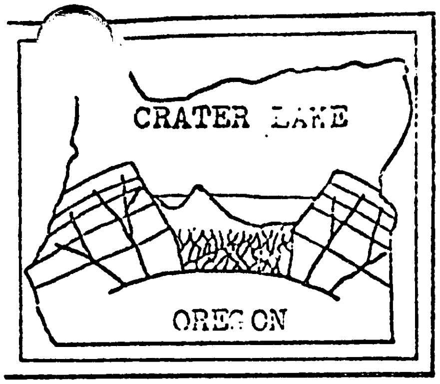

CRATER LAKE NATIONAL PARK -- GEOLOGIC SYNOPSIS

PREPAIRED FOR THE NATIONAL PARK SERVICE BY

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Seasonal Park Naturalist

General Volcanology

A volcano is a conduit or vent which issues magma (molten rock.), pyroclastics and gases which are derived from a magma chamber situated within the earth's crust. As the magma cools and solidifies, igneous rocks (from latin; igne= fire) are formed.

Recently, the theory of new global plate tectonics has been widely accepted by geologists and geophysicists as an explanation of continental drift and volcanic occurances throughout the world. Basical- the continents are floating about as six crustal plates on the earth. Occasionally in geologic time, oceanic plates underthrust the continental plates producing a deep sea trench, a subcontinental zone of deep earthquakes, surficial uplift, deformation and volcanism. These occurrences now seem certain to be happening along the western coast of South America near Chile and Peru, creating the Andes Mountains.

The relationship between plate tectonics and the Cascade Mountains is more complex and ambiguous. It has been postulated that plate underthrusting has occured in geologic time to develop the Cascades. However, since the Cascades are dormant and the deep sea trench, common to other parts of the Pacific, is lacking, combined with uncertain characteristic zones of seismic occurrences under the continental margin, the plate tectonics theory can be challenged regarding its validity a force responsible for the development of the Cascade Mountains.

The basin in which Crater Lake is situated . is known as a lcra. The Dictionary of Geological Terms prepared by the American Geological institute defines a caldera as "a large basin-shaped volcanic depression, more or less circular or cirquelike in form, the diameter of which is many times greater than that of the included volcanic vent or vents, no matter what the steepness of the walls or form of the floor." Hans Rick developed a classification scheme contrasting the differences between calderas and craters. His major points are:

[illegible] Also Classification of volcanic eruption and type the [illegible] on page 6 — [illegible]

1. All calderas are related to volcanic topography.
   Many craters are not related to volcanic topography.

2. Craters are inseparably related to conduits.
   Calderas are related to the roof of the reservoir.

OVER!

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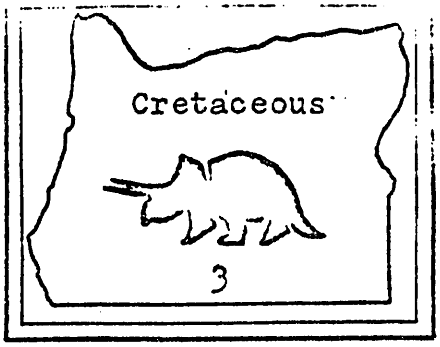
3. Craters are the eruption vents
   Calderas are never entirely eruption vents.

4. Craters are the vents through which ejecta passes. They are positive active volcanic forms.
   Calderas are the result of change in state or volume within the underlying reservoirs. They are negative, passive forms.

5. Craters occur during the active, growing periods of volcanoes.
   Calderas-are marks of decandence and age, although caldera formation may be followed by renewal of activity.



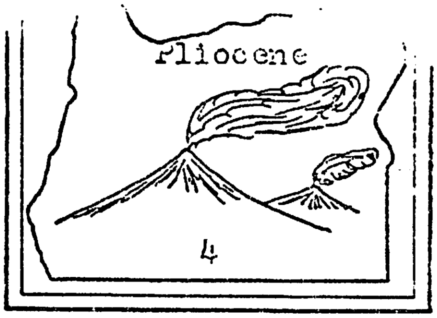
within the earth's crust is therefore classified as a magma chamber. When magma is formed near the earth's crust it tends to rise to the surface due to the self contained gases. However, throughout geologic time the ultimate source of crustal magmas has been from deep levels in the earth's mantle.

Two principle types of igneous rocks exist. First, intrusive igneous rocks are those which did not reach the earths surface and hence, crystallized at depth in the magma chamber. Extrusive igneous rocks is the second classification of igneous rocks. They are derived from magmas or magmatic materials which have reached the earth's surface and are subsequently ejected or poured out in a molten or partly molten condition.

VOLCANIC ERUPTIONS

As the magma rises some of its constituents and the rocks that it penetrates are vaporized into gases by the tremendous temperatures and pressures associated with this geological occurrence. These volatile components are extremely important in the subsequent igneous activity.

The principle volatile component and agent in producing a volcanic eruption is water. Water separates from other magmatic components and migrates to the top of the magma reservoir as the magma nears the earth's surface. The water is vaporized into steam and accumulation occurs if the volcanic vent is blocked. This produces tremendous pressures which eventually must be released. If the temperature is 1800° F or greater, the steam expands several thousandfold as it escapes shattering the rock which sealed the vent, causing magma and steam to be expelled into the air. After this explosion, the magma contains less water but it is still capable of pouring out of the vent. Highly viscous magma forms when the magma is virtually devoid of water.



In time, water will again begin to accumulate as steam and another eruption ensues.

The principle gas associated with volcanic eruptions is steam. Water vapor is generally more than 95 percent of the total discharge, seldom less than 82 percent. The second most abundant gas is carbon dioxide (CO_2) followed by nitrogen (N), sulfur (S), carbon monoxide (CO_3) and chlorine (Cl.) The typical odor of "rotten eggs" emitting form volcanoes during their eruptions can be attributed to sulfurous gases such as hydrogen sulfied (H_2S).

MATERIALS ERUPTED

Various types of materials are erupted from volcanoes. These variations are a result of magmatic segregation in the magma chamber. As crystalization occurs in the cooling magma chamber, the minerals poor in silica and rich in iron, calcium and magnesium are first to develop. Later in the cooling process, the minerals richer in silica and potassium crystalize.

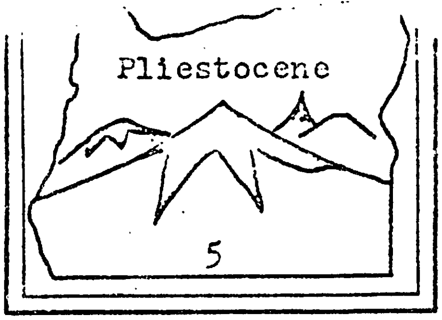
Hence, the magma chamber has three basic layers of liquid rock materials due to different densities of these materials. These layers are:

1. Top layer - lighter, silica-rich residual
2. Middle layer - intermediate minerals
3. Bottom layer -- heavier crystals, rich in iron, magnesium and calcium.

Fissure eruptions can tap any one of these layers and eruptions can develop at any time during the cooling process.

PYROCLASTIC DEBRIS

Pyroclastic debris (pyroclastic means "broken by fire") are rock fragments that have been blown out of a volcano and deposited on the ground. These materials are named according to their size, texture and composition. The following nomenclature applies to materials



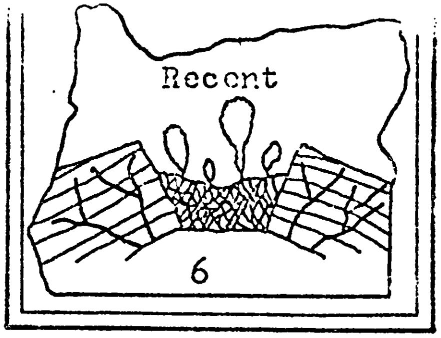
1. Dust: finest pyroclastic debris, comprised of pieces of rock on the order of one ten-thousandth of an inch in diameter.
2. Ash: finer cinders
3. Volcanic Tuff: fine sized material smaller than peas, including dust and ash, when compacted together form volcanic tuff.
4. Blocks: Pieces of the cone or angular masses broken away from the rock that blocks the vent. When blocks are compacted together they form volcanic breccia.
5. Bombs: rounded masses that congeal from magma as it travels through the air.
6. Cinders: small, slaglike, solidified pieces of magma or broken pieces of the cone or plug two-tenths to one inch across.
7. Pumice: pieces of magma up to several inches across that have trapped bubbles of steam or other gases as they were thrown out. After these solidify, they are honecombed with gas-bubble holes that give them enough bouyancy to float on water.

LAVAS

Lava is a term applied to all volcanic material, either liquid or solid, which has reached the earth's surface. They are classified according to composition and textural character, such as percentage and size of gas cavities, amount of crystallization, and selective size of crystals. However, composition is the primary criteria for the classification of lava. It also determines most characteristics of the lava flows. Lava can be classified according to the following information:

1. Basalts: Lavas poor in silica and rich in calcium, iron, and magnesium and are fine grained and dark in color. Generally, basalts are between 1800°-2200° F and are not very viscous. Hence, basalts are able to flow at greater speeds and distances which results in the formation of thin layers of lava.
2. Dacite: Lavas rich in silica and poor in calcium, iron and magnesium are refered to as dacites. Generally, dacite is a viscous lava which forms thick layers of lava and tends to travel short distances from the vent. An excellent outcropping of glassy dacite can be found on Llao Rock.
3. Andesites: An igneous rock of intermediate composition between basalt and dacite. It received it's name because these rocks were first identified in the Andes Mountains in South America. A large percentage of the rocks in the park are andesites.
4. Obsidian: Volcanic glass high in silicates formed by supercooling molten lava.
5. Scoria: It is a highly viscular, frothy, dark colored ejecta, less siliceous and more dense than pumice.
6. Pahoehoe lavas: Hawaiian term for a surface flow which appears ropy or as cordlike corrugations.

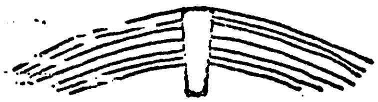
7. Aa Lava: Another Hawaiian term for a surface flow which is characteristically rough, clinkery or blocky. It is formed by the hardening of the surface of the lava flow while the interior remains molten. As the molten rock continues to flow the hardened exterior breaks off into large blocks and chunks.



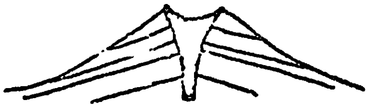
8. Nuée Ardente: (French for fiery clouds) A high velocity (sometimes greater than 100 mph) lava flow of hot, incandescent ash which avalanches down the volcano, irregardless of the incline, by virtue of its extreme mobility.

CLASSIFICATION OF VOLCANIC ERUPTIONS

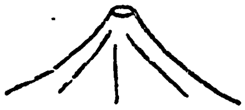
Volcanoes are classified according to the materials which accumulate around the conduit. Therefore, the following list has been developed as a classification scheme for volcanic eruptions:



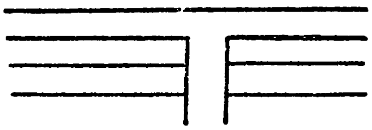
1. Shield Volcanoes: Hawaiian type eruption, relatively quiet; a broad gently sloping volcanic cone of flat domical shape. Examples are Mauna Loa and Kilauea in Hawaii and local examples are Timber Crater and Mt. Thielsen.



2. Composite Volcanoes: (Syn: Strato-volcano) A large volcanic cone built of alternating layers of lava and pyroclastic material. Examples are Mt. Shasta (California), Mt. Rainier (Washington) and a local example is Mt. Mazama.



3. Cinder Cone (Syn: Ash cone): A conically steep shaped cone formed by the accumulation of volcanic ash or clinkerlike material around a conduit. A local example is Wizard Island.



4. Fissure Flow: Lavas escape from fissures rather than from central vents. More copious flows do not produce volcanoes but rather large, level plateaus such as the Columbia River Basalts in the Pacific Northwest.

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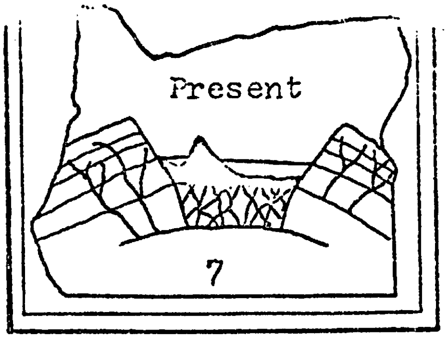
SUMMARY

Thus, volcanic landscapes have evolved throughout geologic time. The dynamic earth creates pools of magma which are brought to the earth's surface by various gases. The ensuing eruption creates deposits of extrusive igneous rocks composed of various constituents and size categories. The final product is that which we presently see, the volcanic landform.



GEOLOGY OF CRATER LAKE NATIONAL PARK

Setting

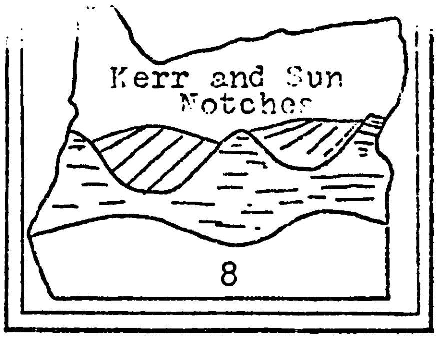
Throughout the Pacific Northwest a chain of mountains exist which are known as the Cascade Mountains. The Cascades are comprised of two distinct mountain provinces. The first is known as the Western Cascades. They are located west of the park and are older in geologic age (Eocene to Upper Miocene basic volcanics,) as well as being wider and havingless physical relief. According to the Davis approach to landform classification, these mountains are submature to mature, with the original volcanic structures well disected by stream erosion.

The second mountain province in the Cascade system is the High Cascades, a part of the Pacific "Ring of Fire." These mountains stretch from Mt. Baker, in Washington, to Lassen Peak in Northern California. This belt of mountains is between 20 to 25 miles in width and is composed of Pliocene and younger volcanoes. Davises landform classification groups these mountains in a youthful topography category. Crater Lake National Park is situated in this province of mountains.

To the east of the Cascade Range the Columbia River Basalts are located. This lava plateau is composed of many layers of Miocene basalts. These basalts covered from 200,000 to 300,000 square miles of the Pacific Northwest and are up to 10,000 feet in thickness. Beneath the High Cascades, the lavas of the Columbia River Basalt plateau interfinger with lavas of the Western Cascades.

PRE-MAZAMA LAVAS

Prior to the development of Mt. Mazama (during the lower Eocene to upper Miocene epochs) vulcanism occurred throughout the area. To the south of the locale where Mt. Mazama eventually erupted a shield volcano developed. Named Union Peak by the Chauncey Nye party (because of



of fluid lavas. Subsequent to this development, cinder cones formed on the broad flanks of Union Peak while a summit cone was formed by explosive eruptions from the central conduit. Eventually, a very viscous mass of lava congealed in the central vent terminating the volcanic activity of Union Peak. Today, Union Peak appears as a matterhorn due to glaciation of the peak during the Pleistocene epoch of geologic time.

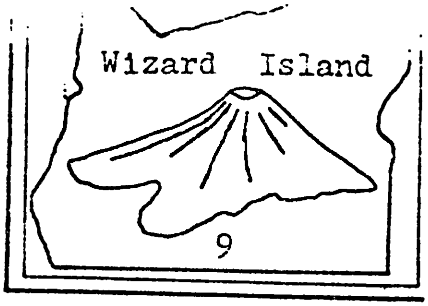
During the late Pliocene other pre-mazama lavas were erupted in the northwest corner of the park. Most of these eruptions were quiet flows of basic lavas while pyroclastic explosions were almost completely absent. Many of these happenings can be attributed to the occurrences associated with the development of Desert Ridge.

MAZAMA ERUPTS

Mount Mazama developed in a depression between Union Peak, to the south, and other volcanic cones to the north. The oldest visible Mazama lavas were issued from a vent near the Phantom Ship. This vent is known as the Phantom Vent and can be seen at the lake level as a dark triangular area on the caldera wall directly across from the Phantom Ship. The Phantom Vent was the main conduit for the Phantom Cone which was engulfed by later Mazama lavas. Today, the Phantom Ship is a dike of that cone and it can be seen from the Rim area at many view points.

The early cone of Mt. Mazama grew principally by effusions of hypersthene andesite from summit vents. As Mt. Mazama developed, the lavas became more viscous. The thickest flows were issued just prior to the comencement of the andesitic period. These include:

1. Palisades and Roundtop flows: resting on glacial deposits, these were the thickest flows reaching a mazimum thickness of 500 feet. However, these were derived from fissures further down the flanks of Mazama rather than from summit vents.



2. [illegible]side Point flows: also located on top of glacial deposits and they were issued from fissure flows.

3. Grotto Cove, Watchman and Sentinel Points: all of these have some thick flows of andesitic lava from recent eruptions.

These thick fissure flows were responsible for widening the base of Mt. Mazama and did not add to the height of the mountain.

Minor explosive, intermittent eruptions occurred throughout the growth of the main cone. These eruptions were composed primarily of angular blocks and ash indicating low temperature eruptions. Today, as a result of this activity, impressive pyroclastic debris can be found on the cliffs below Sinnott Memorial, Garfield Peak, Eagle Crags and Dutton Cliff.

Presently, the caldera wall displays vivid colors produced by solfataric action. The rising gases and solutions from Mt. Mazama altere the lavas to soft masses of brown material composed mainly of kaoline and opal which were stained by iron oxide. In other colorful places the coloration was produced by the chemical alteration of the rocks.

Summit vents issued most of Mazama's andesites. However, Mazama was not a single symmetrical cone since the dips of the lavas indicate an eccentric position of the primary vents. Angular unconformities in the caldera walls are a result of shifting or simultaneous activity of several vents. Hence, Mt. Mazama was a series of overlapping composite cones. The main vents are presently located one-half to one mile south or southeast of the present center of Crater Lake.

After Mazama had developed into a major volcano its flanks were fractured by radial fissures which formed dikes. This occurrance is common in older volcanoes and is produced by; 1) weight of the lava in the central conduit; or 2) increased pressure of magma in the magma chamber causing doming of the volcano. Today, sixteen dikes are visible on the

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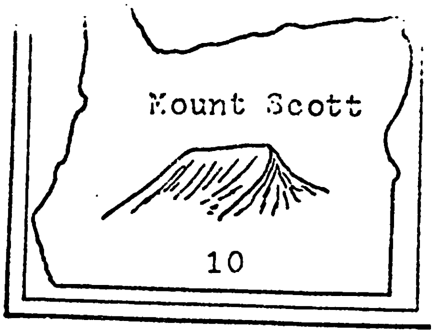


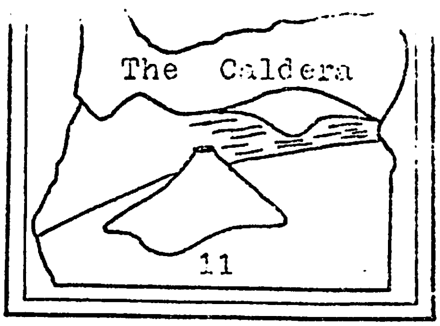
Wh[illegible]. Mazama had nearly reached its maximum height, the center of volcanic activity moved from the summit of the volcano to the northern side. This norhtward shift of vents can be attributed to; 1) northward enlargement of the magma chamber; 2) a result of internal assemilation of the cone; or 3) as a consequence of ring fracture stopping (the most likely explanation.) Thus, a semi-circular arc of vents opened along the northern wall approximately 5000 feet below the original summit. These vents include:

1. Watchman Dike and flow: one of the earliest occurrences composed of andesite.
2. Hillman Peak: the highest point above the lake level consisting of andesite.
3. Sentinel Rock flow and vent: andesite.
4. Llao Rock: a thick dacite flow which occupied an old glacial vall
5. Grouse Hill dome and flow: dacite.
6. Cleetwood flow: an inclined dacite feeder vent.
7. Redcloud and Cloudcap: dacites.

Contemporary with the development of parasitic cones another eruption occured to the north of Mt. Mazama forming Timber Crater. It is composed of olivine, basalt and basaltic andesite and is a shield volcano. Capping Timber Crater are two pyroclastic cones.

It is believed that Mt. Mazama reached a maximum height between 10,000 and 12,000 feet above mean sea level. This height was determined by projecting glacial striations, found around the rim of Crater Lake, upward with an ever increasing angle (as they normally occur.) Through mathamatical calculations the height of Mt. Mazama was computed.

Throughout the history of Mt. Mazama the mountain was clad with glaciers. A glacier is simply a body of ice which accumulates more ice each year than is ablated or melted away. Some of the glaciers on Mount Mazama were up to ten miles in length and up to 1000 feet in thickness.



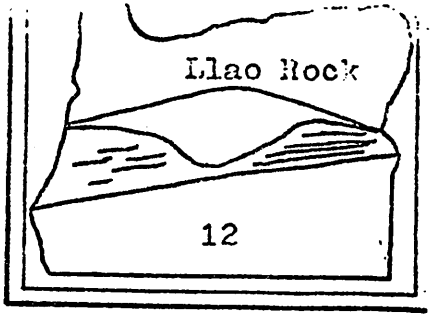
Various glacial features can be found within the park as a reminder of past glaciation of the [illegible]. Some of the more noticable glacial features are: [illegible]:

1. Glaciated "U" shaped valleys: Kerr and Sun Notches display large glaciated "U" shaped valleys.
2. Striations: located throughout the rim area, they are easily observable at North Junction on the Rim Drive.
3. Moraines: few exist today, especially in the Sun and Kerr glacial valleys because they were eroded away when the glaciers melted due to renewed volcanic activity. However, several can be seen in the road cuts between park headquarters and Rim Villag
4. Cirques: the best example of this glacial feature can be found on the northwestern side of Mt. Scott.

The culminating volcanic activity of Mt. Mazama occurred following a long period of quiescence. The early materials erupted during the final eruptions of Mt. Mazama were composed of fine dacite pumice. This material was explosively discharged to great heights in the atmosphere where the prevailing winds then transported them northeastward as far as Canada. These eruptions probably enlarged Mazama's conduit thus greatly reducing pressures in the magma chamber.

The next stage of culminating eruptions experienced frothy magma being expelled in great volumes. Instead of being explosively discharged the magma was poured onto the slopes of the mountain. This process formed a nuée ardentes flow which swept down the mountain at ever increasing speeds. These flows reached a maximum speed of 35 mph and inundated all forms of life within the area. North of the park, carbonized wood can be found in the road cuts caused by trees being incorporate within the lava flow.

After the nuée ardentes occurred, enough gases remained in the magma chamber to produce a few minor explosive eruptions. The ejecta was quite fine and limited in distribution, with the main lithic types consisting of dark-brown and reddish crystals, rich scoria and small



How[illegible] Williams estimated the volume of material ejected by Mt. Mazama prior to the collapse of the mountain. In his studies in 1942, he concluded that 6.5 cubic miles of material (lithic fragments, crystals and liquid magma) WAS erupted from the mountain. However, revised studies by Williams and Goles (1968) indicate that this figure WAS conservative. They presently believe that Mazama erupted the following amounts of materials:

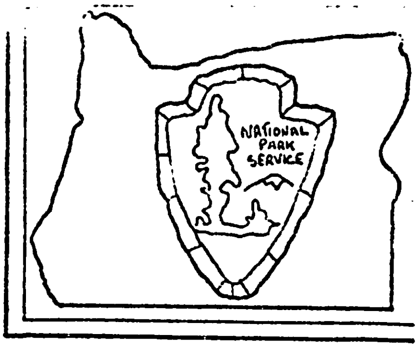
1. Total volume erupted - lithic fragments	1-2 cubic mi
2. Total Volume - erupted crystals	2-3.5 cubic mi
3. Total volume of pumiceous fragments and glass shards	8-14 cubic mi
TOTAL	17-19.5 cubic mi

NO NEW PARAGRAPH! →

Since these materials are roughly equivalent to two times the volume of liquid magma, it is believed that Mt. Mazama erupted approximat 10 cubic miles of liquid magma.

Within several days following this eruption, Mt. Mazama collapsed. Williams and Goles (1968) estimated that approximately 15 cubic miles (not 17 cubic miles as was earlier believed) of the mountain top was engulfed in the collapse. The collapse occured some 6600 years B.P. (before present.) This produced a caldera which was 4000 feet in depth and 6 miles in diameter.

An analysis of the amount of material erupted and the amount that collapsed reveals a discrepancy; approximately 10 cubic miles of material was erupted from Mt. Mazama, however 15 cubic miles of material collapsed to form a 4000 foot caldera. Thus, if we had more material collapsing than was erupted from the mountain, how could this deep[illegible] caldera have been formed? The only possible explanation indicates that another geological phenomenon was associated with Mazama's eruptions to produce the caldera. It was elucidated by Williams that subterranean withdrawl of Magma, either through fissures in the walls of the magma chamber or by recession of magma at still greater depths could have work



in conjunction with the eruption/collapse processes to form the basin.

Following the dramatic collapse of Mt. Mazama, it became dormant. However, 1000 years (BP) renewed volcanism occurred producing two smaller cones (now submerged beneath the lake's surface), and one cone (Wizard Island) above the surface of Crater Lake. These lavas helped to seal the basin by filling in the cracks and crevasses forming an impermeable bottom in the caldera. In time, water accumulated in this basin through the rain-and snowfall. Since evaporation was less than the water accumulated, the lake surface and depth continued to increase until eventually it reached an equilibrium between precipitation and evaporation. The final result produced the deepest lake in the United States (1932 feet deep), a national hydrologic bench mark, and an area of unsurpassed beauty preserved as one of <u>your</u> national parks for the present and the future!

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