousand years ago Mt. Mazama began to erupt volcanic ash and pumice. At first the eruptions were weak and irregularly spaced, but they gradually increased in intensity and frequency. For a period of several weeks these eruptions continued. Pumice fragments ranging in size from fine dust to several inches in diameter were hurled from the vent. At the time of these eruptions the prevailing wind was toward the northeast. The pumice was light enough to be blown in that direction. The coarser fragments fell on the slopes of the volcano while the finer material was carried farther by the winds. In the Diamond Lake area the pumice fragments are mostly between 1 and 4 inches in diameter. Farther to the northeast, the material becomes progressively finer.

As the pumice fragments become smaller away from their source the thickness of the deposit diminishes. The thickness of the pumice blanket has been mapped by the use of isopach lines, which are lines representing equal thickness of the deposit. At every point beneath the 5-foot isopach, for example, the pumice is 5 feet thick.

After the pumice eruptions, which probably lasted for several weeks, the landscape around Mt. Mazama must have presented a grim appearance. The pumice covered the land like a blanket of dirty snow. Heat from the frothy glass killed the vegetation for miles around Mt. Mazama and produced a desolate wasteland.





The pumice accumulated to a depth of 5 feet in the immediate vicinity of Diamond Lake, Cinnamon Butte, Kelsay Point, and Windigo Pass. To the north and west the deposit becomes progressively thinner, and has a thickness of only 6 inches in the Fish Creek Desert and Toketee Falls areas. The 6-inch isopach line extends northeast to the vicinity of Bend, Oregon, some 70 miles from Mt. Mazama.

When the eruptions of pumice ceased, Mt. Mazama was silent for a period. Later, a few spurts of steam and pumice spouting from the vent signaled renewed activity. The eruptions rapidly increased in intensity; then came a series of stupendous explosions that must have been audible for hundreds of miles. A foamy mass of incandescent pumice and hot gas bubbled over the lip of the crater. Unable to overcome the force of gravity as had the earlier, less voluminous eruptions of pumice, the foamy mass rushed down into the valleys surrounding the volcano, with velocities approaching 100 miles per hour. This rushing cloud of frothy, glowing, pumice fragments and rapidly expanding gases—a glowing avalanche—enveloped the countryside.

The high content of hot gas gave the glowing avalanche extreme mobility. A portion of the gas and pumice that boiled over the lip of the volcano rushed down the Rogue River valley a distance of 35 miles; some flowed to the northeast as far as Chemult, 25 miles distant; and part of it flowed across the low saddle to the north of Mt. Mazama and rushed on toward Diamond Lake. The topography to the north of the saddle channeled the avalanche toward the south end of Diamond Lake. Somehow, the glowing avalanche passed over the surface of Diamond Lake, was funneled through the gap at the northwest corner of the lake, and continued down Lake Creek. Wells dug near the summer homes on the west side of Diamond Lake reveal the glowing-avalanche deposits in that area are between 25 and 30 feet thick. The avalanche flowed down Lake Creek as far as its confluence with the North Umpqua River. This is the present site of Lemolo Lake. Part of the material was diverted westward across Toolbox Meadows and continued down the drainage of Lava Creek and the Clearwater River. This fork of the avalanche came to rest about halfway between the Lake Creek drainage and Toketee Ranger Station.

It is not clear just how a glowing mass of pumice and gas could pass over the surface of a body of water such as Diamond Lake; but the evidence is clear—the amount of avalanche material exposed below Diamond Lake is sufficient to fill the lake, perhaps many times over.

Two theories have been advanced, seeking to explain how this might have happened. One geologist has suggested that the first wave of pumice would have floated on the surface of the lake, providing a carpet across which successive waves flowed. The pumice is light enough to float on water; and the theory is plausible.

Another theory asserts the avalanche occurred during the winter when the lake was frozen. The rushing mass of hot gas and pumice presumably flowed over the ice, which was insulated from the intense heat by the 5-foot layer of airborne pumice that preceeded it. Adding strength to this theory is the fact that the winter winds in the Diamond Lake area blow toward the northeast, which is precisely the direction they must have been blowing at the time the airborne pumice was erupted from Mt. Mazama. As stated earlier, the airborne pumice stretches toward the northeast from Crater Lake. This theory, too, then, offers a possible answer to the puzzle.

The pumice of the glowing-avalanche deposit is easily distinguished from that which earlier fell from the air. Whereas the airborne pumice is well sorted (i.e., all the particles are approximately the same size at a given point), the avalanche material consists of lumps of pumice of varying size, set in a matrix of very fine, dust-like pumice fragments. Some of the largest lumps of pumice have been found at the extreme limits of the avalanche deposits. The airborne pumice is a yellowish tan color; the avalanche pumice is usually pinkish tan. The pink coloration is the result of stains from the iron-bearing gases that it retained after coming to rest. As the glowing avalanche rushed down the stream drainage, it encountered thick forests, though timberline was then at a lower elevation than at present. The force of the avalanche bowled over even the largest trees and swept them along in the turbulent cloud. As the avalanche came to rest, the buried trees were carbonized by the intense heat retained by the pumice fragments and gases. Lumps of charcoal are found scattered through the deposit, and are exposed in road cuts near Clearwater Falls, Lemolo Lake, and White Horse Falls. This charcoal has been identified as remnants of pine and fir trees like those presently growing in the area.



Road cut exposing charcoal logs in washed pumice deposit

Because the airborne pumice deposits and the glowing-avalanche deposits consist of soft, uncemented particles they are rapidly eroded and washed away by streams. Much of the material has been washed down the North Umpqua and Clearwater Rivers and has been redeposited in stratiform layers. Banks of washed pumice up to 100 feet thick are exposed in road cuts along the North Umpqua Highway west of Toketee Falls. A well dug at the Toketee Ranger Station cut through approximately 75 feet of this material. The washed pumice also contains charcoal fragments.

These are abundant in several exposures, including those at Toketee Ranger Station and Slide Creek.

Radiocarbon dating has been performed on several charcoal specimens from the glowing avalanche deposit, though none of these was from the Diamond Lake area. The most reliable date yet obtained is 6,640 years $\pm$ 250 years B. P.¹ This means the showers of pumice which fell on the Diamond Lake area, and the avalanche of scorching pumice which plunged rapidly down the drainages in the area, occurred about 6,640 years ago.

¹Before Present

There is evidence that man watched the fiery holocaust in the area—at least from a distance. Charred Indian sandals have been found beneath the airborne pumice deposit near Paisley, some 80 miles east of the Crater Lake region. It is likely that some forest animals were trapped by the speeding glowing avalanche, but no remains have yet been uncovered in the Diamond Lake area.

Each day the streams remove a little more of the veiling mantle; and each new road cut exposes some new facet of the hidden past. The somber peaks and crystalline waters of the Diamond Lake area continue to reveal secrets jealously kept since their cataclysmic, formative days.

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The Geologic History of the Diamond Lake Area



GEOLOGIC HISTORY OF THE DIAMOND LAKE AREA *(continued)*

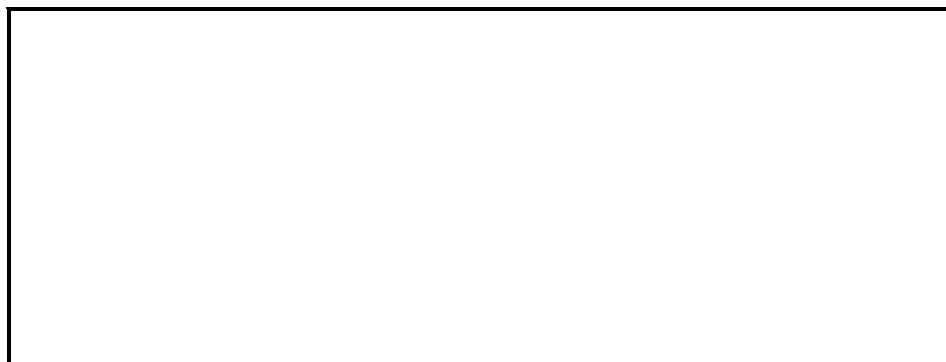
GLACIATION OF THE ICE AGE

Approximately one million years ago, at the close of the Pliocene, the Great Ice Age descended on the area. The alternate advances and retreats of ice and snow lasted until a scant 10,000 years ago.

As the Ice Age crept upon the area, the winter snows high on the slopes of Mt. Bailey and Mt. Thielsen remained a little longer each spring. The climate grew gradually cooler, and soon the snows did not melt during the summer, but remained to be buried by the next winter's snows. In this manner, ice and snow began to accumulate on the higher peaks in the Diamond Lake area. The weight of new snow compacted the old, producing dense granular, glacier ice. The dense ice flowed imperceptibly down the flanks of the mountains—the glaciers were advancing over the landscape.

The volcanic peaks in the Diamond Lake area became inactive about the time glaciers began to form on them. The peaks were thus unable to resist the attack of glacial erosion. Younger High Cascade peaks, such as Mt. Mazama some 15 miles to the south of Mt. Bailey and Mt. Thielsen, continued to expel lavas and grow in stature, despite the erosive effects of the glaciers. Striations left on the rocks high on Mt. Mazama indicate glaciers once crept down the sides of the mountain. The striated lavas are overlapped by younger flows, indicating the volcano continued to spew out lava throughout and after the period of glaciation. Mt. Mazama retained its conical form despite extensive glaciation.

Meanwhile, the glaciers began to gouge at the sides of the extinct volcanoes in the Diamond Lake area. Glaciers crept radially away from the higher peaks such as Mt. Bailey, Mt. Thielsen, and Howlock Mountain. The flanks of the defenseless mountains were hollowed out in great scoops, forming cirques. The ice creeping down the east slope of Mt. Bailey merged with the glaciers flowing down the west slope of Mt. Thielsen. These were joined from the south by a large glacier whose head was high on Mt. Mazama. The entire area now occupied by Diamond Lake, the lower slopes of Mt. Bailey and Mt. Thielsen, and the area to the south of Diamond Lake were covered by a vast ice field.





Diamond Lake and Mt. Bailey as seen from Mt. Thielsen.

Several times during the Pleistocene the ice advanced and, by melting, retreated. Each time the ice melted, the ground-up rock powder it contained was washed downstream and deposited in layers or beds. These beds of glacial clay are impervious to water. As water from rain and melting snow percolates down through the younger soil and rocks above, and encounters the clay bed, it is unable to penetrate the clay layer and so moves downslope along the top of it. If the clay layer intersects the surface, the water seeps out at that point to form a spring. The numerous springs east of Lemolo Lake, including Crystal Springs and those feeding Spring River, originate in this manner.

The last advance of the glaciers was the most extensive. As the ice covering the valley between Mt. Bailey and Mt. Thielsen melted, it left behind a shallow lake. Diamond Lake measures about 3 miles by 1-3/4 miles, but is only slightly more than 50 feet deep. Melting glaciers furnished the water. The toe of a lava flow from Mt. Thielsen provided a low dam across the north end of the lake. The shallowness of the lake is governed by the elevation of its outlet, Lake Creek, which drains Diamond Lake at its northwest corner.

After the last attack of the glaciers had subsided, the high peaks in the Diamond Lake area had changed shape. Mt. Bailey was no longer a symmetrical cone, but contained large cirques which exposed the layers of lava and cinders that the volcano had extruded near its summit. This mountain, however, was not as severely carved as Mt. Thielsen, which was initially much higher than Mt. Bailey. Glaciers had sculpted the top of Mt. Thielsen from all sides, producing a series of cirques whose edges widened until they met, thus forming long, sharp ridges extending radially from the mountain tops. These ridges are called arêtes. The soft cinder beds were more

easily glaciated than the dense plugs occupying the vents of the volcano. The cirques that developed about the western plug left it standing steeply above the ridges and cirques below as a sharp pinnacle, or matterhorn. This spire is between 100 and 200 feet high and has given rise to the nickname which is applied to Mt. Thielsen, "The Matterhorn of the Cascades".

Mt. Thielsen also is called "The Lightning Rod of the Cascades", and with good reason. This peak is frequently struck by lightning, resulting in the creation of a geological oddity—fulgurites.



Lightning strikes tip of Mt. Thielsen during night storm.

The name fulgurite is derived from the Latin for thunderbolt. Fulgurites are blebs, coatings, or tubes of bubbly glass, formed by the instantaneous fusion of rocks or sand when struck by lightning. The intense heat fuses the rock to a bubbly glass devoid of even the smallest crystals which generally are present in glassy volcanic rocks.

The fulgurites on Mt. Thielsen are splotches, or bubbly coatings, of brownish-green glass which resemble drops of paint spattered on a greasy surface. Occasionally the fulgurite takes the form of a glass-lined hole in the rock, less than an inch in diameter and tapering several inches into the interior of the rock. Such carrot-shaped forms are called "lightning tubes". The great majority of the fulgurites on Mt. Thielsen are confined to the uppermost 5 or 10 feet of the summit. Obviously, the top of Mt. Thielsen is an imprudent spot to select for sitting out a thunderstorm!

Fulgurites have been reported atop other sharp Cascade peaks, notably Union Peak.

Other peaks in the Diamond Lake area are more-or-less glacially carved, depending primarily upon their elevation. The size and thickness of glaciers on the lower peaks was insufficient to produce extensive glaciation.

The last melting of the glaciers, which occurred about 10,000 years ago, littered the slopes of the mountains with rock material varying in size from large boulders to fine dust. This

material had been frozen in the glacier, and simply was dumped on the ground when the ice melted. Forests have re-established themselves on the mountain slopes, and at present the heavy forests and glacial debris obscure most of the lava flows on the lower slopes of the volcanoes in the Diamond Lake area.

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The Geologic History of the Diamond Lake Area



GEOLOGIC HISTORY OF THE DIAMOND LAKE AREA *(continued)*

THE INTRACANYON BASALTS

Some time after the growth of Pig Iron Mountain and Watson Butte (which began about 12 million years ago), and the retreat of the last glaciers (which occurred at least 10,000 years ago), lava flows unlike any others in the area poured out of the earth's crust several miles to the north of Diamond Lake. These are the intracanyon basalts of the Clearwater and North Umpqua drainages.

The flows consist of dense, light grey, olivine basalt. The lava welled up from a fissure east of the Pig Iron Mountain — Watson Butte — Elephant Mountain mass. Elbow Butte possibly was the vent from which it issued. The molten lava was extremely fluid and flowed out in copious sheets that rushed away from the vent like thin mud. Some of the material rolled up the drainage of the North Umpqua River almost 3 miles to the base of Kelsay Point, but the bulk of the flows rushed down the valley of the North Umpqua and circled the north boundary of the Pig Iron Mountain — Watson Butte — Elephant Mountain Mass. A portion flowed down the Clearwater River drainage to the south of the mountain mass and rejoined the flows circling the mass to the north. From this point the lava continued down the drainage of the North Umpqua River for several miles.

The edges of the intracanyon flows chilled to jagged, clinkery blocks as the bulk of the lava flowed on. This blocky lava may be seen along the North Umpqua Highway in the vicinity of Lava Creek and Clearwater Falls. At the latter place, the Clearwater River tumbles over the moss-covered, jagged blocks creating one of the most scenic spots in the Umpqua National Forest.

The valleys surrounding the Pig Iron Mountain — Watson Butte — Elephant Mountain Mass, previously eroded by streams, were now partially filled by these lava flows, giving them flat floors. These flows produced the broad level areas such as Thorn Prairie to the north of the mountain mass; and Mowich Park, Toolbox Meadows, and Fish Creek Desert to the south of it.





Toketee Falls cascades over columnar jointing of intracanyon basalts.

The sudden alteration of the configuration of the stream valleys disrupted the drainage pattern in the area. The streams draining the surrounding mountain mass now abruptly disgorged onto the broad valley floor instead of continuing down their old water courses to the bottom of a deep canyon. These streams hugged the contact between the old mountain mass and the fresh lava beds, and flowed westward along this contact. Since the flows filled the North Umpqua and Clearwater valleys, the subsequent stream erosion along Clearwater River and Mowich Creek to the south of the mass, and along Loafer Creek to the north of it, has carved new, narrow canyons as much as several hundred feet deep along these contacts. The waters of the North Umpqua River were diverted along the contact at the northern edge of the flows between the intracanyon basalt and the High Cascade and Western Cascade rocks.

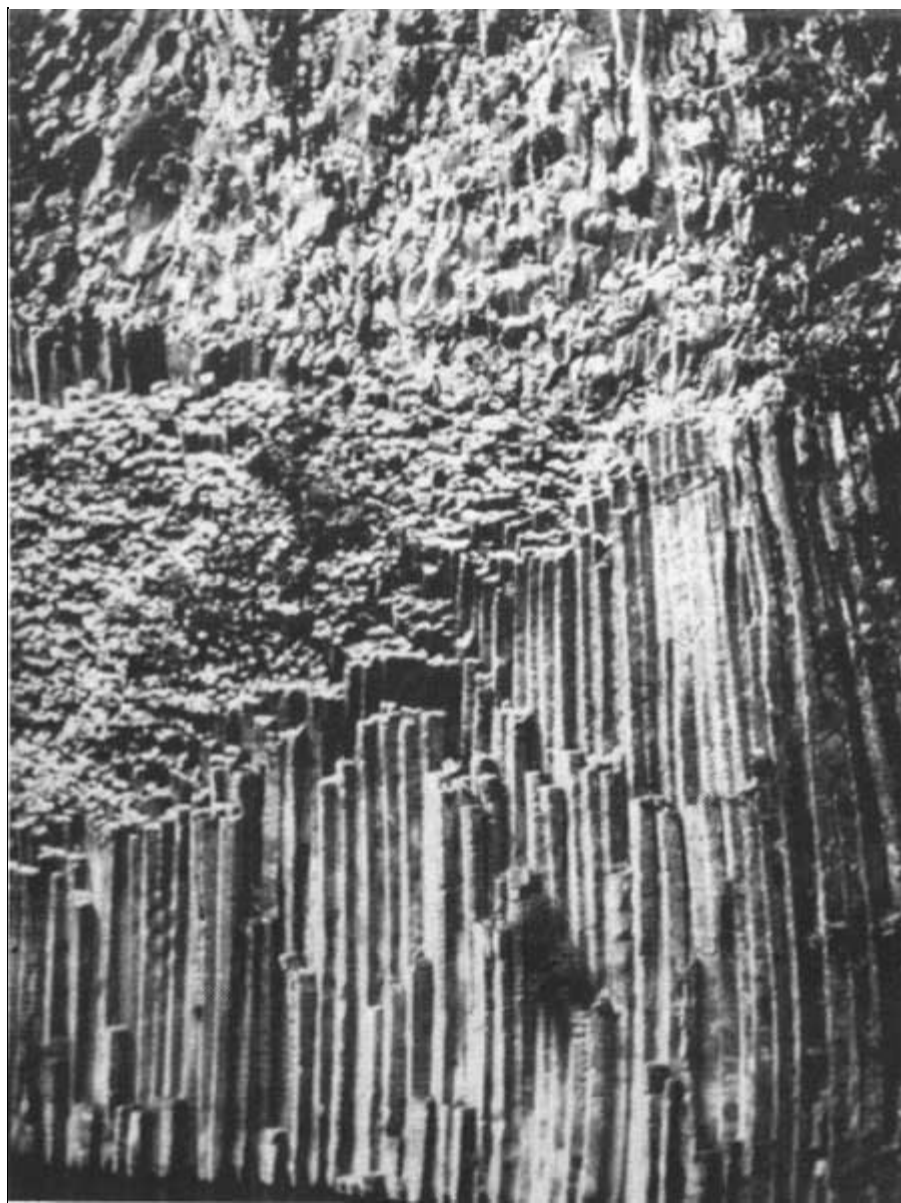
The tributaries of the Clearwater River which drain the area south of Mowich Park and southeast of Fish Creek Desert flow directly across the flat top of the intracanyon basalts and plunge abruptly into the steep canyon of the Clearwater River. Because the erosive power of these streams is less than that of the larger river, they have cut into the rocks much less, and upon reaching the deeper canyon tumble sharply into it. Watson Falls, almost 300 feet high, is formed where Watson Creek drops from its shallow stream channel over the lip of the

Clearwater River Canyon.

Fish Creek, which skirts the Fish Creek Desert on the south, flows along the boundary between the intracanyon flows and the older rocks to the south. It appears that the major streams existing at the time the intracanyon flows filled the canyons were diverted along the margins of these flows; and the smaller streams which developed subsequent to the lava flows wander over the surface of the intracanyon lavas.



Columnar jointing on Pig Iron Mountain.



Columnar jointing near Soda Springs.

A very pronounced aspect of the intracanyon flows is the prominent development of columnar jointing. Most of the columns are vertical, and range up to 50 feet in height and 2 to 3 feet in diameter. The columnar jointing is particularly well exposed at Soda Springs, about 5 miles west of Toketee Ranger Station.

This jointing, in large part, is responsible for the development of waterfalls such as Toketee Falls, Slide Creek Falls, and Watson Falls. As the rock weathers the columns tend to collapse, leaving sheer vertical walls. The height of the waterfalls plunging over these walls is dependent upon the height of the columns; the height of the columns, in turn, is dependent upon the thickness of the flow in which they formed. The lofty spires standing erect between the canyon walls along the North Umpqua River between Eagle Rock and Toketee Reservoir were formed in the same manner.

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