The spectacular scenery that one sees while traveling through the Columbia River Gorge from The Dalles to the city of Portland has its origins 40-36 million years ago in the late Eocene and early Oligocene epochs. It was during this time that the Western Cascades began to develop. The low, shield style volcanoes were a result of a subduction zone off the coast of Oregon. According to Orr and Orr, this volcanic phase was the result of a collision between the east moving Farallon plate and the northwest moving North American plate. As the Farallon plate slid below the continent, an island arc above the melt zone developed (103). These eruptions lasted for around 20 million years (Williams, H. 70).

By the mid-Oligocene, volcanoes were erupting at full capacity in the Western Cascades. The subduction zone off the Oregon coast sped up, moving seafloor and sediment under the continent. These eruptions were violent enough for ash to be found as far away as John Day (Bishop 116). Although the eruptions created a large mountain range, Oligocene rocks are rare to find because they have been heavily eroded and covered by more recent flows. In her book "In Search of Ancient Oregon," Bishop tells us that the only Oligocene age rocks found in the Gorge are at the trailhead for Latourell Falls. They are andesites that can be identified by their grey color that contrasts against the darker brown and black of newer rocks from the Columbia River Basalt Group (123-24).

A layer of strata that is called the Ohanepecosh Formation is associated with volcanic activity of the late Eocene to middle Oligocene. It is most commonly found in the area around Mount Ranier, but also can be found in the Gorge. It is a severely folded and slightly metamorphosed layer of sedimentary strata that contains conglomerate, sandstone and siltstone that has been inter-bedded with volcanic rock. The metamorphism gives the rock a reddish or greenish color. It is mainly volcanic rock that has come from eruptions in Washington, been washed down stream, and deposited along the banks of the Columbia (McKee 178).

The next distinctive layer of strata that we are concerned with is called the Eagle Creek Formation. It is mainly mudflow, ash and debris from the Little Butte Volcanic Series (McKee 175). The Formation is dated from the middle Oligocene to the early Miocene. This layer is younger that the Ohanepcosh and came from stratavolcanoes in the area from Roseburg to Salem (Orr & Orr 105). A pre-field trip excursion to the Gorge yielded a photo of the Eagle Creek Formation, shown in figure 1. There is surprisingly little information about the details of the Eagle Creek Formation, however we will see in time how it plays an important role in the geology of the Gorge.

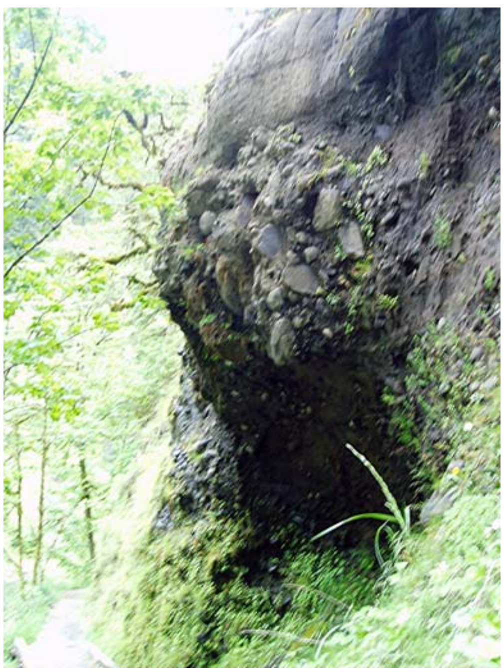

Figure 1-- Eagle Creek Formation
(Photo by A. Losasso)

In the early Miocene, Oregon looked very different than it does today. The topography has been described as looking something like the rolling hills of Ohio (Bishop 128). The Western Cascades were eroding away and becoming less active. For reasons unknown but widely debated, the subduction of the Farallon plate slowed drastically and the Cascade island arc began to shut off. Each geologist and their writings have a slightly different theory, and it appears that the tectonics of this time are not thoroughly understood, even by experts.

About 17 million years ago, the middle Miocene ushered in a period of folding and faulting and the beginning of the Columbia River Basalt eruptions (Orr & Orr 144). Additionally, the landscape during the middle Miocene was being tilted west and north by the Idaho batholith, so the massive Columbia River Basalt flows tended to extend further in that direction (Orr & Orr 291). Like much of Oregon's geology, the Columbia River Basalts are the source of a plethora of theories that are widely debated. Some are entirely plausible, and some are fantastic and not supported by any evidence whatsoever. One fanciful theory states that a meteorite hit Oregon. However, there are no shocked minerals, no geophysical markings of any kind, and no meteorite induced chemistry to support the theory (Bishop 131).

There are more realistic explanations for the origin of the Columbia River Basalts. Prior to the eruptions, the Farallon plate had been moving east and subducting under the continent. Some geologist think the subduction zone ran over a mid ocean ridge, putting a large amount of material under the earth. This is plausible, but does not entirely explain the phenomenon (Bishop 131). Orr and Orr assert that "back arc-spreading" is responsible for the Columbia River Basalts. While the North American Plate moved north, the crust of the northwest swung clockwise as if on a hinge somewhere in central Washington (292). Williams concurs with the back-arc spreading theory (69-80). Back arc-spreading caused the crust to the east of the Western Cascades to be thinned, resulting in widespread faulting. A diagram by Williams gives a simplistic illustration of this theory (figure 2).

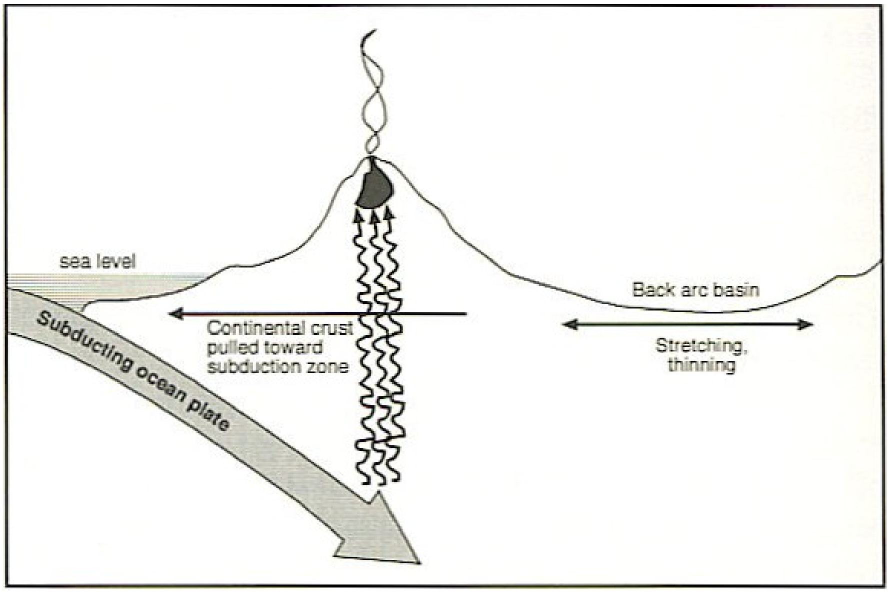

Figure 2--Back Arc Spreading (Williams, H. 80).

The most current theory states that the Yellowstone Hot Spot was once over eastern Oregon. The first Columbia River Basalt eruptions began where the Steen's Mountains are today. There was a huge shield volcano there, and as magma from the hot spot rose it created large fissures that opened and flooded out basalt. (Orr 292). Bishop tells us there is further evidence for the hot spot theory in the form of clusters of dikes along northeastern Oregon. These dike clusters are called "swarms." As the North American plate moved north and west, the fixed hot spot created swarms further and further to the southeast. It is no coincidence that the further southeast one goes, the younger the rocks get (132-34). Based on the last year of geology classes, this researcher believes that the Columbia River Basalts were the result of a combination of tectonic activities working together. It seems likely that the Yellowstone Hot Spot was one component, back arc-spreading another, and subduction a third. Who knows what missing components have yet to be discovered? The magnitude of eruptions needed to produce the Columbia River Basalts would have had to be huge, and it seems that a number of volcanic and tectonic elements would have had to be operating in tandem.

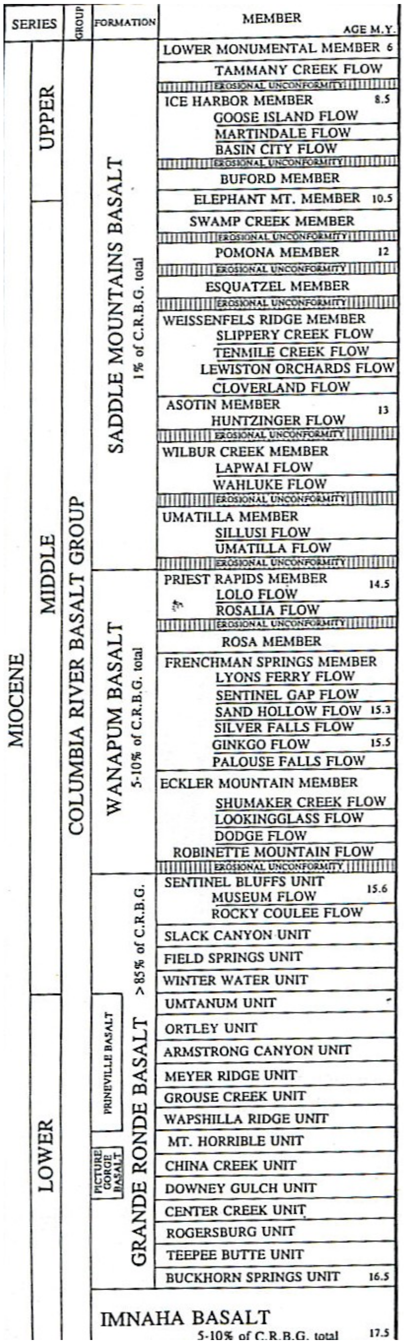

Figure 3--CRBG Stratigraphy. (Orr & Orr 293).

The Columbia River Basalt Group comprises over 300 separate flows, divided into 6 major formations. Orr and Orr have created stratagraphic diagram of them, seen in figure 3. The first formation is the Imhana Basalt, which dates around16.6 million years old and is thought of as chemically primitive. These flows did not greatly effect the Gorge (Bishop 140). The next series is known as the Grande Ronde Basalt formation. It dates from 16.5-12.6 million years old and was the largest, most rapid, and most voluminous of the CRBG. There are an estimated 120 flows that stemmed from northeast Oregon, southeast Washington, and western Idaho. This formation makes up many of the layered cliffs seen in the Gorge. It is important to remember that these flows were separated by thousands of years, and each basalt layer had time to erode and create a layer of soil and sediment. This allowed entire forests to grow and flourish before the next river of lava flooded the land.

In some places, the Columbia River was dammed by the flows, and as hot lava hit cool water, pillow structures were formed. Pillow basalt of the Grande Ronde Formation can be found at Multnomah Falls and at some outcrops near The Dalles (Geology Magazine 7). From atop Crown Point on the west end of the Gorge one can see Rooster Rock, which is a broken off piece of Grande Ronde Basalt. Within the Grande Ronde Basalt Formation time frame lie the Picture Gorge Basalt and the Prineville Basalt. These formations are not of primary concern in our discussion of the Gorge.

The next phase of eruptions dates from 14.5 to 12 million years ago and is named the Wanapum Basalt Formation. These flows came from vents between Hanford and Pendleton and followed the pattern of flow of the Columbia River. Some of this basalt has been found in the Portland west hills area. Like the flows of the Grande Ronde Formation, some Wanapum flows dammed the Columbia and caused the lava to form pillow structures. One flow, named the Priest Rapids flow, actually filled the Columbia River channel. Crown Point represents the pinnacle of that particular flow (Bishop 150). Because both the Grand Ronde and Wanapum Formations blocked the Columbia River, new channels were made. One channel is called the Bridal Veil or Pomona Channel. Bishop tells us that "Today, its mudflow filled cross section can be found between Coopey Falls and Bridal Veil Falls at the western end of the Columbia River Gorge…" (150). Another channel that is a former Columbia diversion channel is called the Crown Point Channel. A trained eye should be able to see these channels from atop Crown Point.

The final phase of Columbia River Basalt Group began 12 million years ago and lasted about 6 million years. It is known as the Saddle Mountain Basalt Formation. The Pomona Flow is largest of this series and flowed from north-central Idaho down the Columbia Gorge to Portland. Unlike earlier formations, it only partially filled the river's

channel. This flow can clearly be seen in the Gorge between Hood River and The Dalles. One can separate it, in part, from earlier flows in the Gorge by its hackly jointing (Bishop 174, McKee 277). In a basaltic flow, the top portion of the flow cools faster than lava below it. The top layer looks more broken up or "hackly" because the mineral crystals do not grow large. This portion is called the entablature. The bottom portion cools much slower and this gradual cooling allows the mineral crystals to grow large and arrange in a symmetrical pattern, making blocky columns called the colonnade (figure 4).

Figure 4--Blocky & Hackly Jointing.
(Photo by A. Losasso)

By the late Miocene, about 12-5 million years ago, the eruptions of the Columbia River Basalt Group slowed, and the area began another period of folding and faulting. This episode of orogeny is called the Cascade Arch. It had a large impact on the Gorge. McKee tells us about the section of basalt we are concerned with. "The section, which is about 2,100 feet thick, climbs gradually westward out of the Columbia Plateau to a crest near Bonneville Dam. From there it descends until finally it disappears under the younger strata at the west end of the gorge. The total structural relief of the arch in this part of the range is about 2,800 feet. In other words, the axis of the Cascades has been raised this amount since late Miocene time" (McKee 186).

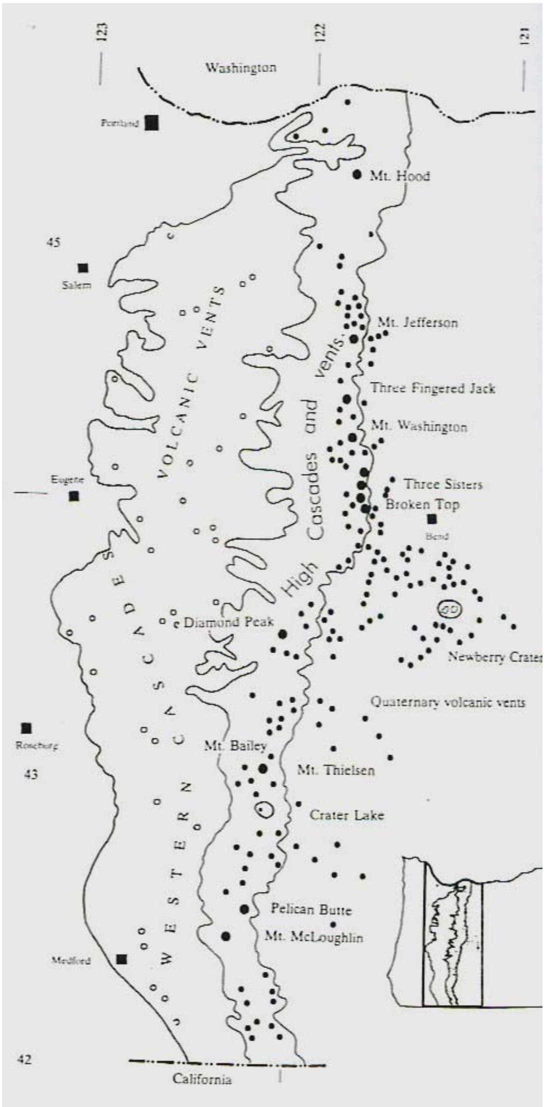

Figure 5--Map. (Orr & Orr 142).

The subduction zone off the coast of Oregon stirred around 10 million years ago, and a new period of volcanism began. North America continued to move northwest, and the Pacific seafloor subducted underneath it. The zone at that time was what is called a triple junction, which means that three branches of a mid-oceanic ridge were being overrun by the North American continent. The movement that this caused on the interior crust of Oregon was described by one geologist as a “geologic taffy pull” (Bishop 170). Additionally, the remnant of the Farallon Plate, now called the Juan de Fuca Plate, changed from a northeasterly collision course to a more head on easterly collision (Orr & ORR 106). The subducting plate steepened, causing the volcanic arc that was once the Western Cascades to shift to the east and begin building the Plio-Cascades, which are the ancestors of the current High Cascades. Figure 5 shows a map of the High and Western Cascades.

By 9 million years ago, the Columbia had carved its approximate modern channel. As the eruptions of the Columbia River Basalt Group slowed down, eruptions of the Plio-Cascades began (Williams 83). Volcanic debris from these eruptions was sent down the Columbia River. These sediments were deposited in the Gorge and in the Portland Basin and are collectively called the Troutdale Formation. "Deposited during the late Miocene and early Pliocene, the Troutdale Formation consists of gravels and sands that are still quite loose. Some are perched atop Crown Point" (Bishop174).

The Ancestral Cascades erupted, in part, in the area around what would become Mount Hood. The explosive andisitic basalt created the Rhododendron Formation, which is made of tuff, lava, and mudflow from small stratavolcanoes that erupted around 9 million years ago. Around this time, an Ancestral Cascade eruption intruded a very different kind of magma into a small area of the Gorge. The Wind and Shellrock Mountain diorite is found on either side of the Columbia River between Stevenson and The Dalles. It is an unmistakable white rock, in sharp contrast to the black and brown basalt that surrounds it. There is not a great deal of research information available on the Wind and Shellrock Mountain diorite. Some geologist believes that Wind Mountain comes from the same type of volcanic neck that is found at Beacon Rock, which is the eroded core of a vent that produced Cascade andisite (McKee 189). Pre-filed trip explorations give us a view of Wind Mountain from atop nearby Dog Mountain (figure 6). A close up look shows just how different the Wind and Shell Rock Mountain diorite is (figure 7). It is clearly an interloper among the basalt cliffs.

Figure 6-- Wind Mountain. (Photo by A. Losasso)

Figure 7--Wind Mountain Diorite. (Photo by A. Losasso)

In the early Pliocene (5-1.8 million years ago) the climate warmed and North American glaciers began to melt. There was a considerable amount of folding and faulting, especially in the basin and range of eastern Oregon. The “crustal taffy pull” continued and migrated westward, thinning the crust in the Portland Basin. (Bishop 190-191). There are numerous faults under the Portland basin from the West Hills to the East Bank and under the Lloyd Center. There are also faults under Gresham. By the middle Pliocene, vents in the Portland basin opened up and small volcanoes and cinder cones erupted. This has come to be called the Boring volcanic field. It lies geographically from the “Portland basin and the Cascade foothills north and west of Mount Hood” (Bishop 192). These small volcanoes were gas rich, creating lightweight basalt with a “diktytaxitic” (frothy) texture. At the same time, sediments were still being carried down the Columbia and creating the top portion of the Troutdale Formation. Bishop tells us that this formation is now a major aquifer for the Portland area (193). Pleistocene volcanism also included the eruptions of the High Cascades, including Mount Hood and Mount Jefferson. All of the High Cascade peaks seen along the skyline today were built during this time. Following the Pliocene, there was major glaciation and the enormous floods that filled the PDX basin (199).

The history of the glaciers that were sculpting the surface of the Northwest around 1.6 million years ago is as complicated as the plate tectonics that were causing orogeny and volcanism. “Understanding the early Pleistocene glaciers is about as easy as unraveling a crime scene after it has been bulldozed” (Bishop 202). That being said, it is clear a novice geologist is ill equipped to understand the complexity of the Pleistocene ice age. Let it be enough to say that locally, in Oregon, there were glaciers atop Mount Hood that went as far as 170 miles south during the end of the Pleistocene ice age. This period is sometimes called the Frasier Glaciation (Bishop 202). Mount Hood's predecessor is called Sandy Glacier Volcano and lies on Hood's western base. Hood's oldest lava is 600,000 years old and differs from Sandy Glacier Volcano in that it is composed of mostly gray andisite and not basalt. Bishop calls Hood a "geologic layer cake" with layers of mudflow and ash from intermediate eruptions as the icing between darker, more mafic, basaltic cake (210-11).

In the Portland Basin, the Boring volcanic field continued to erupt all throughout the Pleistocene. These flows built small shield volcanoes and cinder cones that include Mount Scott, Rocky Butte, Powell Butte, and the hill where the Oregon Zoo now sits. Our own Sylvania Campus of PCC sits on a Boring volcano vent, Mt Sylvan (Orr & Orr 209). There are more than 100 Boring volcanic vents, and local geologists believe that because the Portland Basin is still expanding, there is a likelihood of future eruptions in the area. Although a map of Boring volcanic field would be helpful, this researcher has been unable to locate one.

Late in the Pleistocene, a huge lake in southwestern Montana was caused by a glacier that dammed up a canyon in northern Idaho. The Clark Fork River runs through this canyon, and when glacier blocked its outlet, an enormous body of water was created. Eventually, the water melted through the glacial ice dam and sent a torrential flood through southeastern Washington and down the Columbia River Gorge (Bishop 227). This happened not just once but an estimated 40-89 times. At times the Columbia River was backed up by ice blocks as well, and this created Glacial Lake Columbia (Alt 115). There are 300 feet of sediment in the Portland basin as evidence of these floods. As the water slowed in the Portland basin, it deposited a gravel bar that runs west from Rocky Butte for 5 miles, almost reaching the Willamette River. We now know this bar as the

Alameda ridge (Bishop 227). A portion of the flood sediment found is granitic rock that is normally only found in high elevations. Because the sediment is angular rather than rounded, it could only come to the Gorge and Portland basin by rafting on an iceberg that floated down with the floods. These displaced rocks are known as flood or glacial erratics, and they can be as small as soil and pebbles to as large as 160 tons (Alt 173-74). The floods sculpted the Gorge, changing it from a characteristic V shaped river valley to the type of U shaped valley normally associated with glacial erosion (Alt 162). The south side of the Canyon was eroded severely, leaving high cliffs scoured and scabbed. At times the water was high enough to top Crown Point, meaning the channel was completely full (Bishop 227).

The floods of Glacial Lake Missoula and Glacial Lake Columbia, once called the Bretz floods for the man who first theorized them in the early 20th century, created large scarred land in eastern Washington. Bretz was intrigued by these scablands, and his study of them gave way to his theory (Alt 15-16). It has been deduced that as the flood water rushed over the Columbia River Basalts, it carved braded channels and deeply scarred the landscape. Figure 8 shows the location of Glacial Lake Missoula and the scablands.

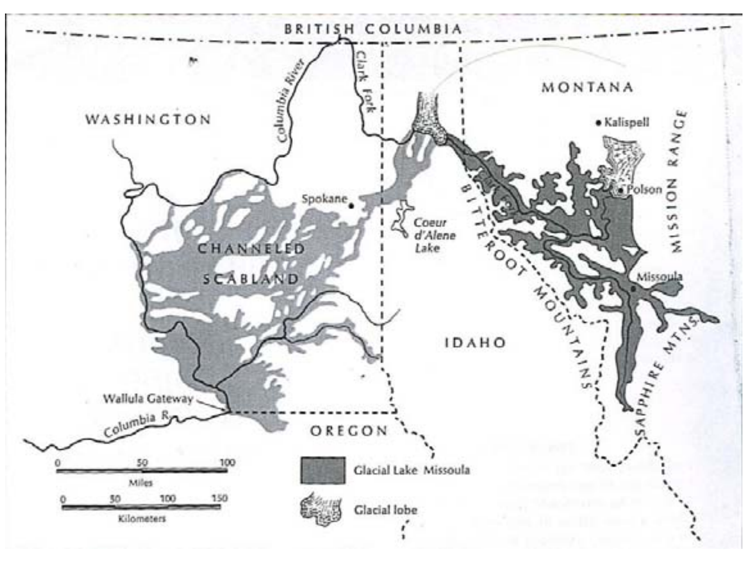

Figure 8--Scablands (McKee 286).

Recent geologic time began about 10,000 years ago and is called the Holocene. This period is marked by high volcanic activity at Mount Hood. Notably, at the Northern base there is a pile of basaltic andisite called the Parkdale flow. It is about 7,700 years old. It is aa rather than pahoehoe, meaning it is silica rich and very different from earlier flows (Bishop 238). The most recent phase of Mount Hood eruptions began 1,800 years ago. These were mostly ash eruptions and this time frame at Mount Hood is called the "Timberline eruptive period" (Bishop 238). The youngest eruptions on Mt Hood were in 1871-1872 and have come to be known as the Old Maid episode. These eruptions sent a lahar down the Sandy River. Although it appears quiet to the untrained eye, Mount Hood is clearly still an active volcano, sending out small steam, ash and gas occasionally.

Other geologic Holocene activities of interest in the Gorge include landslides. These landslides have occurred mostly on the north side of the Gorge. The reason for this is twofold. First, the topography of the area is tilted slightly to the south, making the land to the north side a bit unstable. The other reason has to do with the Eagle Creek Formation. The somewhat slippery deposits of the Eagle Creek Formation sit below much heavier basalt from the Columbia River Basalt Group. It works something like a banana peel, making the rock above it slip off. (Alt 162). Figure 8 illustrates the point.

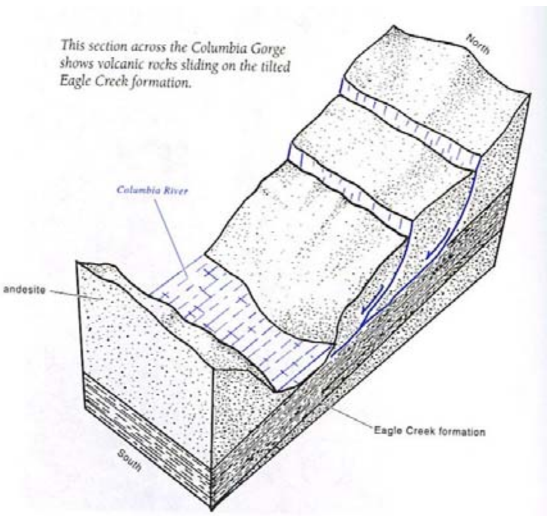

Figure 8—Landslides. (Alt, 160).

Perhaps the most famous landslide in the Gorge is the legendary Bridge of the Gods. The Bridge of the Gods was a landslide in the area around Cascade Locks that dates to somewhere between 1400 and 1700 C.E. (Bishop 252). Native American lore tells us that a very large slide once created a land bridge across the Columbia. Today, all that is left of the Bridge of the Gods are a few small gravel bars in the center of the river. A picture from the top of Dog Mountain shows us a recent landslide (look behind the steep hillside in the foreground). Landslides are unpredictable, but it is certain that there will be more of them in the Gorge in years to come.

It is clear that the geologic history of the Columbia River Gorge is complex and has been greatly simplified by this researcher. Still, a look back into the past 30 million years proves that the area in which we live is still very geologically active. In Portland and in the Gorge we are at risk of large scale earthquakes from numerous faults and dangerous volcanic eruptions from Mount Hood, not to mention the danger of landslides and floods. Portland and the Columbia River Gorge provide some of the most breathtaking scenery to be found in the northwest, but one can argue that it may not be the safest place to live and to play. For those of us who love to look at what 30 million years of geologic activity can do, it is well worth the risk.