Chapter 1

Portland's Landscape Setting

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Portland is often perceived as being a coastal city but it is actually situated 80 miles from the ocean in the Willamette Valley, a large synclinal depression between the Cascade Mountains and the Coast Range. This valley, 200 miles long by 30-40 miles wide, slopes gently northward and is occupied by the Willamette River, the longest north flowing river in the continental United States. Portland straddles the lower 20 miles of the Willamette until its confluence with the Columbia. The Columbia River, of course, rises several hundred miles to the northeast in the Canadian Rockies, and transects the Cascades and Coast Range on its way to the sea. In Portland, both the Columbia and Willamette Rivers are within 10 feet of mean tide level and feel the daily ebb and flow of the tides. In addition, the presence of ships, loading cranes, and the hustle and bustle of dock areas, give Portland an aura of the sea.

Sixty miles to the east is the crest of the mountains, appearing as a dark green ridge in the distance except for the intermittent snow capped sentinels, e.g., Mt. Hood. The Cascades are a major natural barrier. This is expressed in many ways, but perhaps most strongly through their effects on weather and climate. The abundance of clouds and rain on the west side is well known. This in turn produces the dense conifer forests for which the Pacific Northwest is so justly famous. The Cascades also stand as threshold and gateway to the more continental and sunny east side -- the Columbia plateau, Blue Mountains, and beyond. These two features, then, the mountains and the sea, are part of the environment and ambience of Portland, and yet they are both distant phenomena.

The Portland landscape itself may be capsulized as consisting of a broad valley floor, the confluence of two rivers, a longitudinally elongated ridge of hills, and a spattering of extinct volcanoes (see map frontis). These features are a function of Portland's location in a young orogenic region, with faulting, folding, and volcanism all in evidence. The other major factor contributing to landscape character is Portland's location near the debouchure of the Columbia River from the Cascades. This great transverse passageway provides a sea level conduit between the east and west side of the mountains and is of special significance since the major events that have shaped Portland's landscape history have come primarily from the east. Curiously, these include both what are among the largest lava and water floods on the face of the earth. This essay begins and ends with these spectacular but disparate events.

COLUMBIA RIVER BASALT

The primary rock type of the Portland area is Columbia River basalt. The his-

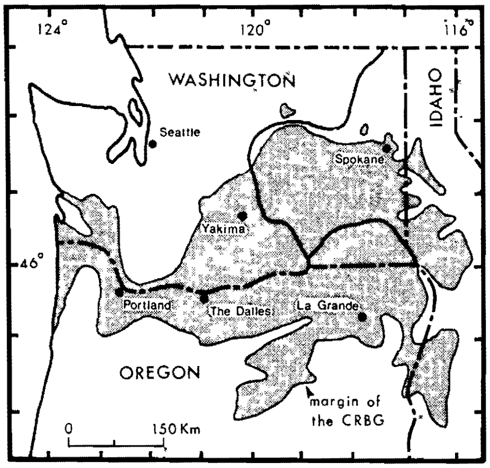

Figure 1.1. Generalized distribution of the Columbia River Basalt, including all of the individual flows (from Tolan, Beeson, and Vogt, 1984, p. 90).

tory of the fissure flows which compose this material is extremely interesting and great strides have been made in recent years in working out their differentiation, timing and movement (Hooper, 1982; Swanson, et al., 1979). They represent a great volcanic pile of flood lavas erupted from north-northwest trending vents to the east of the Cascades some 17.6 million years ago. They cover an area of 80,000 square miles stretching from Idaho to the Pacific Ocean, with their finest development occurring on the Columbia Plateau in northeastern Oregon and southeastern Washington (Figure 1.1). In places the basalt reaches depths of over 10,000 feet (Reidel, et al., 1982), but thicknesses decrease to the west and in Portland they are only about 1,000 feet thick.

Not all of the flows reached western Oregon. The ancient Cascades existed at the time, as did the ancestral Columbia River, and the westward flowing lavas could only cross the Cascades through this gap (Beeson and Moran, 1979). There has been much speculation about the location of ancestral channels of the Columbia River (Hodge, 1938; Lowry and Baldwin, 1952). Recent analysis of the flows through paleomagnetic polarity and chemical composition indicates that while there have been substantial changes in channel location during the last 15 million years, the river has remained within 50 miles of its present location in the Cascades, generally to the south of the present Columbia River Gorge (Fecht, Reidel and Tallman, 1985) (Figure 1.1). Evidence from intercanyon flows beneath the present location of Mt. Hood suggests that the river formerly flowed to the southwest, emptying into the central Oregon coast near Lincoln City (Tolan, Beeson and Vogt, 1982, p. 92). Its channel was forced northward by later flows until it reached its present location. This gives rise to the intriguing idea that many of the headlands on the Oregon Coast are actually intercanyon flows, representing ancient Columbia River channels (Allen, 1984).

The individual flows of the basalt average about 50 feet in thickness. Between flows there were often long intervals in which weathering and erosion occurred. Consequently, many of the flows overlie one another unconformably. In some cases weathering horizons and soils are found. One of the most extensive of these is the "Vantage horizon" named for a town in central Washington where up to 200 species of tree fossils are found; the Ginko being one of the more common. In the Portland area, the Vantage horizon is thin and discontinuous but fossil trees up to six feet in diameter have been discovered in it (Diller, 1896, pp. 508-511). The chief significance of the Vantage horizon in Portland is that it

Figure 1.2. Oblique aerial view to the west-northwest of downtown Portland and the Portland Hills anticline. The sharp break in slope where the Portland Hills fault is thought to exist can be seen along the right margin of the hills. The traverse valley across the Portland Hills in upper left of the photo is the path-followed by U. S. Highway 26. Bridges shown from left to right are: Marquam, Hawthorne, Morrison, Burnside, Steel, and Broadway. The photo was taken in 1969 so the Fremont Bridge to the north of the Broadway Bridge is not yet constructed (copyright photo Delano Photographics, Inc.).

contains limonite (strongly weathered iron oxide clay). These low quality deposits were heavily mined in the Lake Oswego area from 1865 to 1894 (Hotz, 1955, p. 91). Iron Mountain, about two miles west of Lake Oswego, now a site of exclusive housing developments, was a major source of the iron ore.

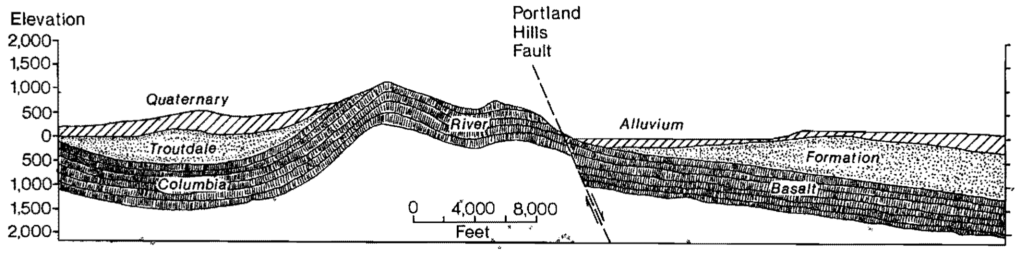

Figure 1.3. Geologic cross section of the Portland Hills showing anticlinal structure as well as the location of the Portland Hills Fault (after Balsillie and Benson, 1971, p. 116).

Remains of the smelter, built of large basaltic blocks, still stand in George Rogers Park by the river in Lake Oswego.

The Columbia River basalt in the Portland area has been strongly folded and faulted as well as dissected by erosion. The most prominent structural feature is the Portland Hills (Tualatin Mountains), an elongated ridge 500-1,000 feet high and 20 miles long by three miles wide, trending northwesterly along the western margin of the central business district (Figure 1.2). The Portland Hills is basically an anticline with synclinal counterparts in east Portland and the Tualatin Valley to the west, buried by as much as 1,500 feet of sediments (Schlicker and Deacon, 1967, p. 17). The east side of the Portland Hills rises abruptly from the valley floor as an impressive escarpment along a straight and sharp boundary which may be a fault (Figure 1.3). The evidence for a fault is not conclusive and the primary geologic maps of the area do not show it (Treasher, 1942; Trimble, 1963). Circumstantial evidence is strong, however, and several workers have argued for its presence (Schlicker and Deacon, 1967; Balsillie and Benson, 1971; Schmela and Palmer, 1972). Seismic activity in the Portland area is relatively low but earthquakes do occasionally occur and it is assumed that the Portland Hills fault is active (Dehlinger, et al, 1963; Schlicker, Deacon, and Twelker, 1964; Heinrichs and Pietrafesa, 1968). Given its presumed location directly under the city center, Portland State University, and the Trojan Nuclear Power Plant at Rainier, its disposition is clearly more than academic.

The Portland Hills is the site for many of the more exclusive and prestigious housing areas of Portland as well as Washington Park with the Zoo, open air water reservoirs, Oregon Museum of Science and Industry, Rose Gardens, and Japanese Gardens. North of Washington Park are Macleay and Forest Parks, a complex of more or less natural areas of forests and trails forming one of the largest urban parks in the United States.

TROUTDALE FORMATION

The Columbia River basalt is locally overlain by up to 1,500 feet of late Pliocene or early Pleistocene sandstone and gravels (Hodge, 1938). This deposit, known as the Troutdale Formation, occurs as a huge fan localized near the debouchure of the Columbia River from the Cascades and consists of two different facies; the upper facies is primarily sandstone of locally derived basaltic materials, presumably eroded from the ancient Cascades. The lower member consists of gravels containing abundant cobbles of quartzite,

schists, and granites which tie it to the ancestral Columbia River and source regions to the east (since the volcanic Cascades do not contain crystalline materials). In addition, the restriction of these deposits to the northern Willamette Valley and Columbia River Gorge, indicates that the ancestral Columbia River was near to its present location in Pliocene time (Tolan and Beeson, 1984). The age of the Troutdale Formation is estimated at between ten to two million years with deposition occurring throughout this period (Tolan, Beeson, and Vogt, 1984, p. 93). The type locality for the deposit is near Troutdale, Oregon along the east side of the Sandy River. Although buried under much of Portland (and providing an excellent aquifer) it outcrops occasionally, especially where it has been upfaulted or folded, as along the east side of the Portland Hills.[1]

BORING LAVAS

If one were to stand on a prominence in the Portland Hills and look eastward over the city, the general impression would be that of a low plain rising gently to the east occasionally interrupted by isolated conical hills. These are ancient volcanoes that erupted locally at the close of the Troutdale deposition from six million to perhaps a few hundred thousand years ago. They consist of both cinder cones and shield volcanoes and are composed of high-alumina basalts similar in composition to the High Cascade volcanoes, e.g., Mt. Hood. In fact, they may have been initiated by the uplift and emplacement of the High Cascades (Tolan, Beeson, and Vogt, 1984, p. 93). Their local distribution is restricted to a 30-40 square mile area in the lower Willamette Valley and foothills of the Cascades.

As many as 90 individual vents and flows have been identified (Figure 1.4). The material of these volcanoes is known as Boring lavas from their occurrence near the town of Boring, Oregon (Treasher, 1942). The lava is characteristically light gray (rather than dark gray or black as is more typical of the Columbia River basalts) and its structure tends to be massive or blocky rather than columnar (Allen, 1975, p. 149).

The Boring lavas were apparently quite viscous because they did not flow far from their vents. Many of the isolated hills formed by these eruptions are well known local landmarks, e.g., Mount Scott, Rocky Butte, Mount Tabor, Kelly Butte, and Mount Sylvania. The best and most accessible example of their volcanic character is Mount Tabor where a small vent has been excavated so the throat and dipping cinder beds are nicely displayed.[2]

Erosion has strongly modified the shape of some of the volcanoes. Rocky Butte, for example, was directly in the path of the Missoula flood waters that

1 *An excellent exposure of Troutdale gravels may be seen near downtown Portland on N. W. Cornell Road just before the first tunnel at about N. W. 34th. Park immediately before the tunnel and walk up the path on the south side of the road which leads to an old gravel quarry site. The material consists of well rounded, coble sized, and strongly weathered gravel clasts of basalt, granite, marble, and quartz.*

2 *Mt. Tabor is located off S. E. Belmont and 69th Street. Turn right at the park entrance and drive about two blocks. The excavation reveals the internal characteristics of the volcanic vent beautifully; it is well worth the trip to see it. A small sign erected by the Geological Society of Oregon Country states that Portland is the only city in the United States with a volcano within its limits.*

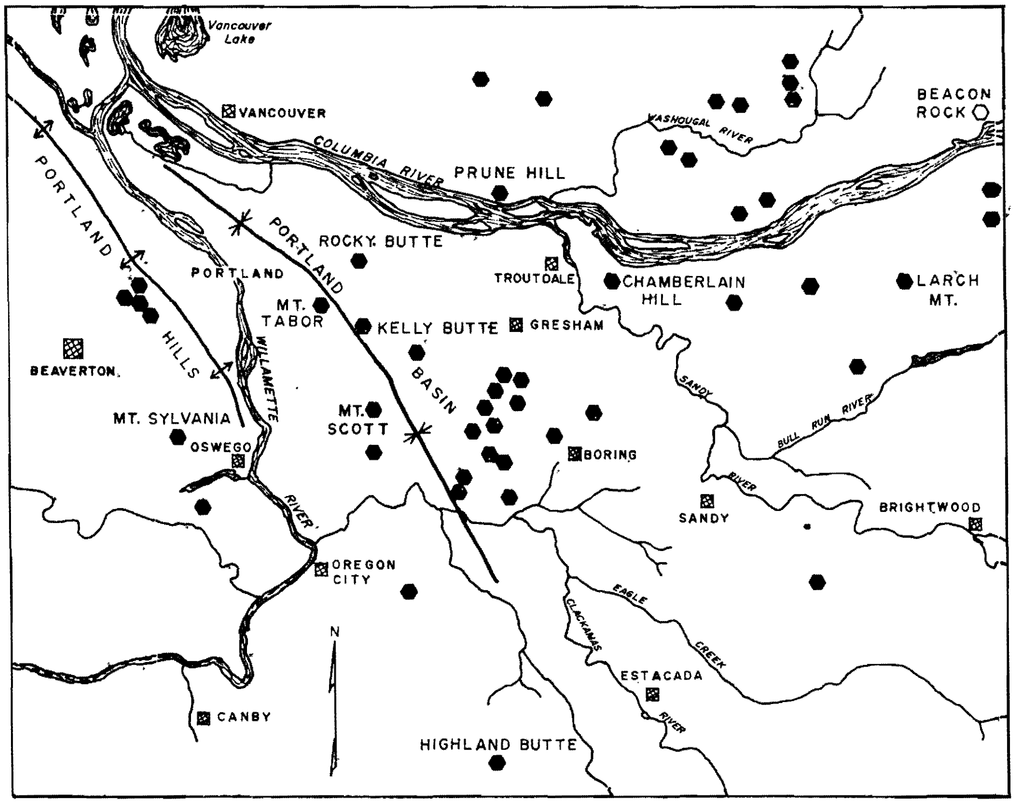

Figure 1.4. Distribution of Boring volcanoes. Three are considered to be shield volcanoes - Larch Mt., Mt. Sylvania, and Highland Butte, while the rest are primarily cinder cones (modified from Allen, 1979, p. 75).

coursed through the Columbia Gorge at the end of the last ice age. Its east facing slope has been cut into a vertical bluff and there is a large depression or pothole to its lee where the waters boiled around the obstacle (Bretz, 1925, p. 255). Rocky Butte also has Troutdale gravels exposed in its sides. Apparently the eruption encapsulated and lifted the gravels since they are exposed at an elevation of about 500 feet above the surrounding surface (Trimble, 1963, p. 41).[3]

Allen (1975) has pointed out that the volcanic vents are approximately aligned with other structural features in the area. For example, the entire west side of the Portland Hills is built of Boring lavas from vents located near the axis of the anticline (Figure 1.4). The lavas flowed predominantly to the west. An interesting feature here is the presence of lava tubes. Several buried caves and tunnels have been discovered and are of engineering concern since

3 *A visit to the top of Rocky Butte is strongly recommended. This is perhaps the best place in Portland to have a 360 degree panorama of the city, Columbia River, Boring volcanoes, and the West Hills with the central business district nestled at their base. Take Fremont Street off N. E. 82nd Avenue to 91st Avenue where you turn north and follow road to the summit.*

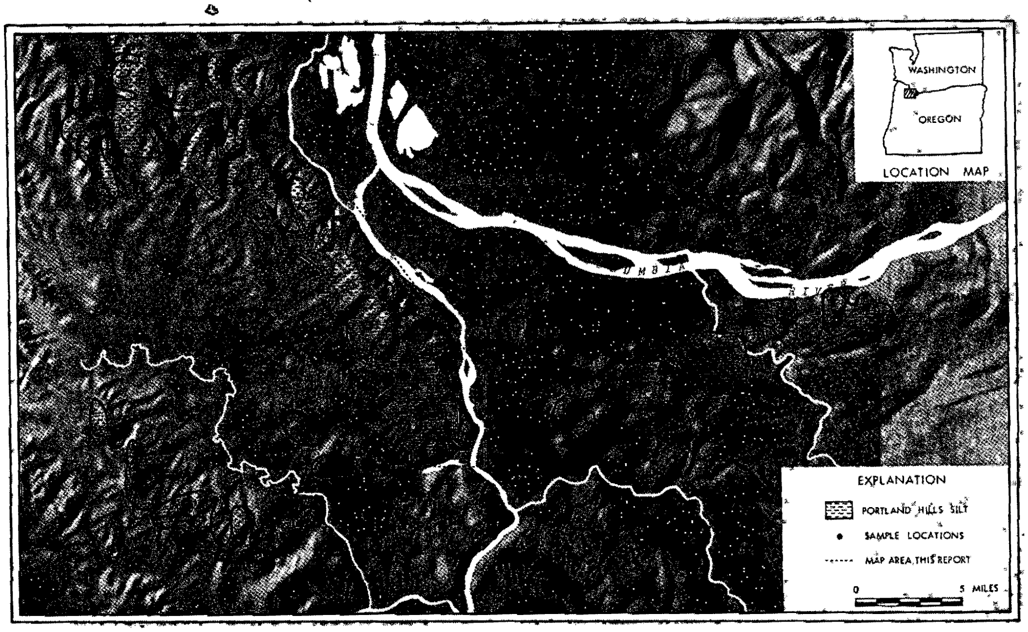

Figure 1.5. Principal areas of Portland Hills Silt. Base map is 1:250,000 raised relief map of Portland-Vancouver area (modified from Lentz, 1981, p. 4).

they underlie important surface structures such as N. W. Barnes Road and St. Vincent Hospital (Allen, 1974).

PORTLAND HILLS SILT

Elevations above 600 feet in the Portland Hills are commonly blanketed with a massive silty deposit reaching depths of up to 100 feet (Figure 1.5). The origin of this material, known as the Portland Hills Silt, is somewhat puzzling because it contains scattered pebbles and stratified bedding, but it is far above know water levels for the region. Earlier workers interpreted it as being water deposited (Diller, 1896; Lowry and Baldwin, 1952), but most recent investigations have argued for an aeolian origin (Theisen, 1958; Theisen and Knox, 1959; Trimble, 1968, Lentz, 1981).

The silt is thickest near the Columbia River and thins with distance away. It occurs on elevated terrain southeast of Portland between Gresham and Boring and in the Mt. Scott area south to the Clackamas County line (see map frontis). Its best development, however, is in the Portland Hills where it is thickest on north and northeast slopes facing the river (Figure 1.5). It thins to less than 50 feet on the west side of the Portland hills, and by the Chehalem Mountains, 18 miles to the southwest, it is only 8 to 10 feet thick. This provides an impressive rate of decrease in depth of five feet per mile. Even more spectacularly, the silt thins from 10 feet in the Chehalem Mountains to zero in only four miles to the southwest in the Red Hills of Dundee (Parsons, 1981). For this reason Parsons (1981) is reluctant to abandon the idea of a water origin for the silt (he would apparently explain its elevated location by tectonic displacement).

Most people, however, consider the

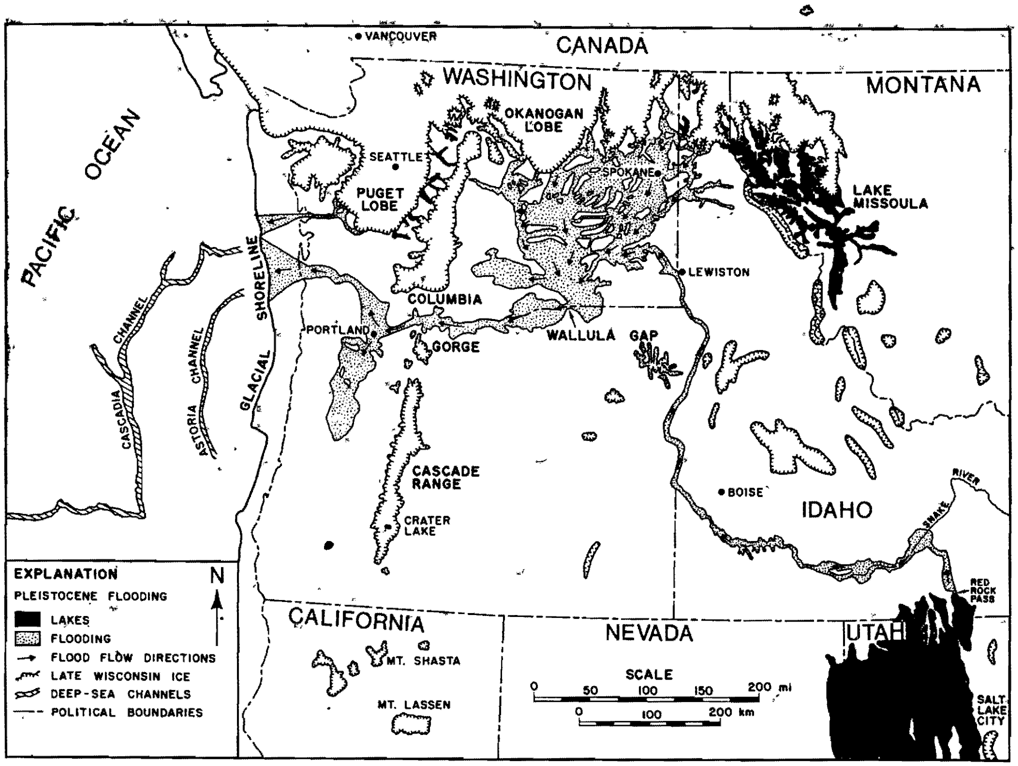

Figure 1.6. Outline of the Missoula Flood. Glacial Lake Missoula in eastern Montana was blocked by lobe of the continental glacier. Eventually, the ice dam was breached and the water surged westward across the Columbia Plateau. Where constrictions existed, e.g., Wallula Gap or The Dalles, the water was backed up as temporary lakes. A large lake also formed in the Willamette Valley. While this is shown as a single event, in actuality it occurred a number of times (from Baker and Bunker, 1985, p. 2).

Portland Hills silt to be wind deposited loess. The material contains large amounts of quartz and mica which could only have come from distant sources to the east of the Cascades. The Columbia River floodplain was the immediate source of the deposit since particle size diminishes and its depth thins with distance from the river. Unlike most loess, the silt is non-calcareous (Theisen, 1958, p. 30).

Lentz (1981) has identified up to four ancient soil horizons in the loess and he correlates them with the glacial periods. This places the silt at from 700,000 to 34,000 years B.P. The wind was easterly for its deposition whereas the modern wind is prevailingly westerly. Recent pollen investigations in the Portland area indicate cooler, drier conditions during the glacial periods (Barnosky, 1984). Such conditions were undoubtedly the result of the greater impact of continentality carried by strong east winds through the Columbia Gorge. The Portland Hills silt is an important factor in local land use and engineering since it becomes very unstable when wet (Schlicker and Deacon,

1967, p. 49). Landslides, mudflows, and slumps are all common on steep areas in the Portland Hills where expensive homes are located. This becomes especially critical in mid-winter after several days of rain have saturated the land. The silt also has low permeability and is not good for installation of septic tanks and drain fields.

MISSOULA FLOODS

Except for the folded and faulted structures and the scattered volcanoes protruding from the valley floor, much of Portland's landscape is composed of unconsolidated sand and gravel. These deposits occur as gently sloping to flat surfaces at multiple levels in the form of terraces. These features can best be seen in east Portland. As one proceeds away from the Columbia or Willamette Rivers, he is faced with a series of marked rises in altitude interspersed with broader treads like giant stair steps. The highest level occurs between 375-400 feet above sea level. Considering a maximum flood stage of 50 or even 100 feet for the river, the origin of these deposits becomes extremely interesting. Clearly, they are not related to the modern river.

The first explanation for the elevated deposits was suggested by Oregon's premier geologist, Thomas Condon, who attributed the gravels to river deposition in a great impoundment caused by formerly higher sea levels in what he called "Willamette Sound" (Condon, 1871). Although this interpretation stood for a number of years, there were problems with it. The sediments contained occasional large boulders, reaching seven feet or more in diameter, including some composed of granite. Such erratics were also known to occur at elevated positions along the Columbia River Gorge and into eastern Oregon and Washington. Based on his marine perspective, Condon explained the erratics as being ice rafted from the Straits of Juan de Fuca and the coast of British Columbia. This required rock-laden icebergs to travel southward along the Pacific coast and then 60 miles up "Willamette Sound" as well as through the Columbia Gorge into eastern Oregon and Washington (Condon, 1902, p. 63).

Later workers, most notably J. Harlan Bretz, thought that the erratics came not from the coast but the interior of Washington and Idaho. Bretz (1919, p. 502) called the impounded sediments "the Portland Delta." Based on his work on the Channeled Scabland of east central Washington, Bretz postulated a huge flood of catastrophic proportions sweeping through the Columbia River Valley (Bretz, 1925). This flood (actually floods) has had more impact on the Columbia Gorge and Willamette Valley than any other event in recent geologic time. In order to understand the local landscape one must be cognizant of these spectacular events (Figure 1.6).

That such floods occurred is now accepted as common place, but in the 1920's it was considered an "outrageous hypothesis" (Baker, 1978). Bretz was confronted in eastern Washington by a vast network of dry canyons or coulees cut deeply into the plateau. These formed a huge, anastomosing, and dendritic drainage system where the loess and basalt had been strongly stripped and scoured creating in Bretz's aphorism, a "channeled scabland" (Bretz, 1923, p. 618). In all, 2,800 square miles of the region had been scoured into the basalt and 900 square miles were buried under depositional materials (Bretz, 1928, p. 446).

Although Bretz was faced on all

sides by strong arguments of how these features could have been created by ordinary events, he was convinced that their origin could only be explained by a relatively brief but enormous flood. Many leading geologists at the time considered his concept a return to catastrophism. Without presenting all of the evidence he marshalled in favor of the flood, suffice it to say that the theory is now almost universally accepted.

The source of the floods was eventually pinpointed in western Montana where the advancing continental ice had blocked the valley of the Clark Fork River to a height of 1,000 feet so its drainage could not escape. A lake 250 miles long and 2,000 feet deep (Glacial Lake Missoula) developed behind the ice dam (Pardee, 1942). The glacial dam eventually failed allowing up to 500 cubic miles of water to surge southwestward across northern Idaho and the Columbia Plateau creating the channeled scabland (Figure 1.6).

The on-rushing water encountered constrictions in its path at Wallula Gap near the Oregon-Washington border, where the Columbia River cuts across the Horse Heaven anticline, and at The Dalles where the Columbia Gorge penetrates the Cascades. In both cases huge temporary lakes were formed. The water level at The Dalles, just 90 miles east of Portland, was 1,100 feet above sea level, whereas in the Portland area the water level was 400 feet. This provides a gradient of 700 feet in 90 miles or 75 feet per mile! One can only imagine the velocity and force of such a torrent.

Once beyond the Gorge the water either entered into a higher sea level or spread laterally and filled the Willamette Valley. If the latter case is true it is somewhat puzzling why it should do so since there is no obvious constriction in the Columbia River valley below Portland as in the other cases mentioned. Bretz thought the ocean was 350 feet above present sea level. This would have allowed for the construction of the Portland Delta which he considered to have been deposited subaqueously, with the river being 100 feet deep above this surface when it was built (Bretz, 1925, p. 212). A more recent proponent of a higher sea level as a cause of impoundment (but not for catastrophic flooding) was Lowry and Baldwin (1952).

The other major interpretation is that the flood waters themselves were sufficient to temporarily inundate the valley. Allison (1935) stressed the importance of icebergs in transporting erractics into the valley and thought that a huge ice jam might have caused the impoundment. Trimble (1963) also argued against a higher sea level, pointing out that late Pleistocene sea level rises of the order required have not been reported from other parts of the world. Also the time of ponding coincided with the glacial maxima when sea levels should have been lower, not higher. This is given support by the discovery of a 300 feet deep channel underlying the present Columbia River in east Portland cut during the late Pleistocene when sea level was lower, and backfilled with sand as sea level rose during the Holocene. A wood sample taken from the sediments at a depth of 200-300 feet yielded a C-14 date of 8,910 + or - 115 years (Hoffstetter, 1984, p. 65).

Trimble's interpretation for the cause of ponding was hydraulic damming "whereby more water entered the valley system than was able to escape through the restriction" (Trimble, 1963, p. 65). The narrowest point in the channel below Portland is between Kalama and

Carrolls, Washington, 35 miles downstream where the channel is 1.8 miles wide at an elevation of 350 feet. The amount of water required for such an opening to serve as a constriction so water would rise to an elevation of 400 feet throughout the Willamette Valley for several days or weeks boggles the mind. The resolution as to which major interpretation is correct continues to elude us, and yet it is essential for working out the details on how the Portland landscape was created. The answer may lie in information still uncovered such as in the various ponded deposits or in the deep sea sediments of the Astoria fan (Bretz, 1969, p. 541; Griggs, et al., 1970).

By whatever mechanism, evidence is clear that there was a huge impondment of water in the Willamette Valley reaching 125 miles to the south slightly beyond the town of Eugene. The maximum height of the water was 400 feet above sea level as testified by a number of large ice-rafted erractics found throughout the valley up to that altitude (Allison, 1935). A classic example can be seen southwest of Portland on the Pacific Highway between McMinnville and Sheridan.

The floor of the Willamette Valley is almost entirely covered by gravel, sand, silt and clay. Maximum depth of the deposits under Portland is 250 feet but at most localities the depth is 100 feet or less. The deposits thin to about 30 feet farther south in the valley (Trimble, 1963, p. 62). One of the most dominant characteristics of the gravels is steeply dipping forset beds, formed as the high velocity water flowed into calmer water. The beds dip mainly to the west and south indicating direction of water movement. Particle size also decreases away from the Columbia Gorge reflecting diminishing energy levels as the sediments were deposited into the ponded water. Trimble (1963, p. 59) considers the material as lacustrine since deltaic deposits are only part of the total picture with much of the alluviation taking place in slack water.

Five distinct terrace levels occur in the Portland area. In north Portland there is a clearly distinguishable level at about 150 feet above sea level. The campus of the University of Portland and Willamette Boulevard occurs on this planar-like surface. Well marked terraces also occur at 200, 250, 290, and 330 feet above sea level in east Portland although the exact elevation varies slightly from place to place. This is because the surfaces had original slope to them, they have been modified by erosion since, and they may have undergone differential uplift from tectonic processes. Nevertheless the terraces are marked features of the landscape and can be seen on virtually any east-west street leading away from the Willamette River. All five levels are beautifully displayed on N. E. Glisan Street which runs halfway between Rocky Butte and Mt. Tabor.

Although the terraces are fundamentally depositional features, there is also considerable evidence of erosion. As the debris-laden flood waters surged from place to place in the valley, and when the impounded water eventually began to drain, both bedrock and depositional surfaces were scoured and eroded. One path of the flood waters the northwest through Vancouver, Washington where a channel 50 feet deep and several miles long was cut in the gravel. Lackamas Lake is located near the eastern edge of this channel.

Another broad erosional swath was cut to the southwest in a line extending from Rocky Butte and Mt. Tabor to Lake Oswego. One may see evidence

of this on the Mt. Tabor 1:24,000 USGS Topographic map where numerous elongated hachured contour lines exist on the elevated terrace surfaces. Sullivan Gulch, a dry channel where the present I-84 freeway and rapid transit system (MAX) is located, was also cut into the gravel. As the water moved to the south it gouged the narrows at Oregon City stripping surfaces to bedrock and creating patches of scabland extending southwestward from West Linn to the Tualatin Valley (Stauffer, 1956, p. 22).

The water poured through the Lake Oswego Gap and scoured out giant potholes and depressions. Much of the material eroded from Lake Oswego was deposited in a fan to the southwest in the Tualatin-Durham-Cipole area. Many gravel pits are located in this region. Evidence that the water came from the west is westward dipping forset beds, plus the presence of limonite pebbles in the gravels similar to those found at Iron Mountain near Lake Oswego (Lowry and Baldwin, 1952, p. 20).

Immediately to the south near the town of Sherwood is a low drainage divide between the Tualatin Valley and the Willamette Valley. This area, known as the Tonquin scabland, is a miniature replica of what exists in the Columbia Basin of northeast Washington. There is an elongated north-south complex of channels scoured and plucked so that virtually no soil or vegetation exists in many areas. It is thought to have been created when water from the Tualatin Valley spilled southward into the Willamette Valley (Stauffer, 1956; Allison, 1978, p. 194).

The terraces provide a tremendous number of unanswered questions as to their origin and evolution. It is known that the highest terraces are the oldest and the lowest the youngest. This is proved by depth of weathering and soil development on the different surfaces (Trimble, 1963; Parsons, 1982). But they have all presumably been modified by floods subsequent to the one in which they were deposited. In addition there is a distinctly younger deposit of sand and silt disconformably overlying the terrace surfaces. This material ranges from a veneer to over 100 feet in depth and occasionally occurs in channels eroded in the earlier fill (Trimble, 1963; Allison, 1978, p. 196).

There has been considerable speculation as to the age, timing, extent, and number of floods. Bretz initially postulated a single huge flood; later he expanded this to seven or more floods (Bretz, et al., 1956). Glenn (1965) and Waitt (1980) presented evidence for 40 floods. Most recently, a study has been published claiming evidence for 89 floods (Atwater, 1986)! Exactly how each of these relate to one another is extremely difficult to unravel (Baker and Bunker, 1985). Allison (1978) believed that the events were of a twofold nature. First came a series of smaller floods from the multiple breaching of the glacial dam for Lake Missoula. The water was ponded in the Willamette Valley and flood deposits were laid down. Eventually as the land uplifted and the Columbia River became entrenched, these surfaces were left as terraces. Later came the "big bore," a much larger single flood which was primarily erosional (Allison, 1978, p. 179). It was this flood, Allison argued, that eroded the upper terrace surfaces, cut Sullivan Gulch and the channel now occupied by Lackamas Lake, scoured through the gap at Oregon City and Lake Oswego, and deposited the top coating of younger gravels disconformably on the older cut and fill surfaces.

This theory provides a good working

hypothesis as to the processes involved but the exact mechanisms for the implacement of the terraces and evolution of the various features have not been worked out. We do not even know the exact ages of the various surfaces. The date of the last flood, however, has been well established at about 13,000 years ago (Mullineaux, et. al., 1978). Consequently, Holocene and recent modifications to the surfaces have come about under essentially subaerial conditions. Stream dissection, aeolian processes, mass wasting, and soil development have all left their mark on the modern landscape. Man, too has brought about modifications. Nevertheless, the surfaces retain much of their original character and ample evidence remains for landform students of tomorrow to analyze and interpret. This is particularly true since much of the Portland area is now occupied by residential or commercial activities, with many restrictions through land use policies, to prevent the development of new quarries. It is interesting that in spite of its abundance, sand and gravel in the Portland area is an acutely limited resource. As a matter of fact, most aggregate products are now either crushed or transported in from pits up or down valley (Gray, Allen, and Mack, 1978).

In conclusion, Portland has been the scene of a series of spectacular geologic events. It began with huge lava floods issuing intermittently from eastern Oregon through the Columbia Gorge to inundate the area. Over time these flows were folded, faulted, buried under sediments, penetrated by local volcanoes, weathered, and eroded. Most recently, another series of floods originated to the east of the mountains, this time consisting of vast amounts of water choked with rock debris and ice; these torrents surged through the Portland area, cutting and filling to create the terraced landscape we now see. The overwhelming impression that one is left with after reviewing these events is the great power and scale at which they operated. They can be described only by superlatives. Portland has indeed had a dynamic and exciting geomorphic past.

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