Discovery Park

A Field Trip Exploring the Stratigraphy and Glacial History of the Seattle Area

J Figge 2007

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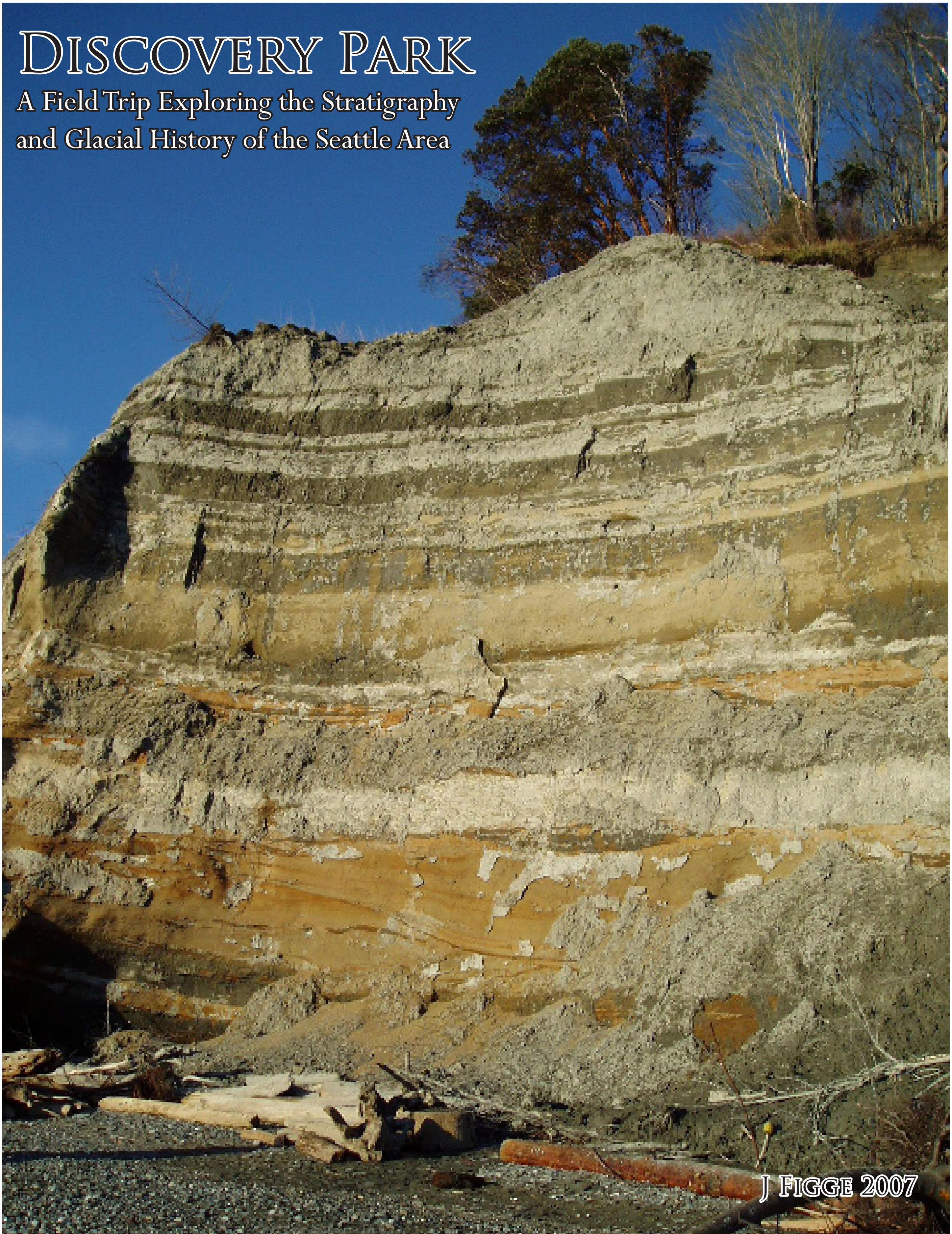

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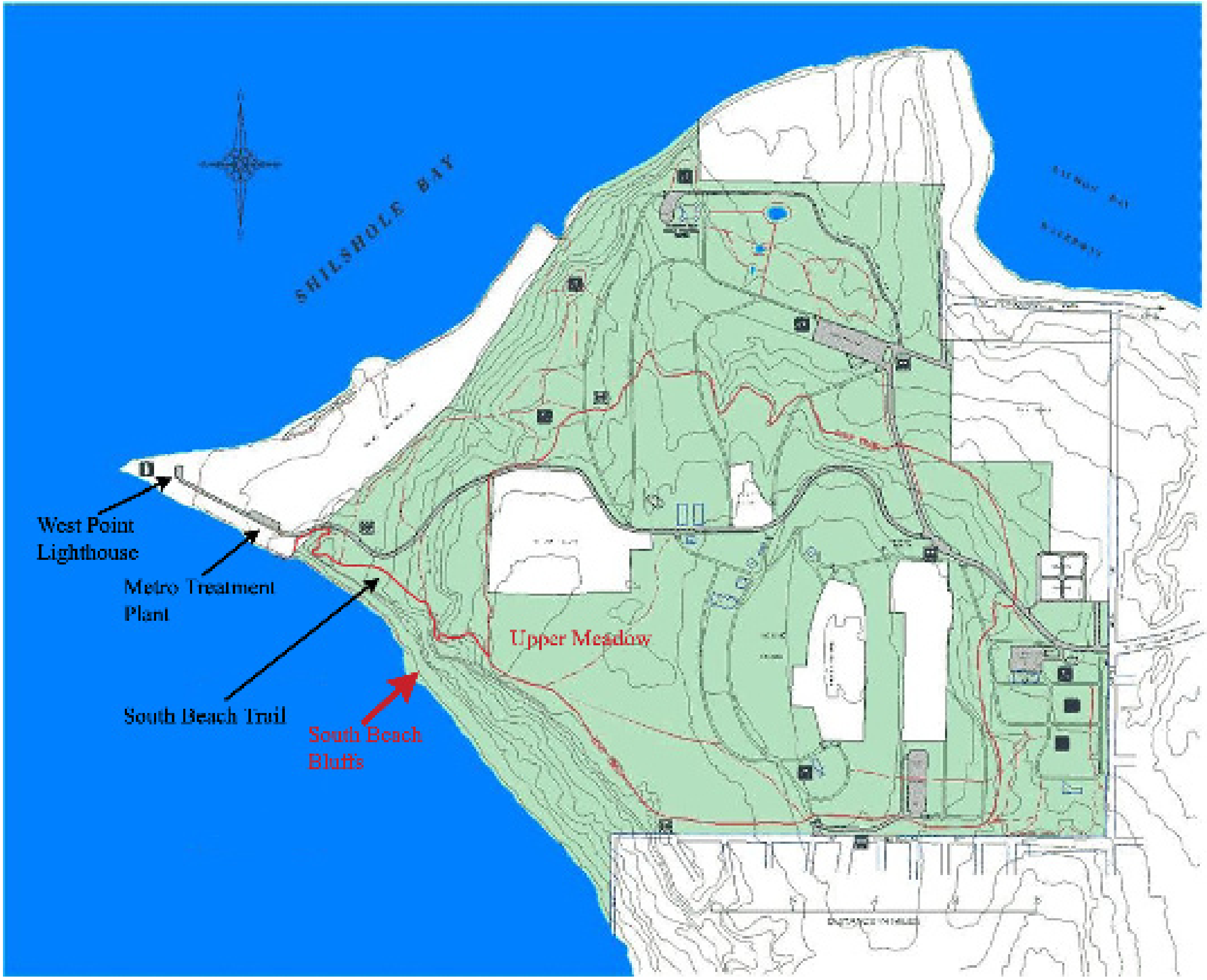
PDF File Version

South Beach, Lawton Bluffs

Introduction

The stratigraphy of the Seattle area is comprised almost entirely of sediments accumulated during the last advance of the Cordilleran Ice Sheet, between 18, 000 and 12,000 years ago. In that event, a large lobe of ice (the Puget Lobe) advanced south out of Canada, eventually filling much of the Puget Sound Basin. At its maximum extent, that ice was 3000 feet thick over the Seattle area, and extended to a point south of modern-day Olympia. This glacial episode is known as the “Fraser” glaciation, and it is only the most recent in a long succession of glacial episodes which have characterized the last 2 ½ million years of the Pleistocene.

Contrary to popular interpretations, these glaciers did not serve to “carve out” the Puget Sound Basin. Instead, their effects here have been largely depositional, adding a thick layer of sediments on top of the older landscape. In the most recent advance, over 300 feet of sediments were deposited across the lowlands, from which nearly all the modern topography has been sculpted. The character of this sediment “package” reflects on the depositional and erosional processes which accompanied this last glacial advance, the processes which produced the modern landscape here.



Discovery Park. Map courtesy of the Seattle Department of Parks and Recreation

Nowhere are the sediments associated with the Fraser Glaciation better exposed than on the beachfront cliffs at Discovery Park in northwest Seattle. These exposures were first noted in the early 1900's, and were studied in detail over the 1950's and 1960's. At these dates, this property was part of Fort Lawton, a US Army post. In the 1970's, the land was given to the City of Seattle, which developed it as a very popular park. Since that time, it has become the "classic" glacial stratigraphy field trip in the Seattle area, a popular destination for hundreds of geology students each year.

Directions:

This trip starts and ends in the parking lot at the Metro plant at West Point. This lot is not available for use by the general public, but a permit can be obtained at the park office for use by school groups.

For the general public, the best plan is usually to park in the south parking lot, stroll down to the meadows above the bluffs, then take the south beach trail down to the waterfront. Under this plan, it is most convenient to consider the Vashon Till before you return back up the trail to examine the Esperance Sand. This will save you a return (round) trip to examine that section.

The Olympic Mountains, view from South Beach

From the parking lot at the Metro plant, head down to the beach and walk south for about .4 miles to the bluffs along the shoreline. The prominent buttress with the reddish base is a good place to target.

NOTE: At high tide, you cannot go further down the beach than this buttress. For that reason, this trip is best done when the tide is out. Tide tables are easily obtained from on-line sources.

As you walk down the beach, consider:

Over the last 2 ½ million years, the Puget Sound Basin has been invaded numerous times by ice advancing out of the Cordilleran Ice Cap in British Columbia. While we have evidence for at least six such advances, there were likely other episodes for which all evidence has been lost. These glacial episodes alternated with non-glacial periods of equal or greater duration, during which the region likely looked much as it does today. In this respect it can be seen that the modern non-glacial setting is only the most recent in a long history of such settings, each of which was subsequently erased with the next advance of the ice. In time, such will be the fate of the modern setting.

The sediments deposited in those earlier glacial episodes are not exposed at Discovery Park. This area is part of a deep basin (the Seattle Basin) which lies north of the Seattle Fault. Here, bedrock lies beneath some 500 meters of accumulated sediments. On the surface, the oldest deposits exposed date from the non-glacial period prior to the Fraser Glaciation. That period is known as the Olympia Interstade (a stade is a glacial period, an interstade a non-glacial period), and these deposits are known as the Olympia Beds.

The Olympia Beds, at tidewater

Trip Log:

The Olympia Beds

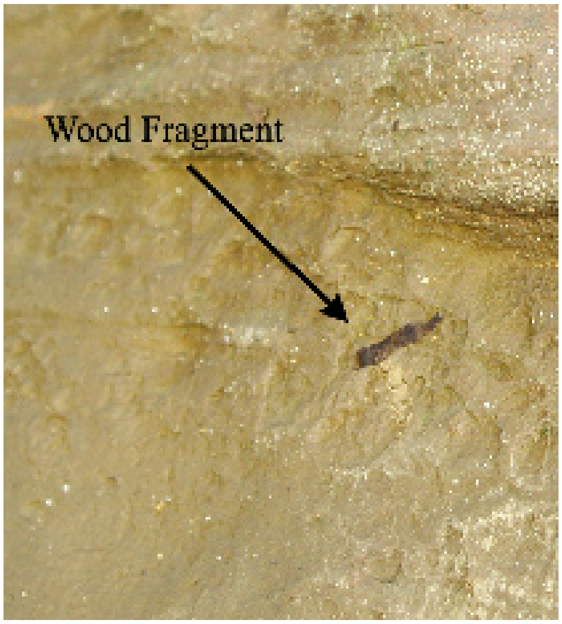
The lowest section of the bluff, the lowest 70 feet at the prominent buttress, contains sediments with a distinctly reddish hue. These are the non-glacial Olympia Beds, and their reddish color reflects the high oxidation rates associated with warmer climatic settings. The sediments here are clay, silt and sand, and are characterized by layers of silty clay and clayey silt, interbedded with layers of sand. In some places, crossbedding and ripple marks can be seen in the sand layers. These lithologies are consistent with deposition in an environment of small rivers, shallow lakes, and floodplains. The presence of relatively abundant organic material (wood fragments) is a reliable confirmation that this was a non-glacial setting. A few pelecypod (clam) fossils have been found here, a species of fresh water habit.

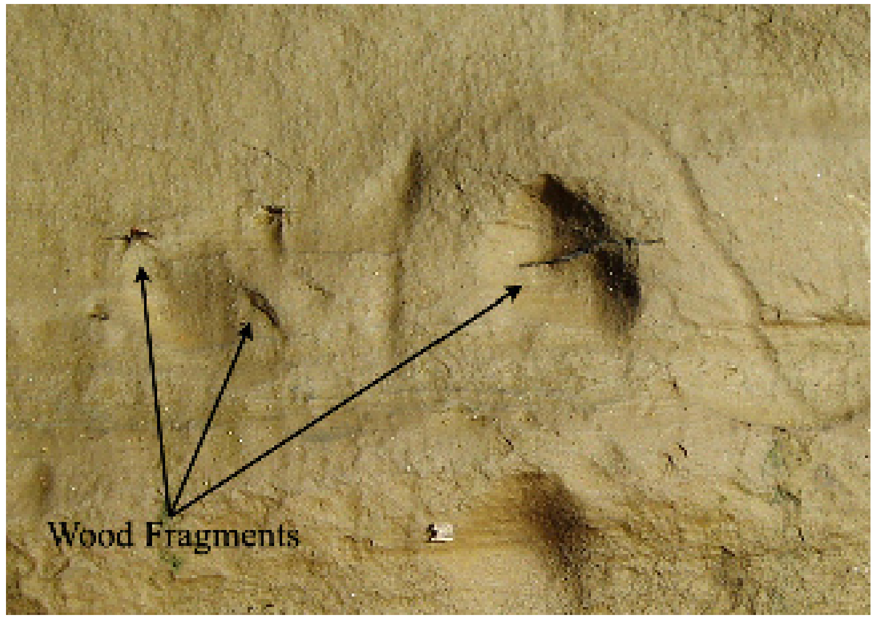
Radiocarbon dates from wood fragments in the lower part of this exposure range from 18-20,000 years ago, approaching the end of the Olympia Interstade. By this date ice was advancing across the international border, just 120 miles to the north. Pollen samples, preserved in the clay deposits of old lakebeds, indicate a dominance of spruce and pine species. These reflect a cooler and moister climate that at present, at a time just a few thousand years before the arrival of the continental ice. Elsewhere, pollen samples from older (35,000 years ago) parts of the Olympia Beds reflect an environment of fir and hemlock species, similar to the modern climatic setting.

(Above and Right)
The Olympia Beds.

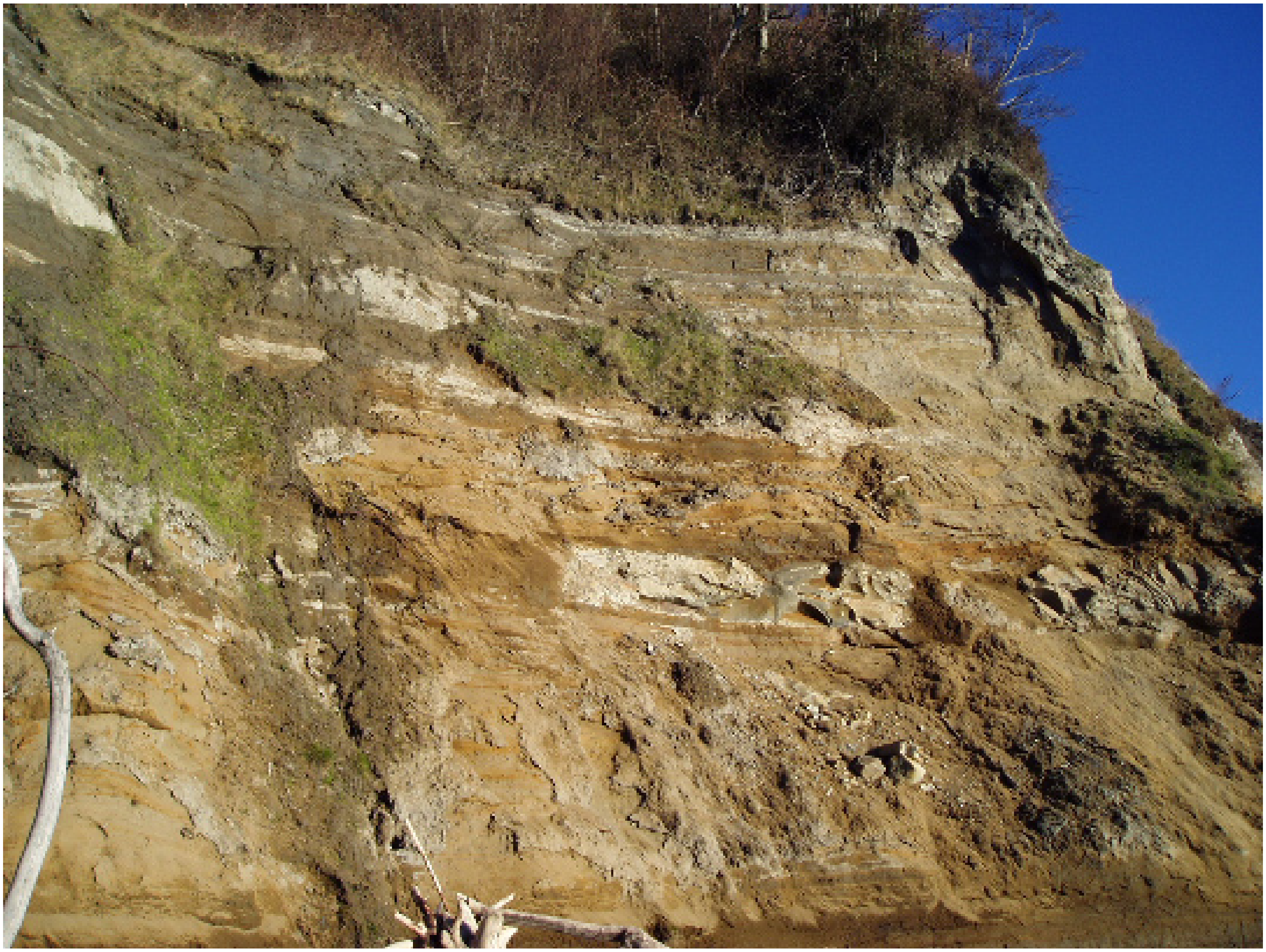
(Above) This section extends to just below the top of the lower bluff. The light-colored beds are, in large part, slope-wash from above that is perched on resistant layers. These sediments dry out and appear white.

Lower image shows the base of exposures here. The gray clay layers are shallow lakebed deposits.





(This Page) The Olympia Beds. Images above show fragments of organic debris (here, wood) that is fairly common in this unit. Radiocarbon dating of fragments like these yielded ages between 18,000 and 20,000 years ago, indicating that these sediments were deposited as the icecap moved south of the border.
Lower image shows the base of the Olympia Beds at this location. These are largely lacustrine (lakebed) clay deposits. Yellow-brown layers are more silty beds.



(This Page) The Olympia Beds. This image shows some of the upper portion of the Olympia section, dominated by beds of sand and clayey silt. At the very top of the image, these beds begin to be transitional with the Lawton Clay above.

The lower image shows a detail from the center of the above photo. The light-colored layer is a clayey silt, while the yellow-brown layers are silty sand. In places, one can discern cross-bedding in the sand layers.

Many of the lower beds here are finely laminated sand and silt layers, typical of a floodplain environment. Sand is deposited as floodwaters first race across the plain, followed by silt deposited under slackwater conditions. The parallel layering of these beds has been deformed as water escaped from the sediments under the load of ice above.

Higher in this section the gross bedding pattern becomes somewhat larger-scale, and the lithologies are of sand and clayey silt. In places, cross-bedding can be seen in the sand layers. Near the top of the section, the distinctive reddish color to the sand fades to gray, presumably an indication of the cooling temperature.

The Olympia Beds are a record of the local setting prior to the last advance of the continental icecap. Overall, they record a setting not remarkably different from that which exists today. Whether a Puget Sound existed in some form at this time is conjectural, but there is nothing in these sediments that suggests a marine setting close at hand. These are the deposits of small streams, floodplains, and shallow lakes, suggesting a somewhat flatter topography than exists at present. Pollen samples reflect a climatic setting much like that seen today, but also reflecting a cooling trend toward the top of the formation as the ice advanced from the north.

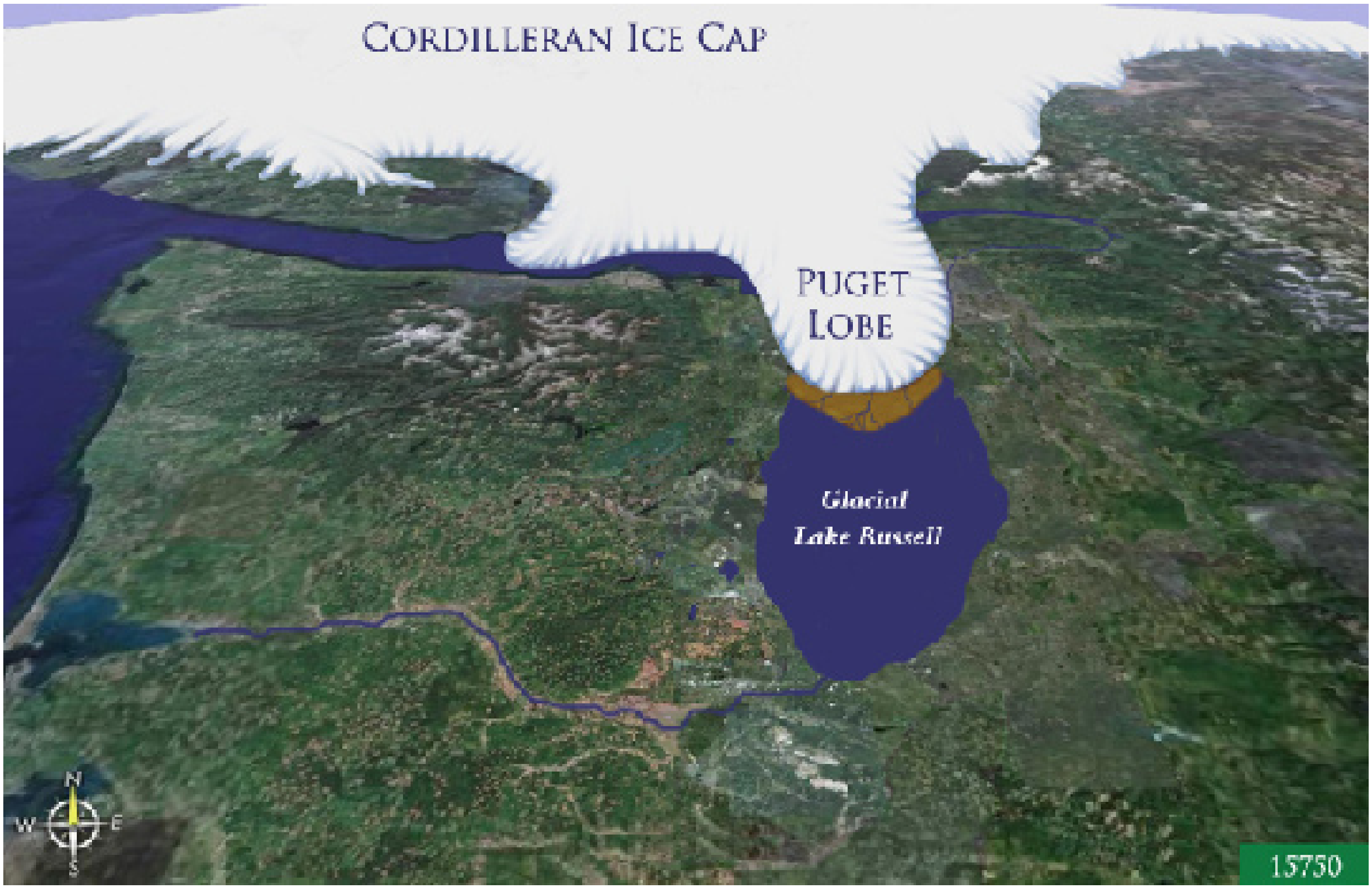
(Left) The Olympia Beds. A detail from the lower part of the image to the right. These sandy layers display cross-bedding, indicating a fluvial (river) depositional setting.

These original structures have been deformed to a degree, likely as the sediments underwent dewatering under the weight of the ice above. In this section, the sand layer appears to have slumped to a certain degree

(Right) The Olympia Beds. This image shows a fresh exposure on some of the silt and clayey silt beds which make up the central part of exposures here. The gray-colored bed is about a meter in thickness.

These exposures were opened by a landslide as part of the slope below failed. Landslides like this are very common along the bluffs here.

(This Page) The Olympia Beds. Images to the right and below show how these sediments have been deformed since their deposition. Most of this deformation appears to be related to dewatering processes which took place as these sediments were compressed under the weight of 3,000 feet of ice. In some places, fairly well-defined flame structures can be seen.



As the Puget Lobe advanced into the Puget Sound Basin, it dammed the north end of the basin and created a large proglacial lake. This lake is called Glacial Lake Russell. The Lawton Clay accumulated on the floor of this lake, from sediments produced by glacial erosion.
Base illustration courtesy of Google Earth. Google Earth is a free program which can be downloaded from www. google.com. It provides 3-D imaging of Earth features.

The Lawton Clay

Deposition in the Olympia Beds continued as the ice advanced to the south, until some time after 16,000 years ago. At this date the large lobe of ice descending from Canada (the Puget Lobe) reached a point where it effectively dammed the north end of the Puget Sound. This happened as the glacier reached the latitude of modern-day Everett. In front of this ice-dam, the north-draining Puget Sound Basin became the site of a large pro-glacial lake known as Glacial Lake Russell. This lake, several hundred feet deeper than the modern Puget Sound, eventually rose to drain south to the Chehalis River, and thence to the Pacific. This is why the Chehalis Valley is so oversized for the modern-day river.

In the calm waters of Glacial Lake Russell, a layer of glacial clay and silt accumulated on the floor of the lake. The process of glacial erosion produces large amounts of silt and clay, a mix of “glacial flour” which colors glacial lakes green. Most of this clay was brought by rivers emanating from the glacial front, but it was supplemented by streams carrying sediment from the surrounding mountains. This unit is known as the Lawton Clay, as it was first described after exposures here (formerly, Fort Lawton). The deposition of this unit was rapid, accumulating some 80 feet over what was less than a thousand years before the ice finally arrived. On the average, this was over an inch of sediment per year.

(Above) The Lawton Clay extends above the Olympia Beds. The transition between the two units here is a gradational one, developing over several feet. This happened as rising Lake Russell encroached on the land above.

(Right) The Lawton Clay. It would be difficult to get to outcrops of the Lawton Clay here, so we largely rely on the Lawton Clay coming to us. Fortunately, frequent landslides bring down samples for our inspection. They can be differentiated from non-glacial clays by the lack of organic debris.

(Above) A classic example of the Lawton Clay. This is a blue-gray glacial clay, and typically shows well-defined bedding layers. It is a soft clay, as shown by the scratch left with the small twig. This clay underlies much of Seattle, and creates drainage and landslide problems throughout the city. It is largely impermeable to water, a condition which promotes landslides in the layers above.

On the positive side, it is a suitable material for making bricks (formerly, a sizeable industry here), and the more massive varieties are suitable for basic ceramic work. This saves the local schools the expense of having to buy clay for grade-school pottery projects.

(Above) The Lawton Clay. Imbedded pebbles are a result of impact with the beach, and are not part of the clay unit.

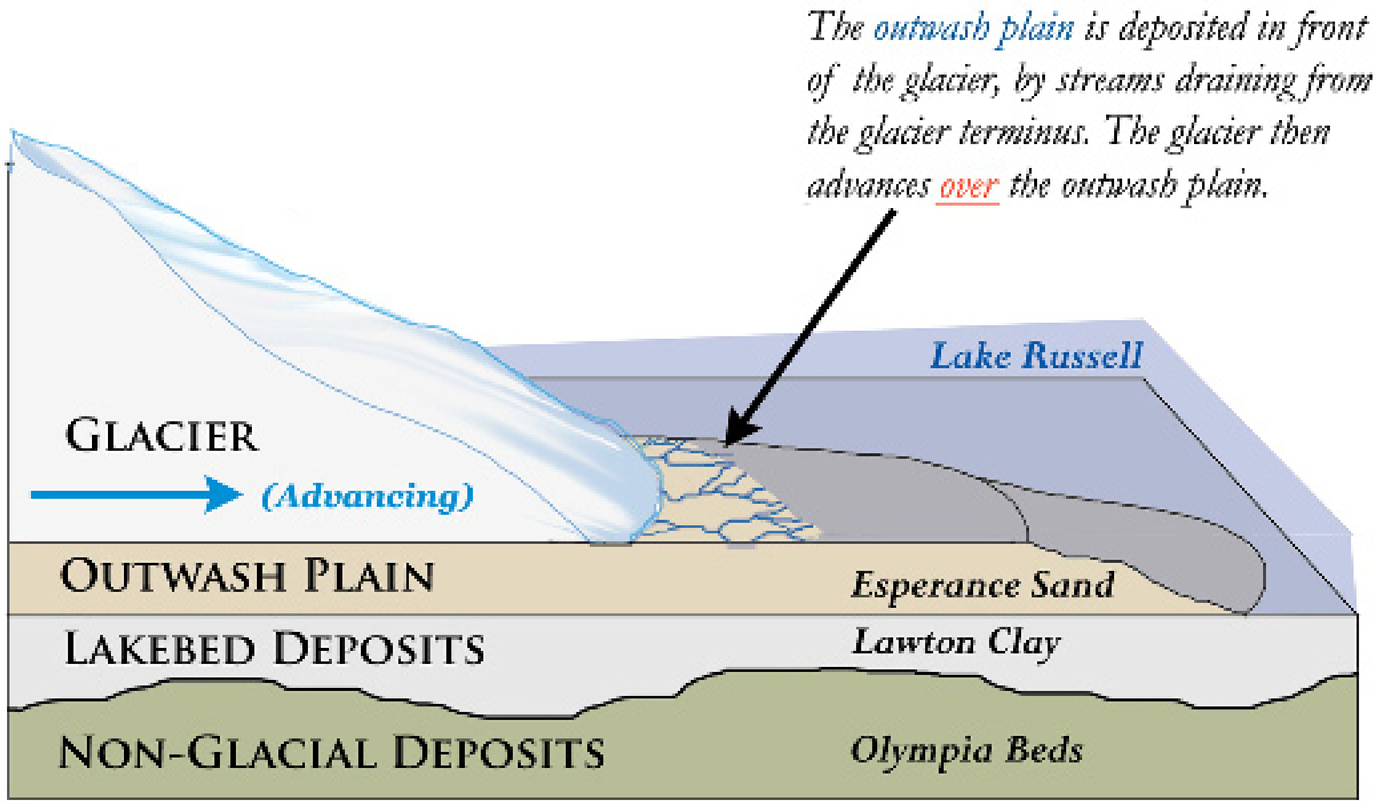
The transition from the Olympia Beds to the Lawton Clay is a gradational one, occurring over several feet in the sediment record. While the uppermost beds of the Olympia section are a silty clay, they contain thin beds of sand not seen in the Lawton Clay above. The Lawton Clay is also distinguished from clay beds in the Olympia section by its lack of organic debris.

Short of climbing the lower bluff (definitely not recommended), there is no place to see an outcrop the Lawton Clay here. While it is impractical for you to get to the Lawton Clay, it is not uncommon for the Lawton Clay to come to you. Over the winter in particular, blocks of clay fall down the cliffs, or are brought down with seasonal landslides. Most of the time, you can find a block or two on the beach. It can be discerned from the clayey layers of the Olympia Beds by its lack of organic material.

The Lawton Clay is a dark gray clay interbedded with light gray silt. In places, it has a bluish tinge. The lower beds are often strikingly laminated, alternating silt and clay on a millimeter-scale. These are similar to classic glacial "varves" – where silt is deposited during spring run-off, and clay is deposited over the fall and winter. Here however, the high depositional rates argue against such an interpretation. On close inspection, it can be seen that the clay layers are considerably thicker, and a regular alternation of layers is not present. The upper part of the Lawton is a clayey silt, much of which is fairly massive in appearance. Smaller sections are laminated, and local ripple marks can sometimes be seen.

(This Page) The Lawton Clay. Image above shows the position of this unit above the Olympia Beds. The transition between the two units is gradational.

Image to the right is a classic example of the Lawton Clay, showing well-defined planar bedding



(Above) The depositional setting of the Esperance Sand, as a glacial outwash plain extending in front of the Puget Lobe.

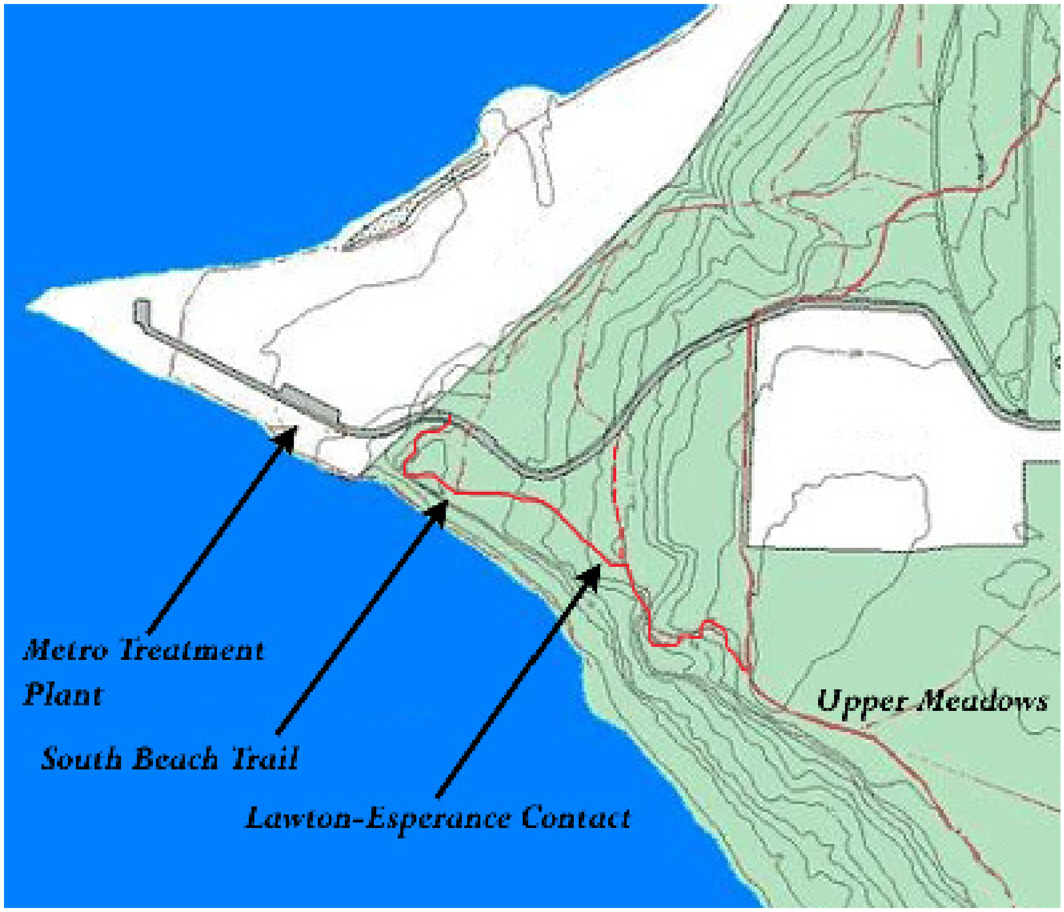
The Esperance Sand

As the Puget Lobe advanced into the quiet waters of Glacial Lake Russell, a large outwash plain of sand and silt accumulated in front of the ice. These sediments were deposited by rivers draining from the glacial front, rivers carrying vast amounts of fine sediments produced by glacial quarrying. As these glacial rivers emptied into the lake, those sediments settled out in the same way as a delta accumulates at the mouth of a river. This outwash plain extended for several miles in front of the glacier. This deposit (largely, sand) is known as the Esperance Sand, named for a small community which used to exist near Lake Ballinger, where it was first described.

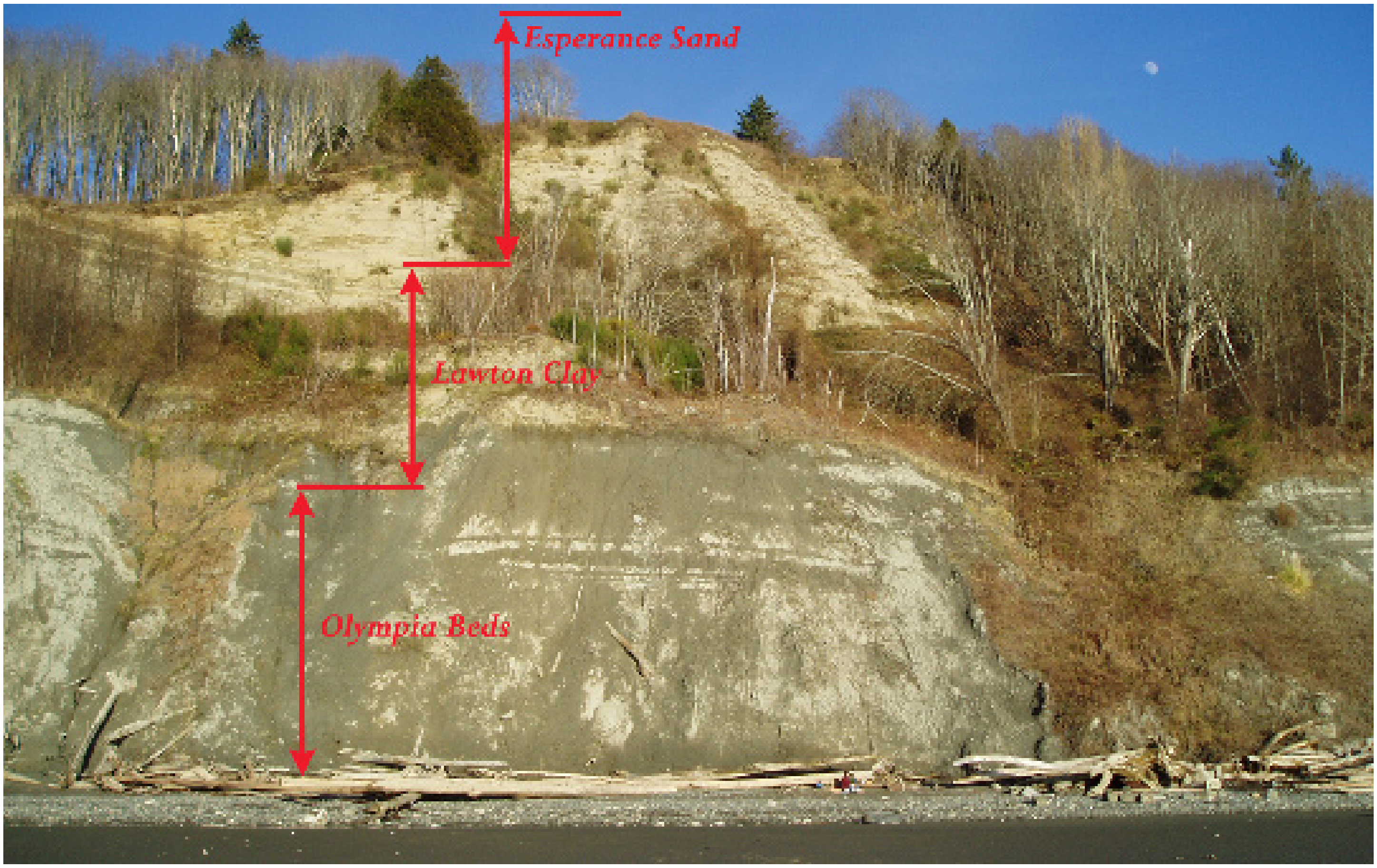
If we want to look at the Esperance Sand, we will have to climb the trail to the top of the bluff, where we can get to it. On the way up the trail, consider the landslides which are an omnipresent feature along these bluffs. These slides happen as the Esperance Sand (which is about 120 feet thick here) accumulates water during the winter. That water drains down through the sand until it meets the Lawton Clay, which is an impermeable layer. Here, water migrates horizontally until it can drain to the surface on a slope. Where it drains out of the slope along the contact between the sand and the clay, it creates a surface on which blocks of sand can slide off the slope. This is the source of most of the landslides in the Seattle area.

As you make your way up the trail, at least during the winter, you can find this contact. Unless it has been raining recently, the trail on the whole is generally pretty dry. It gets a bit damp in the lower portion, but most of it is a well-drained surface. About half way up the trail, at a point just below where it meets with the loop trail, a short section is usually muddy, and often holds some standing water. This is the contact between the Esperance

(Right) Map showing the South Beach Trail route up to the upper meadows area. The Lawton-Esperance contact is show just below the loop trail intersection. Map courtesy of the Seattle Department of Parks and Recreation.



(Below) At the Lawton-Esperance contact, water accumulated in the sand layer drains out of the slope as it meets the impermeable clay layer. This relationship is the source of many of the landslides in the Seattle area.



(Above) The Olympia Beds, Lawton Clay and Esperance Sand. Like the Olympia-Lawton contact below, the Lawton-Esperance contact is a gradational one.

(Right) View toward West Point from one of the trail-side platforms on the South Beach Trail. The West Point lighthouse lies at the end of the point.

Sand and the Lawton Clay, and this wet section is where water is draining out of the sand along the clay boundary. The mud here has a distinctly clayey appearance, a quality which disappears just above.

Climb the rest of the trail to the upper meadow, a pleasant hike under anything but the worst of conditions. Platforms and park benches are situated at the best viewpoints, some of which offer a commanding vista of the Puget Sound below, and the Olympic Mountains beyond. At one of these points, consider what this view might have looked like 16,000 years ago, with Glacial Lake Russell impounded by ice to the north.

(Above) View from the top of the bluffs, just a short distance below the upper meadows. This is a popular viewpoint overlooking Puget Sound.

(Right) A winter view along the upper part of the South Beach trail. In many ways it is a more pleasant hike in winter, when views are not obstructed by summer vegetation. The trail winds its way along the tops of the bluffs, just a short distance below.

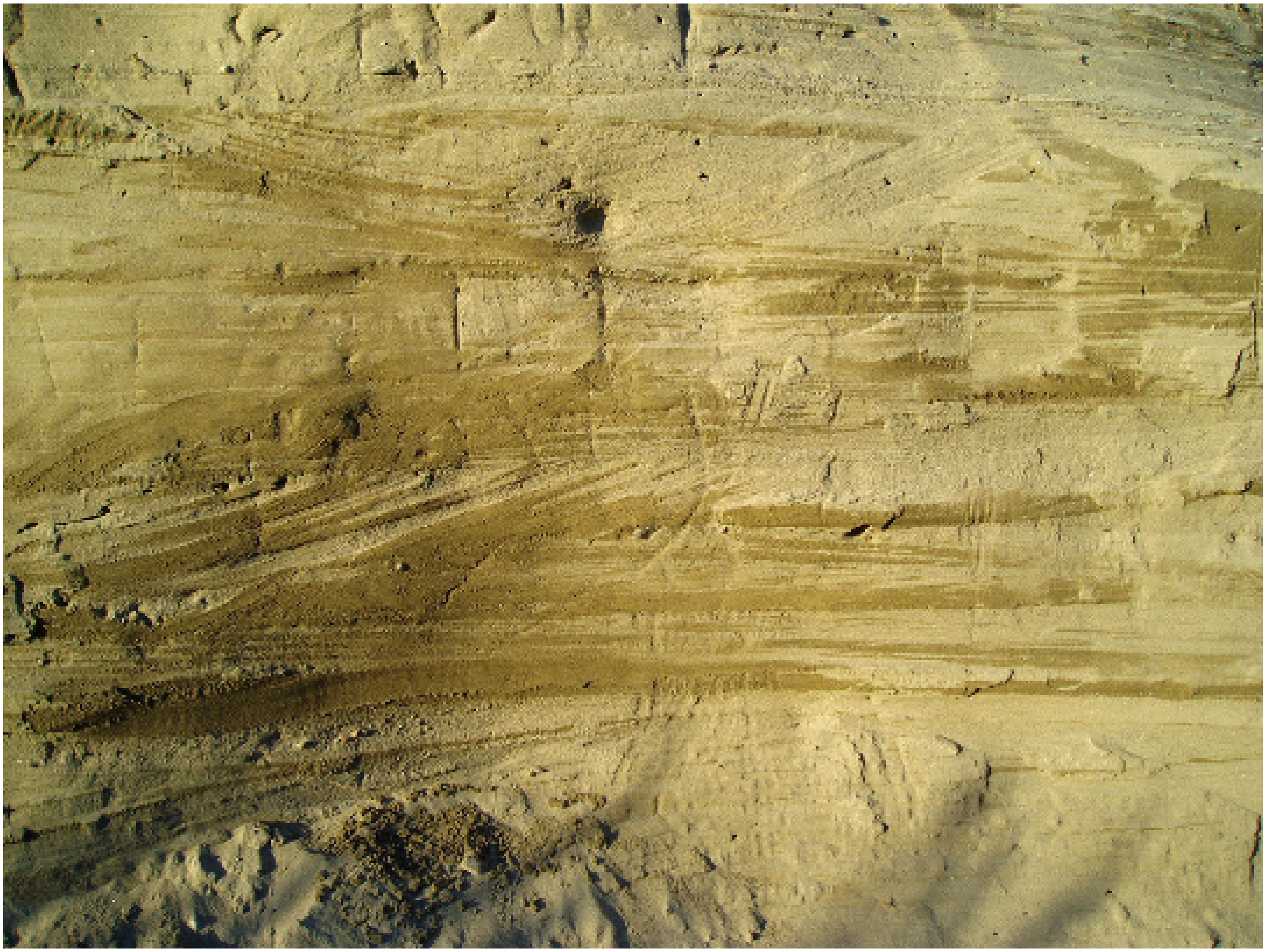
Arriving at the upper meadow, one gains a view of the bluffs below. These are comprised of the Esperance Sand, which accounts for their light color. In order to examine these sediments, we will have to cross the log barrier adjacent to the trail. Crossing the log barrier and taking a well-used path down, exposures of the Esperance Sand are revealed here.

(Right) A view of the bluffs from the side of the upper meadows. These cliffs have likely receded thousands of feet over the last ten thousand years. They remain in the process of active retreat, recently resulting in a closure of the far part of the bluff to public access.

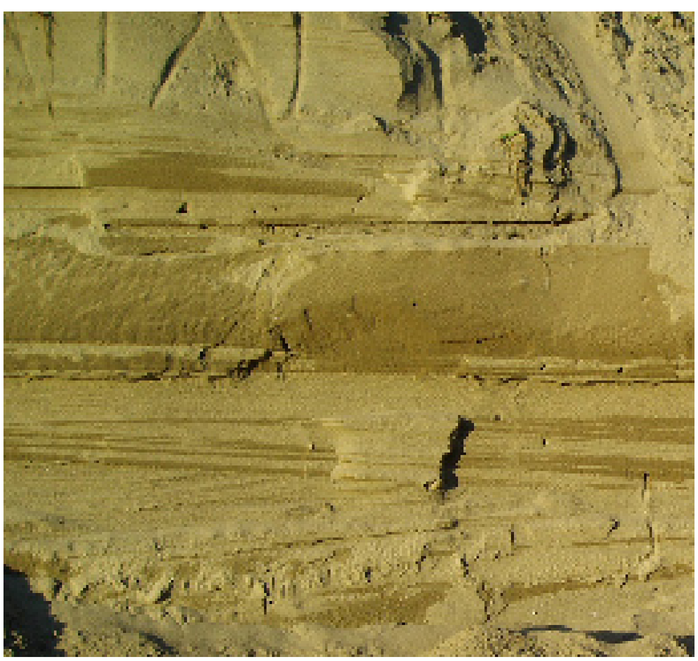
WARNING: It is a violation of Seattle City Ordinance to go beyond the log barrier. The bluffs here are fragile and unstable, and present a hazard to the public. Serious injury or death could result from a fall down these cliffs, and travel on these slopes promotes their erosion. For your own protection, as well as your liability for citation and fines, you are urged not to cross the log barrier.

The Esperance Sand in this location can be divided into two parts, a lower (35-foot) portion which is largely parallel-bedded and contains occasional layers of silty clay, and an upper (85-foot) portion which is a more uniform sand and is typically cross-bedded. The lower portion is interpreted as being transitional between the Lawton and Esperance units, and is typically a finer sand than seen in the upper portion. These sediments accumulated at a somewhat greater distance from the ice front than did the upper unit.

The exposures here on top of the bluff are in the upper part of the Esperance unit. They are comprised of a medium, well-sorted light brown sand, with rare thin silty layers. Very rarely, thin bands of gravel are found. These sediments are extensively crossbedded, reflecting deposition in a fluvial (river) setting. These were rivers emanating from the ice itself, carrying huge amounts of sediment in the process. These overburdened streams deposited their load on this broad outwash plain, frequently changing course as their channels became blocked by sediment. On examining the bedding here, you can see numerous examples of where older sediments were cut by new channels, which were subsequently filled by younger streams. This is a typical depositional pattern for heavily overburdened streams, the kind of streams which built this outwash plain in front of the glacier.



(This Page) Bedding patterns in the Esperance Sand. Cross-bedding is a conspicuous feature in the upper portion of this unit. This reflects the fluvial (river) depositional setting of the outwash plain.



(Right) Bedding patterns in the Esperance Sand. Here you can see how older structures have been eroded away and filled with younger structures. This is a typical pattern in streams overburdened wtih sediment.

On a larger scale, the upper portion of the Esperance Sand was deposited as a series of foreset beds, typical of accumulations in a deltaic (river delta) setting. These develop as sediment flows off the top of the outwash plain (or river delta) and accumulates in beds which dip down the leading slope. These features are not readily discernable here, but they characteristically dip to the southeast – the direction in which the outwash plain grew as the glacier advanced.

The Vashon Till and the Esperance - Vashon Unconformity

The Lawton Clay and Esperance Sand were deposited in front of the Puget Lobe, and are accordingly considered "proglacial" deposits. As the ice advanced, it advanced over this accumulated package of proglacial sediments, which served as a bed for the glacier. In this respect, it can be seen that the ice did not excavate the floor of the Puget Sound Basin. The Puget Lobe continued to advance until it reached its maximum extent at a point near the modern-day town of Tenino. This extent was reached about 14,000 years ago. By this point it had displaced all of the water in Glacial Lake Russell, and completely filled the Puget Sound Basin. In this area, the ice was about 3,000 feet thick.

Shortly after reaching its furthest extent, the Puget Lobe began to decay and retreat rapidly. Within 500 years it had retreated to a point north of Seattle, and within a thousand years most of the Puget Basin was ice-free. As the ice retreated, it covered the lowlands in a veneer of glacial till (the Vashon Till, as it is known). Till is an unsorted and unstratified mix of gravel, sand, silt and clay, and it is classified as a type of moraine deposit – as are all sediments directly deposited by glaciers. It is sometimes known as "ground moraine," but local gardeners disdainfully refer to it as "boulder clay" or "hardpan."

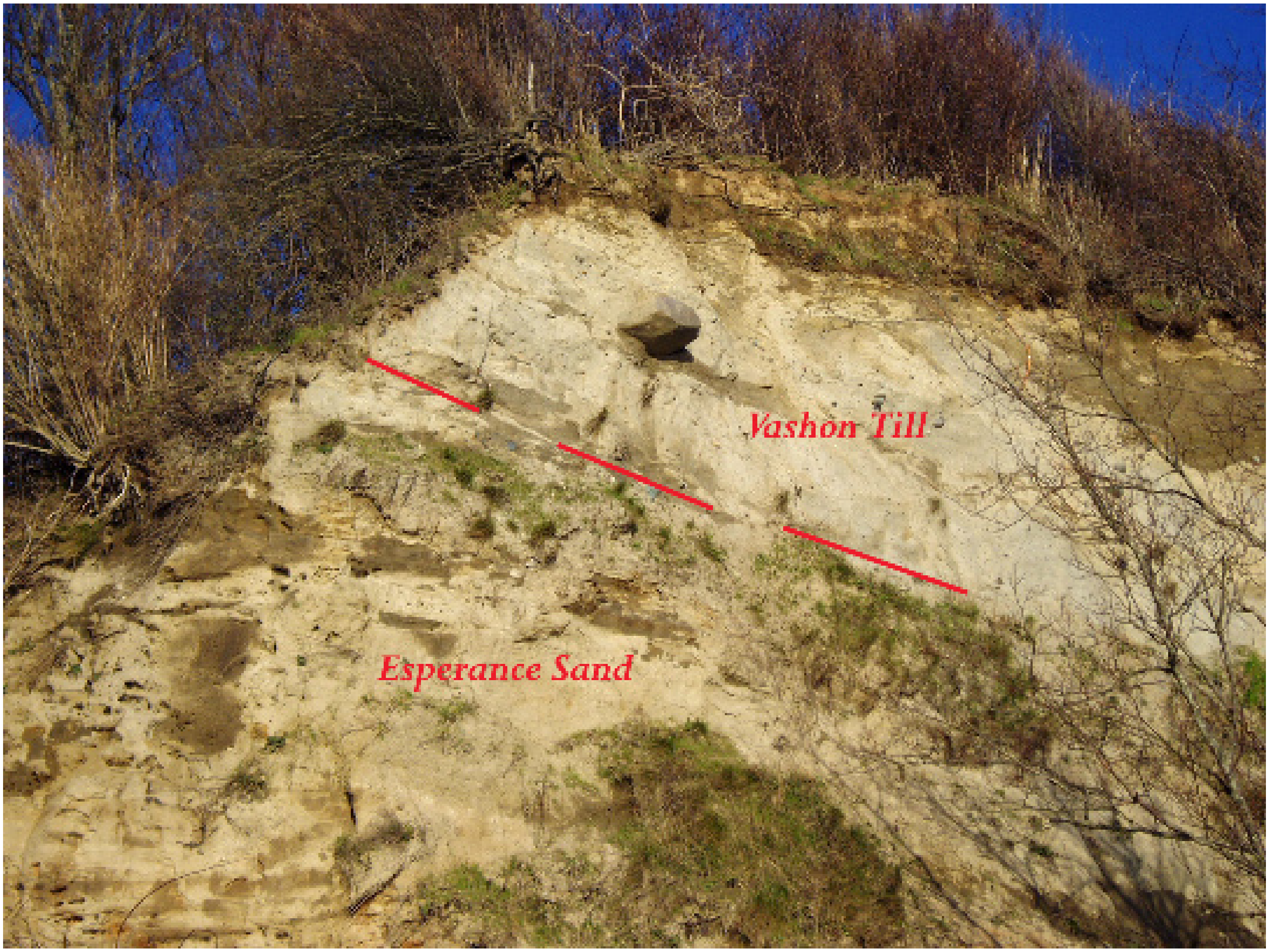
(Below) The Vashon Till, deposited by the Puget Lobe as it retreated from the area. This is the only material directly deposited by the glacier, and is a form of moraine. It consists of an unsorted, unstratified mix of clay, silt, sand and gravel, often including boulders of substantial size.

There is no readily-observable till layer capping the Esperance Sand in the meadow areas on top of the bluffs. If we want to look at the till, we will have to return back down to the beach. By this point, the return is a familiar route. As some consolation, you now have a better appreciation for the ground you are walking down.

As you head down (again), observant travelers will notice a prominent granite boulder on the side of the trail. This boulder is a glacial "erratic," carried by the ice and deposited here as it retreated. This boulder was probably quarried in the Canadian Coastal Range, and was transported well over a hundred miles to this location.

(Right) A granite erratic along side the South Beach Trail. The nearest granite to this location is at Snoqualmie Pass, 60 miles to the east. This boulder was probably picked up in the Canadian Coastal Range of British Columbia. It rode the ice for over a hundred miles before being dropped here as the ice retreated.

Where the trail (and road) arrives back at tidewater, an excellent example of glacial till can be seen in the bluff above (the bluff that the trail just descended). The top ten feet of this bluff are comprised of a layer of sand, silt and rocks of various sizes, including one rather prominent boulder sticking out of the slope. This layer shows no evidence of stratification, and is distinct from the exposures of Esperance Sand below. This is the Vashon Till, deposited by the glacier as it finally retreated from the basin. This material covers most of the Puget Lowland. It is a far more durable layer than the underlying sand, and has preserved the landscape here from extensive erosion. Typically, the Vashon till ranges from 5 to 15 feet in thickness.

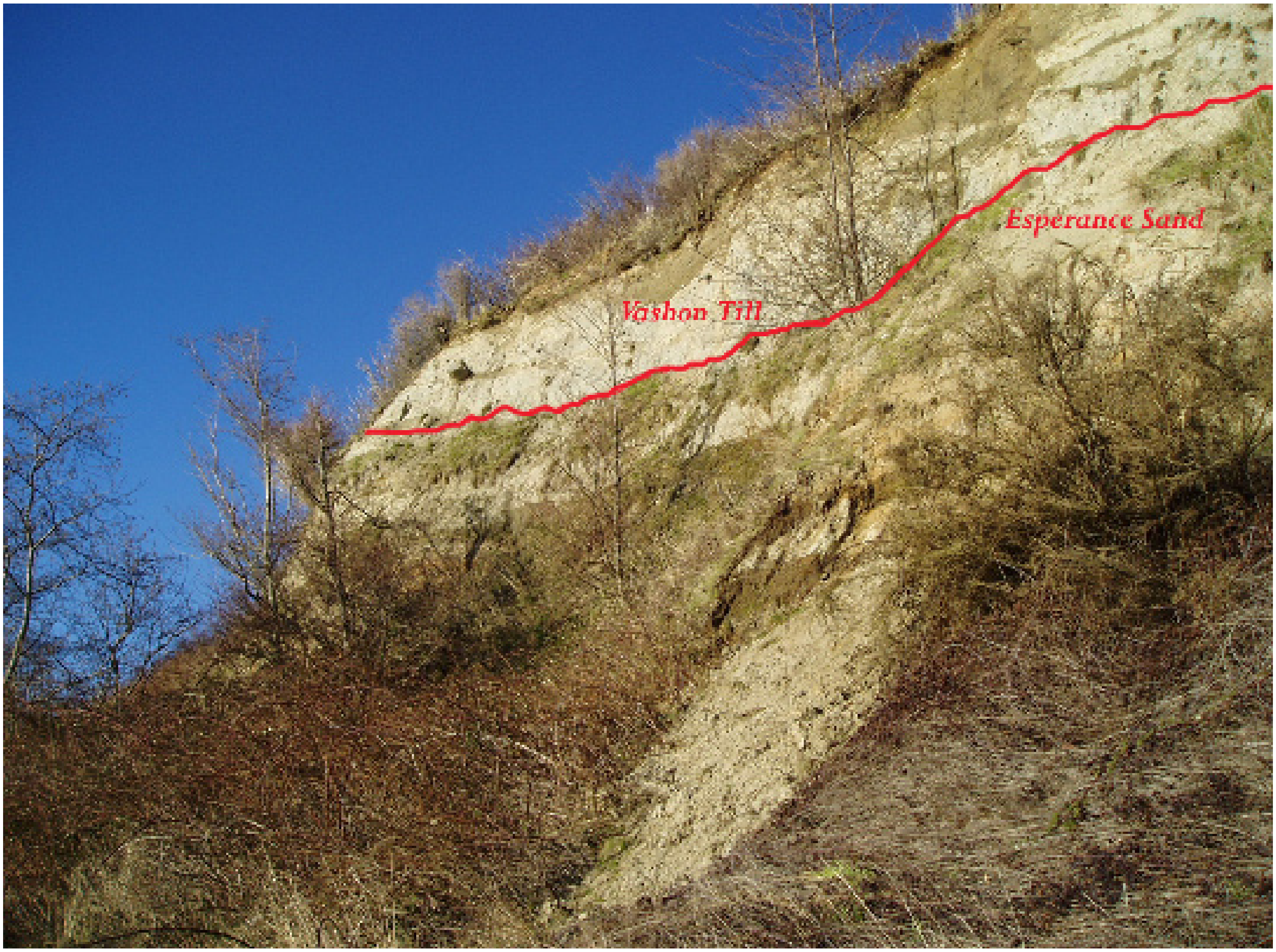


(Above) The Vashon Till, overlying the Esperance Sand. Note the large boulder protruding from the slope.

A unique aspect of till is that it is deposited relatively uniformly across the landscape (as opposed to wind and water-born sediments, which accumulate in low areas), even adhering to steep hillsides. This is easily seen across the region, as a layer of till carpets the lowland hills and valleys on all but the steepest of slopes.

The critical observation here is that this relationship implies that the hills and valleys of the region must have existed prior to when the retreating ice mantled them in glacial till. These hills and valleys are largely eroded out of the Esperance Sand and Lawton Clay. This erosional event is represented by an unconformity (an irregular contact reflecting an eroded basal surface) between the Esperance Sand and the Vashon Till. Looking on the bluff above, you can see that the contact between the two units is an irregular one.

The Lawton Clay and Esperance Sand were originally deposited as flat, horizontal layers of sediment. These units accumulated to over 300 feet in thickness before they were overrun by the glacier. When the ice retreated, it deposited its till layer across a landscape which had already been heavily eroded into something resembling its modern form. That erosional event happened after the Esperance Sand was deposited, but before the Vashon Till was deposited. In that process, truly vast amounts of sediment were eroded away. Across the Puget Basin, every point of land less than 400 feet in elevation represents an equivalent amount of erosion from that original level.



(Above) The Vashon Till, overlying the Esperance Sand. The red line illustrates the irregular (unconformable) contact between the two units. This unconformity is responsible for most of the topography of the Puget Sound Region.

On the Origins of the Puget Sound Landscape

The landscape of the Puget Sound Basin, marked by hills, valleys and troughs, developed through a combination of sub-glacial meltwater erosion and a shaping of the surface by south-advancing ice movement. It would appear that these events largely took place as the glacier was in the process of rapidly retreating. It is important to remember that even as that retreat was underway, the southward movement of the ice continued.

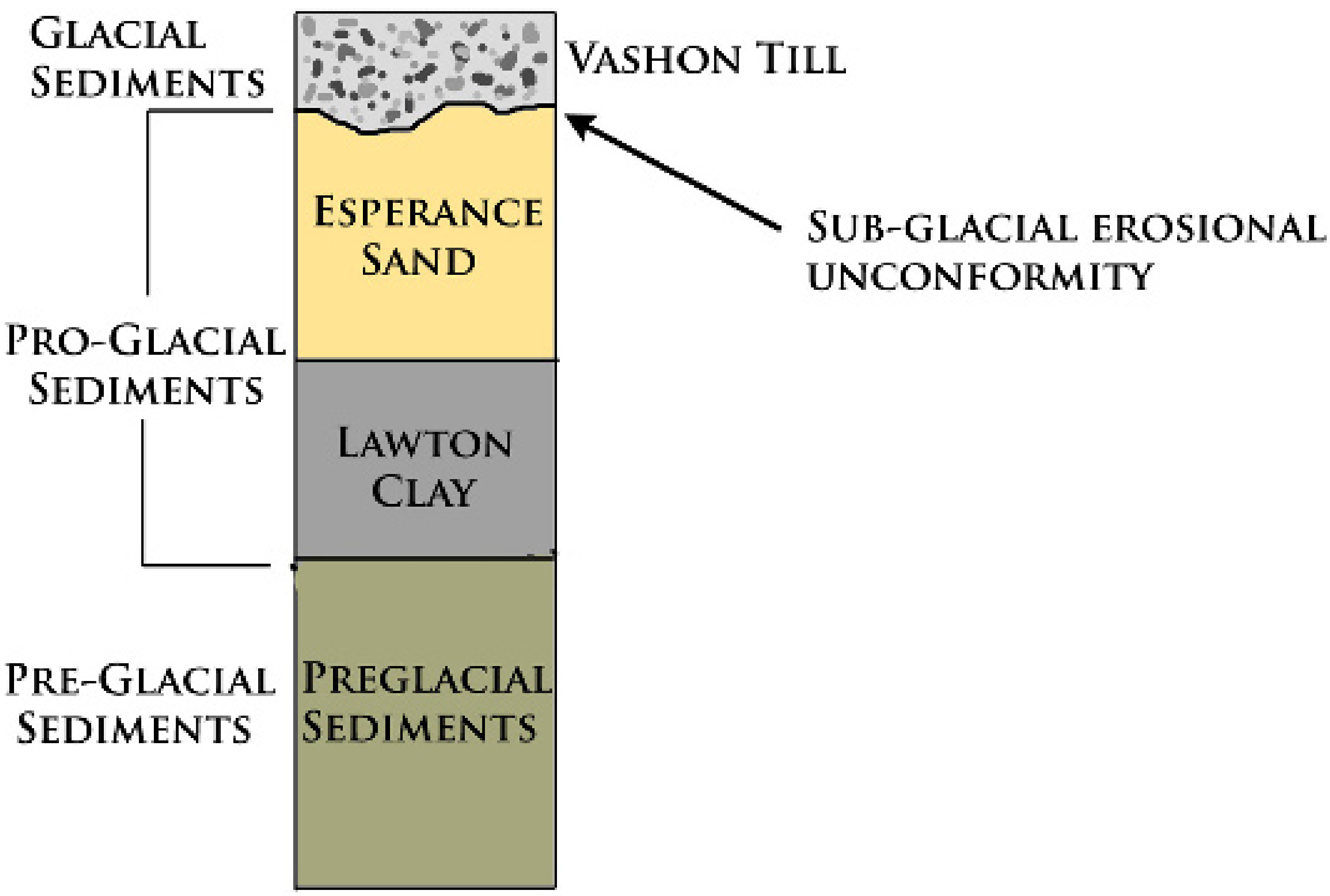
The thinning and retreat of the Puget Lobe was a rapid affair, much of it happening over perhaps just five hundred years in the Puget Basin. As this immense ice sheet melted, vast amounts of water were produced. That water drained to the base of the glacier, and eroded sub-glacial drainage channels into the underlying sediment, parallel to the flow of the ice. Between those channels, contact with the moving ice shaped the intervening hills into streamlined features paralleling the direction of ice movement. These streamlined north-south trending hills are called "drumlins," and they are the dominant landform of the Puget Sound lowlands. The "seven hills of Seattle" are good examples of this. These features are characteristically steeper on their northern (upstream) end, and present a more gentle slope on the southern (downstream) end. Most of the Puget Lowland is patterned in these streamlined features, a pattern known as a "drumlinoid topography."

This "drumlinoid topography" is characteristic of the "upland" areas of the region, of which the Seattle area is one. These upland areas are separated by large troughs which cut the landscape, troughs like the Puget Sound, Lake Washington, Lake Sammamish, and others. These broad troughs also trend north-south, and are thought to have been large sub-glacial drainage channels which collected water from the adjoining uplands and moved it south toward the Chehalis outlet. Given the rate of ice-wastage during the glacial retreat, truly phenomenal quantities of water were being generated in this process.

By 13,000 years ago the ice had retreated to a point where it no longer dammed the Puget Sound Basin, and water could once again drain northward. Following a period of re-adjustment, during which the land re-bounded from being depressed (about 300 feet) by the weight of the ice, and during which sea-levels rose (about 350 feet) as the icecaps melted, the topography of the region was established largely as it appears today.

This is the end of this field trip. Walk the short distance back to the parking lot and return to your vehicles. Drive away and never again look upon this landscape in the same way.

(Below) The stratigraphic column for the Seattle area. Most of the topography of this region can be attributed to the unconformity between the Esperance Sand and the Vashon Till.



(Above) An aerial view of Seattle, looking west. Note the north-south (left-right) alignment of the features here, a reflection of the direction of ice movement.The major bodies of water in this picture fill what are thought to have been north-south draining subglacial river channels cut during the rapid retreat of the icecap.

References:

A great deal has been written on the glacial history of the Puget Sound region. The following references are but a small selection of some of the more informative and comprehensive works by some of the leading researchers in the field.

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Upper Meadow, Discovery Park

South Beach

End