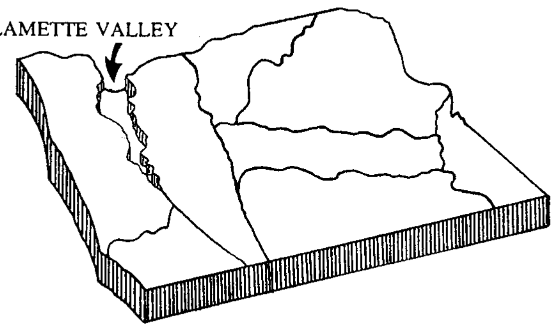
# Willamette Valley

**Physiography**

The Willamette Valley and Puget Sound physiographic province is a lowlands stretching from Cottage Grove, Oregon, to Georgia Strait in Washington. The smallest physiographic division in Oregon, the valley is a level, elongate alluvial plain which narrows at either end for 30 miles before it pinches out. Enclosed on the west by the Coast Range, on the east by the Cascade Mountains, and bordered on the north by the Columbia River, the main valley is 130 miles long and from 20 to 40 miles wide. From 400 feet at the southern end of the valley near Eugene, the elevation drops to sea level at Portland, an average of 3 feet per mile. The overall gradient is to the north and not from the margins toward the middle. The southern end of the valley is narrower but flatter than the northern hilly Salem and Portland areas. Salem is bordered by the Eola Hills to the west, the Ankeny Hills to the south, and the Waldo Hills to the east. The 1,000 feet high Tualatin Mountains are adjacent to Portland on the west, the Chehalem Mountains cross to the southwest, while to the east and southeast smaller volcanic buttes and peaks dot the landscape. Near the center of the valley, the 45th parallel, halfway between the equator and the North Pole, passes close to Salem.

With a watershed of 11,200 square miles, the Willamette River is the major waterway in the valley. Originating at the junction of the Coast and Middle forks near Eugene, the river runs north-northeast to its confluence with the Columbia. Flowing into the Willamette, sediment laden waters of the Coast and Middle forks from the south, the McKenzie, Calapooia, North and South Santiam, Pudding, Molalla, and Clackamas rivers from the Cascade Mountains, and the Long Tom, Marys, Luckiamute, Yamhill, and Tualatin rivers from the Coast Range drain the surrounding areas.

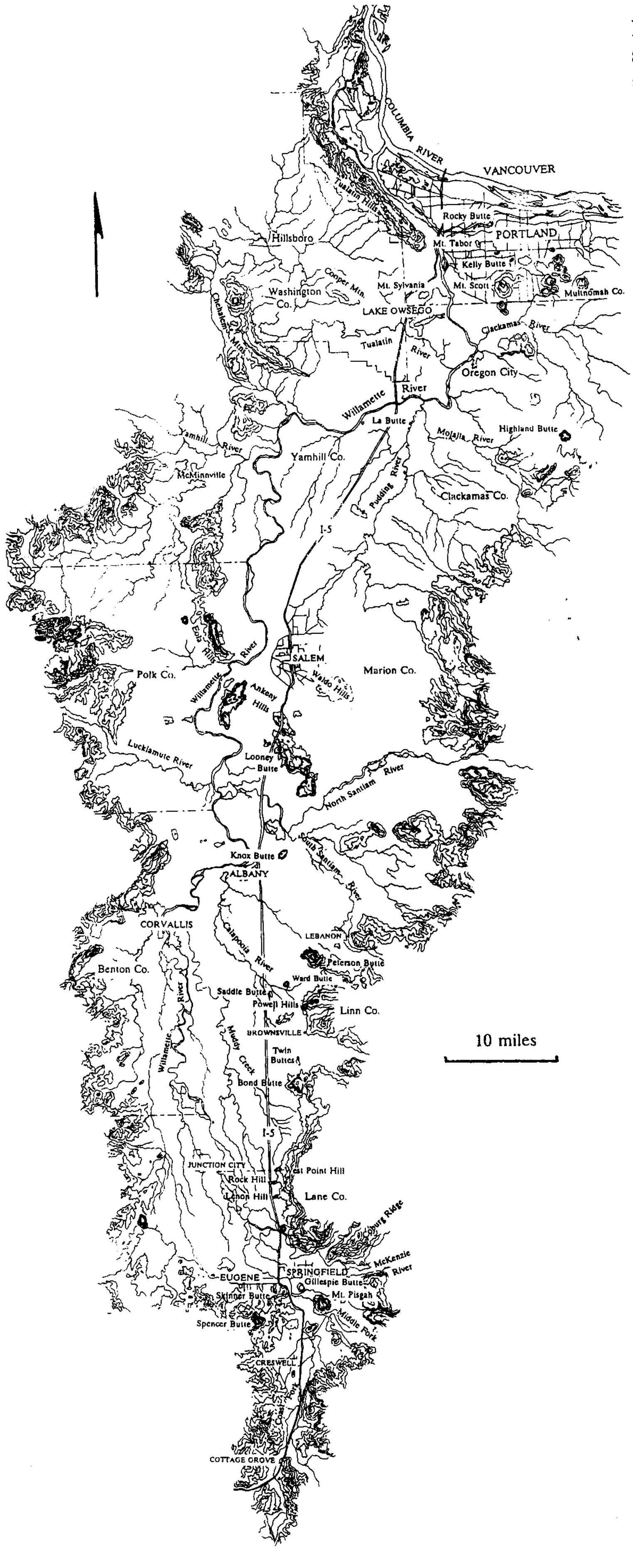
Although comparatively small, the Willamette Valley is the economic and cultural heart of Oregon. As the only natural lowland of any size, its moderate climate supports 70% of Oregon's population as well as intense and varied agriculture.




**Geologic Overview**

Physiologically the Willamette-Puget Sound lowland is similar to the Great Valley of California, but geologically the two are significantly different. The California valley was at one time an inland sea behind the Coast Range, whereas the Oregon province was part of a broad continental shelf of the ocean extending from the Cascades westward beyond the present coast. Structurally the Willamette Valley was more of a coastal marine environment than a true isolated basin or a valley cut by a river. Although subsurface geology of the Willamette Valley is closely related to that of the Coast Range, the later history of the valley is primarily one of glacial events. Thick layers of Late Pleistocene and Holocene alluvium cover all but a few areas of preTertiary rock from Eugene to Portland.

Older foundation rocks here are volcanics that erupted as part of a submarine oceanic island archipelago. Once the archipelago was attached or accreted to the western margin of North America, the volcanic rocks subsided, and a forearc basin formed on top. This basin was to become the focus of marine deposits from the Eocene through Pliocene. Fossils and sediments accumulating in the basin during the Oligocene,




Miocene, and Pliocene reflect shallowing as the ocean shoreline retreated northwestward. These marine sediments were covered in turn by Columbia River lavas that poured through the gorge from eastern Oregon during the middle and late Miocene to invade as far south as Salem.

Uplift and tilting of the Coast Range block and Western Cascades brought about the trough-like configuration of the Willamette Valley and the formation of a number of closed basins on the continental shelf. During the Pliocene and Pleistocene in the northern part of the province, a large lake received silts, muds, and gravels from the Willamette and Columbia rivers. The eruption of the Boring lavas from over 100 small volcanoes near Oregon City as well as east and west of Portland covered these earlier lake sediments, and today the vents project as small buttes.

The dominant signature on Willamette Valley geology resulted from a number of large-scale Pleistocene floods that scoured eastern Washington and the Columbia River gorge leaving deposits throughout the province. Enormous glacial lakes formed in Montana when the Clark Fork River was dammed by ice and debris. Once the ice blockage was breached, rushing flood waters carrying icebergs cascaded across Idaho, southeastern Washington, and down the Columbia gorge. Water backed up into the Willamette Valley creating temporary lakes and strewing a field of boulders in its wake. An unknown number of floods took place during a 2,500 year interval until the climate warmed, and glaciers retreated northward.

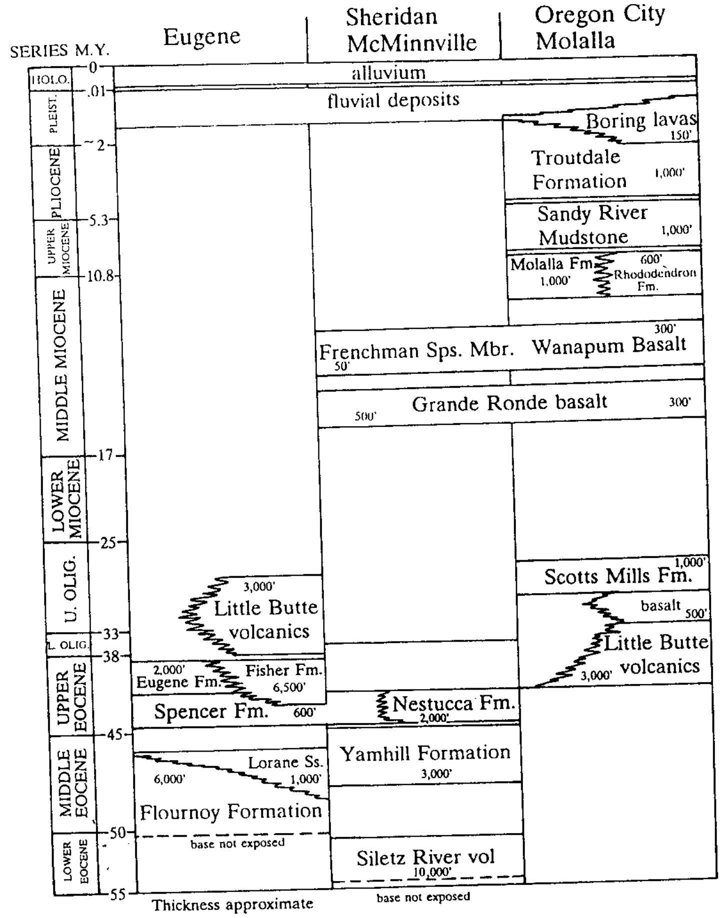
Because of its position close to the offshore subduction zone between Pacific Northwest plates, Oregon experiences a continual number of seismic events, and in the future the state could be the site of catastrophic earthquakes although details of time and place are uncertain. The coastal regions and Willamette Valley would be particularly vulnerable should a strong quake occur.

## Geology

Geologically part of the eastern margin of the Coast Range block, foundation rocks of the Willamette Valley have played something of a passive role against the backdrop of moving tectonic plates. In Eocene time an undersea chain of volcanoes atop the Kula and Farallon plates collided with the westward moving North American plate where they were accreted. With a thickness of more than 2 miles, the volcanic rocks of the island chain form the basement of the Coast Range and Willamette Valley. After docking or making initial contact with North America, the island archipelago was rotated clockwise beginning in the early Eocene. With accretion, the old subduction zone east of the volcanic block was abandoned and a new one activated offshore to the west where it is today.

The slow subsidence of the block created a broad forearc trough along the western margin of North America. From Eocene through Pliocene time the basin was the recipient of deposits that blanketed the earlier volcanic platform. Rivers draining the Klamath Mountains and later the Idaho batholith provided abundant sediments that accumulated in the newly formed basin. During the early Eocene the eastern edge of the subsiding coastal block that was to become the Willamette Valley collected sandstones and siltstones of the Flournoy Formation near Lorane, Philomath, Falls City, the low hills around Camp Adair, and in the southern valley. Where Eocene rocks are exposed in the area north of Corvallis, rolling hills contrast sharply with the flat valley floor elsewhere that is covered with Pleistocene fill.

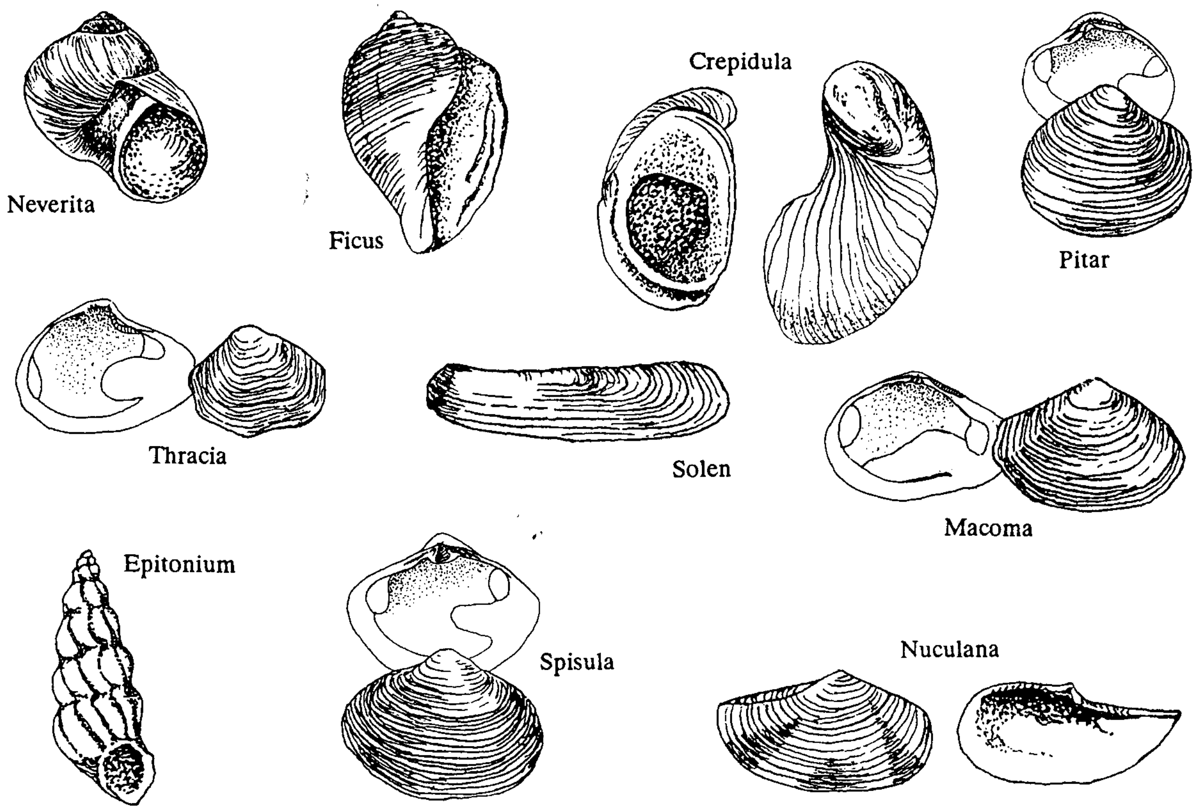
In the northern part of the valley these deposits were followed by middle Eocene Yamhill muds, sands, and silts, mixed with ash and lavas from the ancestral Cascades that were carried into the shallow seaway. Within the Yamhill, shoals of limestones around offshore banks formed the Rickreall and Buell limestones containing broken mollusc shells, foraminifera, and calcareous algae intermixed with volcanic debris. In the northern valley 2,000 feet of Nestucca Formation deposited in a deep water setting extended westward from McMinnville, while near-shore sands, silts, and muds of the shallow marine Spencer Formation produced deltas along the margin. Found along the western side of the valley from Eugene north to Gales Creek in Washington County, Spencer sands are covered by nonmarine tuffs and conglomerates of the late Eocene Fisher Formation. Fossil plants from the Fisher Formation southwest of Cottage Grove indicate a warm, moist tropical climate where broad leaf plants as the Aralia grew close to the shoreline. Beneath Eugene almost a mile of upper Eocene silts and sands of the Eugene Formation extend northward toward the Salem hills. Marine molluscs, crabs, and sharks in this formation suggest warm, semitropical seas. Sediments of the Spencer, Fisher, and Eugene formations were derived from the rapidly growing volcanics of the Western Cascades.




Willamette Valley stratigraphy (after COSUNA, 1983)

**Oligocene**

The Oligocene ocean in the Willamette Valley reached only as far south as Salem. The high-water mark on the western shoreline is recorded by marine sediments in the vicinity of Silverton and Scotts Mills in Marion and Clackamas counties. In the Scotts Mills Formation a transgressive, advancing seaway followed by a regressive, retreating ocean chronicles storm conditions, shallow water, and coastal swamps that gave rise to thin layers of low-grade coal. Coal beds at Wilhoit Springs and Butte Creek were deposited along the margins of the sea as it retreated. Prior to the arrival of the Columbia River lavas in the middle Miocene, the Scotts Mills sediments were tilted eastward and severely eroded.




Invertebrate fossils of the late Eocene Eugene Formation

In the Nehalem Valley fine-grained shallow marine sediments of the Scappoose Formation are contemporaneous with the Scotts Mills Formation. Over 1,500 feet of Scappoose sandstones, mudstones, and conglomerates were deposited in an estuary or delta environment covering a dissected landscape.

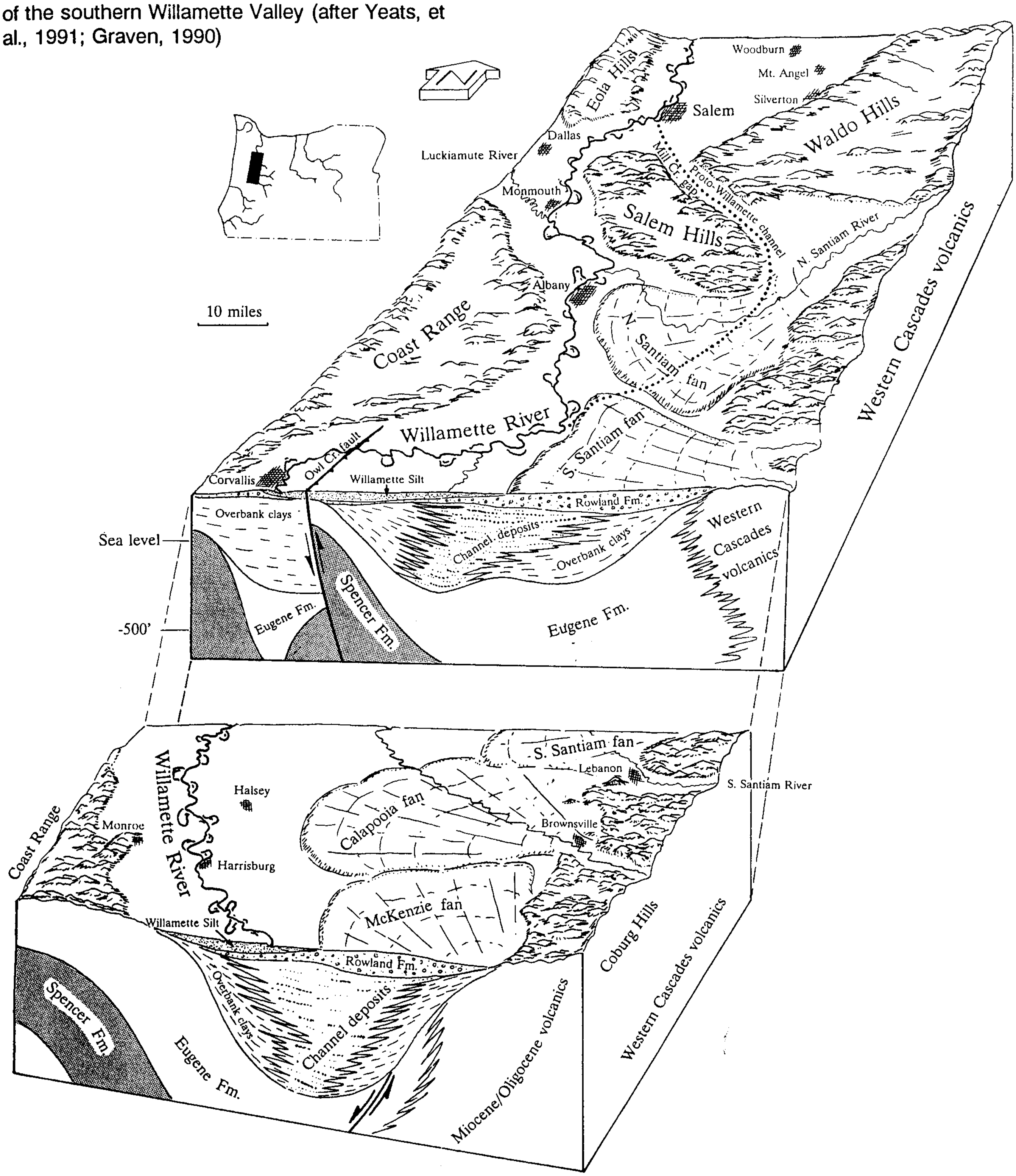
**Miocene**

With slow uplift of the Coast Range, the sea withdrew from the region of the Willamette Valley. The deep shelf and slope environment became shallower as the basin filled. Little is known about the configuration and environment of the Willamette Valley following the regression of the late Oligocene seaway. A broad semitropical coastal plain, where lakes ponded in slight depressions, extended from the ancestral Cascades out to the present shoreline. Black, silty clays lying between weathered Pleistocene and late Eocene Spencer sandstones near Monroe reveal ancient lakebed sediments that contain fossil pollen from coniferous as well as broadleaf plants once living around the lacustrine basin. Much of the pollen from this lake is from plants now extinct in the Pacific northwest.

In middle and late Miocene time, voluminous sheets of basaltic lava from fissures and vents in northeastern Oregon poured through the Columbia gorge and into the Willamette Valley where they reached as far south as Salem. The fluid Columbia River lavas covered the region of the Portland Hills, most of the Tualatin Valley, as well as the slopes of the Chehalem, Eola, and Amity hills. The dark, finely crystalline, collumnar-jointed basalt ranges up to 1,000 feet in thickness. Near Portland the layers of lava produced a monotonous, flat landscape with only the tops of several higher hills projecting above the flows. After cooling and crystallizing, the lavas rapidly decomposed in western Oregon's wet climate so that almost all of the original volcanic landscape has been thoroughly dissected. Dark red soils around Dundee, the Eola Hills, and Silverton Hills are easily recognized as decomposed Columbia River basalts.

Interfingering with the Columbia River basalts in northern Marion and Clackamas counties, 1,000 feet of clastic sediments, mudflows, and volcanic tuffs of the Molalla Formation represent the first terrestrial sediments deposited after the withdrawal of the Oligo-

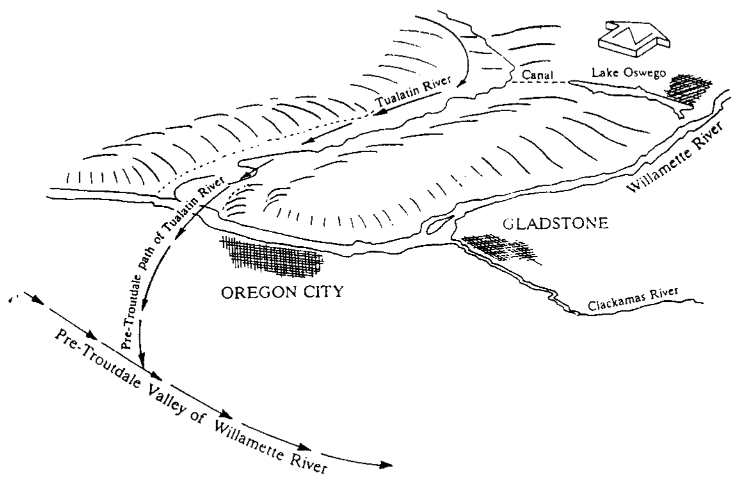
Pleistocene fluvial and flood deposits and structure of the southern Willamette Valley (after Yeats, et al., 1991; Graven, 1990)



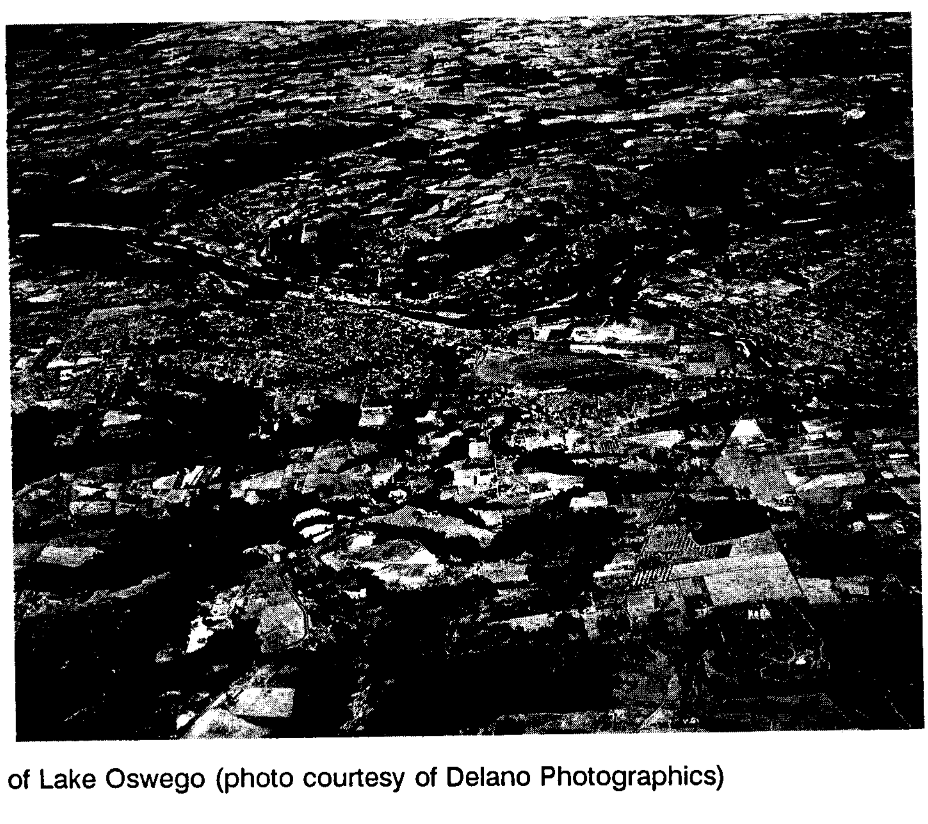
cene seaway. Mudflows here originated when heavy rains on the slopes of ancient volcanoes caused loose ash to flow for miles down valleys. Abundant fossil flora in these sediments suggest a hilly topography covered with Liquidambar, (sweet gum), Platanus, (sycamore), and Carya, (hickory) adjacent to swamps dominated by cypress. Ginkgo and Metasequoia commonly occured in the warm, rainy climate.

Around 1,000 feet of silt in the Portland and Tualatin basins, designated as the Helvetia Formation, sits directly above the Columbia River basalts. Pebbles of basalt quartzite, granite, along with abundant quartz and mica, suggest these sediments were deposited by streams of the surrounding mountains ranges as well as the ancestral Columbia River.

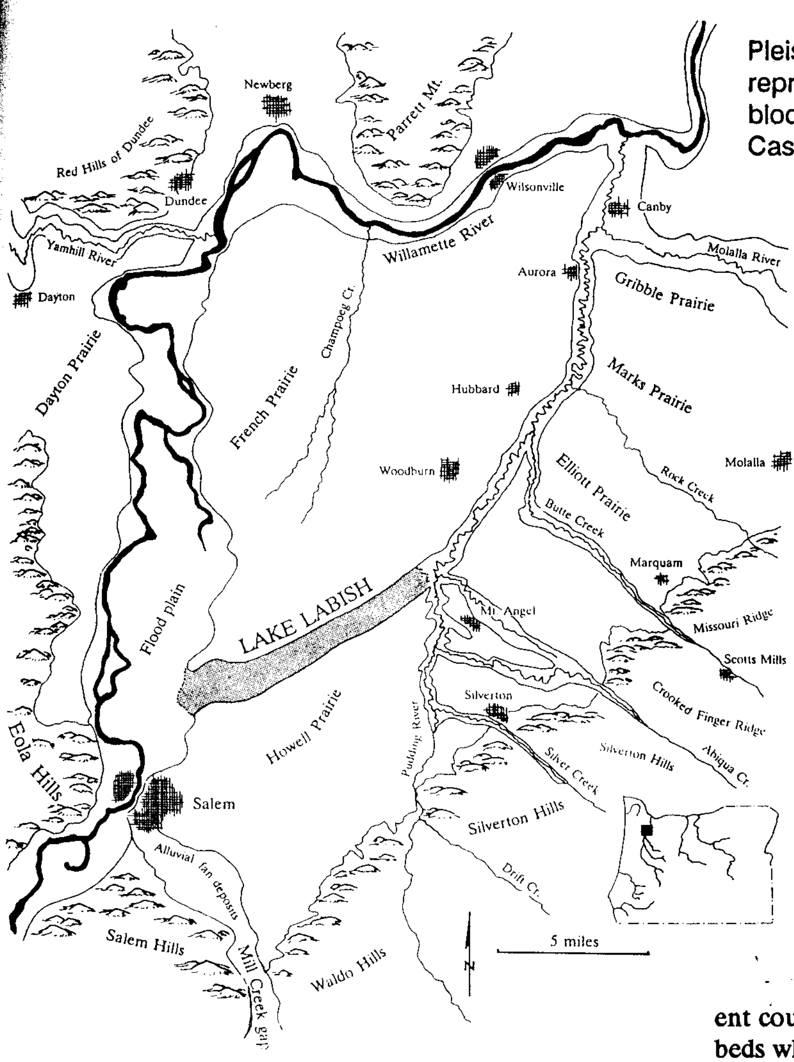
With margins around Portland and Tualatin in the north and west and Sandy on the east, a bowl-shaped structure gently sloped from 700 feet at Sandy to 250 feet at Portland and Vancouver. Flowing in a channel south of its present course, the Columbia River aided by the northerly flowing Willamette River emptied into the basin to form a lake and deposit silts and muds in a delta over 1,300 feet thick. More than 1,500 feet of the Sandy River Mudstone of sandstones, siltstones, and conglomerates filling the Portland basin underlie the city today. Later Pliocene Troutdale gravels from the Columbia River drainage washed into the lake, covering the mudstone to depths of 700 feet. Dissection and erosion by rivers and Ice Age floods removed portions of the Troutdale Formation from the Portland Hills and surrounding areas.




Pathways of the pre-Troutdale Willamette and Tualatin rivers in the northern Willamette Valley. Extrusion of the Boring lavas moved the Willamette River channel northward to Oregon City (after Baldwin, 1957).



Geomorphology of Lake Oswego (photo courtesy of Delano Photographics)




Pleistocene Lake Labish northeast of Salem may represent an older channel of the Willamette blocked by sediments from the Western Cascades (after Glenn, 1962).

**Pliocene**

During the Pliocene epoch, continued subduction of the Juan de Fuca plate and growth of the offshore accretionary wedge brought about the renewed uplift and tilting of the Coast Range and gentle folding of northern Willamette Valley rocks. The end of the wide coastal plain marked the beginning of the Willamette Valley as a separate physiographic feature once the sea had withdrawn to its present position. At this time major folds of the coastal mountain range formed, and outer continental shelf environments were raised over a mile from 1,000 to 2,000 feet below sea level to elevations of 3,000 feet above.

About 5 million years ago in the northern valley Boring Lavas erupted from over 100 small vents, cones, and larger shield volcanoes as Mt. Defiance, Larch Mt., Mt. Sylvania, and Highland Butte. Boring Lavas can be readily distinguished from the older Miocene Columbia River basalts by their fracture pattern. The fine-grained, light-weight Boring lavas break into large blocks and are seldom found in the small columns so common to the Columbia River Basalt.

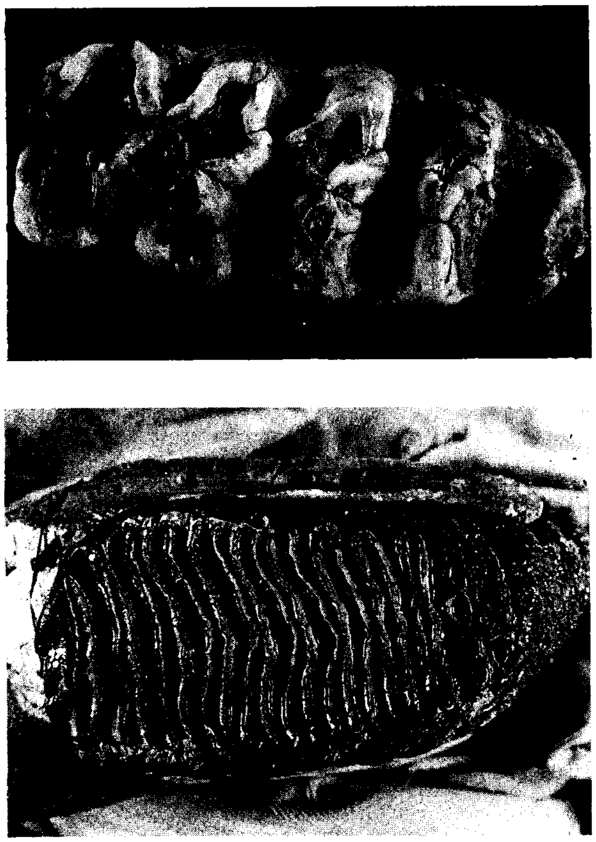
Basalt.

The Pliocene lavas covered the gravels in the old lake bed, and today they make up many of the buttes near Gresham and Boring as well as capping a number of hills in the vicinity of Oregon City. Rocky Butte, Mt. Scott, Mt. Tabor, Kelly Butte, and Mt. Sylvania contain cinders and lavas of these flows, the most westerly of which is along the slopes of the Tualatin Valley near Beaverton and Metzger. La Butte southwest of Wilsonville in Marion County may be the most southern eruption of these lavas. The landscape in the valley and around Portland shows clear evidence of these late eruptions. Flows from Highland Butte southeast of Oregon City pushed the Willamette River ten miles to the northwest near its present course, whereas in Portland lavas filled old streambeds where Burnside Street and Canyon Road are now located. Rocky Butte, a volcanic vent that erupted approximately 1.2 million years ago, and Mt. Tabor, with a small cinder cone projecting from its north side, are presently in downtown Portland. Across the river in Washington, Bobs Mountain northeast of Portland and Battle Ground crater north of Vancouver still have intact cones.

**Pleistocene Rivers**

Just prior to deposition of the Willamette Formation, up to 150 feet of coarse gravel and sand of the Rowland Formation spread over a broad area in the southern Willamette Valley. Divided into two members, the Rowland represents glacial outwash from the Cascades that was flushed into the valley by the North and South Santiam, Calapooia, and McKenzie rivers. This massive outwash unit thins toward the northwest and forms a complex series of coalescing alluvial fans that have bulldozed the Willamette channel off to the western margin of the valley between Eugene and Corvallis.

The valley beneath the Rowland glacial-alluvial fan sequence is filled with almost 300 feet of proto-

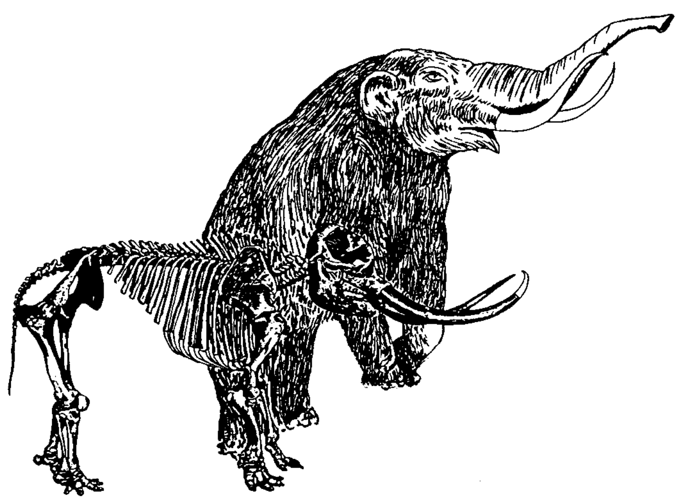


Crown views of elephant teeth clearly distinguish the low cusps of the browsing mastodon (top) from those of the grazing mammoth (bottom). (Fossils courtesy of the Thomas Condon collection, Univ. of Oregon)

Willamette River sands and gravels. Bordered on both sides by bluish clay overbank deposits, these coarse pebbles trace the path of the ancient river as it began filling the rugged erosional surface on top of the Columbia River basalts and older Tertiary units in the valley. Prior to the emplacement of the alluvial fans, the Willamette River may have followed a more easterly pathway in the valley. There is evidence that the old channel between the southern and northern valleys ran through a narrow gap at Mill Creek between Salem and the Waldo Hills.

With uplift and intensive erosion of the land during glacial periods when sea level was lowered, rejuvenated streams began to cut deeply into flood plains. Terrace gravels, recording the many changes in stream levels, can be seen along the Sandy and Clackamas rivers and in eastern Portland where the streets rise in elevation toward Gresham. At that time the ancient Willamette River ran southeast of Oregon City. Here it was joined by the ancestral Tualatin River flowing along the western margin of the Portland Hills. Both rivers wandered over a wide floodplain resulting from thick alluvial deposits which first filled the Portland and Tualatin basins, then backed up the stream valleys, and finally, in places, covered the divides between the streams. As sea level continued to drop, the Tualatin flowed through the channel at Lake Oswego while the Willamette established its present pathway in the Columbia River basalts at Oregon City where cutting action of the river produced the falls. In the final stage, flood waters flushed out the sands of the previously abandoned channel, diverting the Tualatin back into its original southward pathway to merge again with the Willamette. Today water from the Tualatin River is channelled into Lake Oswego by means of a low dam and ditch.

The rich dark soils of what may be a former channel of the Willamette River, now called Lake Labish, can be seen in a straight strip extending for almost 10 miles northeast of Salem in Marion County. The former course of the river was cut off during the Pleistocene when a natural dam of sand from Silver, Abiqua, and Butte creeks blocked the channel. The resulting shallow lake slowly filled with silt and organic



About the size of a modern Indian elephant, mastodon roamed in herds throughout the Willamette Valley during the Pleistocene.

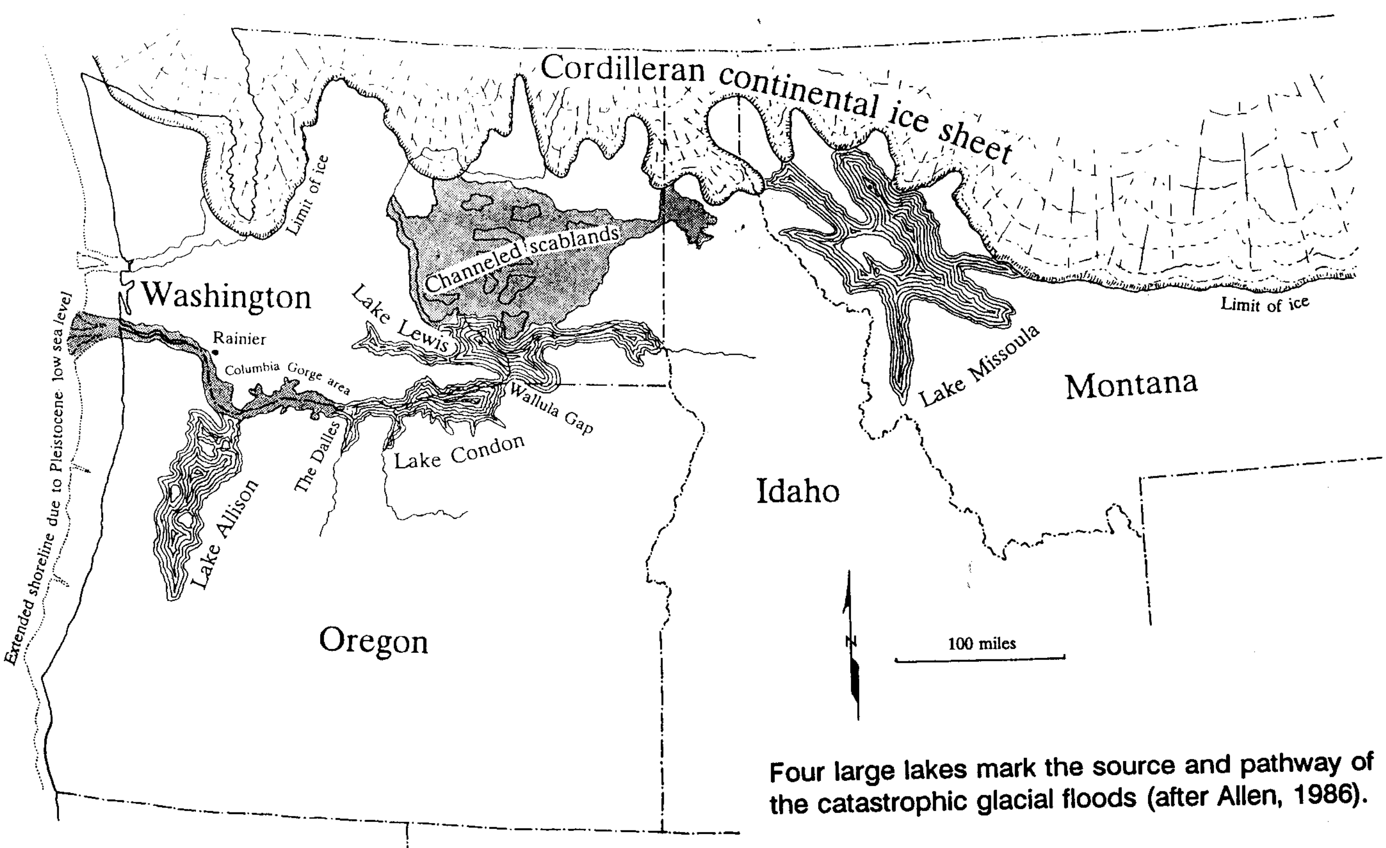
debris to become a marsh. Thick peat deposits in the old lake reflect a long period as a swamp and bog. In this organic layer, bones of Ice Age mammals such as mammoths, mastodon, giant sloth, and bison are frequently found. Unlike the Pleistocene LaBrea tar pits of Los Angeles, the animals were probably not mired in the peat, but carcasses were washed in and covered allowing the remains to be preserved in the oxygen-poor bog away from the attentions of scavengers. Today the fertile soils of Lake Labish support a thriving onion industry.

**Pleistocene**

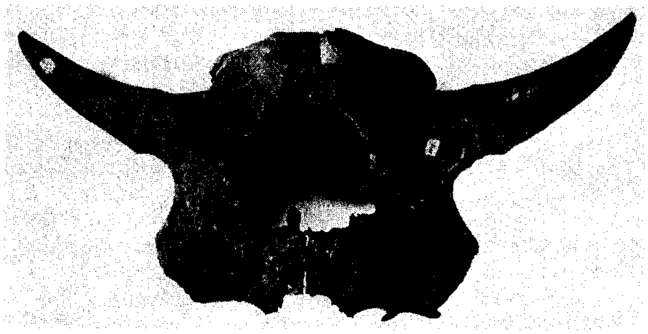
Covering the Boring lavas and Troutdale gravels, a gritty, structureless, yellowish-brown sediment called the Portland Hills Silt was deposited within the last 700,000 years. Commonly 25 to 100 feet thick, the layer mantles much of the Portland area from the Tualatin and Chehalem mountains on the west all the way to the Gresham Hills and Ross Mountain on the east. Microscopically the silt is remarkably uniform, and the identified minerals include many which must have been derived from terrains as far north as Canada. This unique formation has long been something of a geologic puzzle and has been designated as both a wind-blown and water-laid deposit. The physical characteristics of the silt are similar to the palouse strata in southwest Washington indicating that the sediments are wind blown in origin. The Yellow River in China derives its name from comparable Pleistocene loess deposits that blanket vast areas in the northern part of the country. Ground up rock flour, produced by the crushing and milling action of glacial ice, was transported by water to be deposited along flood plains of the Columbia River. Strong Pleistocene winds, collecting the fine dust, carried it aloft in enormous clouds to cover the Portland Hills. Four different layers of silt are separated by three soil horizons. Interglacial, warm intervals are represented by the silt deposits, whereas soil horizons reflect times of glacial advance.

**Ice Age Floods**

Beginning about 2 million years in the past, the Ice Ages mark the advance and retreat of continental glaciers, an event that triggered one of the most catastrophic episodes in Oregon's geologic history. When first proposed in the 1920s by J. Harlen Bretz, the theory of an enormous flood washing across Washington and through the Columbia River gorge was not readily accepted. Careful work by Bretz, however, built up a body of evidence that could not be ignored. Between 15,500 and 13,000 years ago, the Columbia River drainage experienced a series of spectacular floods from ruptured ice dams along its




Four large lakes mark the source and pathway of the catastrophic glacial floods (after Allen, 1986).



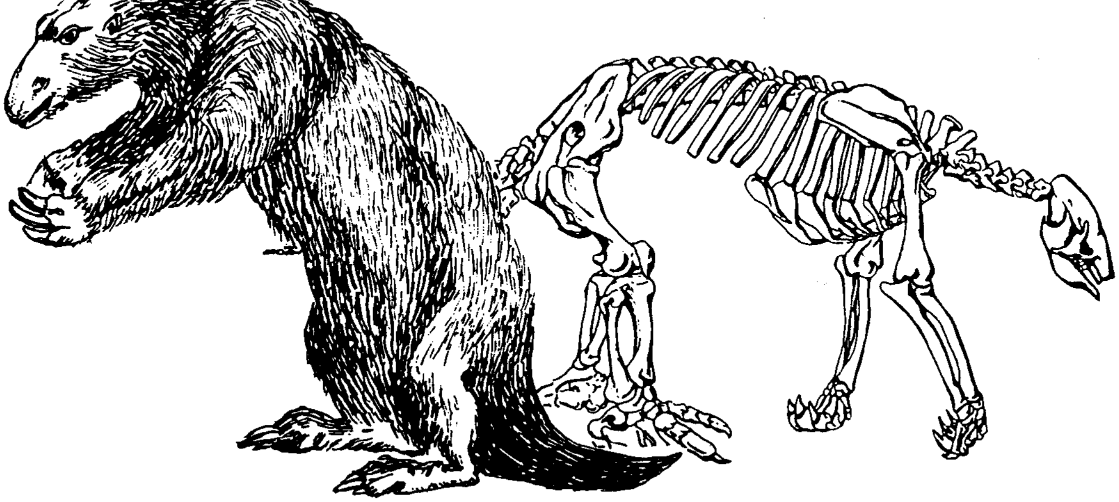
Skulls and skeletal elements of Ice Age bison up to 8 feet high at the shoulder are common in Willamette Valley swamp deposits (specimen from the Thomas Condon Collection, Univ. of Oregon).

canyon and tributary streams high in the upper watershed. The amount of water in a single flood, estimated at up to 400 cûbic miles, is more than the annual flow of all the rivers in the world. The natural reservoir of Lake Missoula filled and emptied repeatedly at regular intervals suggesting that natural processes were regulating the timing of the floods. Once the lake had filled to a certain level, it may have floated the ice lobe or glacial plug that jammed the neck of the valley which, in turn, released enough water to allow the flooding process to begin.

Prior to each flood, an ice lobe from northern Idaho stretched southwest to dam up the Clark Fork River that flows northward to join the Columbia across the Canadian border. Old shorelines visible today high above the city of Missoula, Montana, are evidence that the ice dam backed up a vast lake covering a large area of western Montana. As the ice dam was breached, water, ice, and sedimentary debris poured out at a rate exceeding 9 cubic miles per hour for 40 hours. Flushing through the Idaho panhandle and scouring the area now known as the channeled scablands of southeast Washington, the lake drained in about 10 days.

After crossing eastern Washington, the water collected briefly at the narrows of Wallula Gap on the Oregon border where blockage produced the 1,000 foot deep Lake Lewis. Ponding up a second time at The Dalles to create Lake Condon, the rushing water stripped off gravels and picked up debris, steepening the walls of the Columbia gorge. Near Rainier the river channel was again constricted causing flood waters to back up all the way into the Willamette Valley. At Crown Point flood waters spilled south into the Sandy River drainage and across the lowland north of Vancouver taking over the Lacamas Creek channel. Most of the water exited through the gorge to the ocean, but as much as a third spread over the Portland region to depths of 400 feet. Only the tops of Rocky Butte, Mt. Tabor, Kelly Butte, and Mt. Scott would have been visible above the floodwaters. Surging up the ancestral Tualatin River, the waters covered the present day site of Lake Oswego to depths over 200 feet, while Beaverton, Hillsboro, and Forest Grove would have been under 100 feet of water.

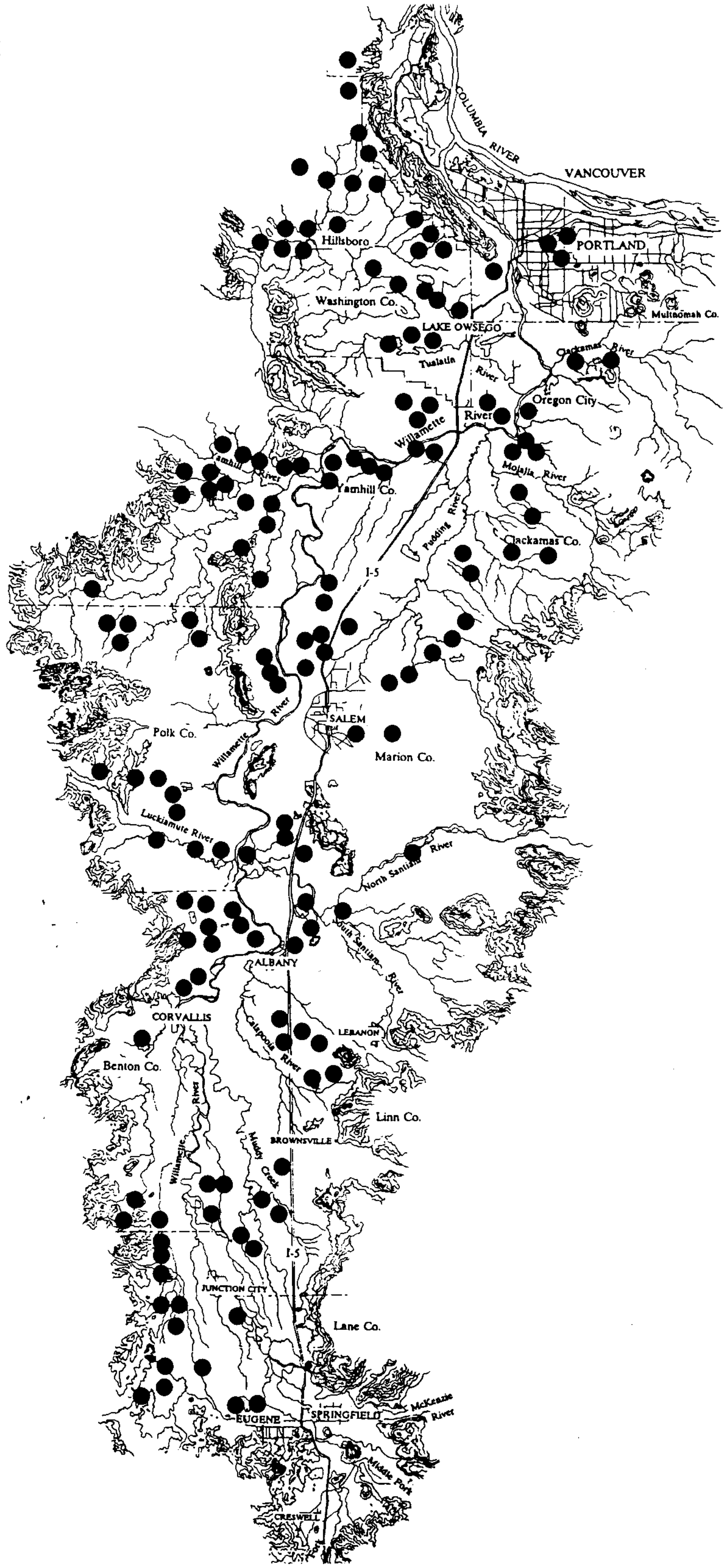
Swampy lowlands in the Willamette Valley yield the bones of the enormous Ice Age ground sloth.



Along with floating icebergs, the rushing waters carried enormous amounts of gravel, sand, silt, and clay in suspension as well as rolling and tumbling along the bottom. In the valley this mass of flood borne sediment was segregated by the narrows at Lake Oswego leaving much of the coarse material in the vicinity of Portland and the Tualatin Valley. A huge sand and gravel bar dammed the Tualatin River for a period to form a small lake 5 miles west of Oswego. Sometime after the flood receeded, the river cut through the bar, and the lake drained, but the basin which had been scoured and deepened by the flooding remains. Sweeping through Lake Oswego, large volumes of the finer sands and silts along with ice rafted boulders that had been collected upstream washed southward into the lower Willamette Valley where they were deposited over the valley floor and lower slopes of the surrounding hills. Sands predominate at Canby and Aurora, and silts, tens of feet thick, were spread as far south as Harrisburg.

The muddy waters filled the central valley temporarily creating Lake Allison. Extending from the Lake Oswego and Oregon City gaps southward almost to Eugene, the surface of this large body of water was over 350 feet above present sea level. The lake formed when the valley was dammed at its north end by ice jams or overwhelmed by the amount of water coming south. Repeated surging as new water came through the gap at Oregon City and ebbing as it drained out kept the lake level in a constant state of fluctuation. The tops of lake silt deposits are commonly 180 to 200 feet in elevation throughout the Tualatin, Yamhill, and Willamette valleys. After a brief interval the water drained back out to the Columbia and the ocean.

The multiple floods had a lasting impact on the channel of the Columbia River and the Willamette Valley. Because the flow of flood water into the Willamette Valley was opposite to the normal northward drainage, the river was disrupted for periods up to two weeks until the waters receeded. Distinct banded layers of Willamette Silt brought into the valley indicate the flood waters must have invaded many times. As flood waters entered the valley they were quickly stripped of coarse sand and gravel when ponding took place. Silt and clay particles, however, remainded suspended in the turbid waters and covered the valley with a layer up to 100 feet deep exposed today along the banks of the Willamette and its tributaries. Surface deposits of these silts are best developed in the southern Willamette Valley where they are subdivided into four members of the Willamette Formation on the basis of subtle mineral and textural differences. Within the Willamette Silts, the Irish Bend Member has been identified as the primary




Glacial erratics carried into the Willamette Valley atop icebergs during large Pleistocene floods are scattered from Eugene to Portland (after Allison, 1935).

sediment of a large-scale flood. Extending over 300 square miles of the southern valley, the Irish Bend silt reaches a maximum thickness of nearly 50 feet just south of Corvallis.

With the separate silt layers in the Willamette Valley suggesting multiple periods of flooding, the precise number of floods is in doubt. Figures proposed are "many floods", "35 floods", or "7 to 8 floods". Whether the floods occurred in "two cycles", "annually", "every 175 years", "over an extended period of time", or were "short-lived" is still conjectural. These floods continued over the 2,500 year interval until the ice sheets permanently retreated northward with a warming climate.

Erratics

Flood waters spilling into the Willamette Valley carried large blocks of ice borne on the torrent. Atop and within the icebergs, rocks and sediment were transported all the way from Montana. Once the ice melted, the stones were dropped as glacial erratics in a wide pattern across the valley. Although more than 300 occurrences of these erratics have been recorded, thousands more lay unrecognized. More than 40 boulders over 3 feet in diameter have been located, and many smaller stones as well as chips and pebbles of foreign material have been noted in farm fields, road-cuts, and along old river terraces.

The Willamette meteorite from near West Linn may have been carried into the valley by an iceberg during flooding (photo courtesy of Oregon Historical Society).

Varying in composition and size, the erratics are granite, granodiorite, quartzite, gneiss, slate, and a few of basalt. With the exception of basalt, these rocks are common to central Montana and not the Willamette Valley. Because of the exotic composition of the erratic material, the path along which they were rafted into the valley can be traced down the Columbia River channel. Erratics were deposited through Wallula Gap to The Dalles where they are found up to 1,000 feet above sea level. In the Willamette Valley erratic fragments are imbedded in the top of the Willamette Silt.

The largest known erratic lies in the valley between McMinnville and Sheridan in Yamhill County. Composed of the metamorphic rock argillite, the boulder originally weighed about 160 tons, but over 70 tons have been removed by tourists. Perhaps the most famous erratic is the Willamette meteorite which may have fallen in Montana only to be transported by floodwaters to where it came to rest near West Linn in Clackamas County. The meteorite was subsequently purchased for $20,000 in 1905 by Mrs. William E. Dodge who donated it to the American Museum of Natural History in New York.

**Structure**

Uplift, tilting, and folding in the Coast Range and Willamette Valley are attributed to the continued subduction of the Juan de Fuca plate. Gentle folding accompanied by faulting with as much as 1,000 feet of vertical displacement produced deep valleys. Columbia River basalts, that had filled the bowl-shaped Tualatin, Wilsonville, and Newberg valleys in the middle Miocene, were depressed to 1,300 feet below sea level by steady eastward tilting of the Coast Range block. Within the Willamette Valley, broad northwest trending anticlinal folds are interspersed with parallel, subdued synclines. The dominant folds are the Portland Hills, Cooper Mountain, and Bull Mountain, as well as Parrett and Chehalem mountains. Separating the anticlinal hills, wide valleys of Tualatin, Newberg, and Wilsonville are gentle synclines or downfolds.

The Portland Hills anticline that formed during the late Miocene and Pliocene is steepened on the east side by a large fault that stretches for over 60 miles northwest and southeast of Portland. This fault system extends southeastward to join the Clackamas River lineament, an alignment of surface fractures on a grand scale that traverses Oregon all the way to Steens Mountain as part of the Brothers Fault zone. Running parallel to this immense feature, the Mt. Angel fault trends northwestward under Woodburn to project into the Gales Creek fault zone of the Coast Range. Northeast of Salem, the butte at Mt. Angel