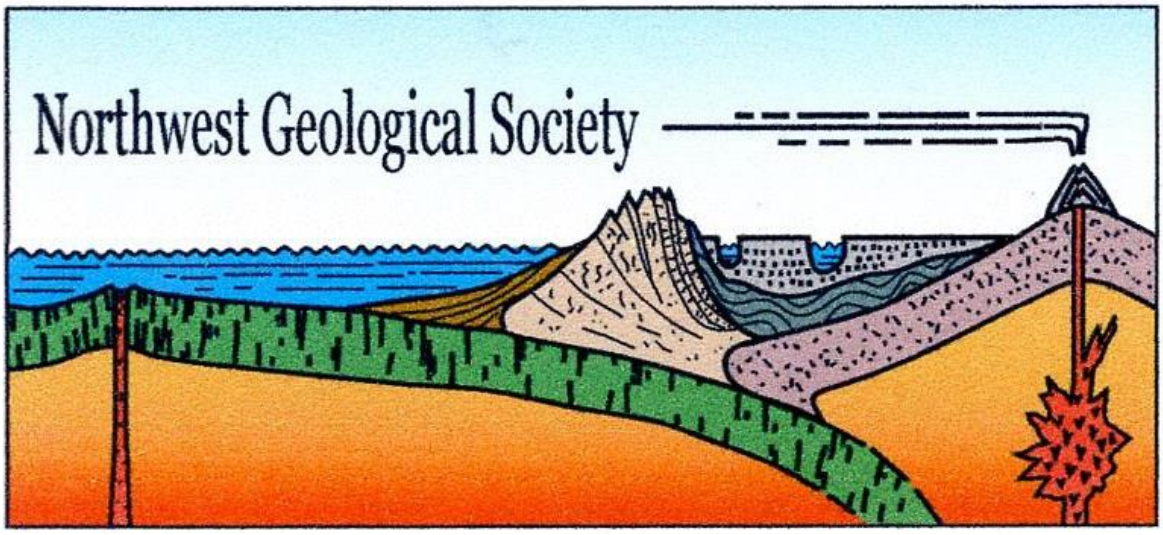

Society Publications in Pacific Northwest Geology

FIELD TRIP GUIDEBOOK #039

JÖKULHLAUPS FROM GLACIAL LAKE PUYALLUP, PIERCE COUNTY, WASHINGTON

October 15, 2011

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With contributions from Derek Booth and Aaron Wisher

NWGS FIELD TRIP GUIDEBOOK SERIES

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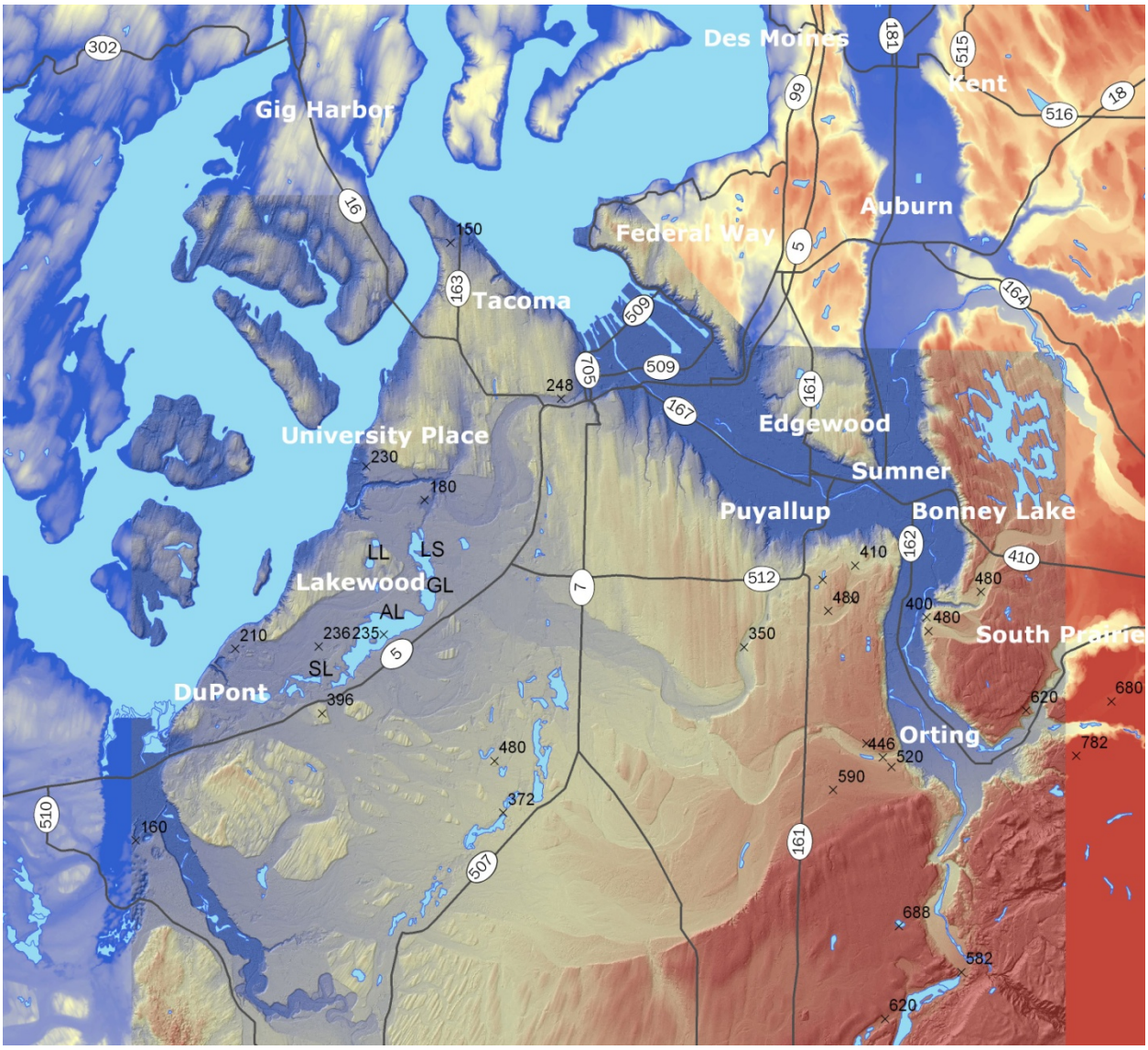
Des Moines
Kent
Gig Harbor
Auburn
Federal Way
Tacoma
University Place
Edgewood
Sumner
Puyallup
Bonney Lake
Lakewood
LL
LS
GL
AL
SL
DuPont
Orting
South Prairie
302
16
163
509
705
167
161
5
99
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515
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164
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162
410
480
400
350
620
680
782
446
520
590
372
507
510
160
688
582
620
150
248
230
180
210
236
235
396

Cover photo:

Acknowledgements

Stop 1: Parker Pacific, Puyallup Highlands
Dave Lonyo, 253.377.1163

Stop 4: ExtraSpace Storage
Domenica Magana, Manager
fac1343@extraspace.com
253.472.6475

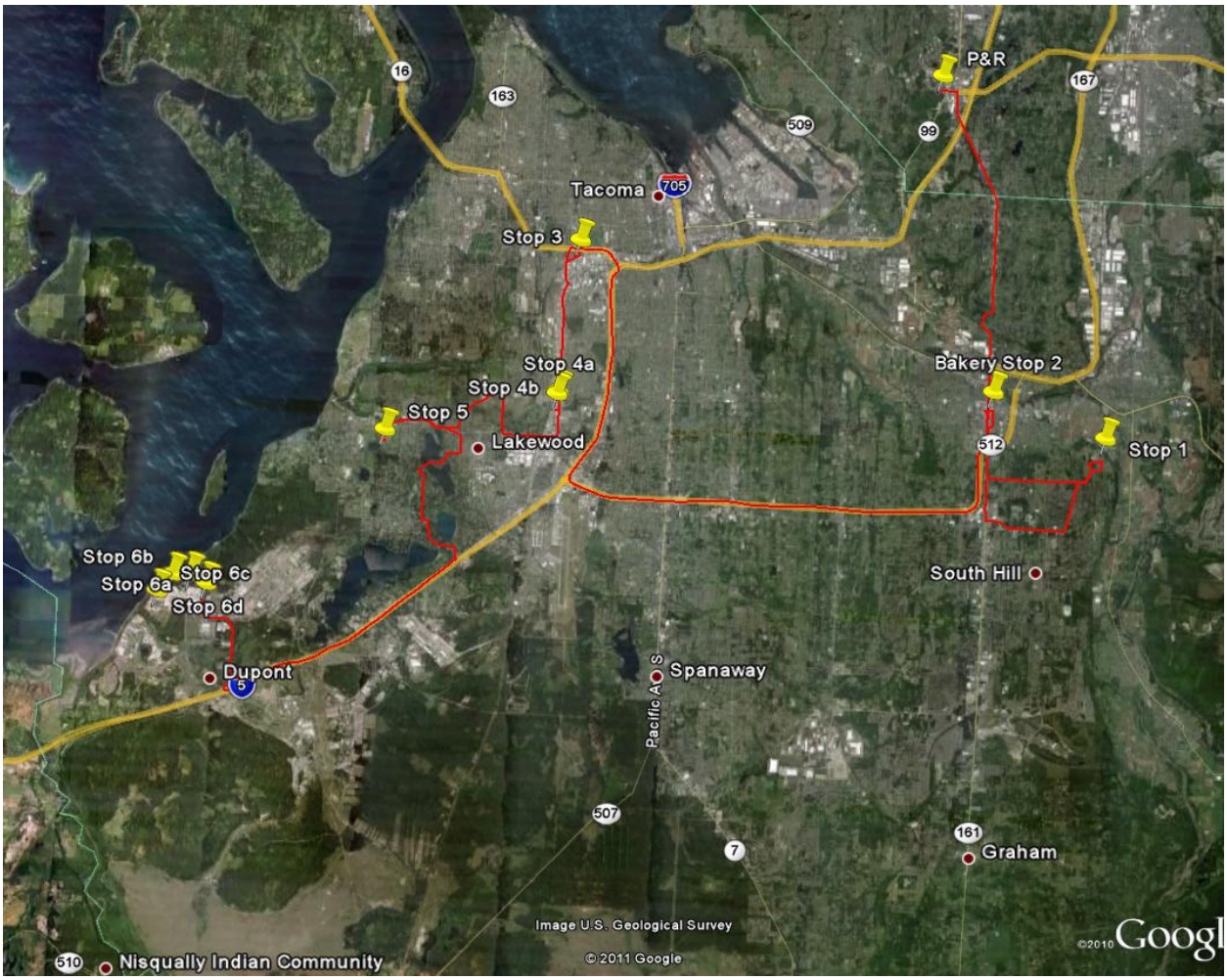
Stop 6: CalPortland Quarry
Jim Tweedy, Manager, 253.912.8500 x18503, jtweedy@calportland.com
Jeff Zurcher, today's host, 253.341.5080, jzurcher@calportland.com
and the crew at CalPortland's DuPont Quarry

Please consider sending an acknowledgment of CalPortland's accommodations for our group and commitment to responsible mining and reclamation to:
1. CalPortland, 2025 E. Financial Way, Glendora, CA 91741, attn: Allen Hamblen, president & CEO.
2. Mayor and/or the city council of DuPont: The Honorable Tamera Jenkins, Mayor, 1700 Civic Drive, DuPont, WA 98327

Itinerary

0730 Leave Tukwila Park & Ride.
0800 Leave South Federal Way Park & Ride. Drive to Stop 1 crossing outburst channels.
0830 Arrive Stop 1, Vista. View and discussion of large troughs that hosted Glacial Lake Puyallup.
0930 Drive to Pioneer Bakery in Puyallup, Stop 2.
0945 Arrive Stop 2. Downtown Puyallup. We have 4 places for coffee and facilities.
1000 Drive to Stop 3. Note geomorphic changes, gravel deposits, and view of South Tacoma Channel from overpass.
1020 Arrive Stop 3, Vista. View and discussion of South Tacoma Channel.
1045 Drive to Stop 4 along terraces related to the South Tacoma Channel.
1100 Arrive Stop 4, ExtraSpace Storage. View of terraces down in valley, from 4a and 4b.
1130 Drive to Stop 5 with views of terraces and deposits along the way.
1150 Arrive Stop 5, Fort Steilacoom Park. Walk to Waughop Lake for lunch, restrooms, and discussion of kettle lakes.
1250 Drive to Stop 6, crossing Lake Steilacoom, roller coaster road, and passing upland till remnants. Note oak trees and gravelly soil.
1330 Arrive Stop 6, Dupont Quarry. Start at stop 6a- overview of quarry, signing forms, and getting gear. Jeff Zurcher of CalPortland will escort us to key stops in the quarry. Stop 6b will be a view of the active wall and will have facilities. Stop 6c will be at an exposure of the Olympia beds. Stop 6d will be at the office to return our gear and use the facilities.
1600 Leave Stop 6, drive to Federal Way Park & Ride.
1700 Arrive Federal Way Park & Ride
1730 Arrive Tukwila Park & Ride

Route Map


P&R
16
163
509
99
167
Tacoma
705
Stop 3
Stop 4a
Stop 4b
Stop 5
Lakewood
Bakery Stop 2
512
Stop 1
Stop 6b
Stop 6a
Stop 6c
Stop 6d
South Hill
Dupont
5
Spanaway
Pacific Ave S
507
7
161
Graham
Image U.S. Geological Survey
© 2011 Google
510
Nisqually Indian Community

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JÖKULHLAUPS FROM GLACIAL LAKE PUYALLUP, PIERCE COUNTY, WASHINGTON

Kathy Troost, Troost Geosciences, LG, kt@troostgeosciences.com, 206.909.9757
Darrell Sofield, LG, aMap, PLLC, dsofield@amazingmaps.us, 360.224.7606
With contributions from Derek Booth and Aaron Wisher

I. INTRODUCTION

While geologists are familiar with some famous outburst floods like from Glacial Lake Missoula, jökulhlaups actually occur today on nearly every continent. We quickly turn to Iceland for modern examples because of the juxtaposition of volcanoes and glaciers, but Alaska has some outstanding examples as well. Jökulhlaups are fascinating to study due to their powerful nature and ability to transport and displace tremendous volumes of sand, gravel, and glacial ice.

For the Pierce County area, jökulhlaups are part of the Vashon recessional story, a story that is evolving with LIDAR mapping, quadrangle mapping, and infrastructure projects providing evidence for multiple recessional lake levels. Likewise the Vashon glacial advance is becoming a more complicated event than originally thought.

"Jökul" is the Icelandic word for "glacier" and "hlaup" is the Icelandic word for flood or floodburst. One pronunciation guide lists *"yer-kul-hloyp". Good luck.*

My interest in this topic began with an initial look at the geomorphology of Central Pierce County when drilling at Ft. Lewis and McCord back in the late 1980's. I read in Walters and Kimmel (1968?) that the Steilacoom Plain was the result of floods from Glacial Lake Puyallup. As I began mapping the area, I hypothesized that the deposits and landforms could be the result of a Jökulhlaup. I believe there is evidence for multiple jökulhlaups in Pierce County, and today I plan to show you some of that evidence.

This is a story of glaciers, megafloods and icebergs. I **love** this story, Thank you for coming to hear my interpretation….my story as I have it worked out so far.

What is a jökulhlaup?

A jökulhlaup is an outburst flood event from an ice-dammed lake (H. Fay, 2000).

1. Forces in ice lobe become critical causing either or both…
   a) Water pressure causes hydraulic jacking
   b) Ice behaves brittlely and fractures
2. Water from subglacial lakes begins draining rapidly
3. Rapid expansion of drain due to friction
4. Stress and strain of the ice changes rapidly
5. Ice behaves brittlely
6. Large chunks of ice break off and float down the flood

Some typical characteristics of jökulhlaup deposits and landforms (Maizels, 1989):

- Massive, homogeneous deposits, hyperconcentrated flows
- Heterogeneity of depositional types
- Well-sorted deposits (waning flows)
- An earmark: openwork gravel to cobbles
- Overlain by erosional surfaces
- Large flood channels
- Terrace incision

- Multiple terraces
- Repeated flows
- Potholes common

Jökulhlaups vary in size as well as location. On Mt. Rainier, commonly debris flows start out as jökulhlaups. Glacial Lake Missoula is considered the grandmother of all outburst floods, with peak flows of 21,000,000 m^3/sec (27.5 M yd^3/sec) and sustained flows of 3,000,000 m^3/sec (27.5 M yd^3/sec). At the Vatnajökull ice cap in Iceland, a jökulhlaup occurs every 6 years in the Grimsvötn caldera. This flood yields about 4.5 km^3 (1.08 mi^3) in discharge with a peak flow of 1,500,000 m^3/sec (1.9 M yd^3/sec) and sustained flow of 50,000 m^3/sec (65.4 K yd^3/sec).

Floodwaters, with or without ice and debris, can be very destructive. In Iceland in 1996 part of a bridge and roadway were destroyed and actually disappeared following a jökulhlaup. Ice blocks, some as large as 60m, are commonly carried in floodwaters.

Geologic Setting for Field Trip Area

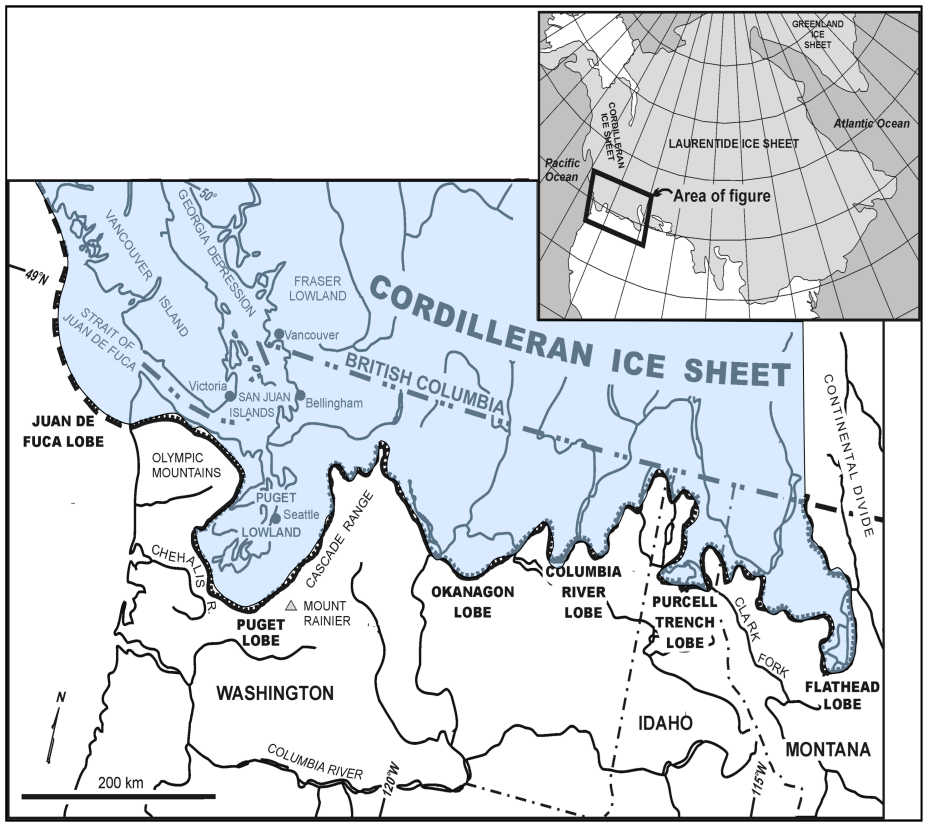


Figure 1. *Extent of Cordilleran Ice Sheet during Fraser Glaciation.*

Modern Landscape

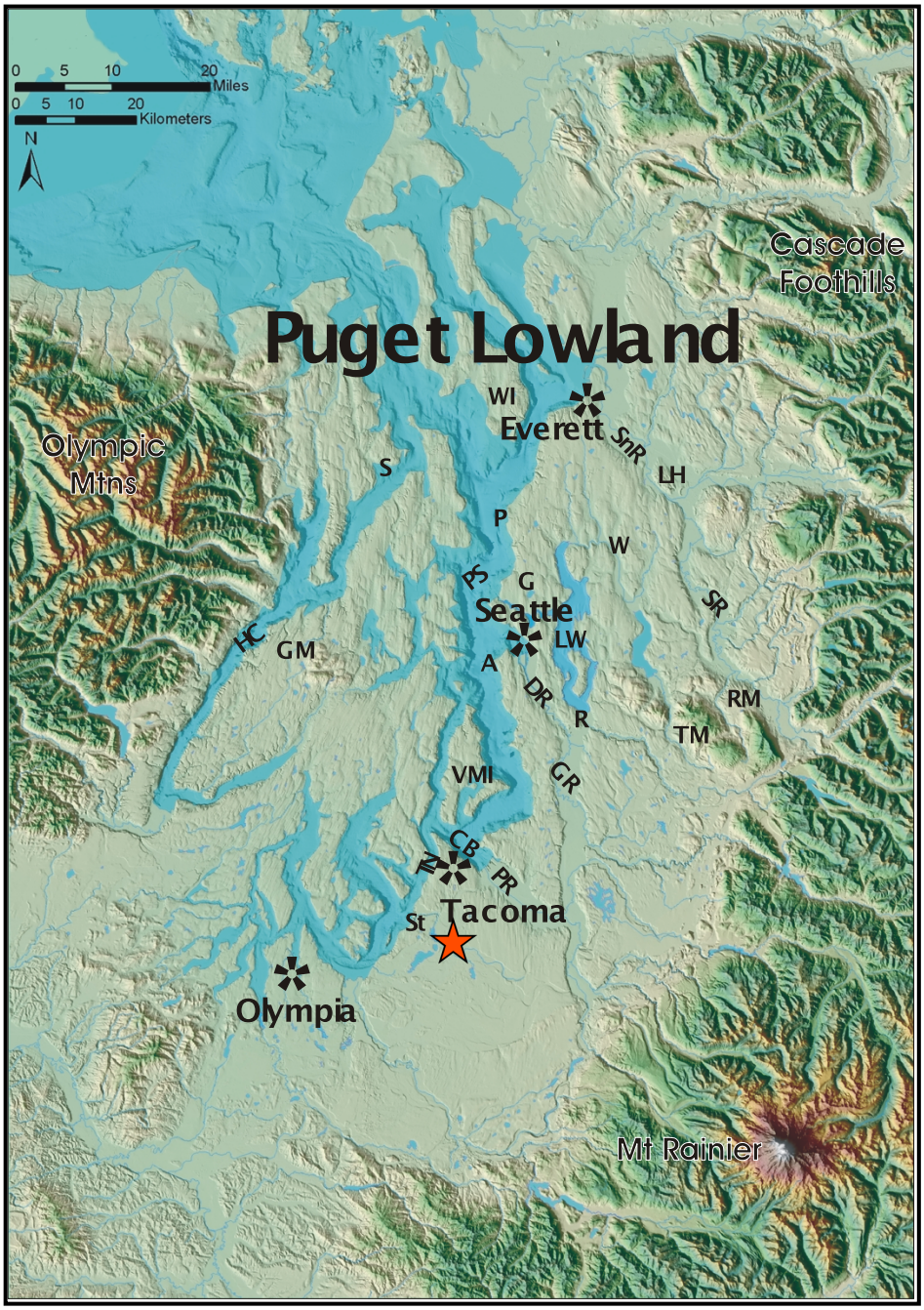


Figure 2. *Note the location of the "red star" relative to the subglacial channels (troughs of Puget Sound).*

Ice Margins during two of the recessional lake stages

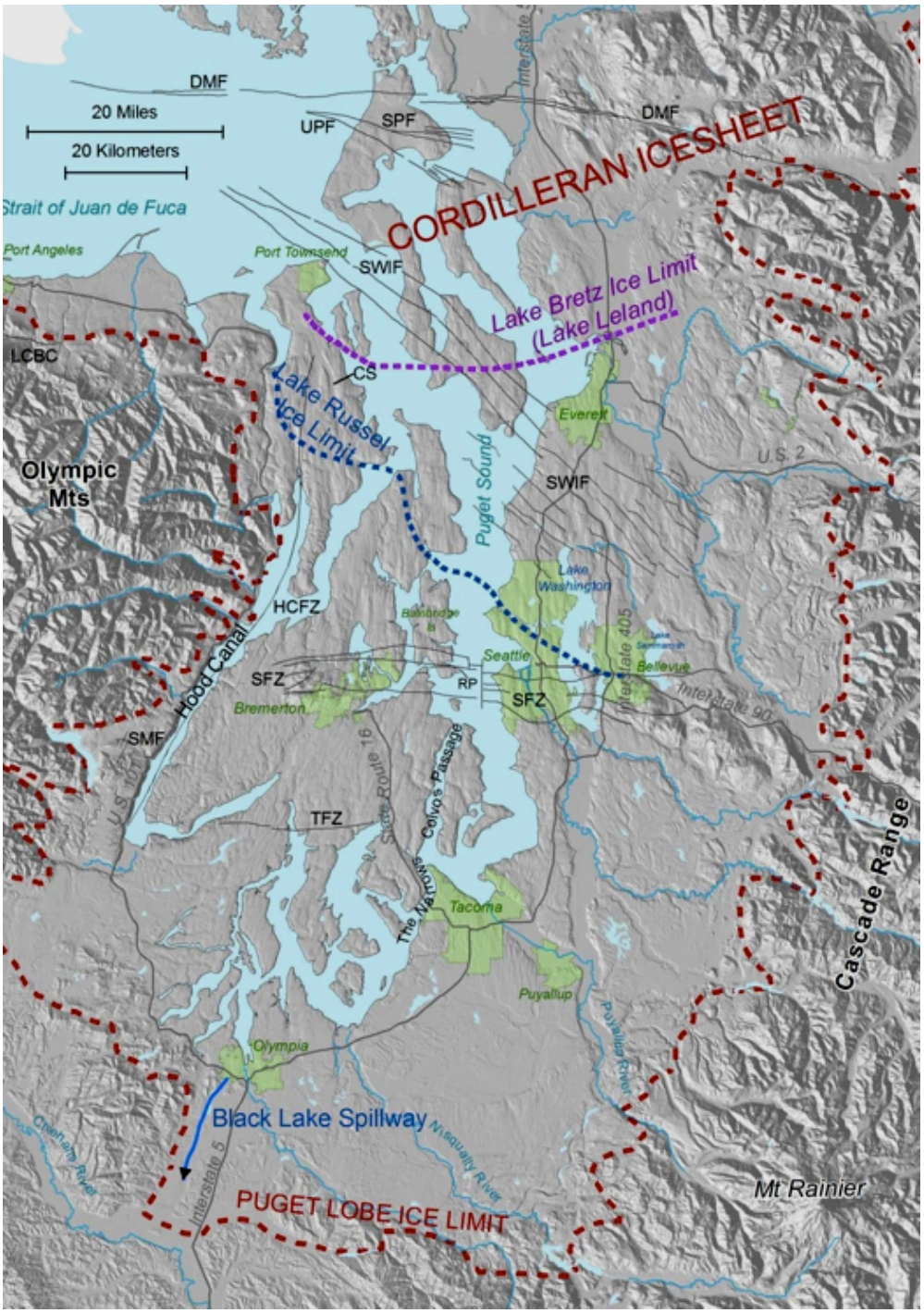


Figure 3. *Initially, only a small recessional lake existed in the south Sound. Larger glacial lakes formed as smaller lakes coalesced as sea level rose during recession of the ice. Spillways opened to allow drainage from one lake to another. Jökulhlaups were instrumental in conveying water from Glacial Lake Puyallup to the glacial lake occupying the south Sound. (Thorson, 1989).*

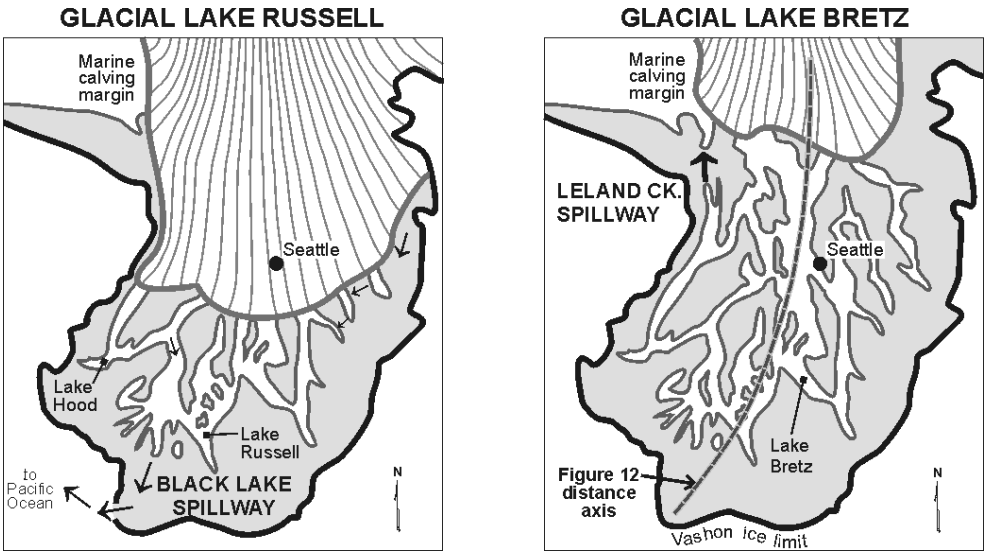


Figure 4. *(Redrawn from Thorson, 1989).*

Ice and Storage

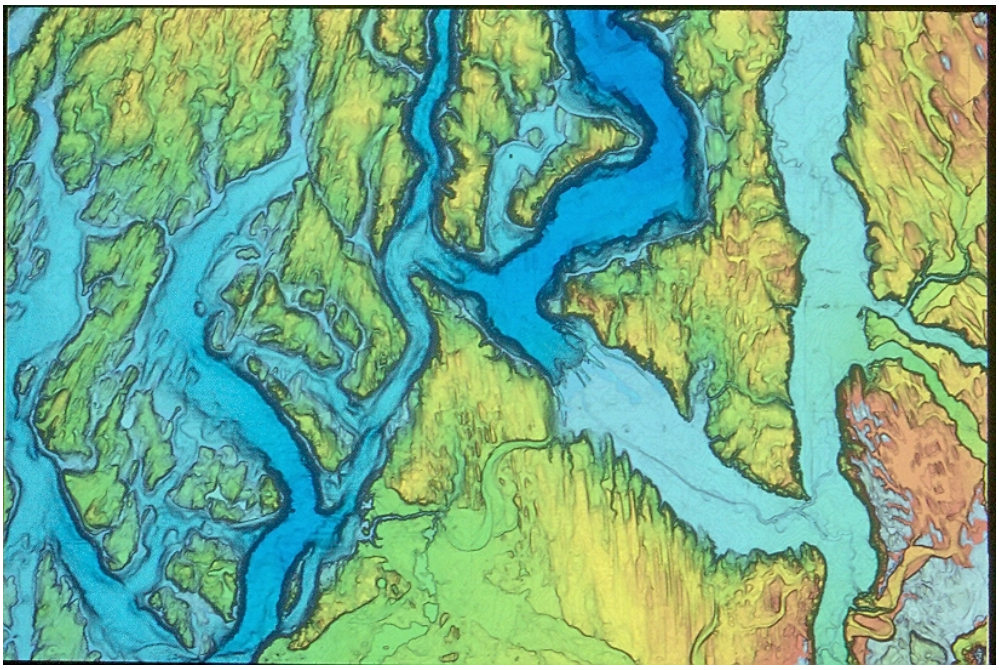


Figure 5. *Hillshade DEM by Ralph Haugerud, USGS in the late 1990s. Note the drumlinized topography and where it is interrupted. Channel features are obvious on this image and are associated with interruptions in the striated grain that indicates glacial movement. Also note the size of the troughs that host the Puyallup and Green Rivers. These landscape features are two of the fundamental requirements for jökulhlaups: ice and storage.*

Current Interpretation

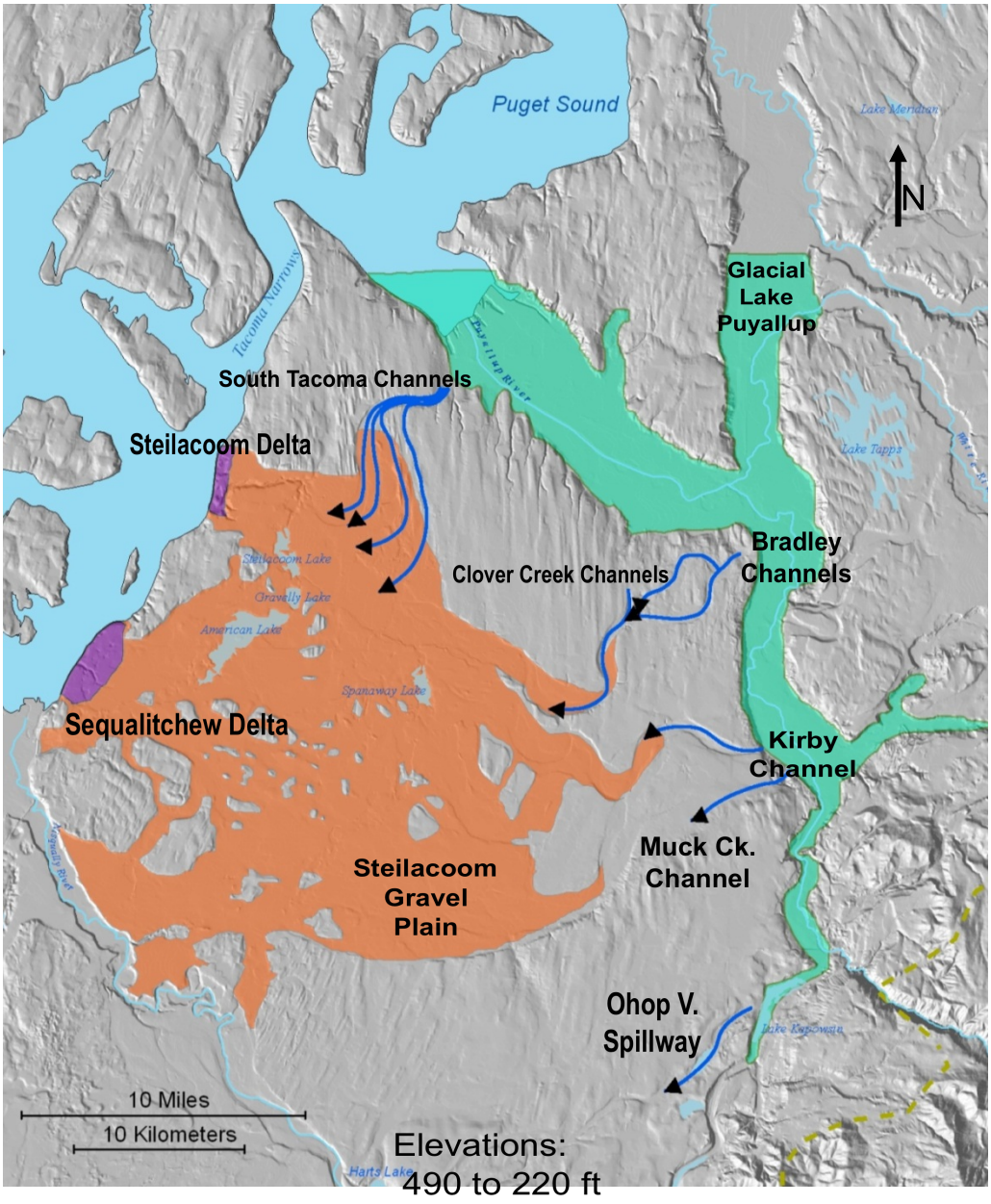


***Figure 6**. Based on calculations of lake volume and the typical discharge of a major Cascade River, it likely took less than a decade to fill Glacial Lake Puyallup. As shown, Glacial Lake Puyallup was approximately 104.5 km3 (25.08 mi3) in volume. The Steilacoom Gravel Plain is approximately 1035 km 2 (400 mi 2) in area and the Steilacoom Gravel is about 31.5 km3 (7.6 mi3) in volume.*

Steilacoom Gravel

The Steilacoom Gravel was originally defined by Willis in 1898 for outwash from deltas formed in ponded water. In 1913, Bretz redefined the Steilacoom Gravel to relate to a proglacial lake in the Puyallup valley and to several rivers that cut channels. Then Walters and Kimmel (1968) clarified the term and mapped the extent (17% of land surface of Pierce County).

- Consistently coarse gravel and cobbles
- Some sorted sand and diamicton lenses
- 2 sands 60 m (~200 ft) thick

- Typically 6 m (20 ft) thick, max 18 m (60 ft) thick
- Susceptible to contamination
- Some areas of low energy deposits, now wetlands

Steilacoom Plain

- Numerous kettles
- Kettle chains
- Swells
- "Island" of till uplands
- Terraces
- Channels

II. FIELD LOG

Field Trip Stops

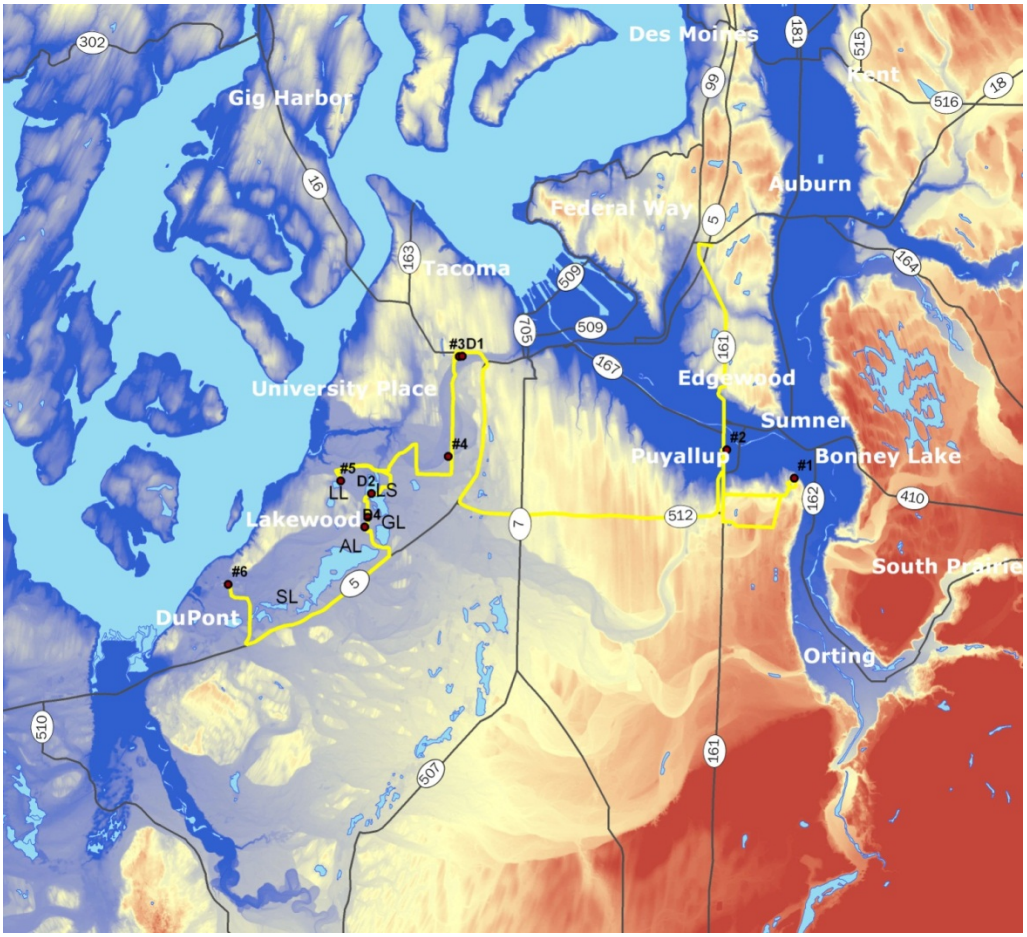


Figure 6.

STOP 1: GLACIAL LAKE PUYALLUP

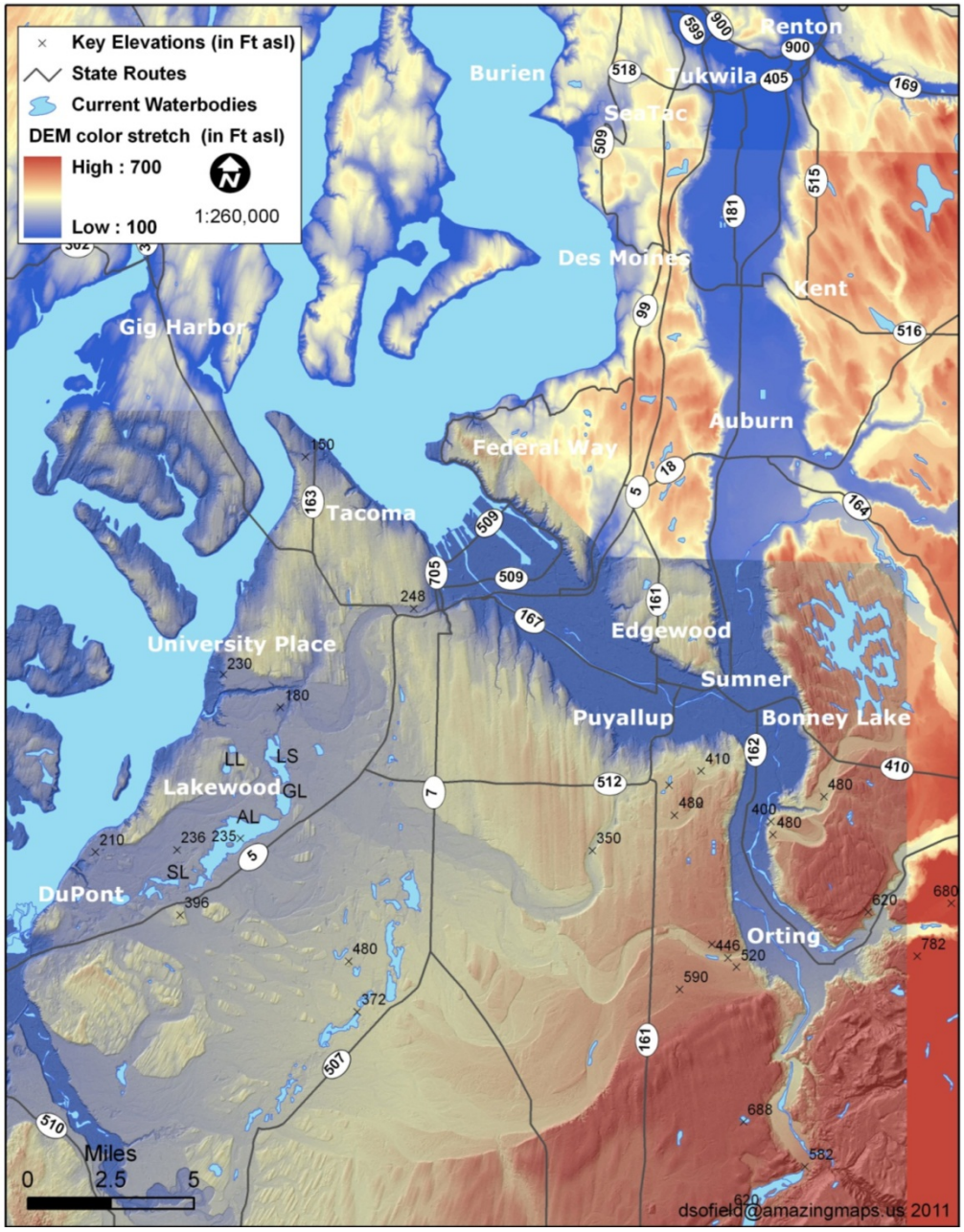
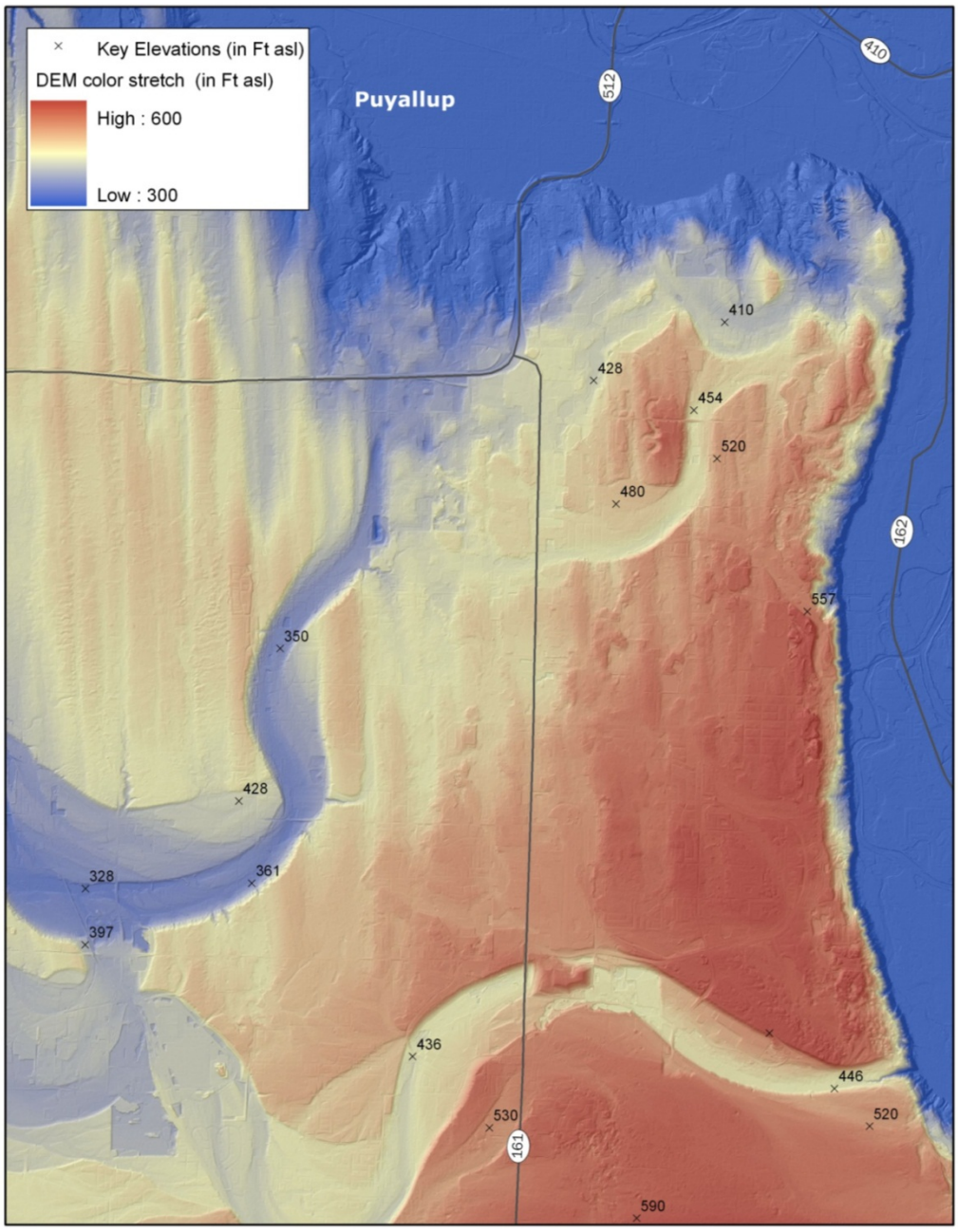


Figure 7.


Key Elevations (in Ft asl)
DEM color stretch (in Ft asl)
High : 600
Low : 300
Puyallup
512
410
162
161
410
428
454
520
480
557
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428
328
361
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436
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446
520
590

Figure 8.

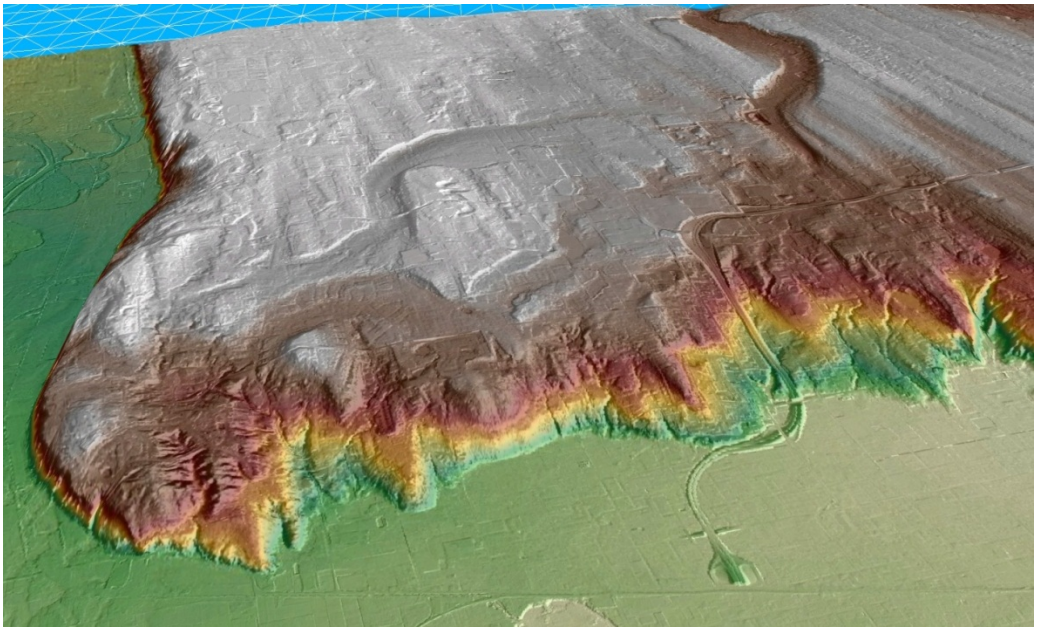


***Figure 9**. Clover Creek and Bradley Lake channels.*

Looking south from the Puyallup valley. The valley is 300 feet deeper than at present, and the upland is 400 feet above sea level, that gives ~700 feet of water height. **discharge that water through a channel with an opening of the size of the channel shown above……** The idea of outburst floods starts to make sense. The triggers are water depth. As glacial lake Puyallup deepens, the bouyancy pressure on the ice cap increases and when the pressure reaches critical, the ice floats releasing the water instantly or in pulses. Another key element is that the subglacial lakes continue to fill, with steady rain and with storm events.

STOP 2: PIONEER BAKERY AND THREE OTHER COFFEE SPOTS

STOPS 3 AND 4: SOUTH TACOMA CHANNEL AND TERRACES

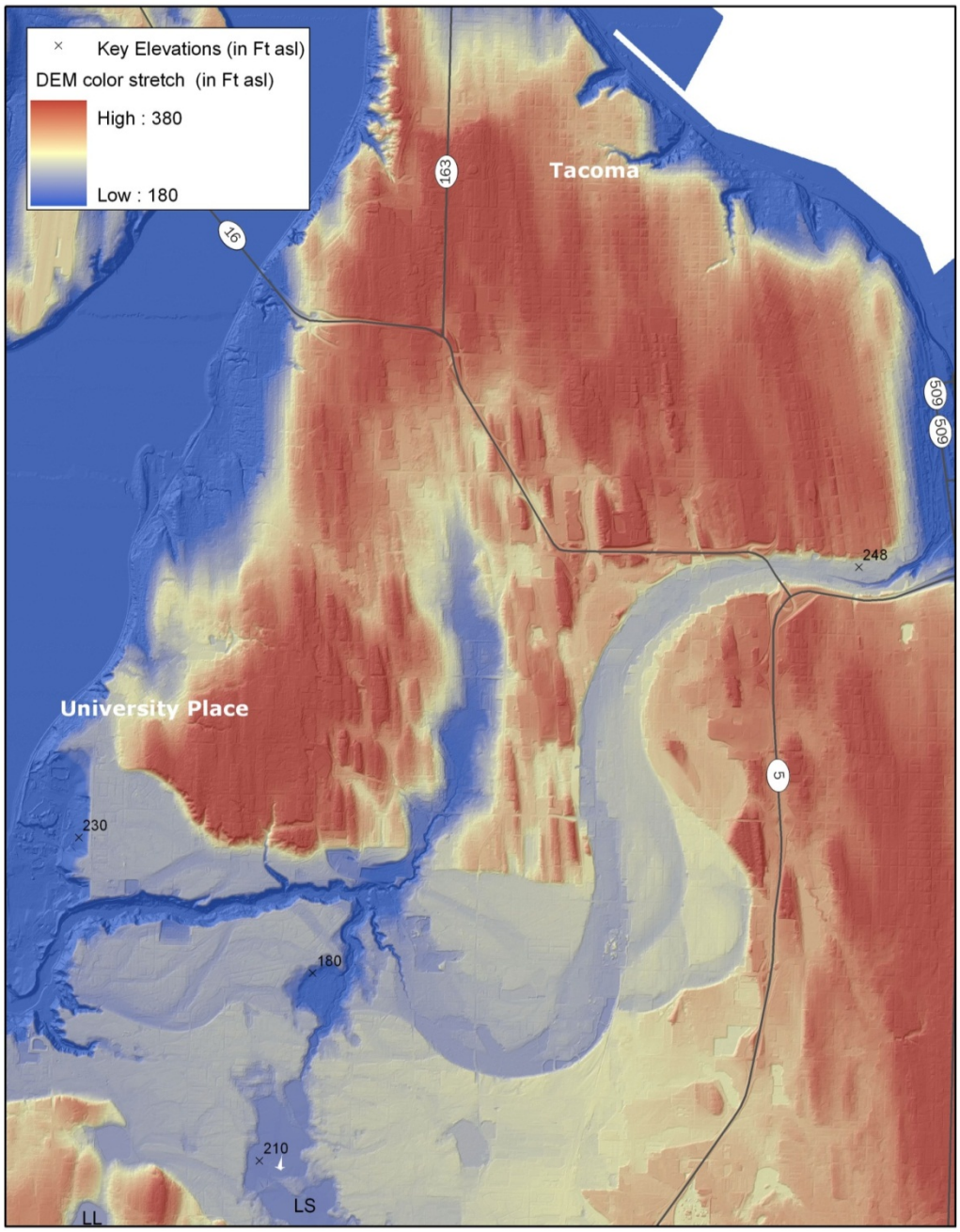


Figure 10.

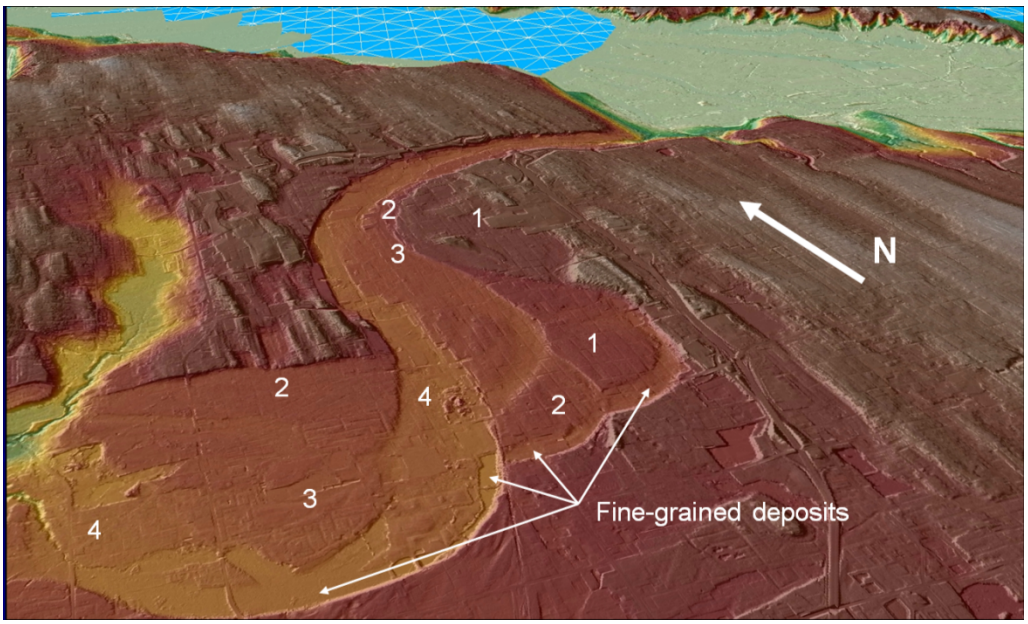


Figure 11.

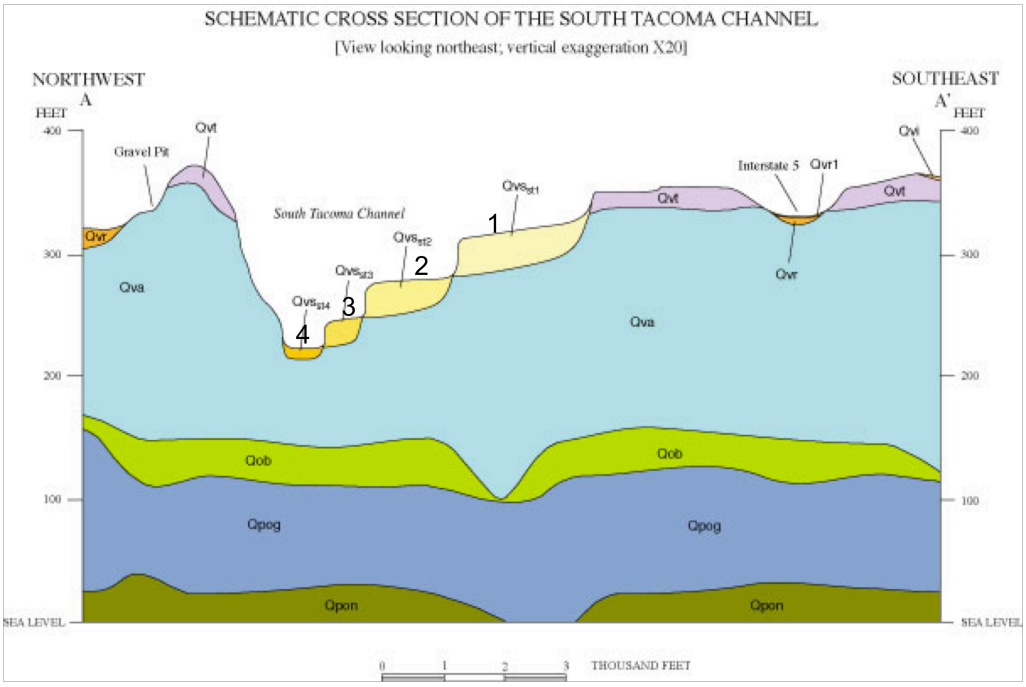


Figure 12. *The glacier has to be less than 125m thick (400ft) at South Tacoma Channel for the jökulhlaups to occur here.*

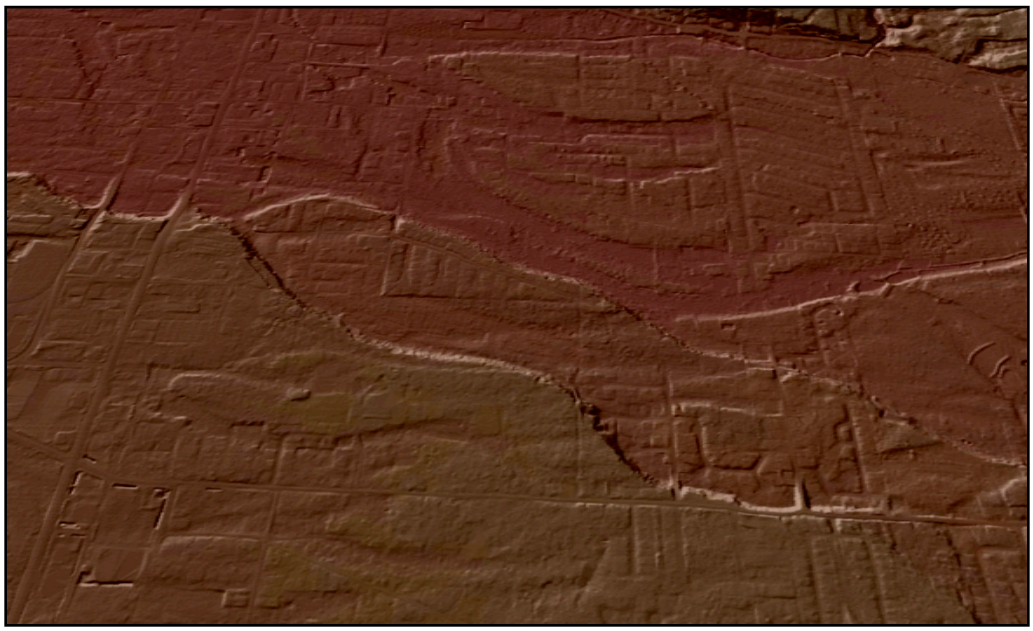


Figure 13. *Bedforms.*

As we've seen in eastern Washington and in Montana, as around the globe, giant bedforms are visible on the ground surface. Here we see what I believe are bed scours, possibly even dare I speculate…..point bars in the middle of the channel? The swales are a few meters high. At the edges of the channels we find peats, silts, some minor clay on top of the Steilacoom gravel.

STOP 5: KETTLE LAKES AND CHAIN OF KETTLE LAKES

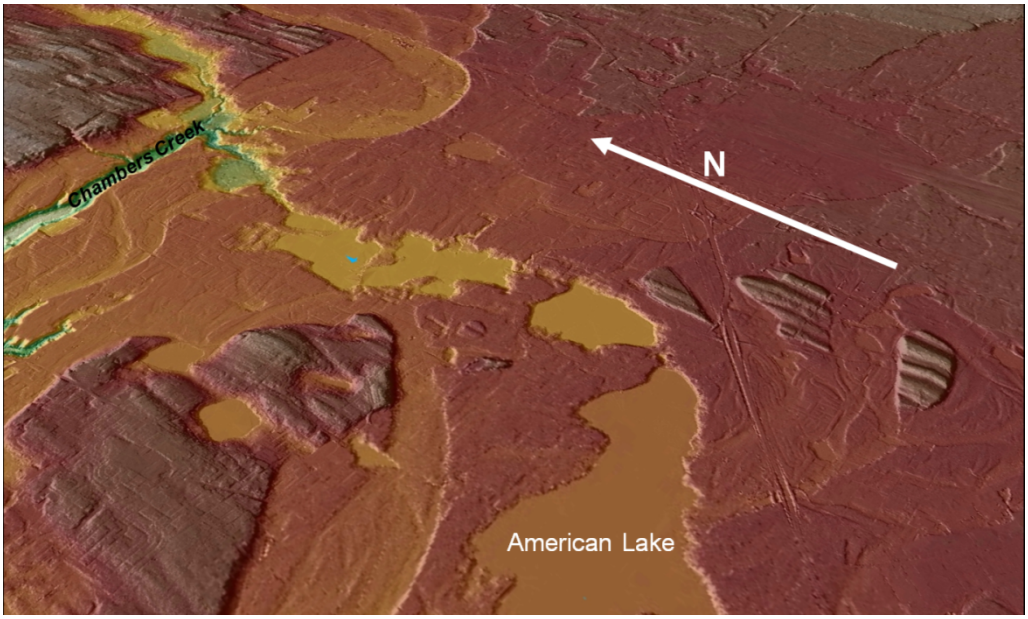
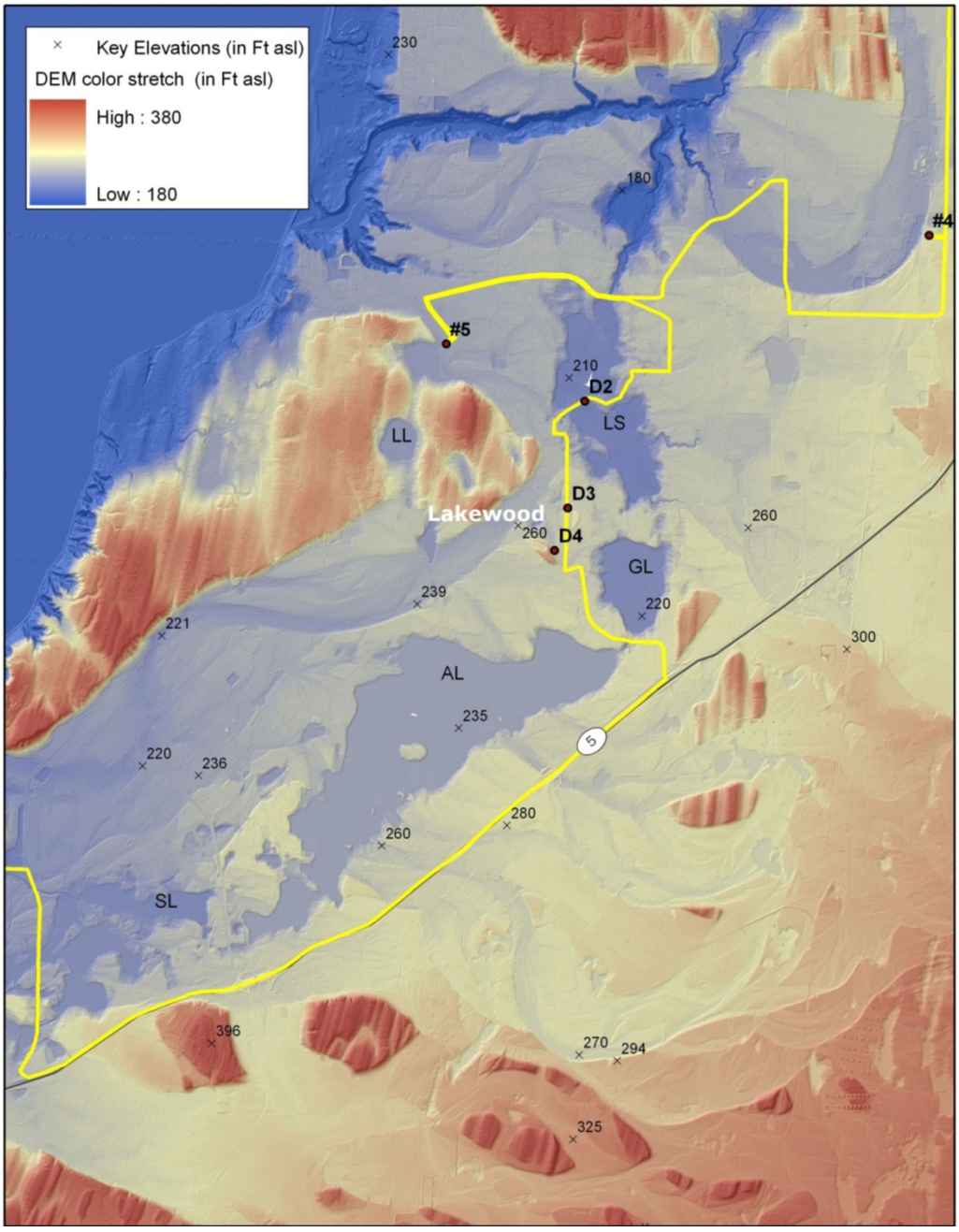


Figure 14. *Note upland till remnants, small kettle lakes, and channels.*


Key Elevations (in Ft asl)
DEM color stretch (in Ft asl)
High : 380
Low : 180
230
180
#4
#5
210
D2
LS
LL
D3
Lakewood
260
D4
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GL
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Figure 15.

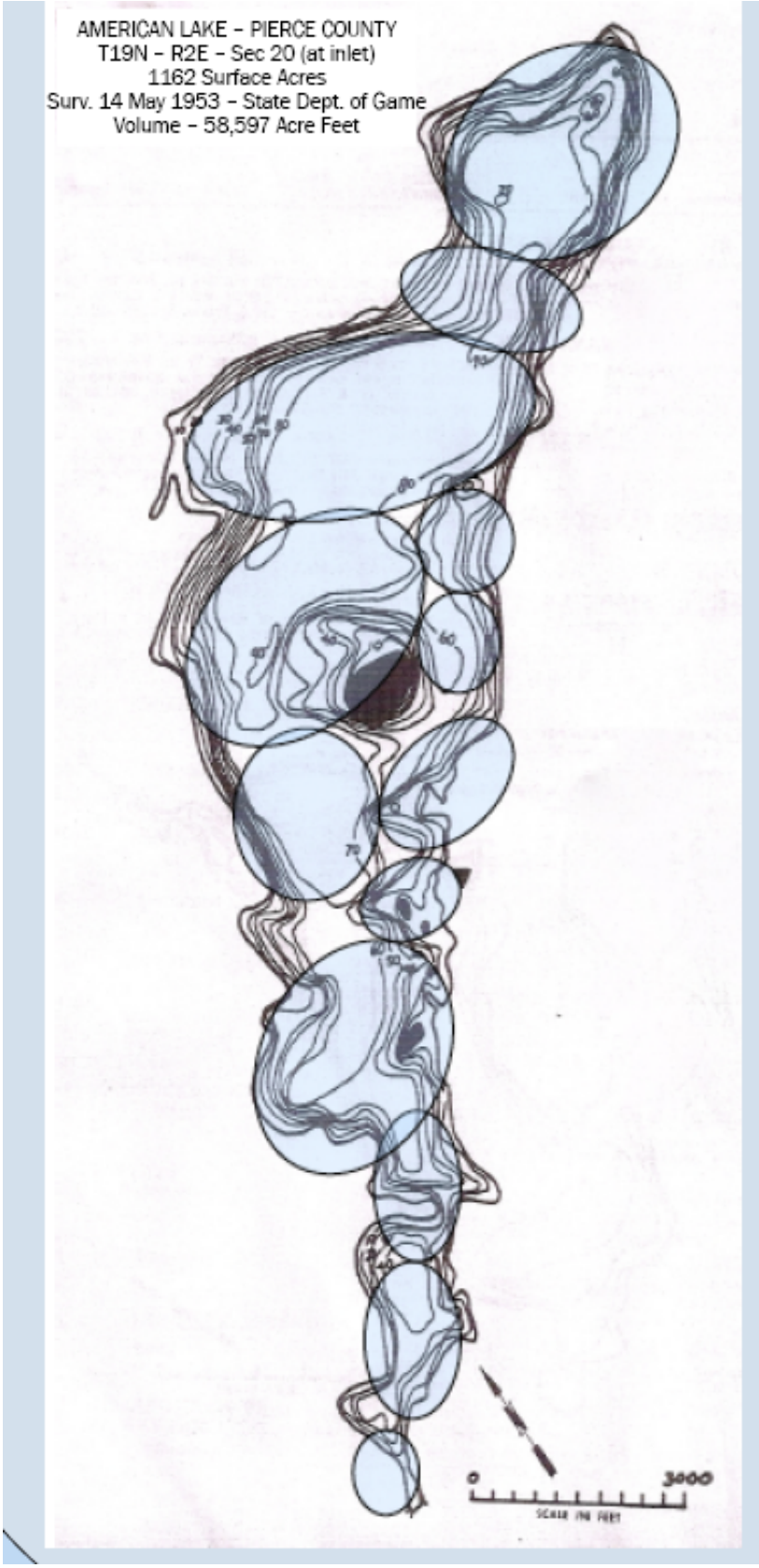

Figure 16. *Possible formation of American Lake. Blue highlights show theoretical placement of grounded icebergs based on lake bathymetry. During flood flow, first one iceberg is grounded, creating a region of low flow velocity. Then others are grounded nearby due to decreased flow on the lee sides of grounded icebergs.*

STOP 6: DUPONT DELTA

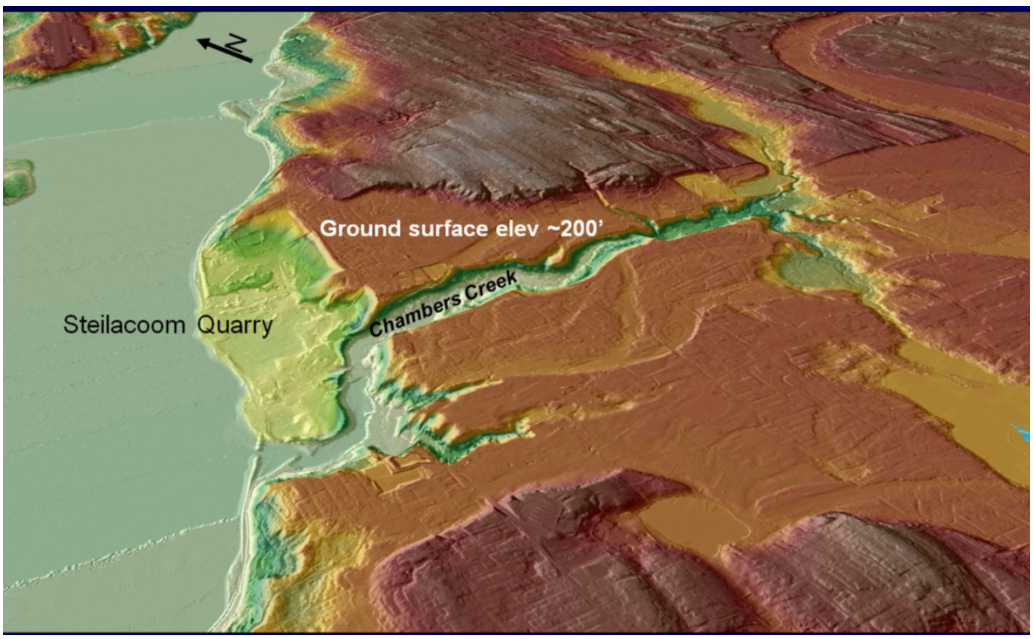

Figure 15. *This is an image of the delta at Steilacoom, similar to the delta at DuPont.*

STOP 6A: DUPONT DELTA AND CALPORTLAND SAND AND GRAVEL QUARRY

Figure 16. *Aerial image of the DuPont delta and CalPortland sand and gravel quarry.*

STOP 6B ACTIVE WALL

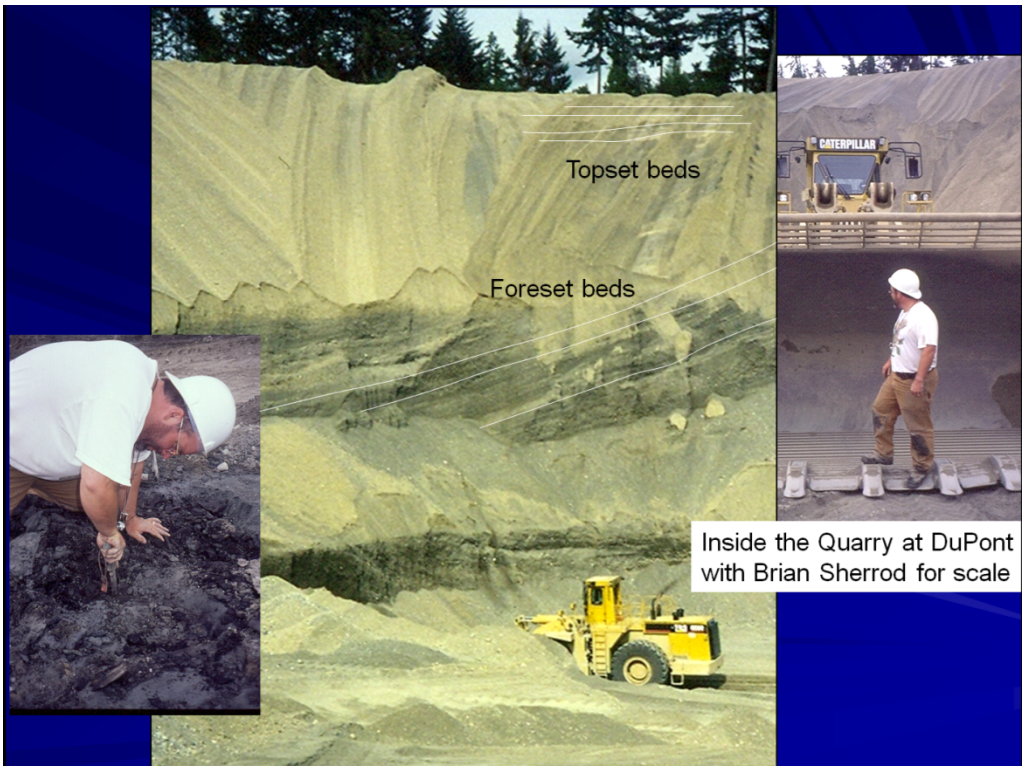

Figure 17. *Large cross beds in gilbert-type delta where flood water and sediment entered Lake Russell.*

STOP 6C: EXPOSED OLYMPIA BEDS

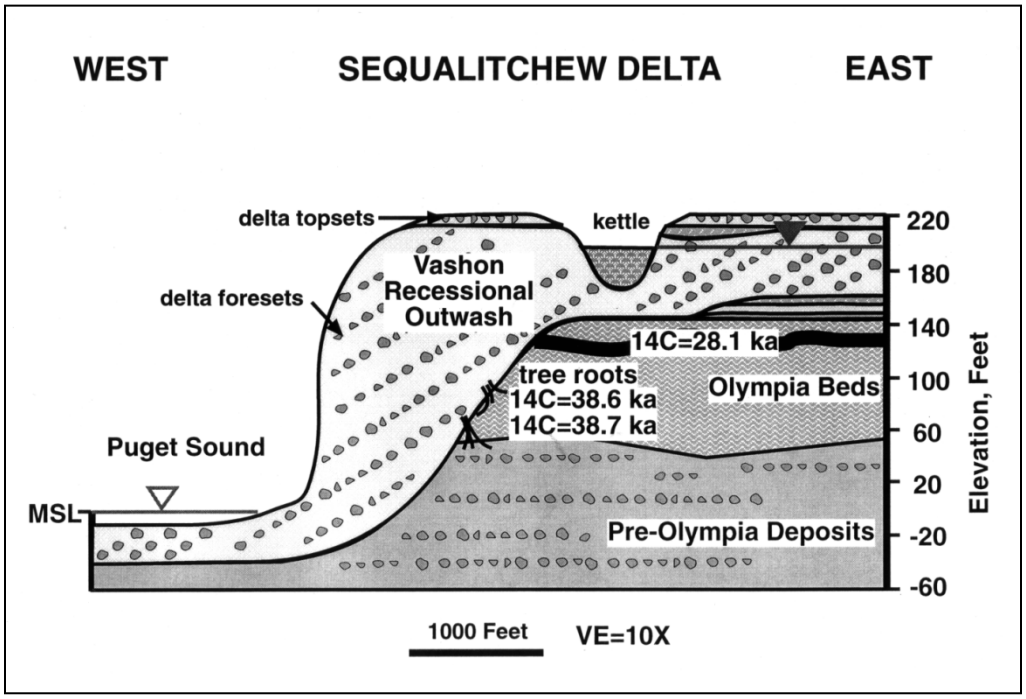

Figure 18. *Cross section showing location of former bluff at Puget Sound during the Olympia non-glacial interval.*

STOP 6D CALPORTLAND OFFICE

III. SOME CONCLUSIONS

- Preliminary size estimate: 2 orders of magnitude bigger than flood discharge of a major Cascade river
- Similar in size to the Icelandic Grimsvötn events 50,000 to 100,000 m^3/sec
- Less than 10 years to fill the lake
- Ice less than 125m thick at South Tacoma Channel
- Origin of Steilacoom gravels consistent with jökulhlaups
- Features on Steilacoom Plain consistent with jökulhlaups
- Storage available
- Gradient available
- May have jökulhlaups deposits elsewhere in the stratigraphic record