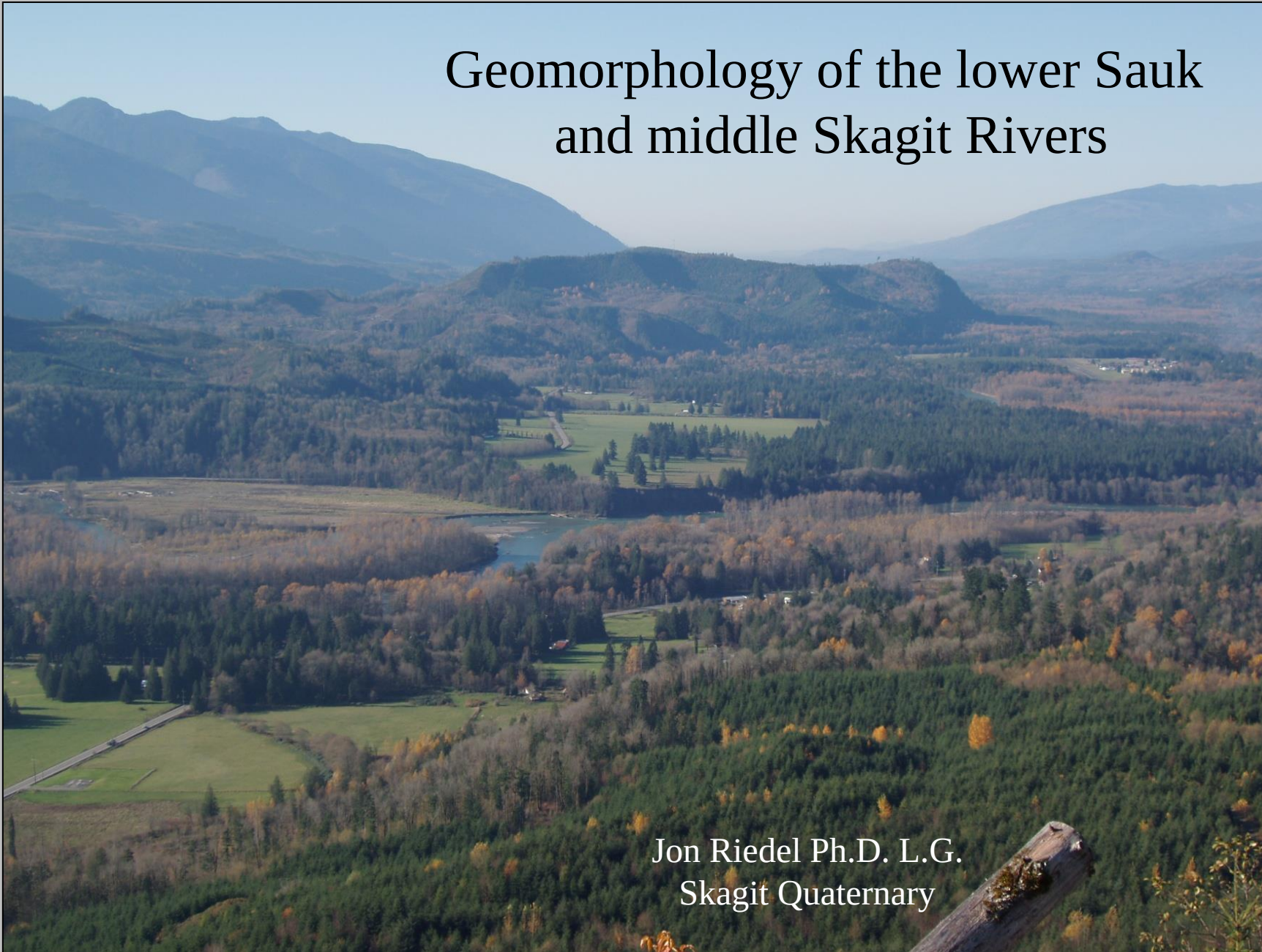
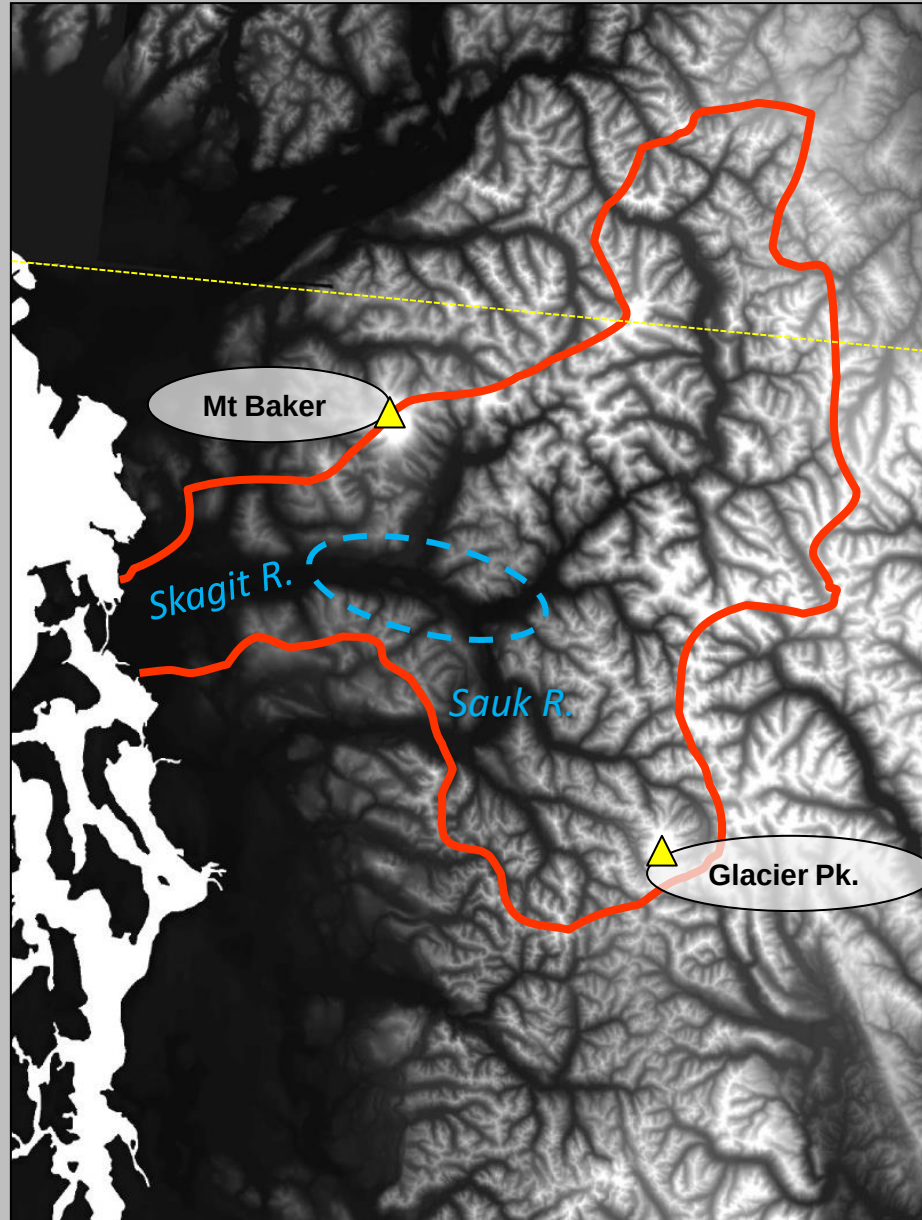


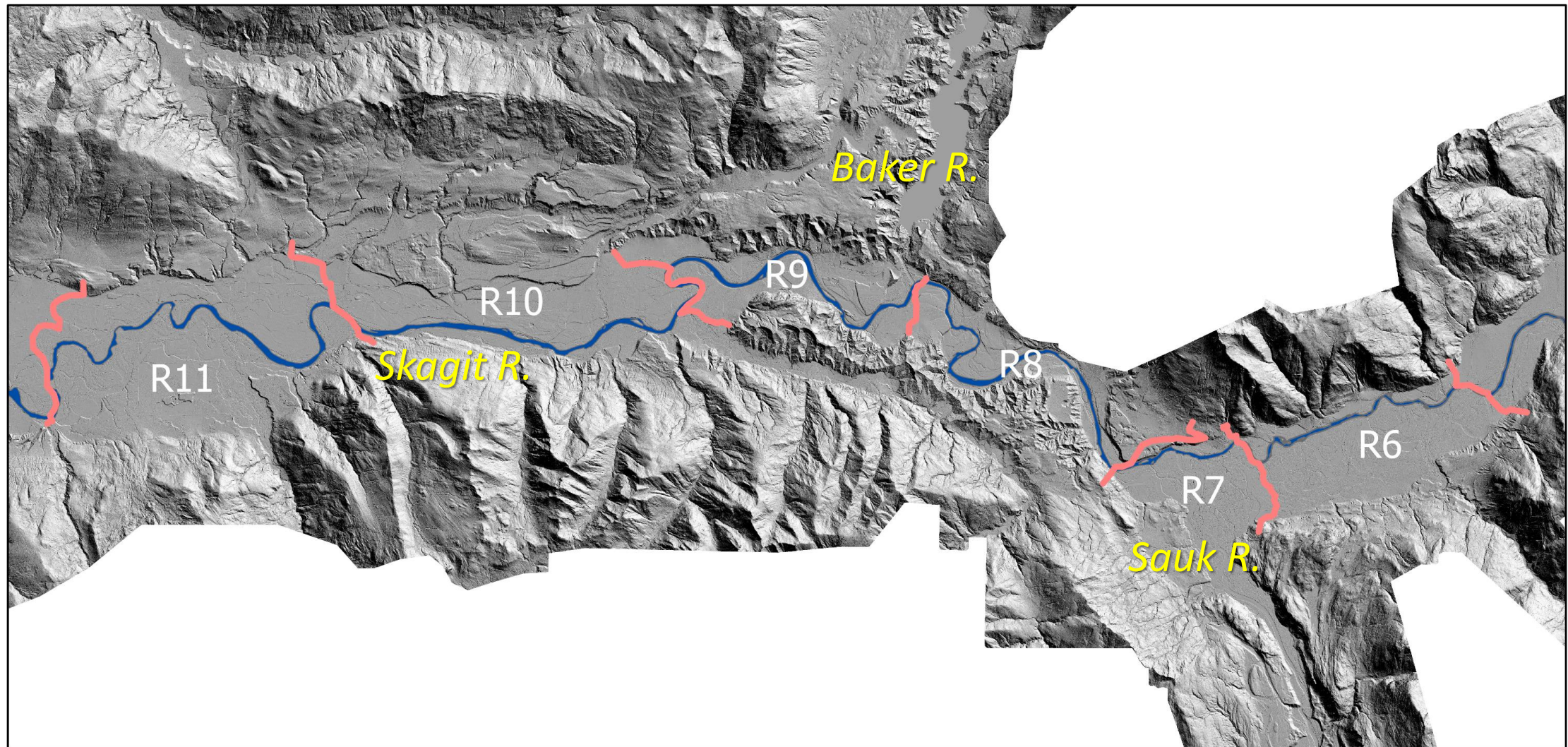
Geomorphology of the lower Sauk and middle Skagit Rivers

Jon Riedel Ph.D. L.G.
Skagit Quaternary



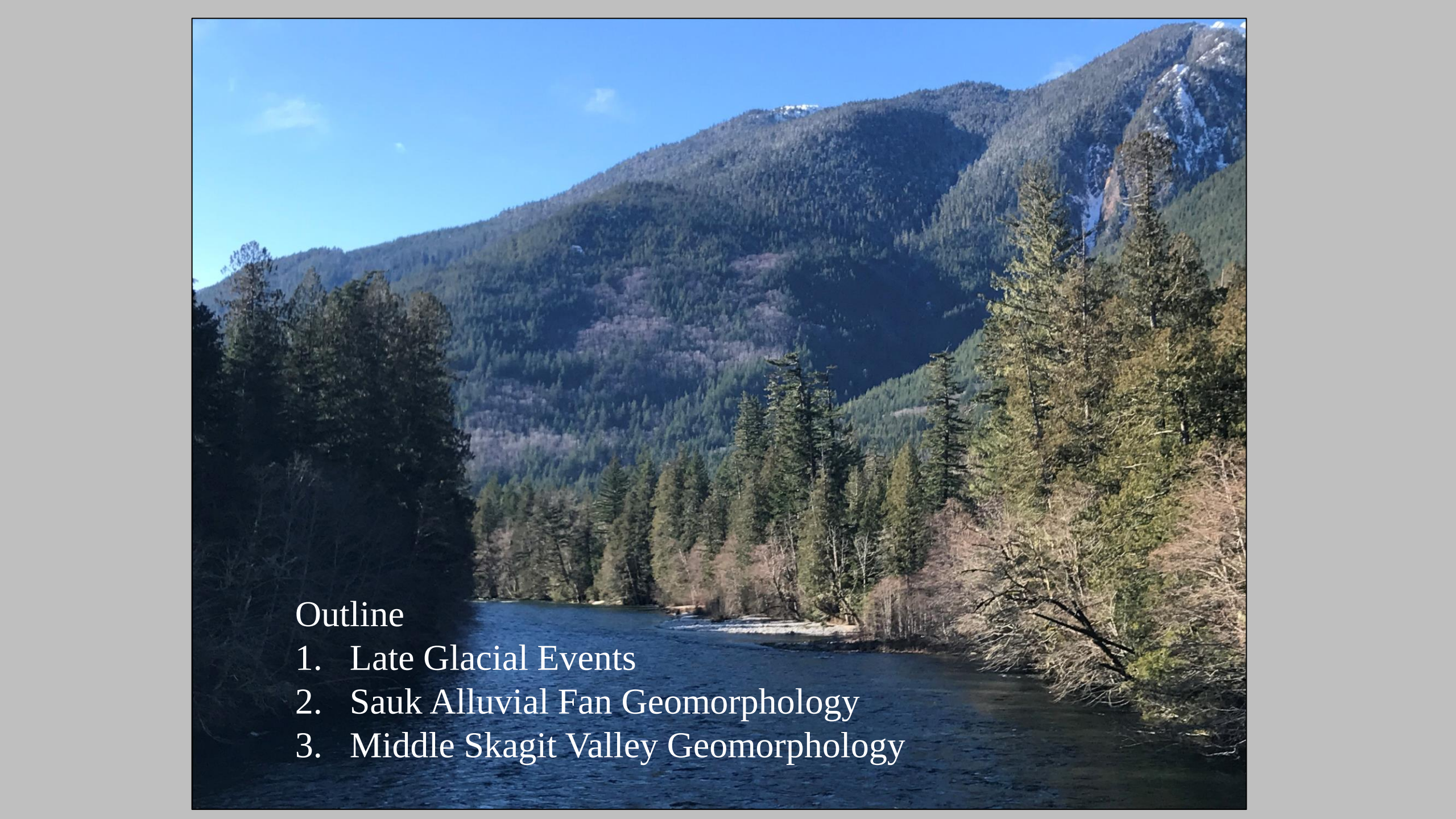


Skagit River Watershed



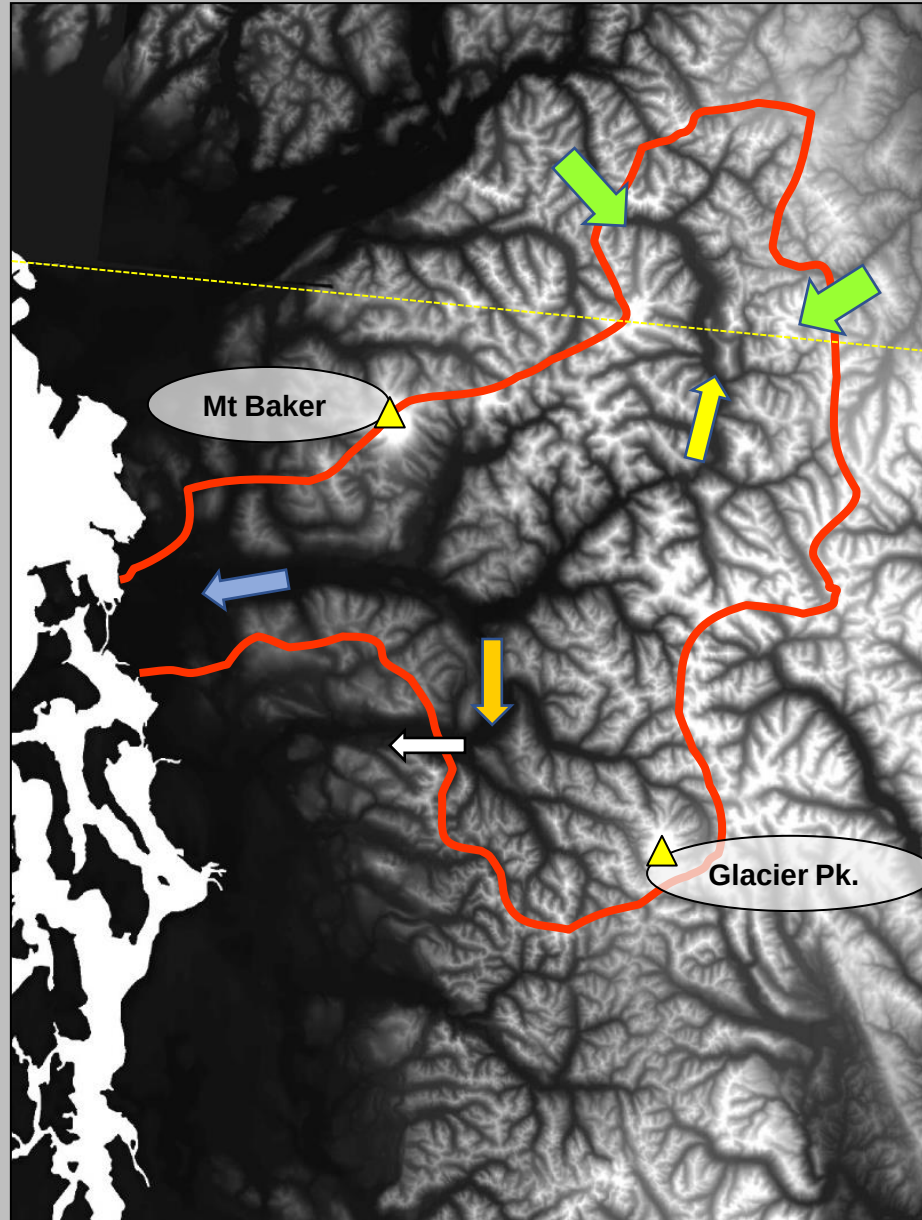
Middle Skagit Valley Geomorphic Reaches



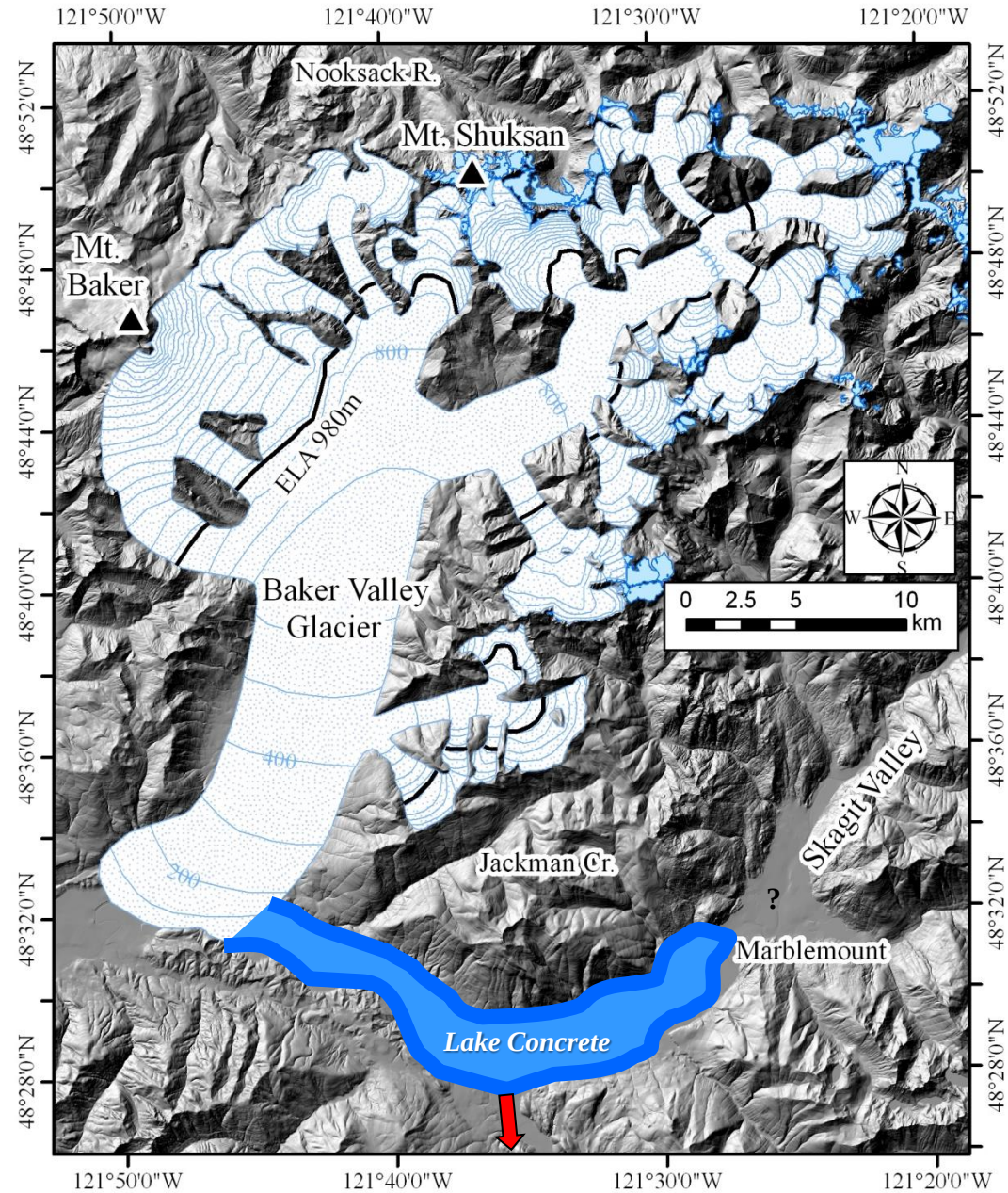


Outline

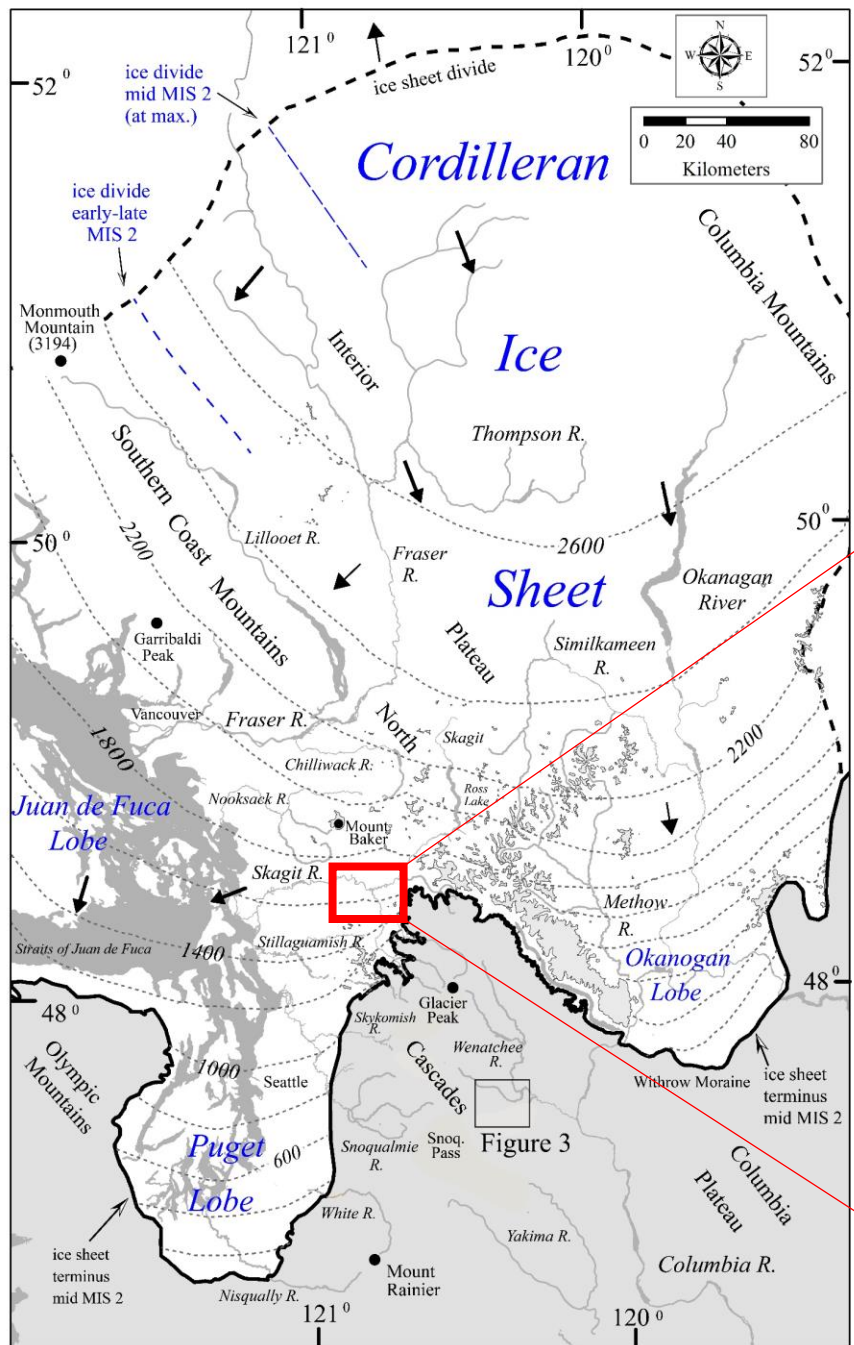
1. Late Glacial Events
2. Sauk Alluvial Fan Geomorphology
3. Middle Skagit Valley Geomorphology



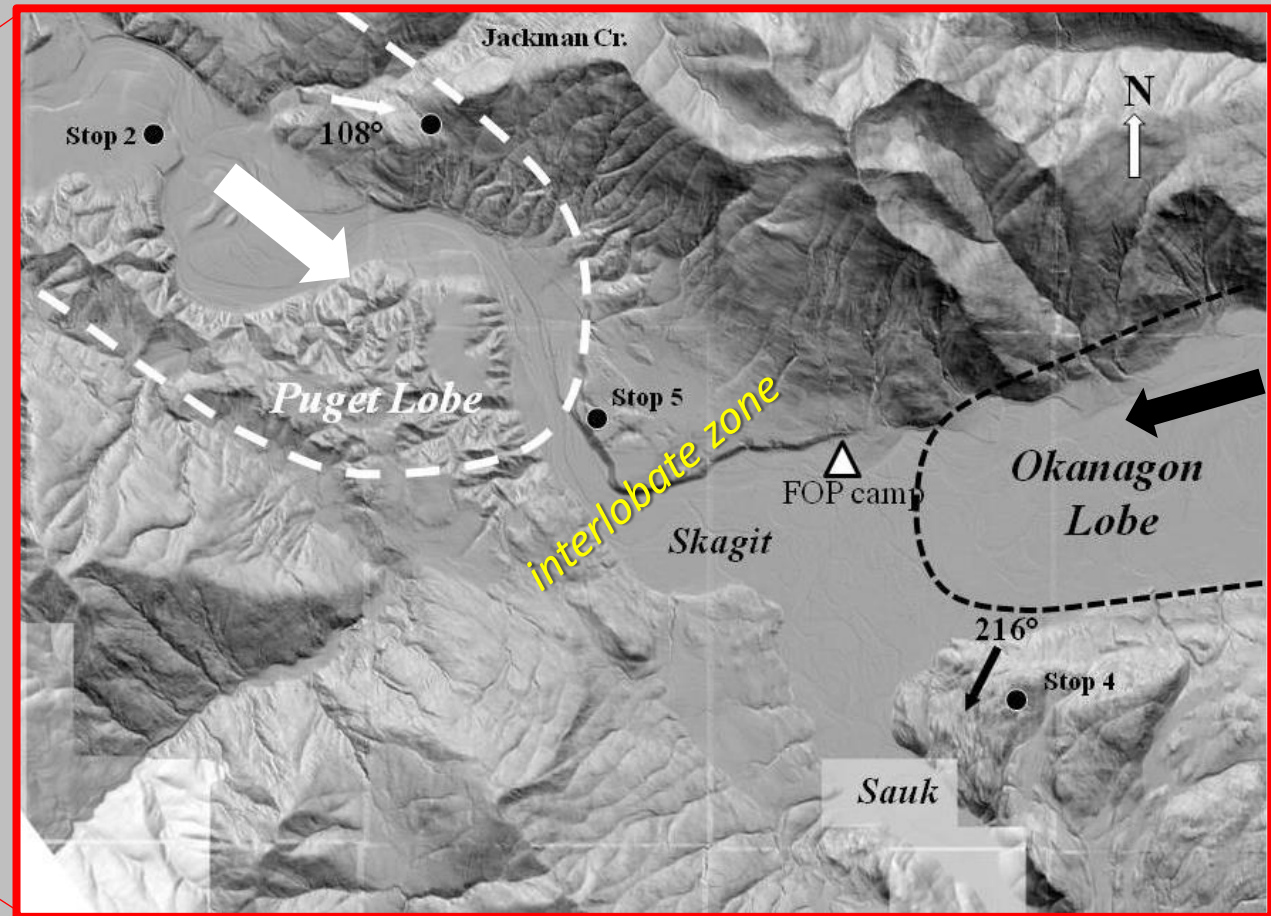
The Dynamic Skagit River Watershed

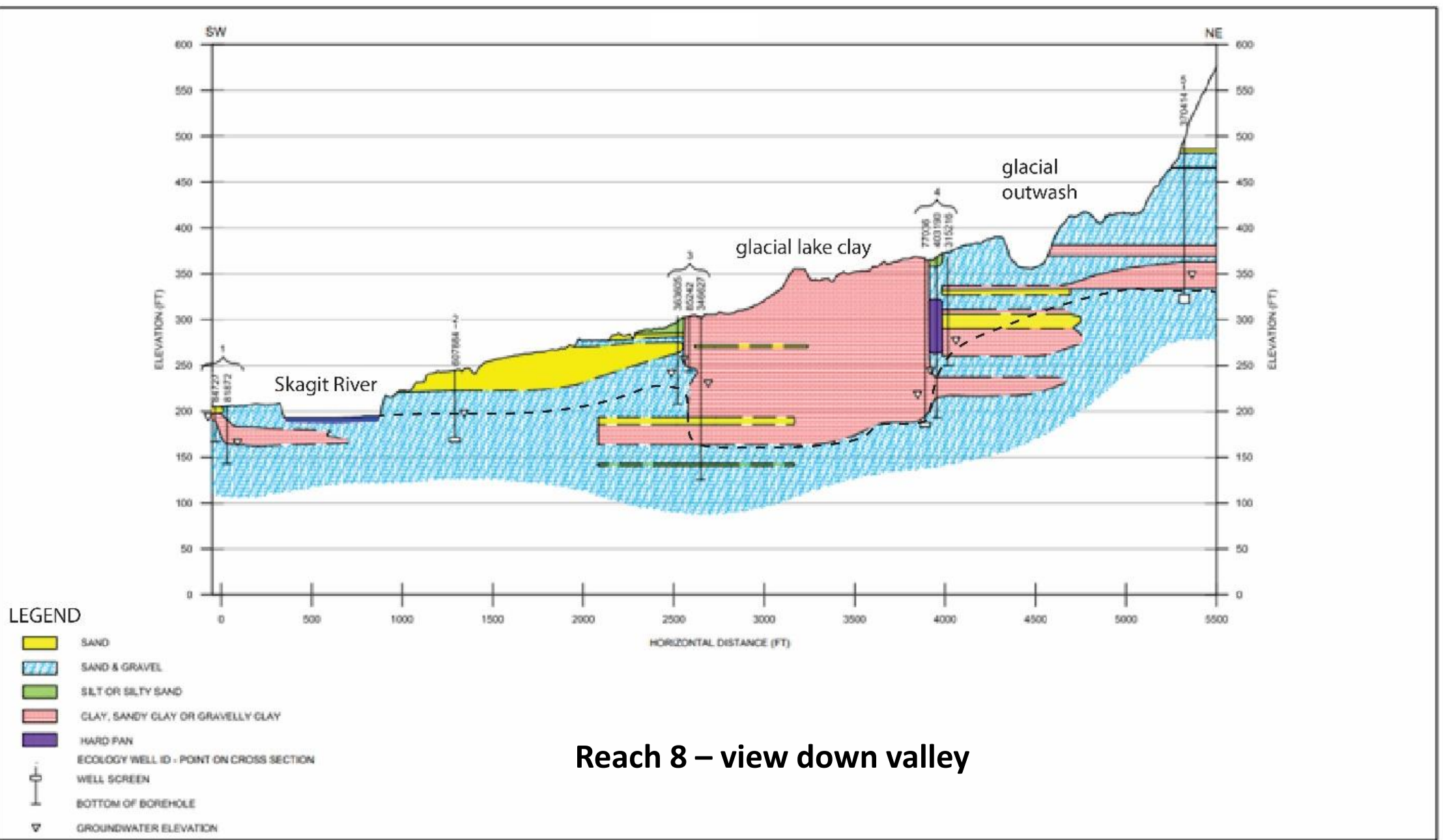


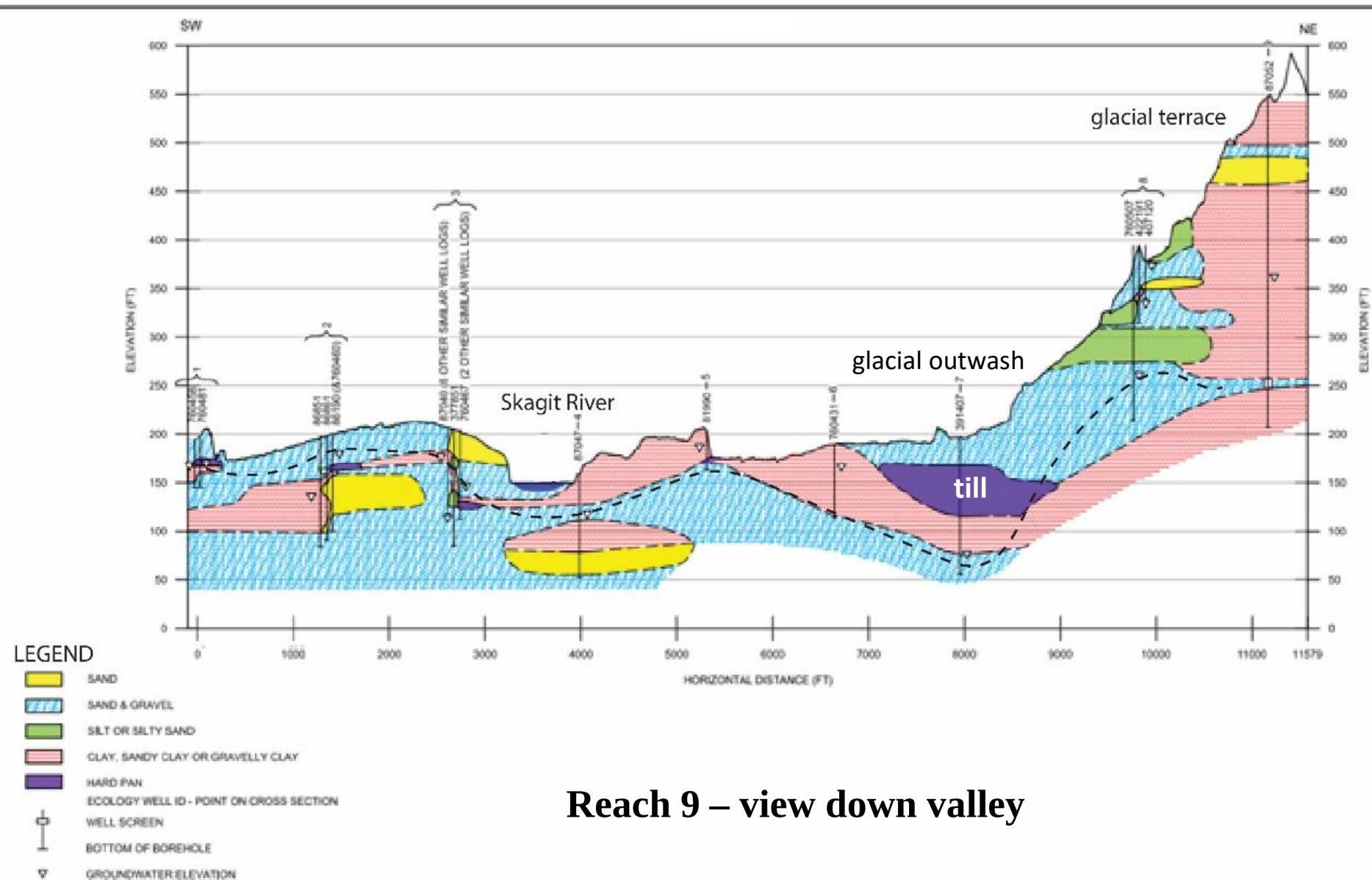
**Baker alpine
valley glacier
25,00 - 30,000 cal. yr. BP**



The Cordilleran ice sheet at its maximum extent ~16,000 cal. yr. BP

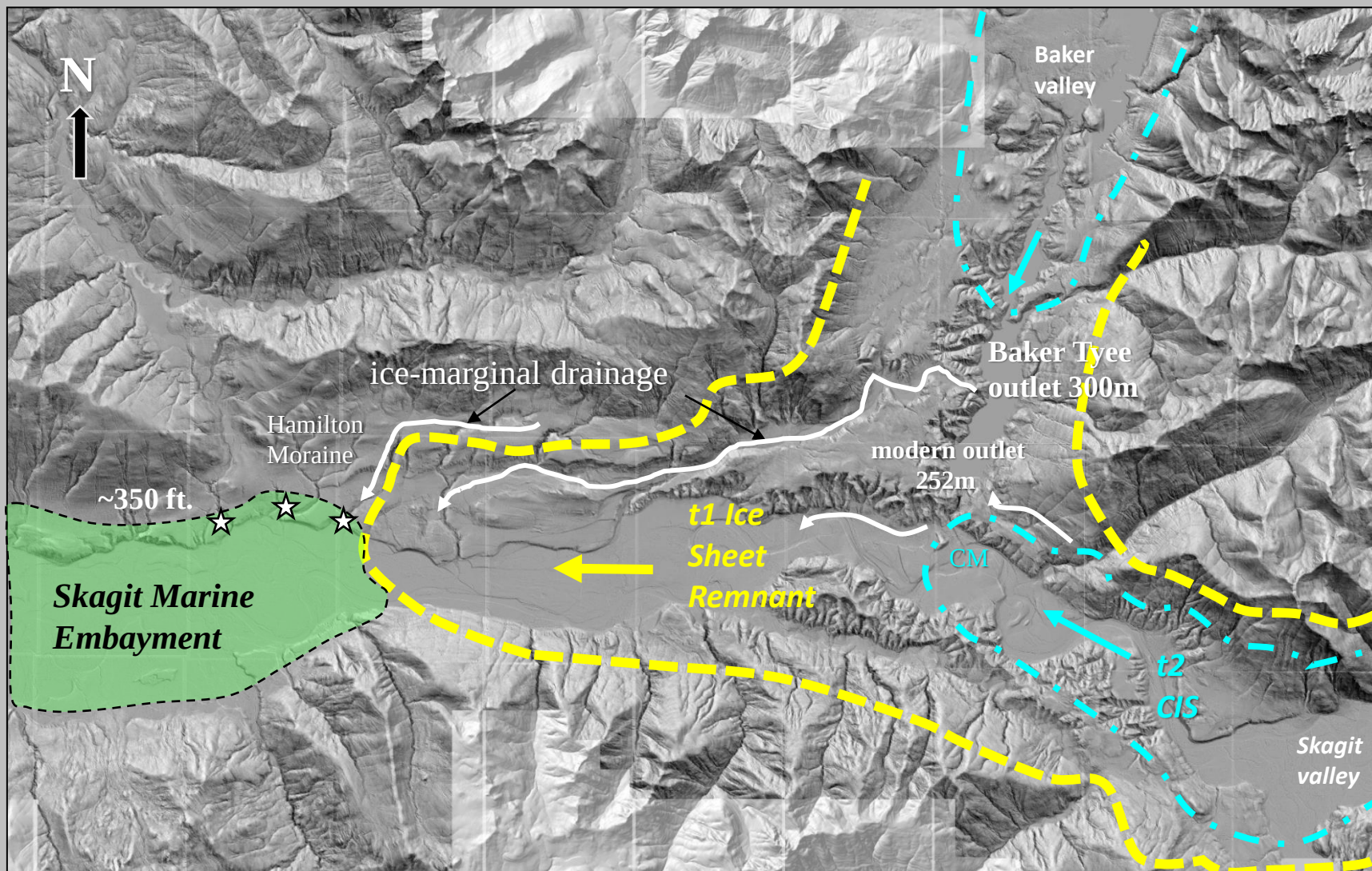


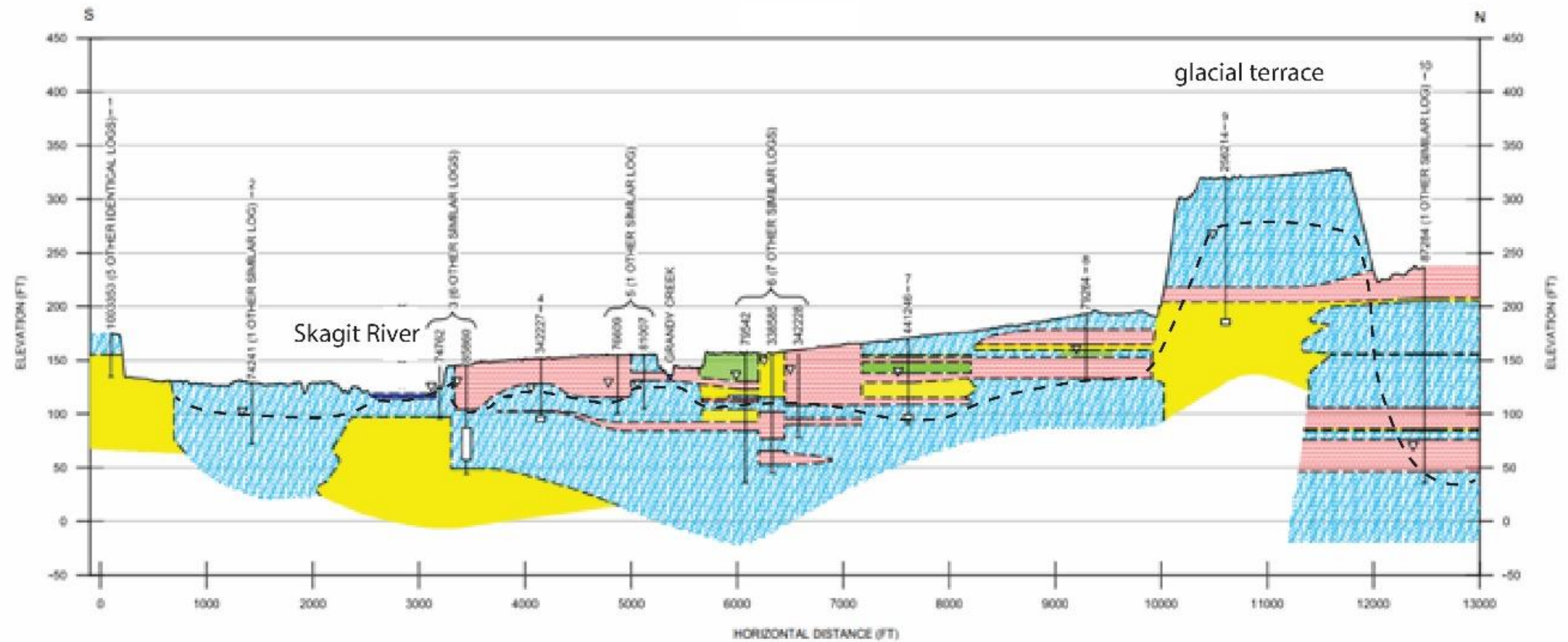




Reach 9 – view down valley

Skagit Marine Embayment ~14,000 cal. yr. BP

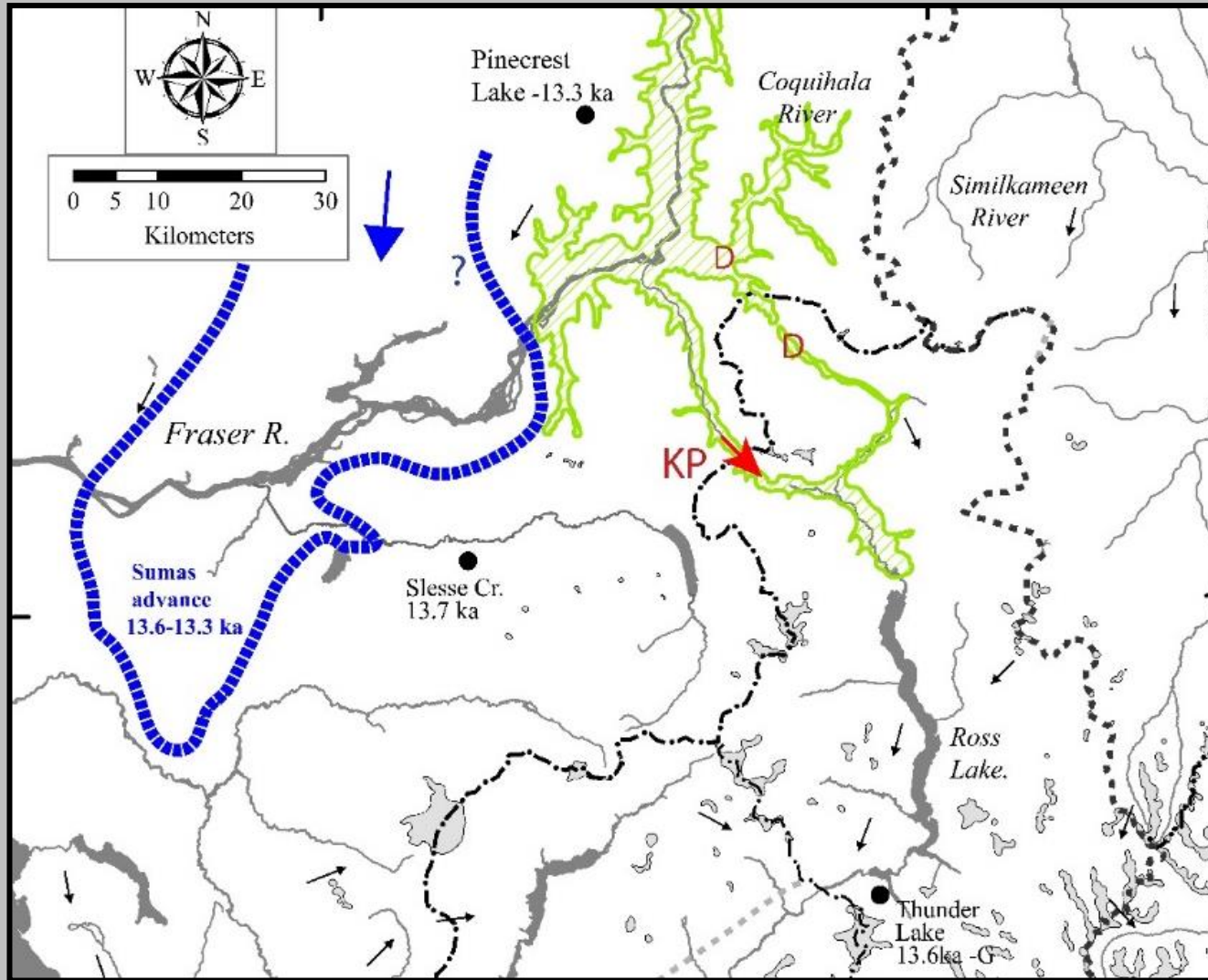




LEGEND

- SAND
- SAND & GRAVEL
- SILT OR SILTY SAND
- CLAY, SANDY CLAY OR GRAVELLY CLAY
- ECOLOGY WELL ID - POINT ON CROSS SECTION
- WELL SCREEN
- BOTTOM OF BOREHOLE
- GROUNDWATER ELEVATION

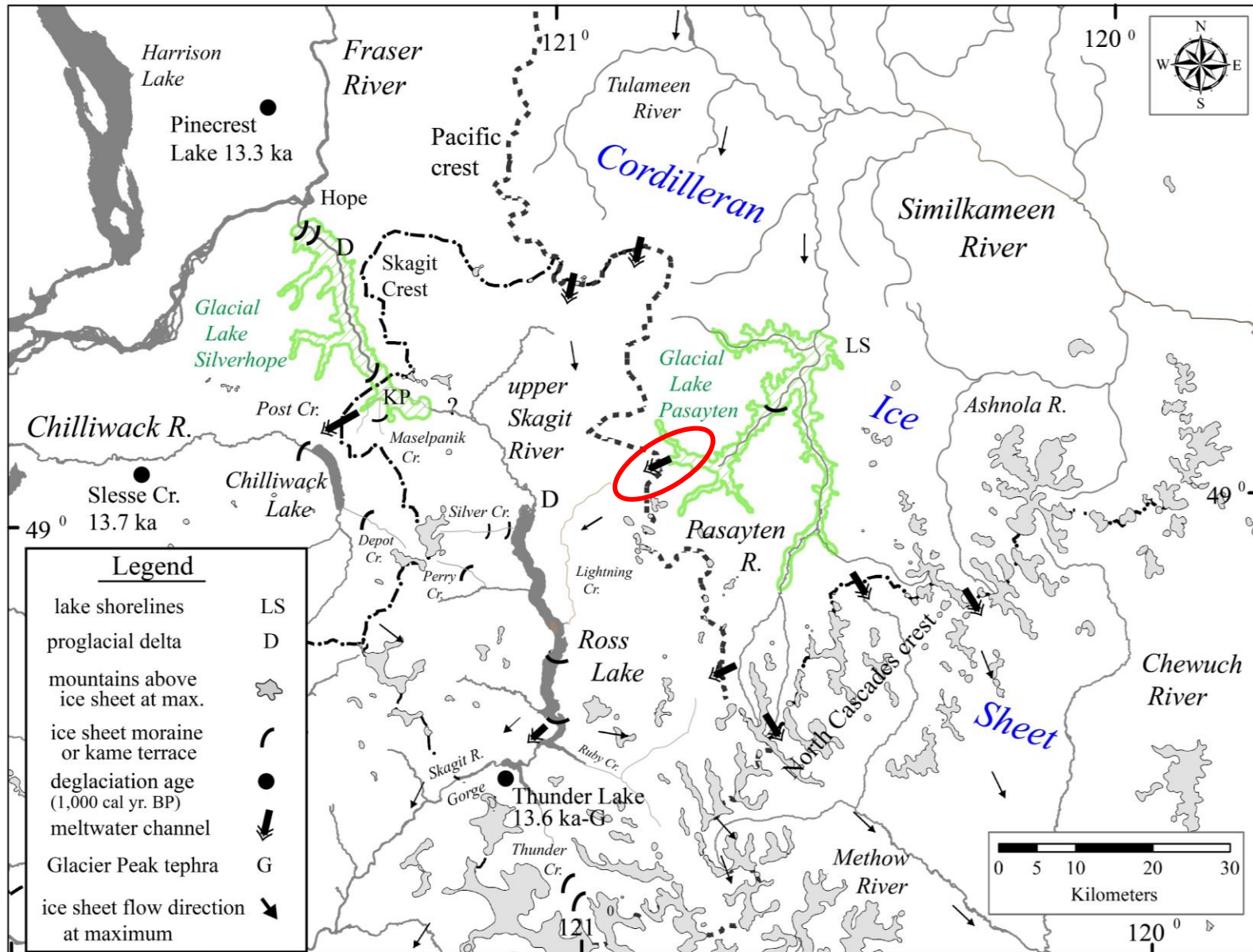
Reach 10 – view down valley



Glacial Lake in lower Fraser River Valley after about 13,600 cal yr. BP.

Based on preliminary evidence, including perched deltas (D), the lake drained to the south via Klesilkwa Pass (KP) into Skagit Valley.





Glacial Lake Pasayten drained to the Skagit via Lightning creek.





2. Sauk Alluvial Fan Geomorphology

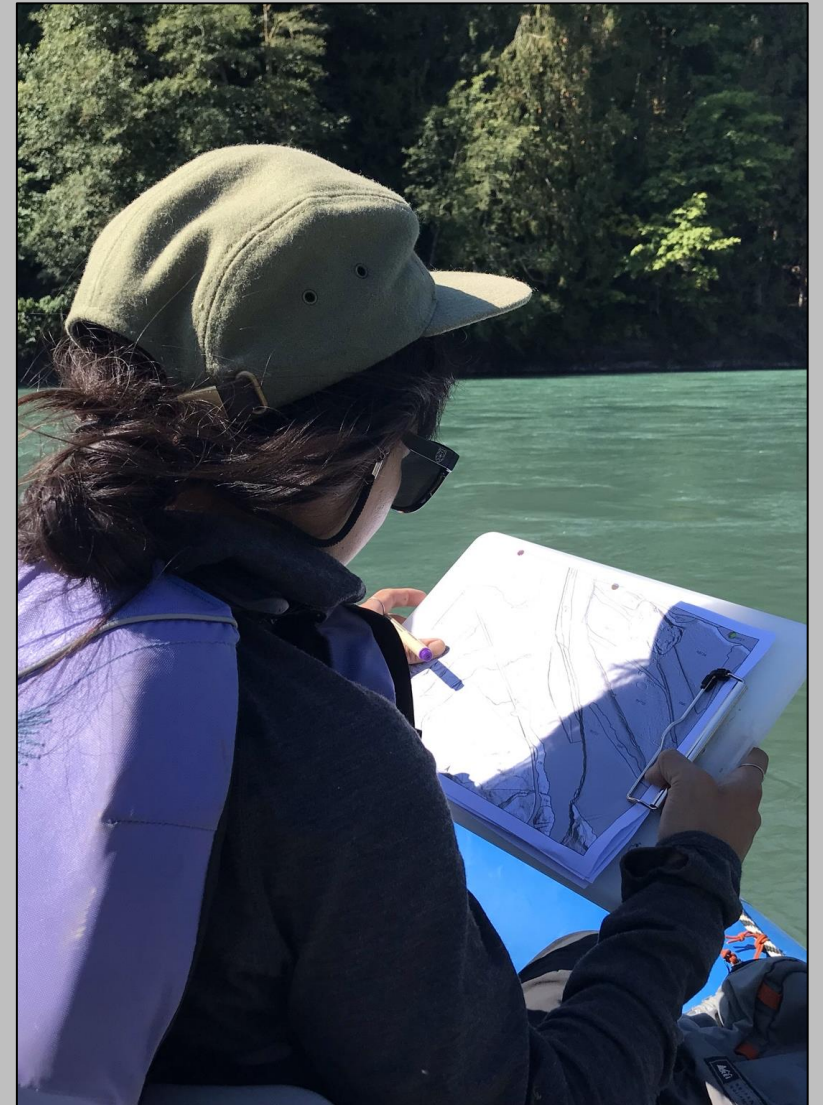
Gus Seixas

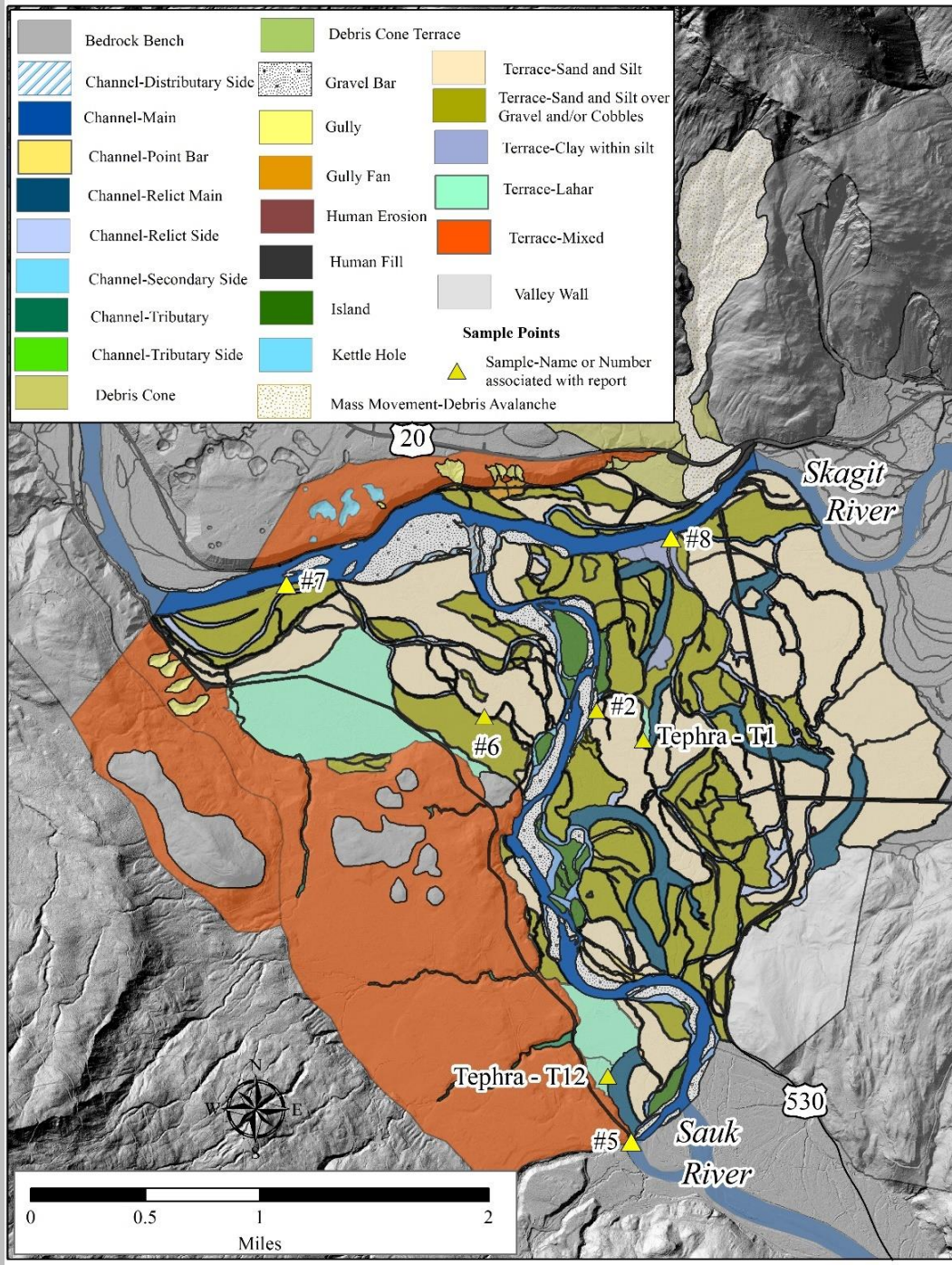


Sharon Sarrantonio

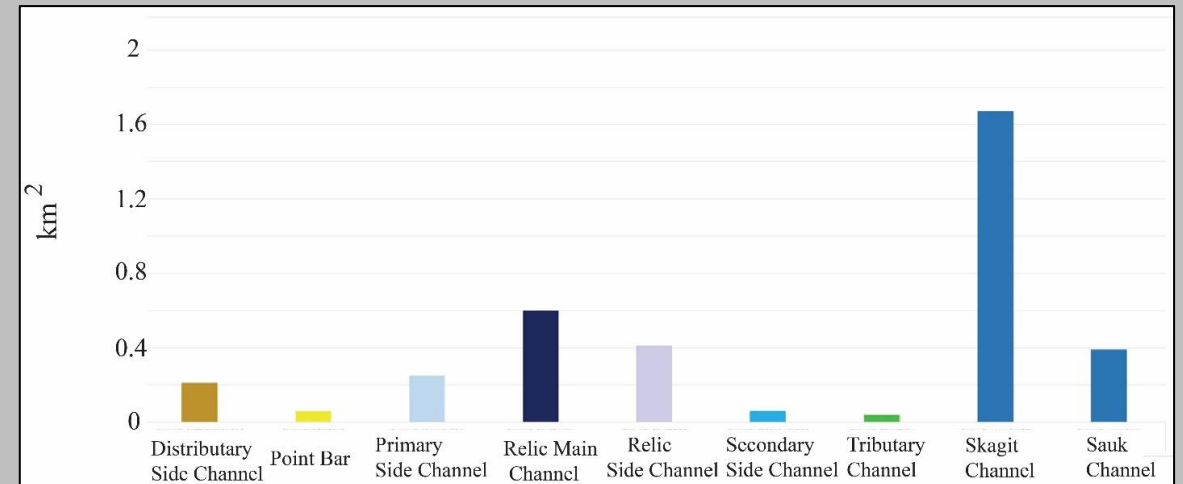


Jeni Chan



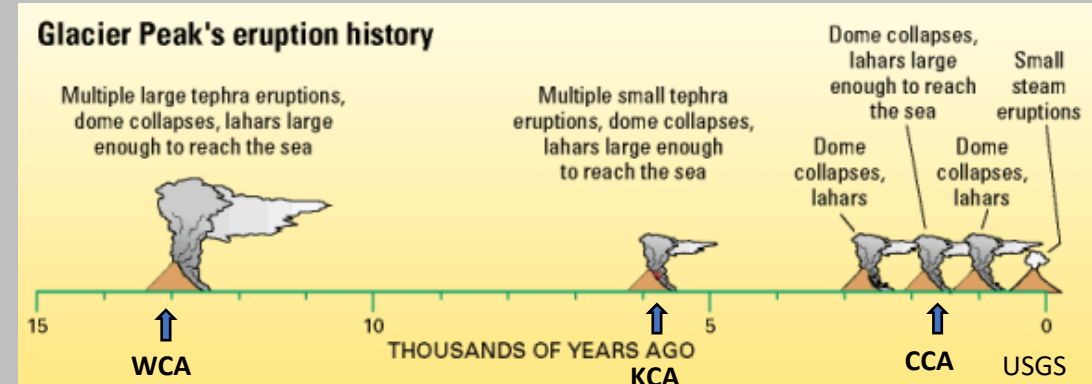
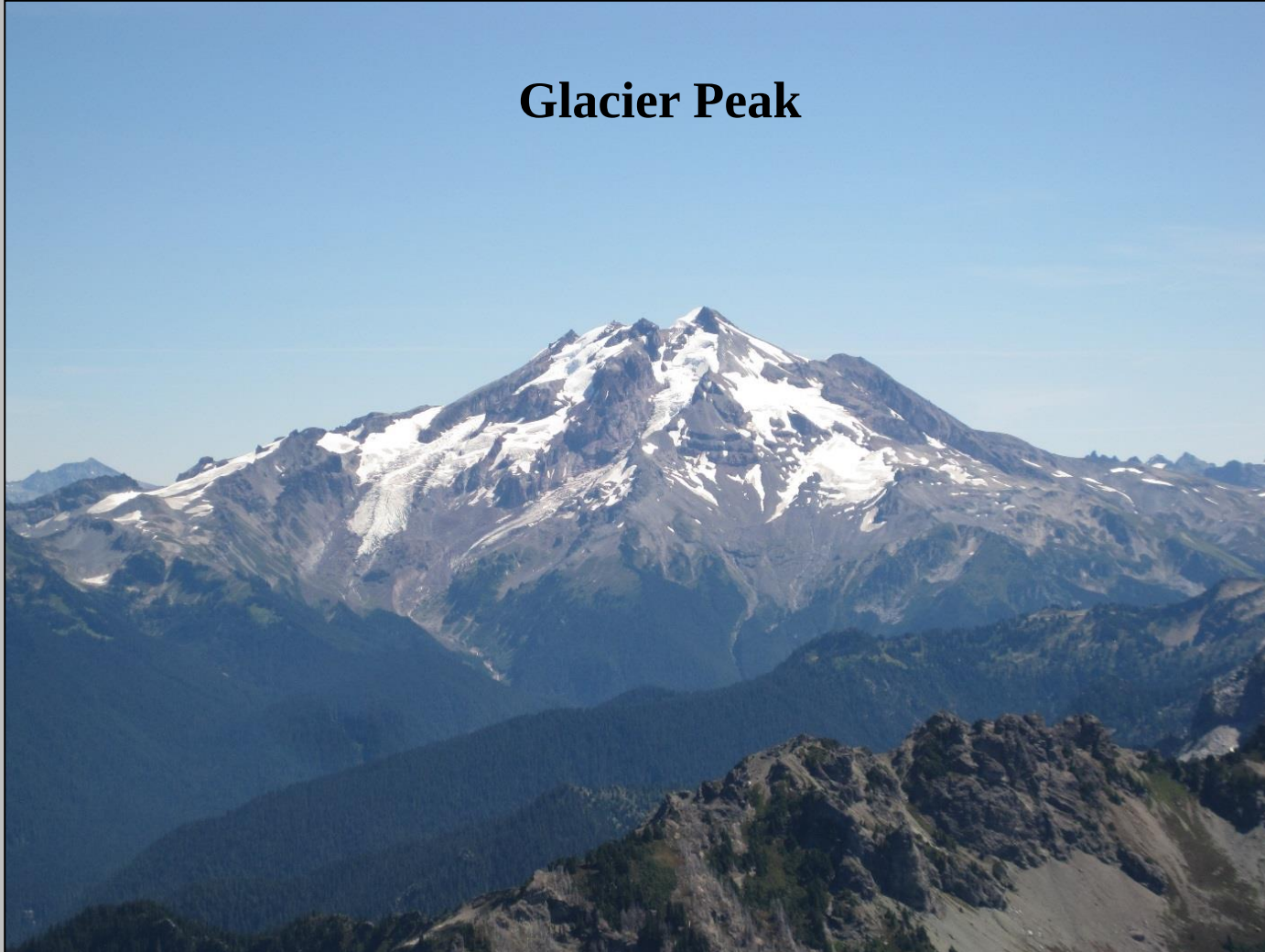


Geomorphology of Reach 7 the Sauk River Alluvial Fan



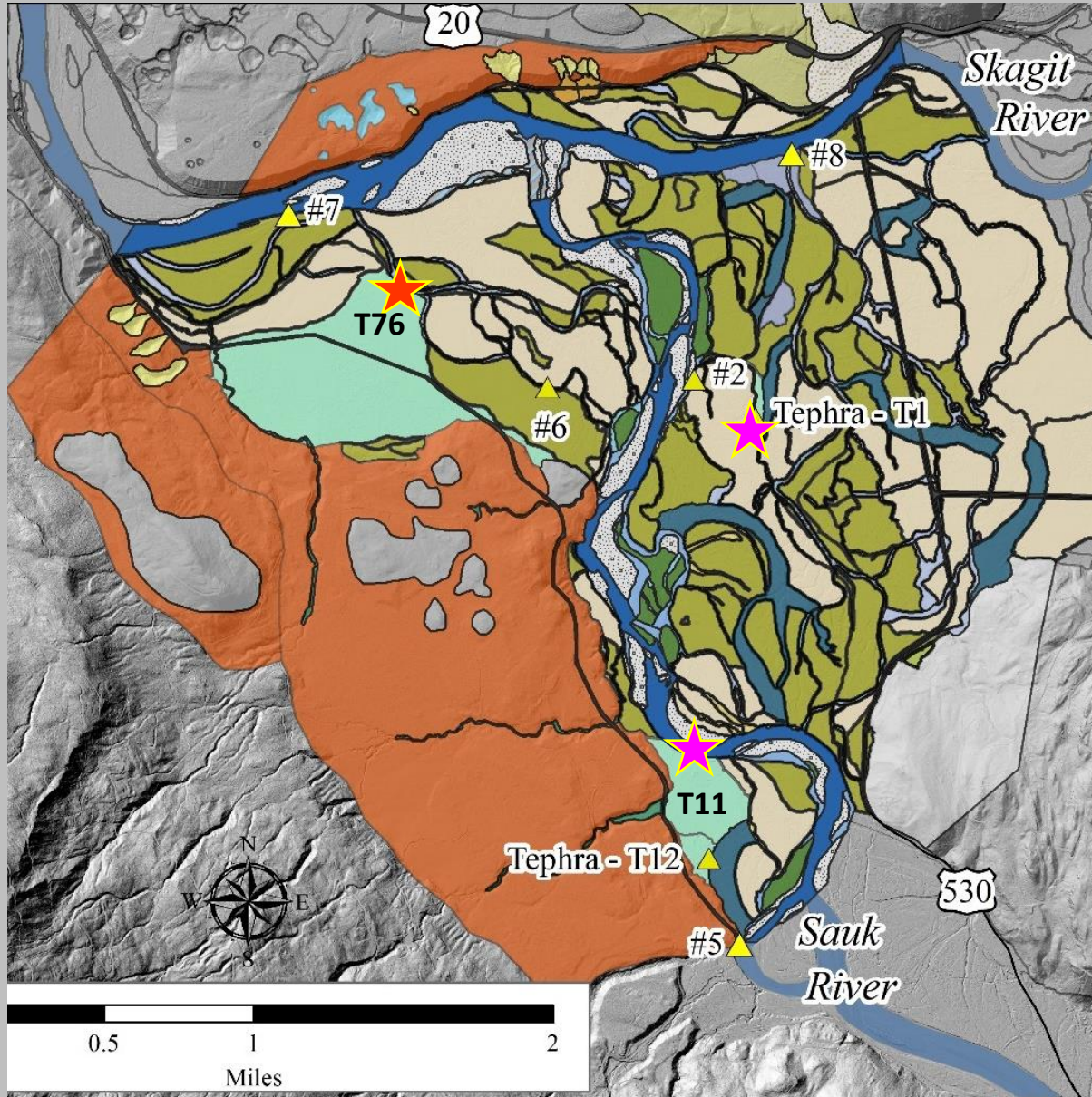
Distribution of aquatic landforms in R7.

Glacier Peak



WCA = White Chuck Assemblage ~13,600 ybp
KCA = Kennedy Creek Assemblage ~5,800 ybp
CCA = Chocolate Creek Assemblage ~1,800 ybp

Sources: Stanton and Dragovich 2009; Vallance et al. 2018



Geomorphology of Reach 7 the Sauk River Alluvial Fan

Lahar Deposit Exposures

- ★ CCA 1800 years (T-76)
- ★ KCA 5800 years (T-1 and T-11)



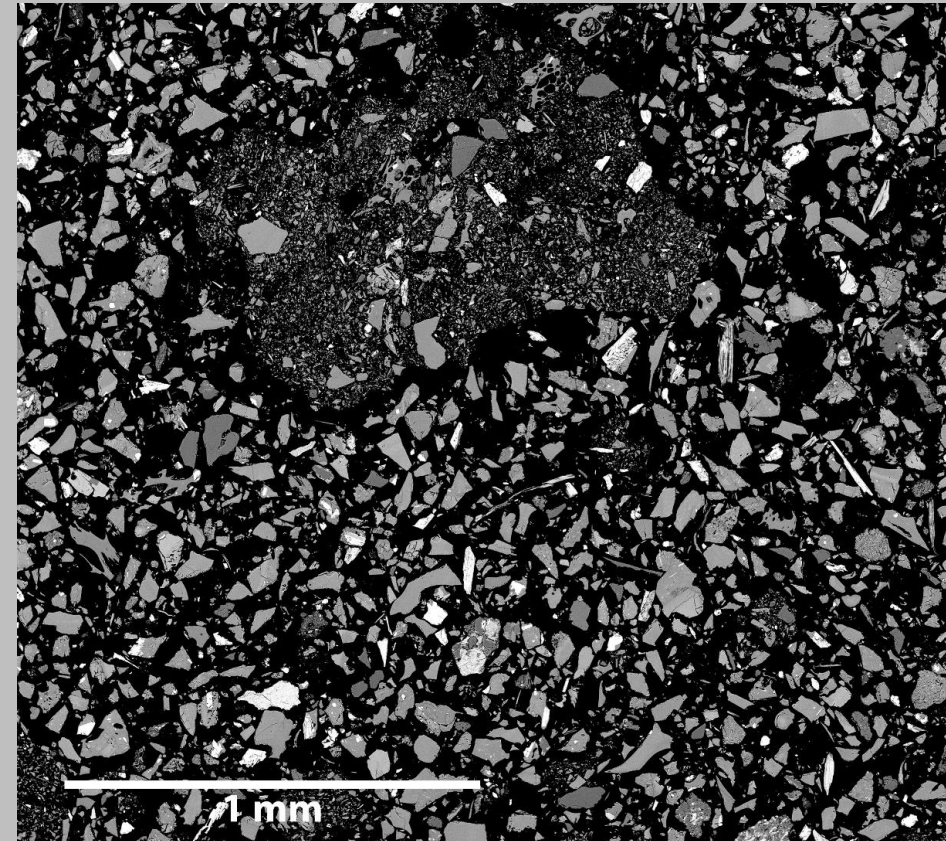
KCA lahar (5,800 cal. yr. BP) capping T1 and T11
on the LB of the Sauk River alluvial fan

2m





CCA lahar (1,800 cal yr. BP) capping T-76
on the distal LB Sauk River alluvial fan



Glass composition of sample:

SiO ₂	TiO ₂	Al ₂ O ₃	MgO	CaO	BaO	MnO	Fe ₂ O ₃	Na ₂ O	K ₂ O	Cl Total	
77.74	0.20	12.23	0.18	1.05	0.00	0.00	1.13	3.68	3.65	0.15	100.0

Chemistry Glass Shards

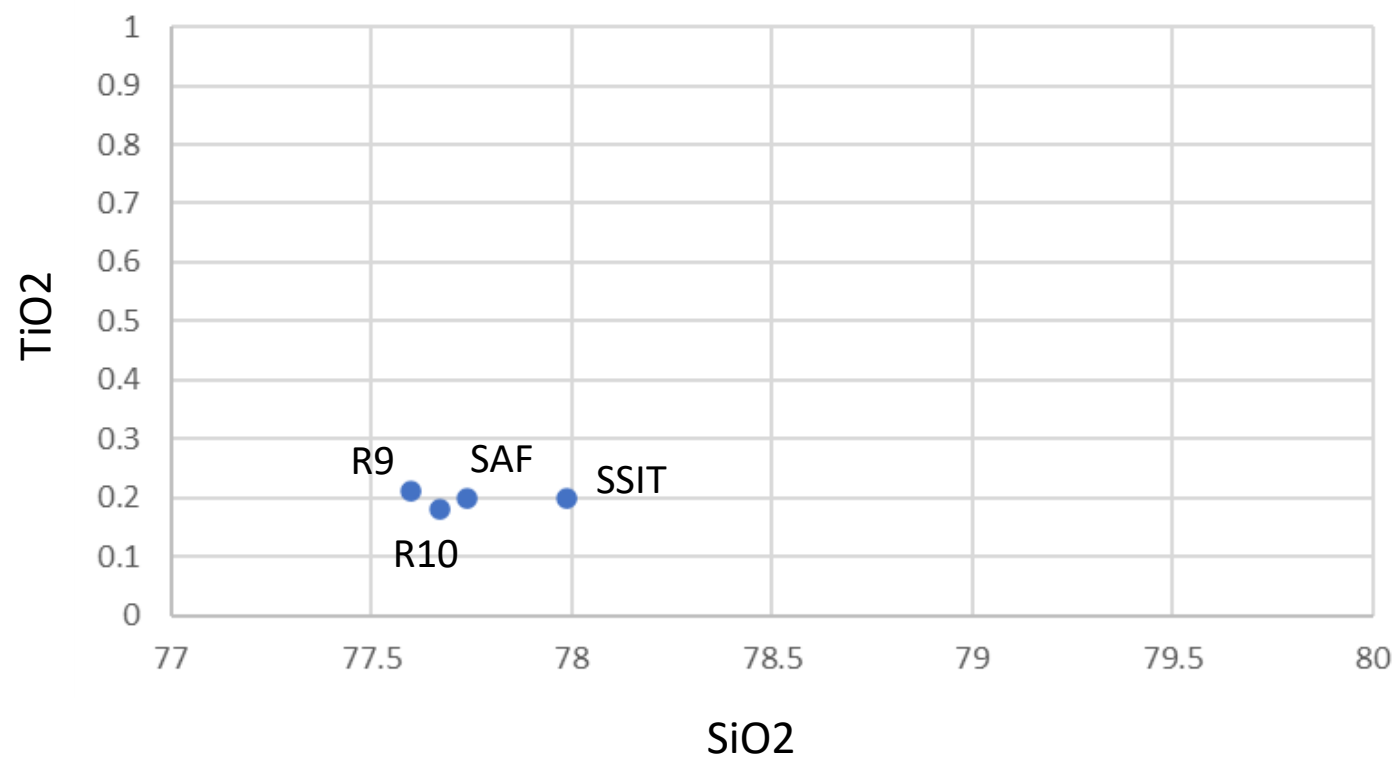
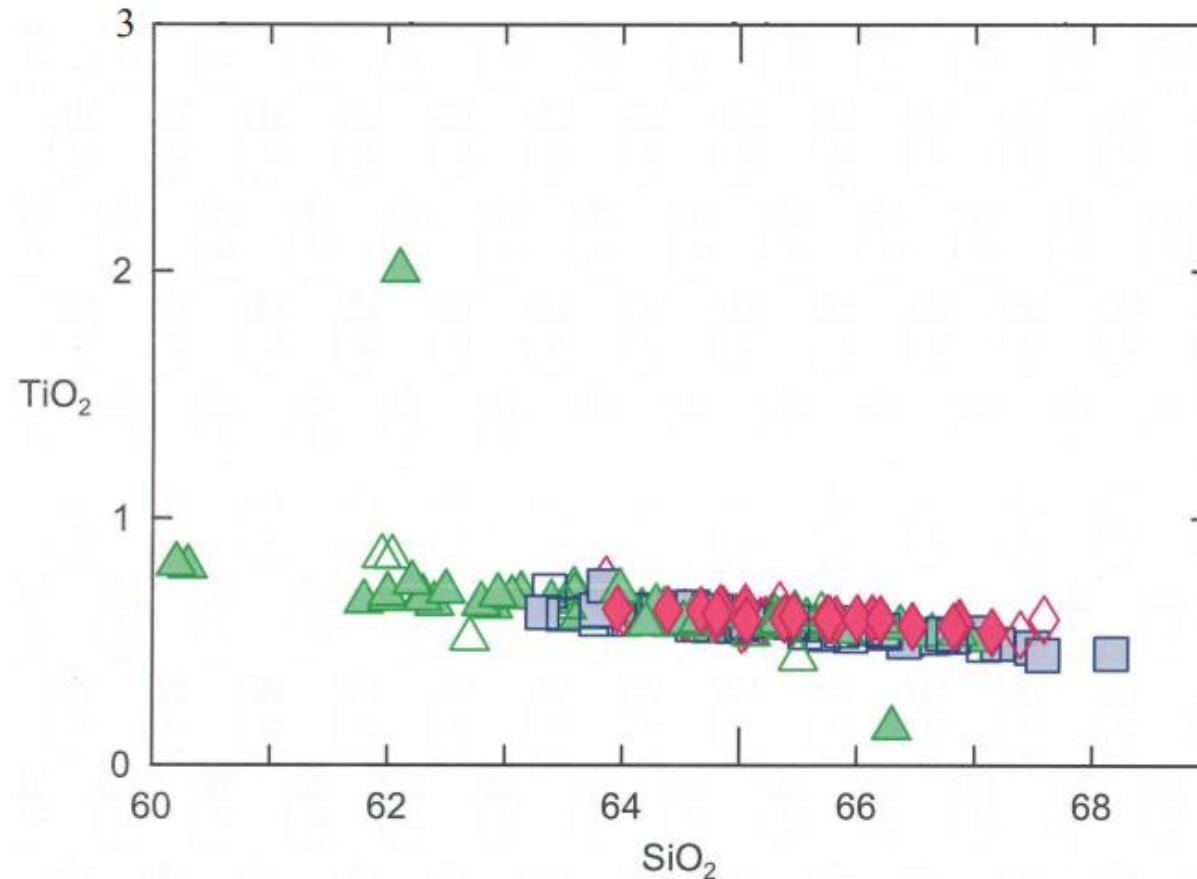
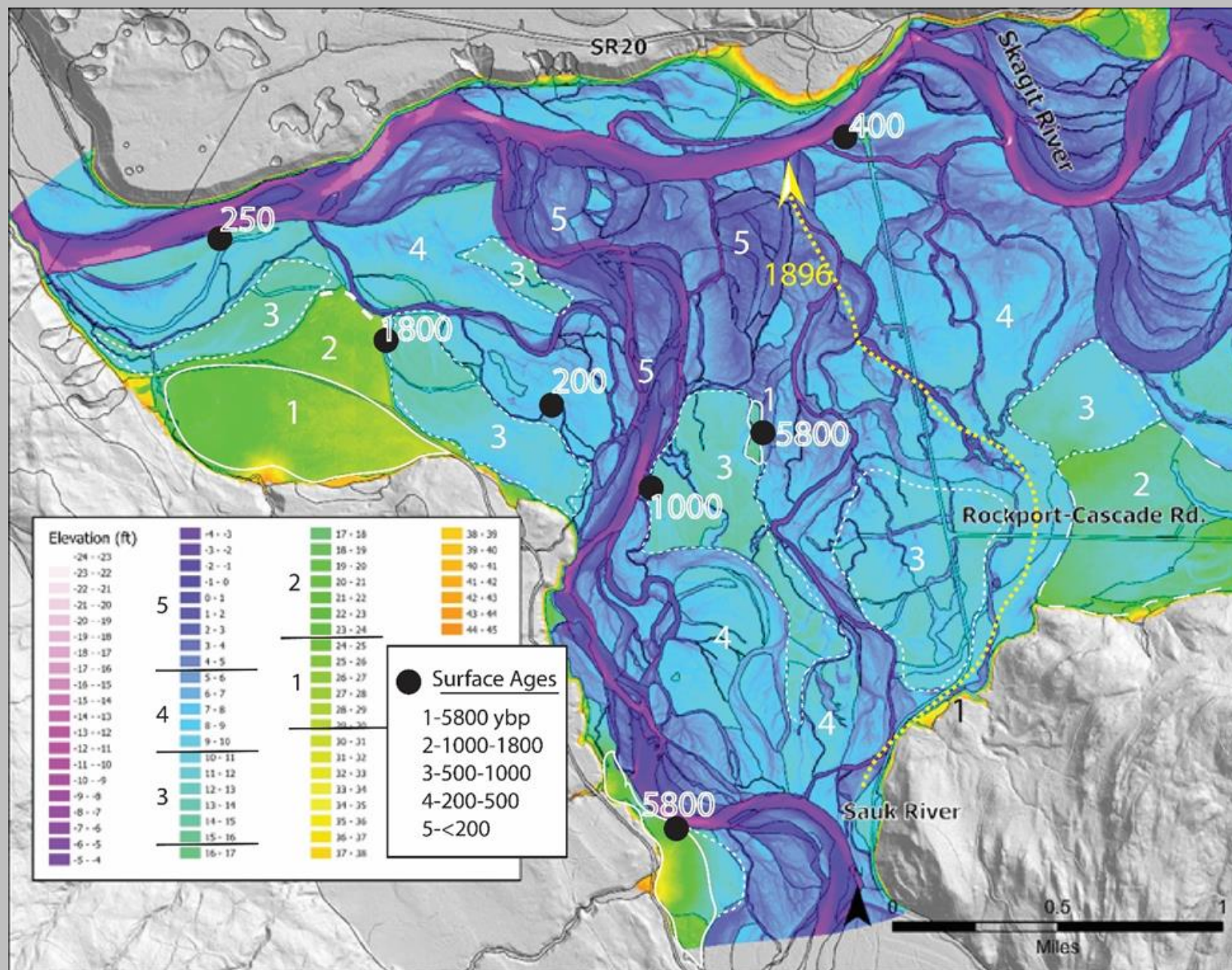


Figure 9. Geochemical data for dacite clasts and dacite flows from multiple geologic units of varying ages. Geologic units include clasts from various lahars, Glacier Peak dacite clasts from glacial outwash, Glacier Peak dacite clasts from Holocene alluvium, as well as dacite flows from the Glacier Peak edifice. We include here Glacier Peak lahars from the ~110Ka Whidbey Formation. Data shows the consistency of Glacier Peak volcanic products over time (~200 ka). This compositional consistency is also reflected in the petrographic consistency of the dacite.



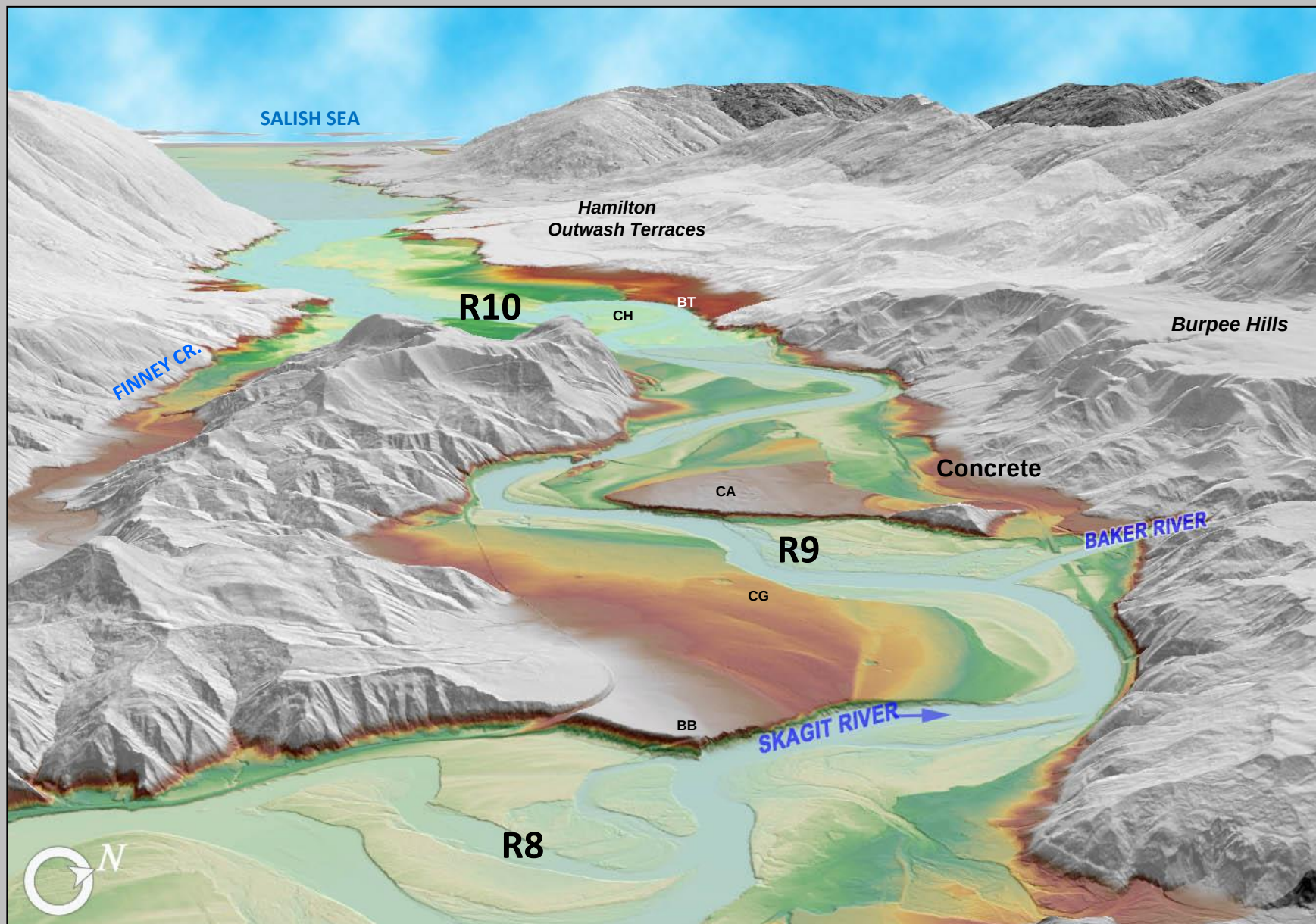
Radiocarbon ages on the Sauk River Alluvial Fan (R7).

Sample Name and Location	Lab #	Raw ¹⁴C age	Calibrated Age YBP Median (95.4%)	Material
Reach 7				
Sauk 2 T2	612387	1,090 ±30	993 (1060-930)	Charcoal
Sauk 5 Osterman	612388	260 ±30	305 (331-276)*	Wood
Sauk 6 T14	612390	210 ±30	187 (222-142)*	Wood
Sauk 7 T76	612389	80 ±30	116 (142-29)*	Wood
Sauk 8	612391	340 ±30	389 (477-312)	Wood



3. Middle Skagit Valley Geomorphology

(REM looking west by Joshua Greenberg, Skagit County)



Units

• C14_Dates

— Reach Divisions

Landform

ALLUVIAL FAN

BEDROCK BENCH

CHANNEL-DISTRIBUTARY SIDE

CHANNEL-MAIN

CHANNEL-POINT BAR

CHANNEL-PRIMARY SIDE

CHANNEL-RELICT MAIN

CHANNEL-RELICT SIDE

CHANNEL-SECONDARY SIDE

CHANNEL-TRIBUTARY

CHANNEL-TRIBUTARY SIDE

DEAD ICE TOPOGRAPHY

DEBRIS APRON

DEBRIS CONE

DEBRIS CONE TERRACE

DEBRIS FAN

ESKER

FAN TERRACE

GRAVEL BAR

GULLY

GULLY FAN

HUMAN EROSION

HUMAN FILL

ISLAND

KAME TERRACE

KETTLE HOLE

LATERAL MORaine

MASS MOVEMENT-DEBRIS AVALANCHE

MASS MOVEMENT-DEBRIS AVALANCHE TERRACE

MASS MOVEMENT-FALL/TOPPLE

MASS MOVEMENT-SLUMP/CREEP

PLEISTOCENE MORaine

PLEISTOCENE TERRACE

POINT BAR TERRACE

SAND BAR

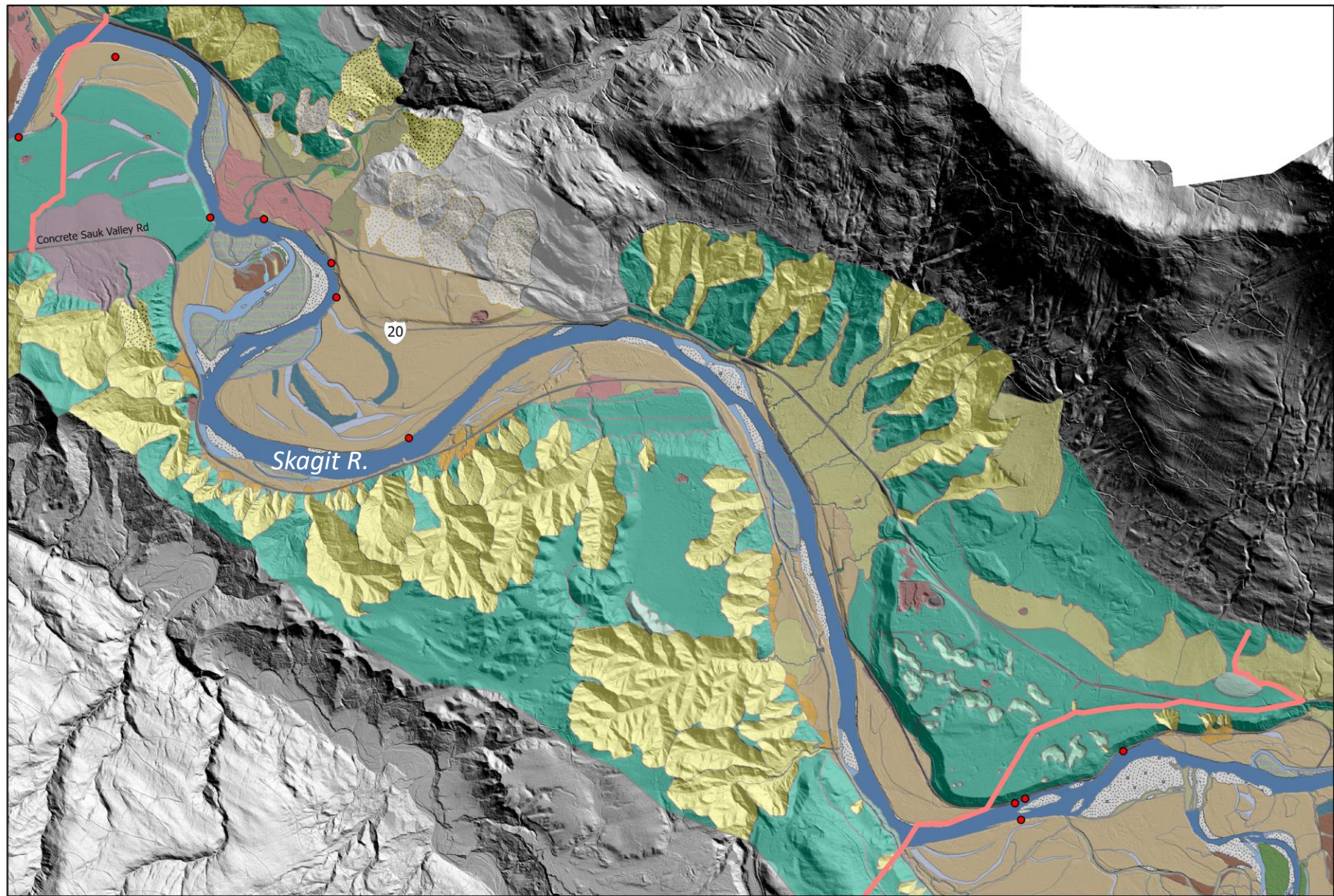
TERRACE

TERRACE-ISLAND

UNDIFFERENTIATED

VALLEY WALL

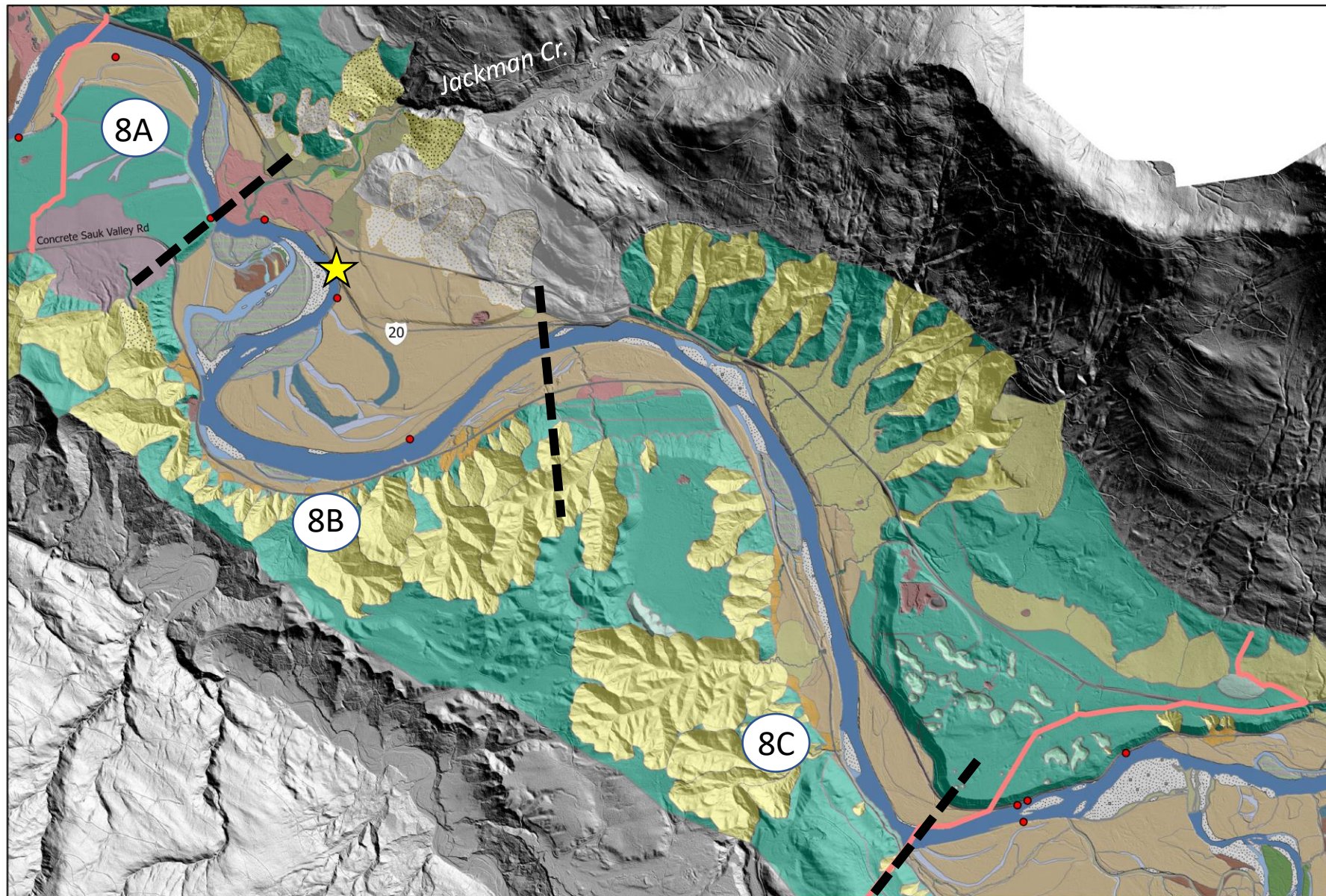
CHANNEL-INCIPIENT SIDE



Skagit River Landforms

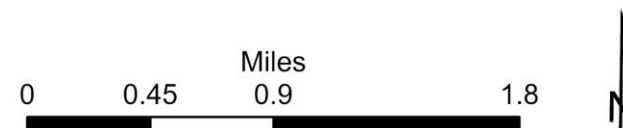
Reach 08





Skagit River Landforms

Reach 08



Kennedy Creek Assemblage (R8 T-47)





Table 9. Radiometric ages on landforms in the middle Skagit Valley Reach 7 to Reach 10. All lab numbers Beta Analytic except Cedar Grove (U. California Irvine).

Sample Name and Location	Lab #	Raw ¹⁴ C age	Calibrated Age YBP Median (95.4%)	Material
Reach 7				
Sauk 2 T2	612387	1,090 ±30	993 (1060-930)	Charcoal
Sauk 5 Osterman	612388	260 ±30	305 (331-276)*	Wood
Sauk 6 T14	612390	210 ±30	187 (222-142)*	Wood
Sauk 7 T76	612389	80 ±30	116 (142-29)*	Wood
Sauk 8	612391	340 ±30	389 (477-312)	Wood
Reach 8				
Jackman Creek	610564	1,460 ±30	1,340 (1386-1301)	Wood
Moen Road T47	610561	5,060 ±30	5,819 (5904-5732)	Wood
Big Boy ⁸	216088	19,880 ±80	23,894 (24144-23767)	Wood in Peat
Reach 9				
Cedar Grove ⁸	UCI44540	25,160 ±140	29,466 (29872-29148)	Wood
Cape Horn	504293	2,440 ±40	2,448 (2540-2356)	Wood
Reach 10				
Grandy Cr. 1 T	610563	4,670 ±30	5,397 (5468-5319)	Charcoal
Grandy Cr. 3 T	610562	2,880 ±30	3,008 (3079-2922)	Charcoal
Birdsview T1-T2 ⁹	307133	20,160 ±80	24,178 (24493-23911)	Wood
Birdsview T1-T2 ⁹	307134	19,940 ±70	24,015 (24525-23738)	Wood
Hamilton T56 ¹⁰	239564	3,210 ±40	3,423 (3492-3355)	Peat

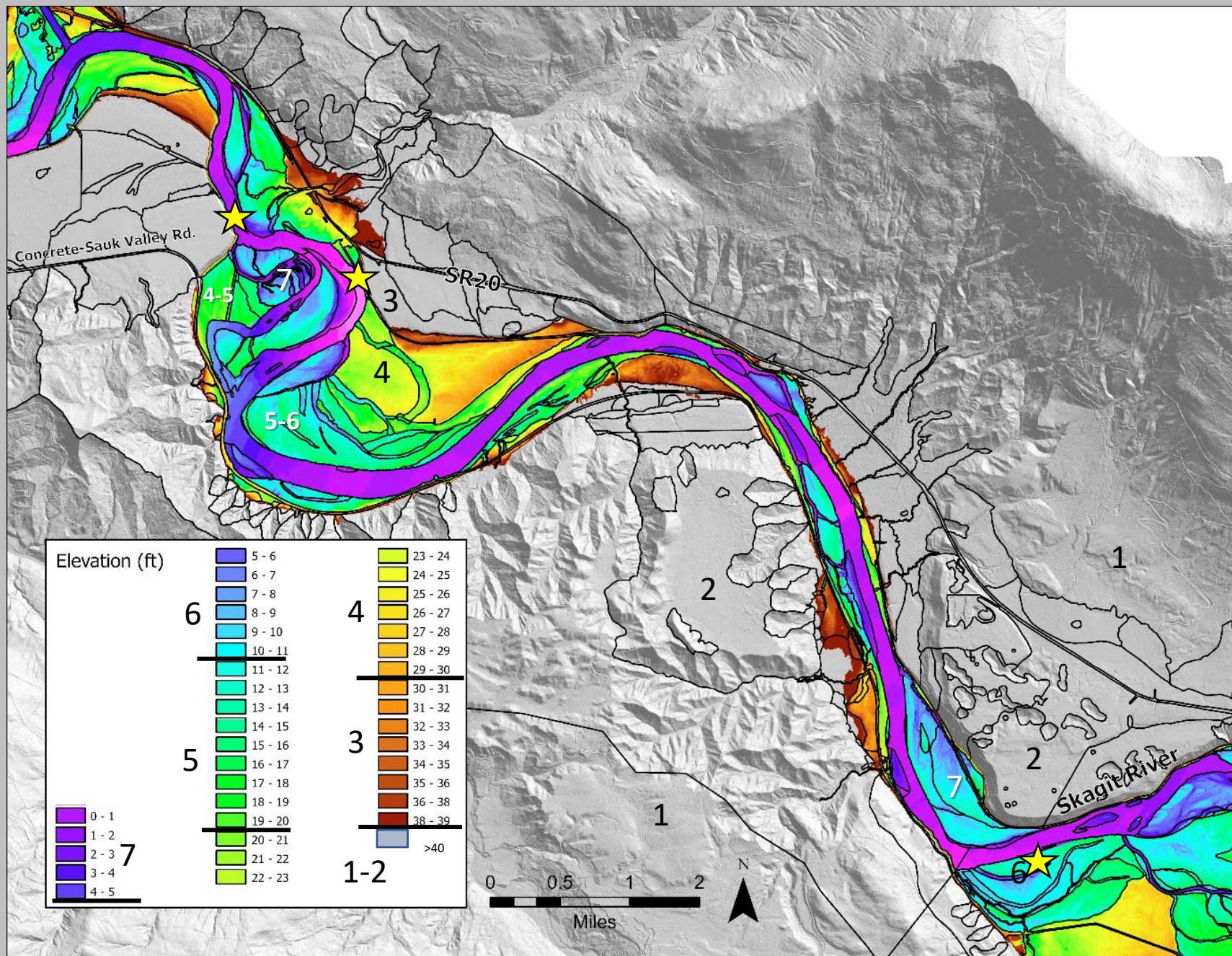
⁸ Riedel et al. 2010; ⁹ Riedel 2007; ¹⁰ Miss and Kopperl 2017 *multiple peaks <95.4% confidence

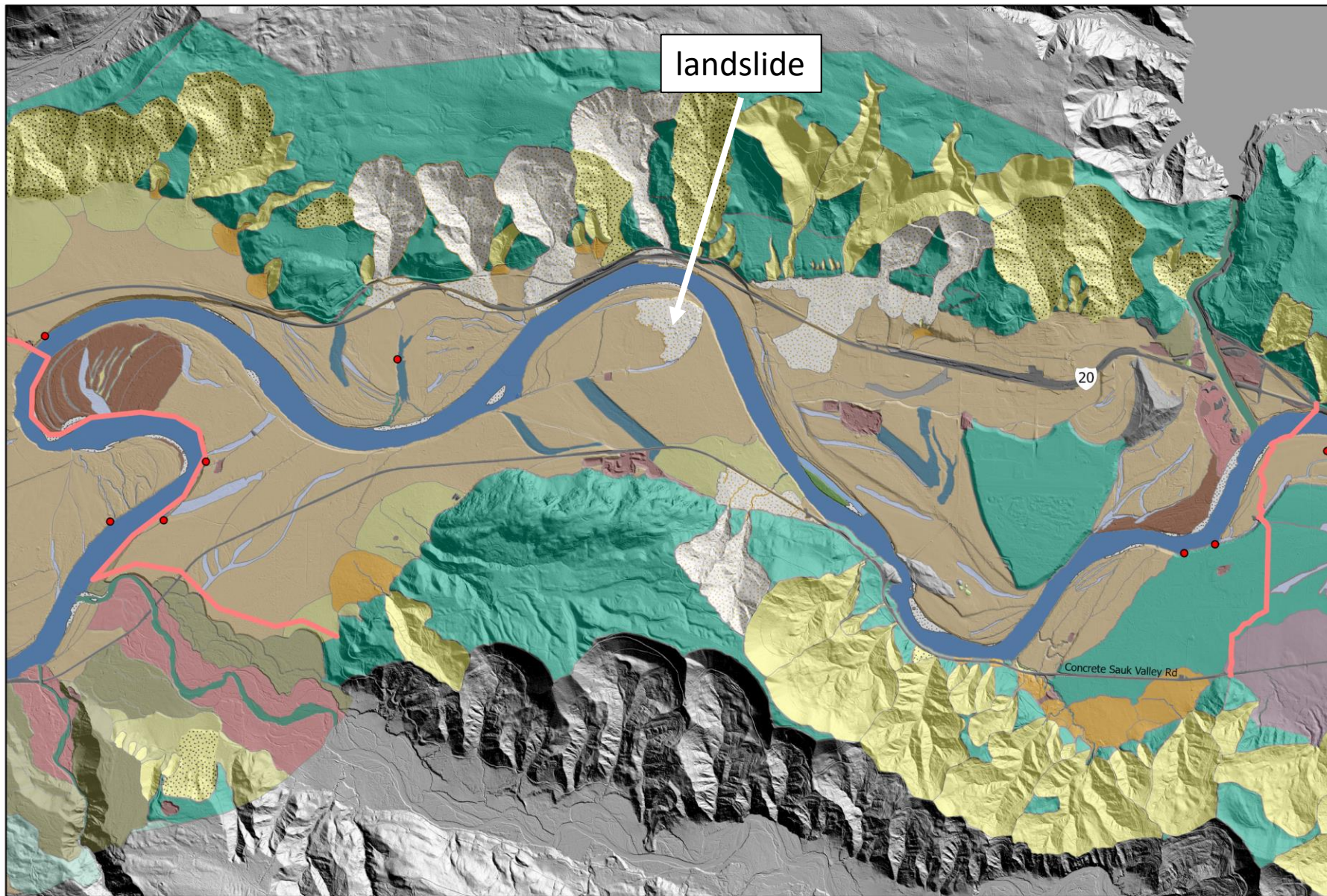
Reach 8 REM

★ Key Stratigraphic sites

Initial Landform Ages in R8

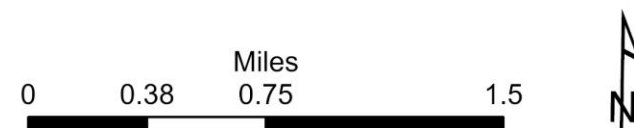
- 1- >13,600 (glaciation)
- 2- 13,600-11,600 (outburst-SME)
- 3- 11,600-5,800
- 4- 5,800-2,440 (KCA)
- 5- 2,440-1,800
- 6- 1,800 – 100 (CCA)
- 7- <100 cal. ybp

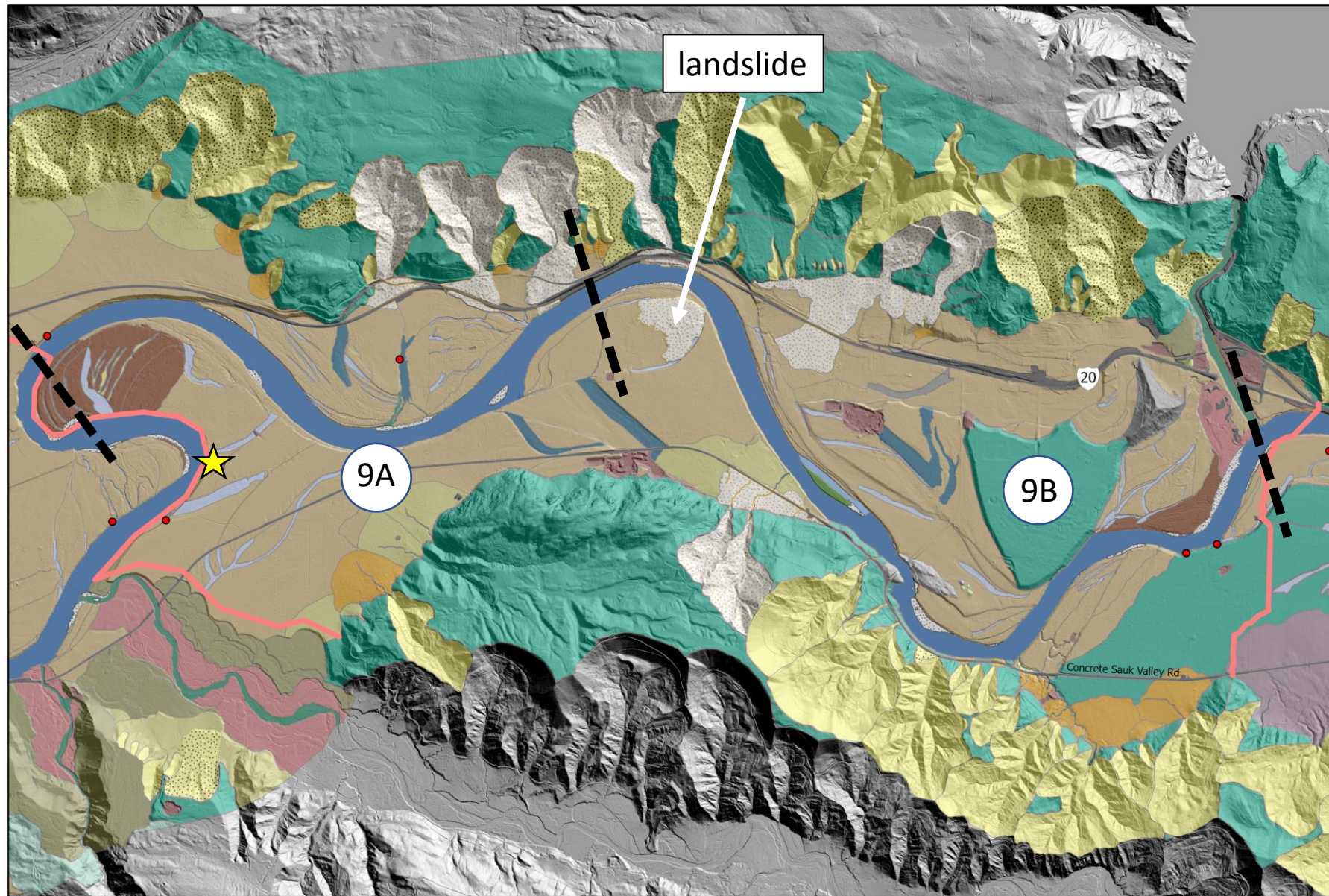




Skagit River Landforms

Reach 09





Skagit River Landforms

Reach 09



Cape Horn Buried Log (2,448 ybp) and CCA Lahar T98



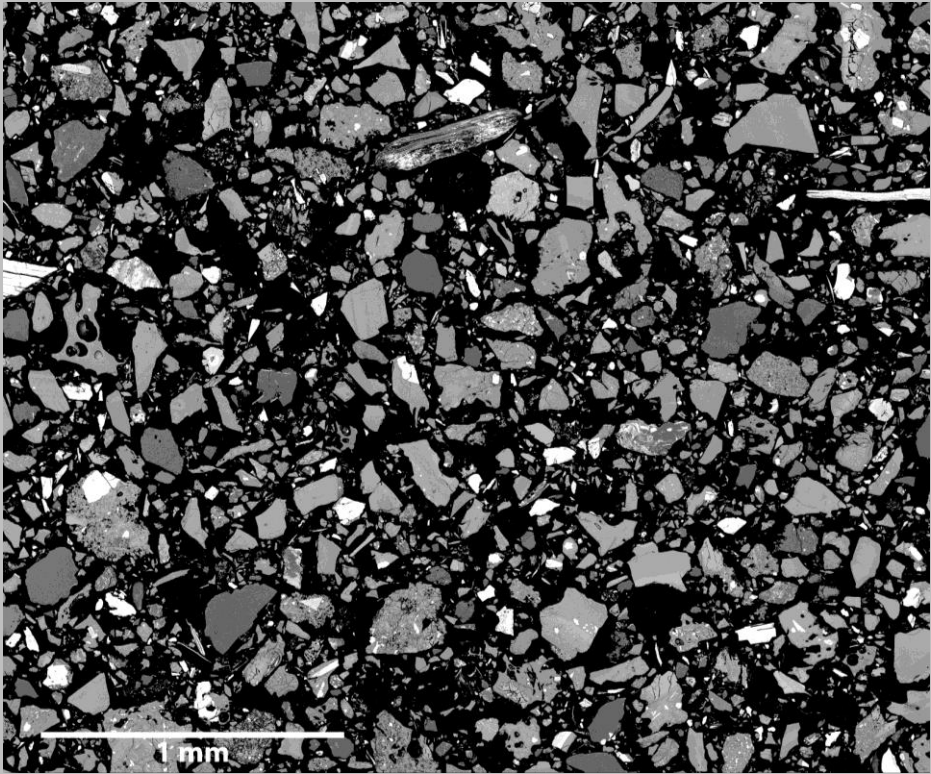
Cape Horn Volcanic Lahar



LB Cape Horn CCA lahar R9 T93



SEM image of Cape Horn lahar deposit

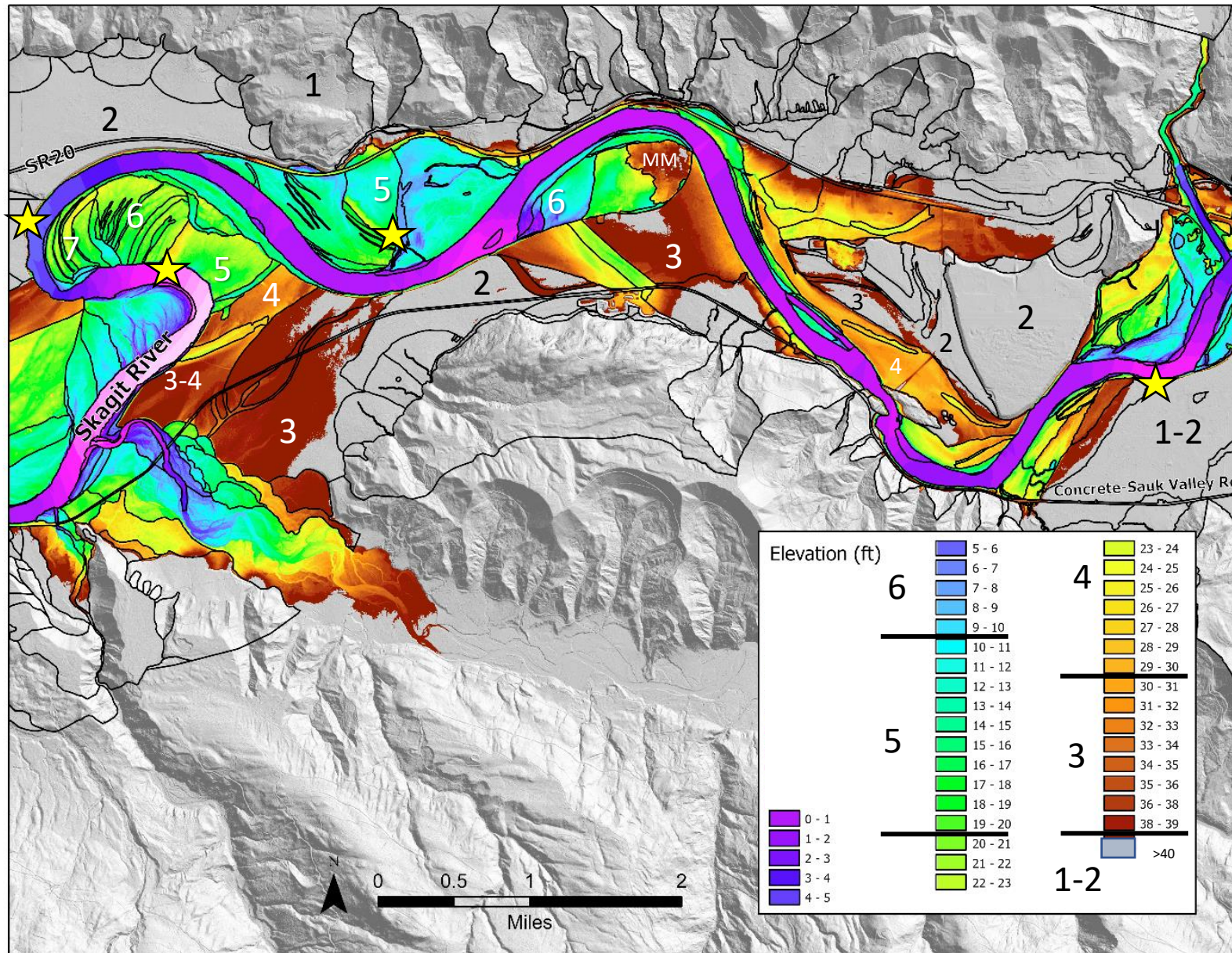


Glass composition of sample:

SiO2	TiO2	Al2O3	MgO	CaO	BaO	MnO	Fe2O3	Na2O	K2O	Cl Total	
77.67	0.18	12.33	0.16	0.95	0.00	0.00	1.09	3.61	3.89	0.13	100.0

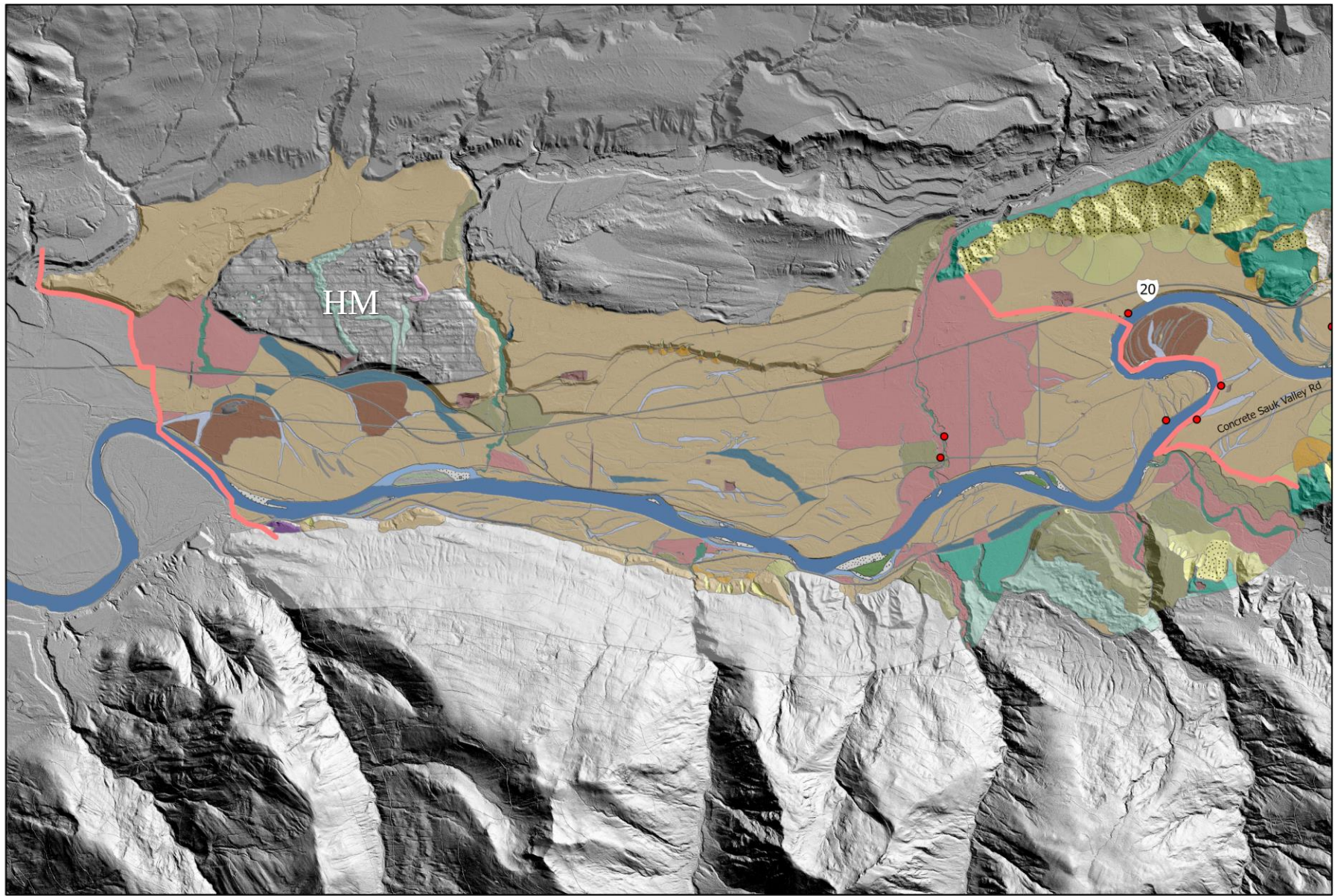
Reach 9 REM

★ Key Stratigraphic sites



Initial Landform Ages in R9

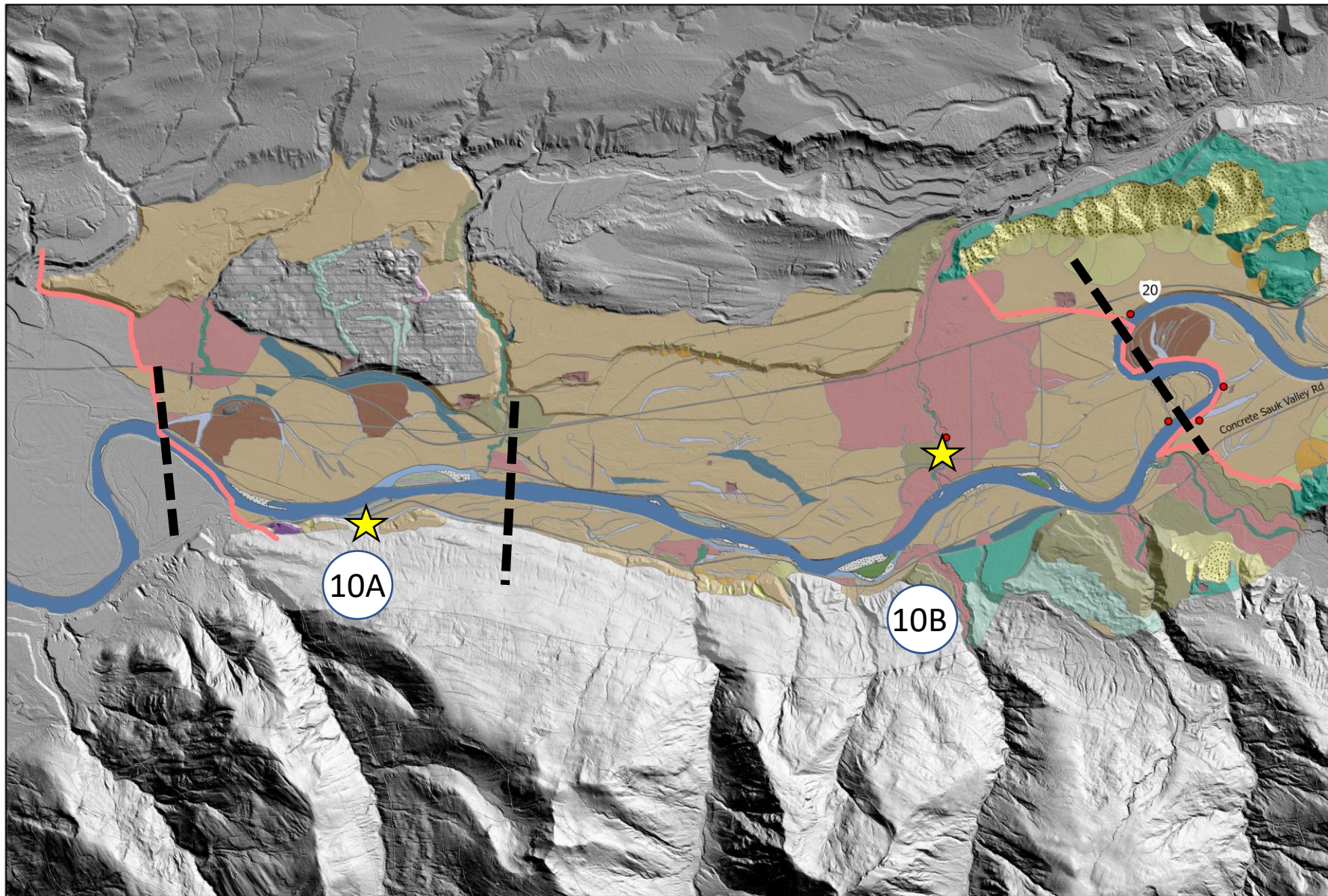
- 1- >13,600 (glaciation)
- 2- 13,600-11,600 (outburst-SME)
- 3- 11,600-5,800
- 4- 5,800-2,440 (post KCA)
- 5- 2,440-1,800
- 6- 1,800 – 100 (post CCA)
- 7- <100 cal. ybp



Skagit River Landforms

Reach 10





Skagit River Landforms

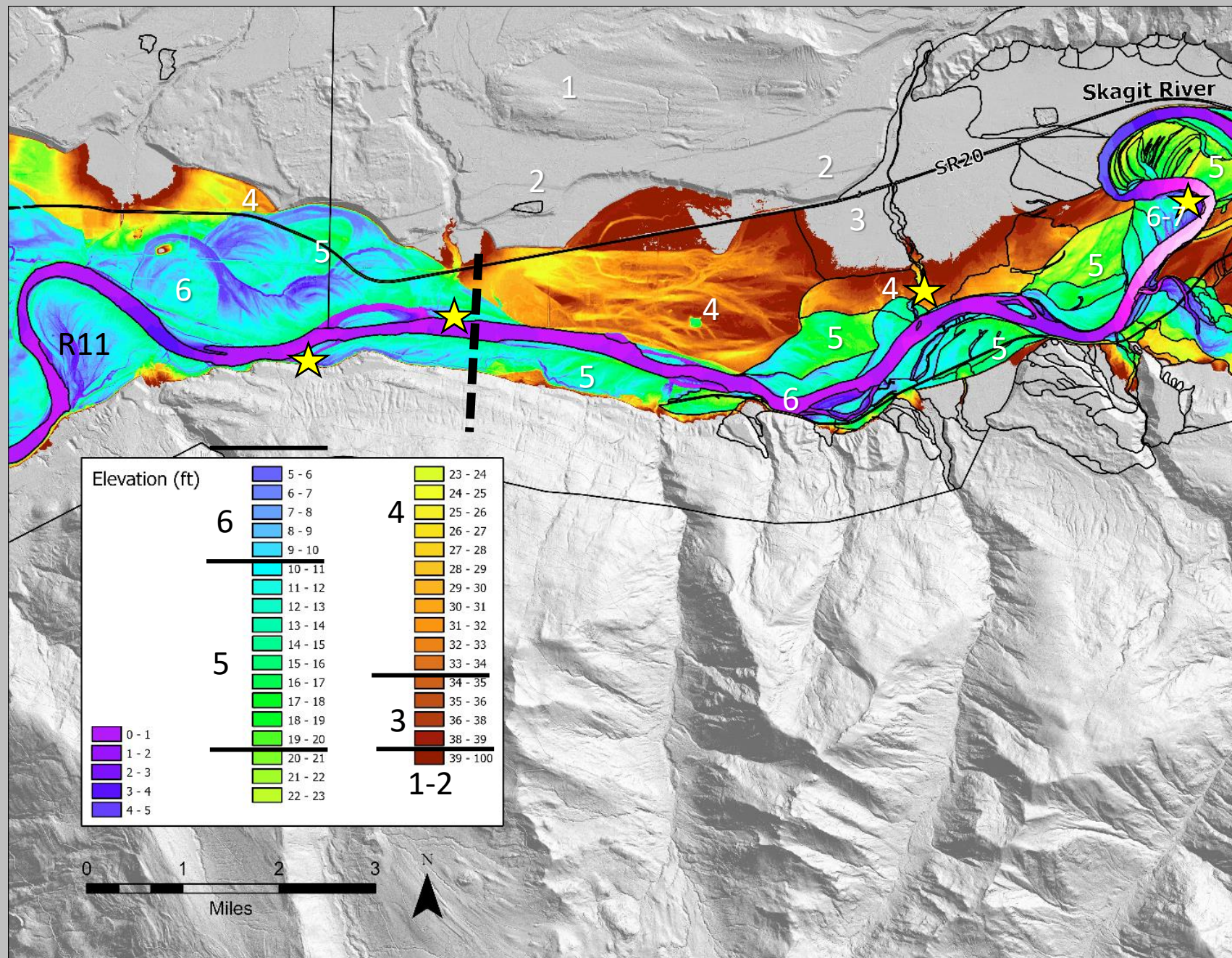
Reach 10



Table 9. Radiometric ages on landforms in the middle Skagit Valley Reach 7 to Reach 10. All lab numbers Beta Analytic except Cedar Grove (U. California Irvine).

Sample Name and Location	Lab #	Raw ¹⁴ C age	Calibrated Age YBP Median (95.4%)	Material
Reach 7				
Sauk 2 T2	612387	1,090 ±30	993 (1060-930)	Charcoal
Sauk 5 Osterman	612388	260 ±30	305 (331-276)*	Wood
Sauk 6 T14	612390	210 ±30	187 (222-142)*	Wood
Sauk 7 T76	612389	80 ±30	116 (142-29)*	Wood
Sauk 8	612391	340 ±30	389 (477-312)	Wood
Reach 8				
Jackman Creek	610564	1,460 ±30	1,340 (1386-1301)	Wood
Moen Road T47	610561	5,060 ±30	5,819 (5904-5732)	Wood
Big Boy ⁸	216088	19,880 ±80	23,894 (24144-23767)	Wood in Peat
Reach 9				
Cedar Grove ⁸	UCI44540	25,160 ±140	29,466 (29872-29148)	Wood
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Reach 10				
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Birdsview T1-T2 ⁹	307133	20,160 ±80	24,178 (24493-23911)	Wood
Birdsview T1-T2 ⁹	307134	19,940 ±70	24,015 (24525-23738)	Wood
Hamilton T56 ¹⁰	239564	3,210 ±40	3,423 (3492-3355)	Peat

⁸ Riedel et al. 2010; ⁹ Riedel 2007; ¹⁰ Miss and Kopperl 2017 *multiple peaks <95.4% confidence



Reach 10 REM Age Model

★ Key Stratigraphic sites

Initial Landform Ages in R10

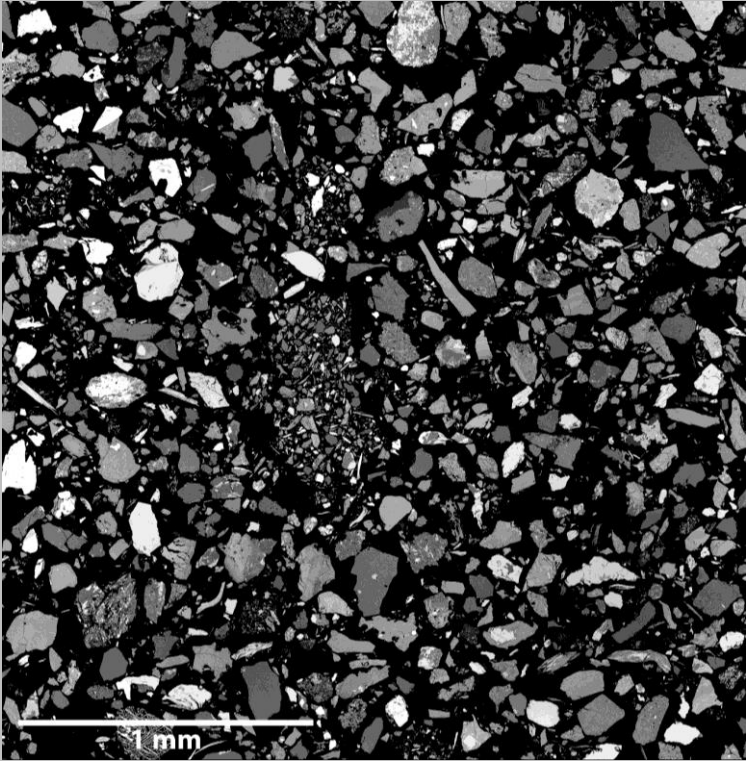
- 1- >13,600 (glaciation)
- 2- 13,600-11,600 (outburst-SME)
- 3- 11,600-5,800
- 4- 5,800-2,440 (post KCA)
- 5- 2,440-1,800
- 6- 1,800 – 100 (post CCA)
- 7- <100 cal. ybp

*In R10a, 6 meander loops in 1800 years = ~300 years each

Chocolate Creek Assemblage 1,800 cal. yr. BP (R10 T-26)



SEM image of Boyd Creek Deposit in lower R10



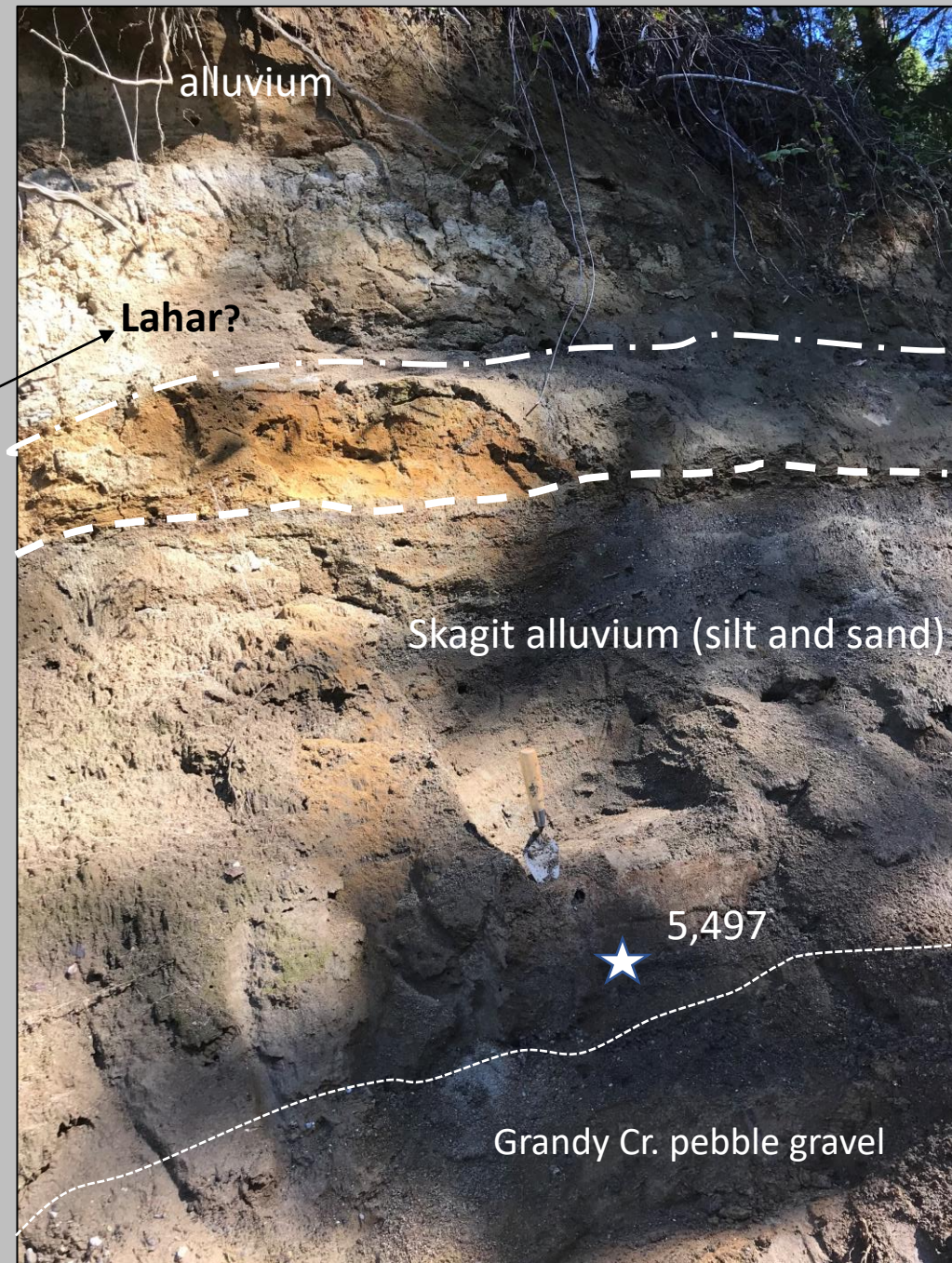
Glass composition of sample:

SiO2	TiO2	Al2O3	MgO	CaO	BaO	MnO	Fe2O3	Na2O	K2O	Cl Total	
77.60	0.21	12.22	0.15	0.98	0.00	0.00	1.18	3.67	3.85	0.14	100.0

RB Grandy Creek Section above Cape Horn Road Bridge R10

-possible lahar deposit contains weathered minerals but no glass

-sections yielded two radiocarbon ages: 5,497 cal. yr. BP low in section and 3,008 cal. ybp in mid section



Geomorphology of the lower Sauk and middle Skagit Rivers

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Skagit Quaternary

