Application of LiDAR for paleo-lake level reconstruction in closed-basin lakes, Kenai Peninsula, Alaska

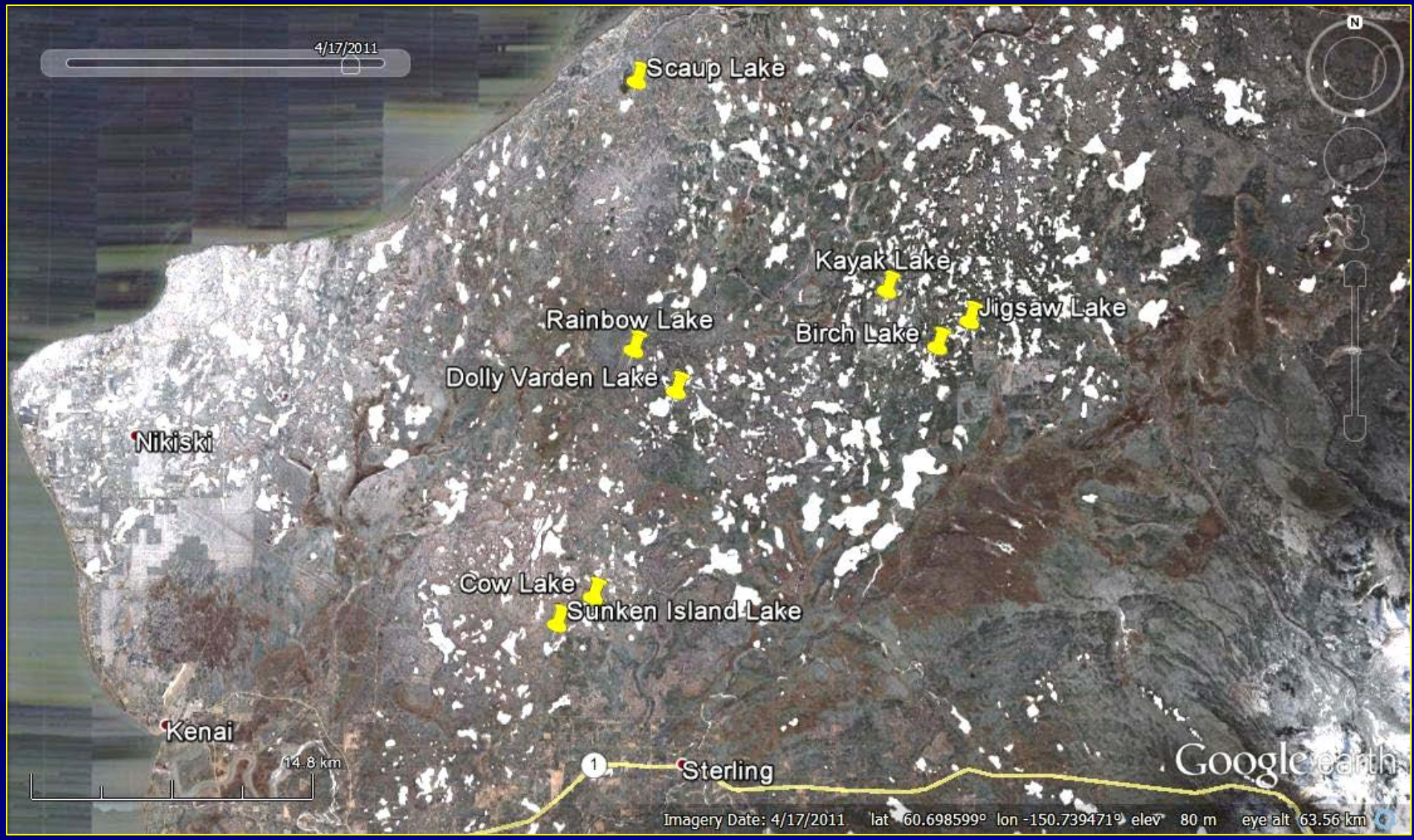
14th International Circumpolar Remote Sensing Symposium

Ed Berg, PhD
US Fish & Wildlife Service (Retired)
Kenai Peninsula College (Adjunct)
September 15, 2016

Topics to be Discussed

- Ice-shoved ramparts
- Wave-cut scarps
- Reconstructing paleo lake levels
- Recovery from 5000 years of late glacial - early Holocene drought

Paleo lake level study lakes



Moosehorn glacial (19 ka) kettle moraine topography

Ice-Shoved Ramparts are berms around lakes pushed up by lake ice

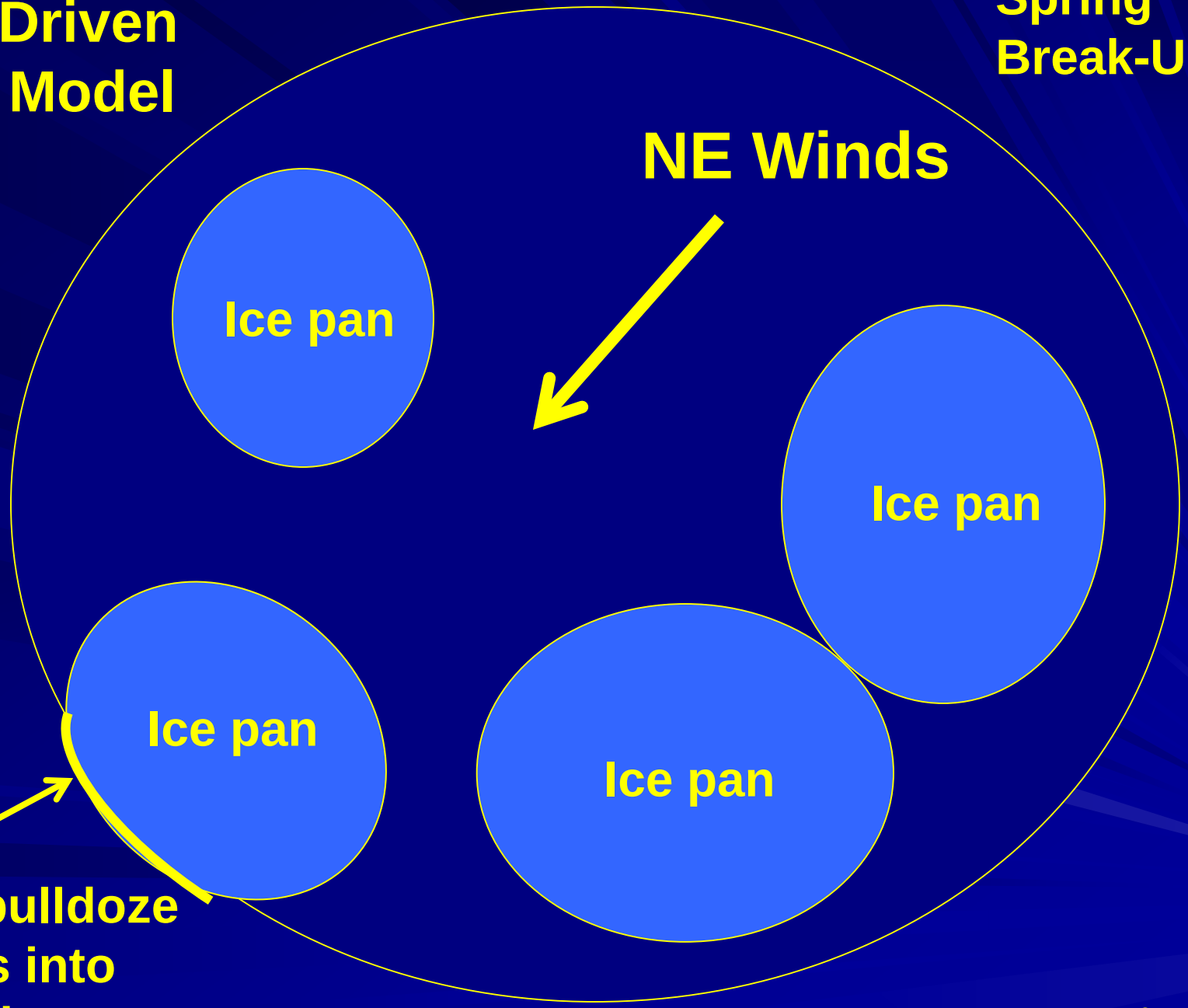
Rampart

Barabara Lake

Elephant (Spirit) Lake Ramparts

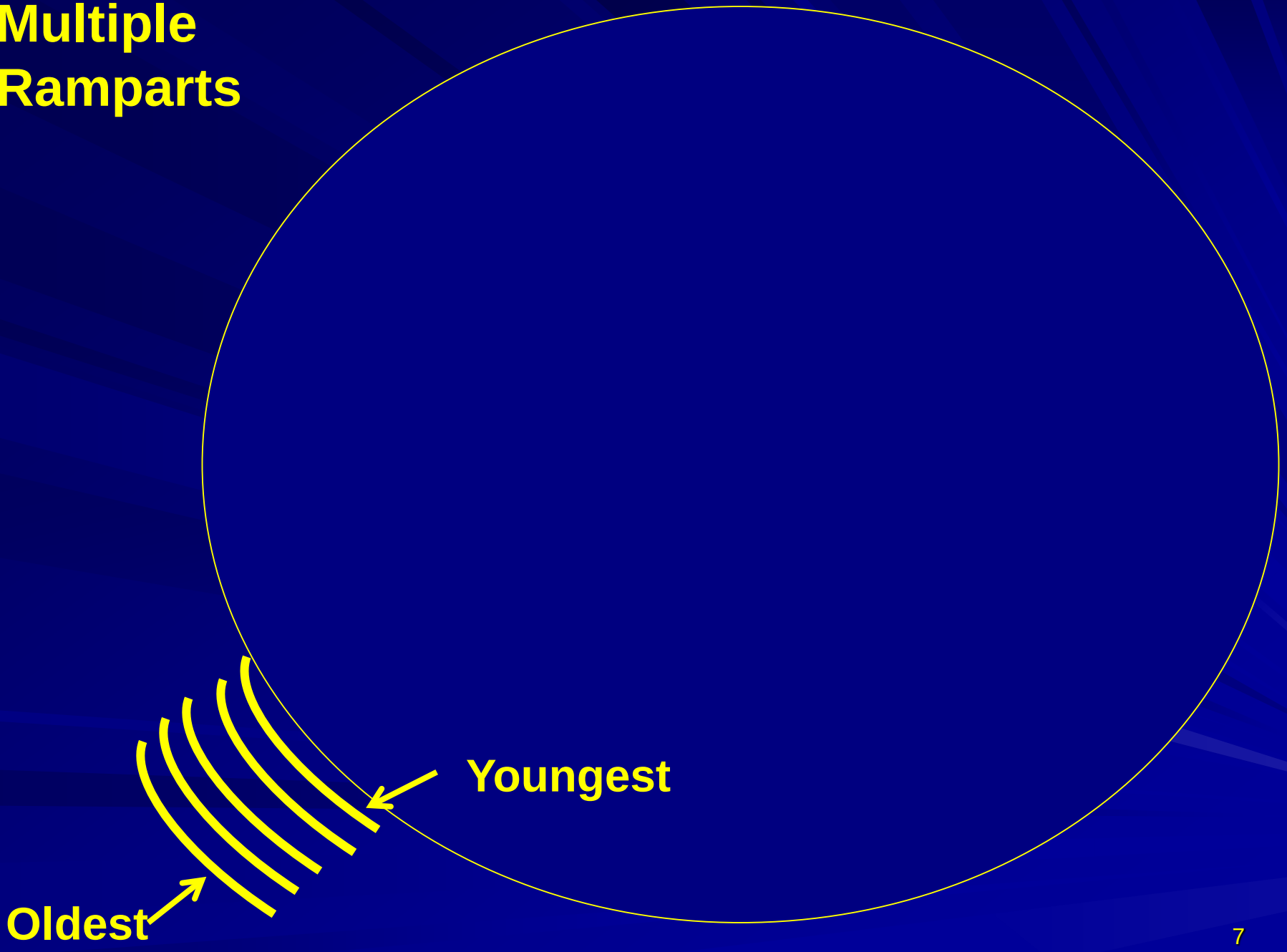
I. Wind-Driven Ice Pan Model

Spring Break-Up



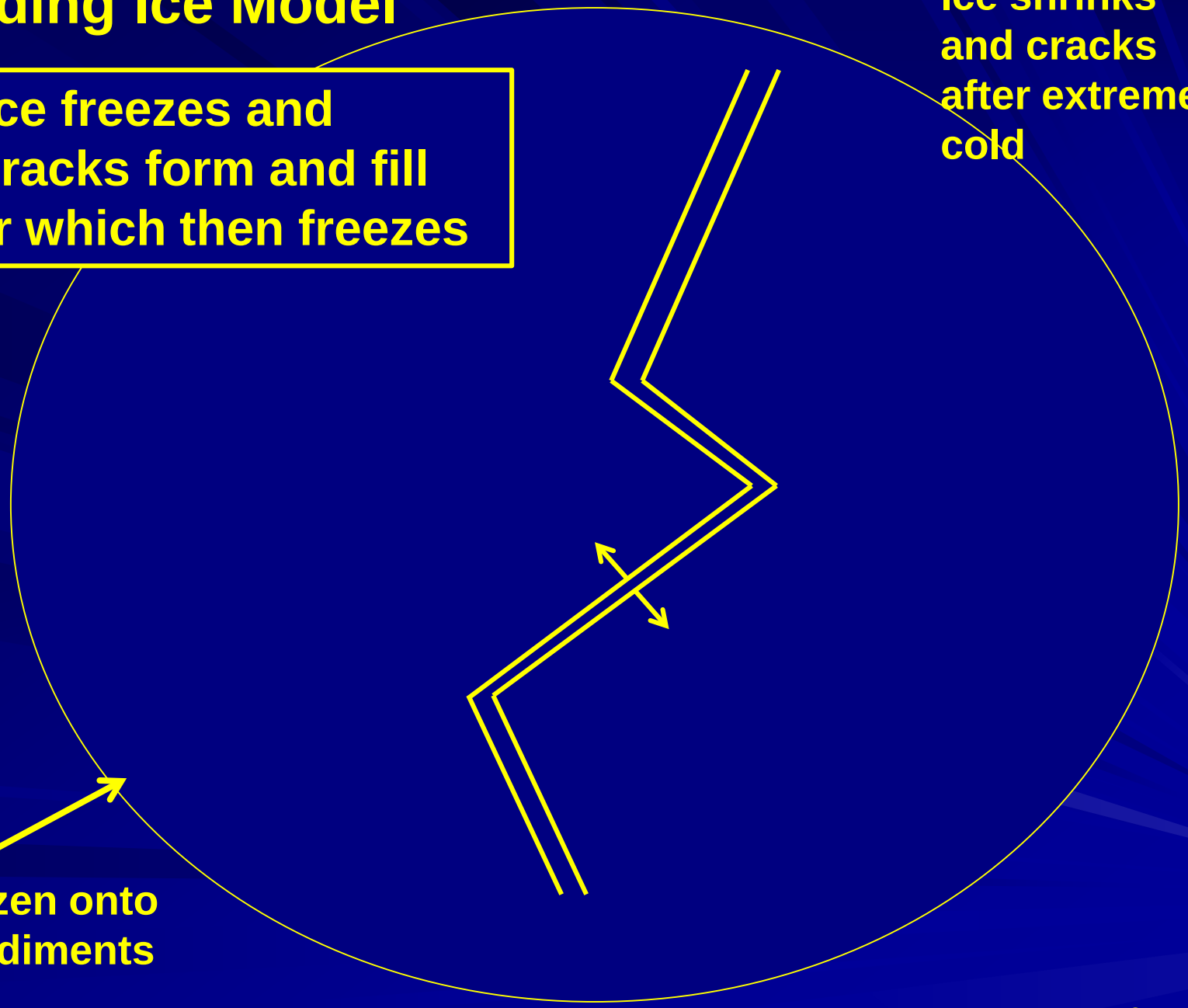
Ice pans bulldoze sediments into shoreline berm

Multiple Ramparts



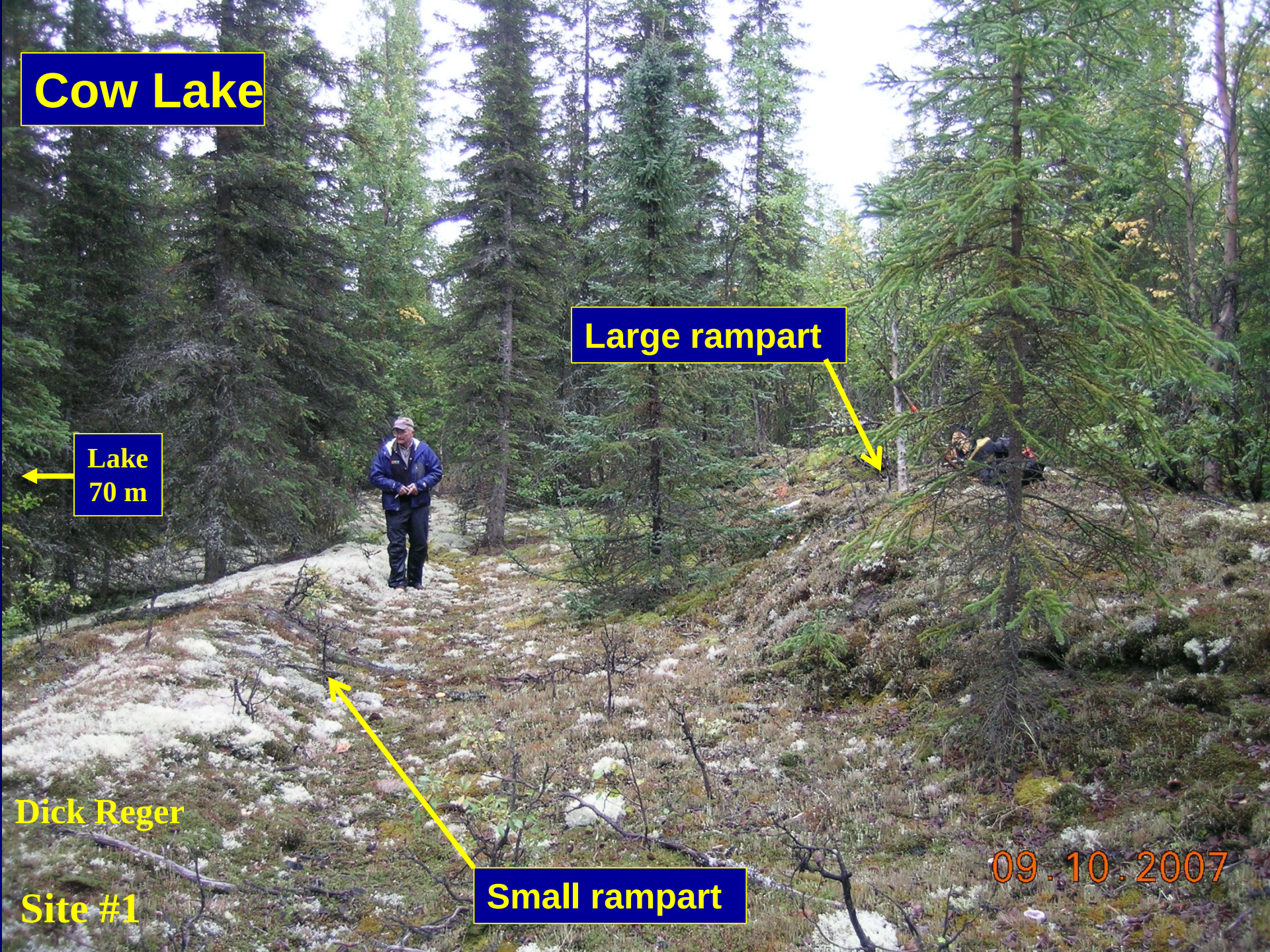
II. Expanding Ice Model

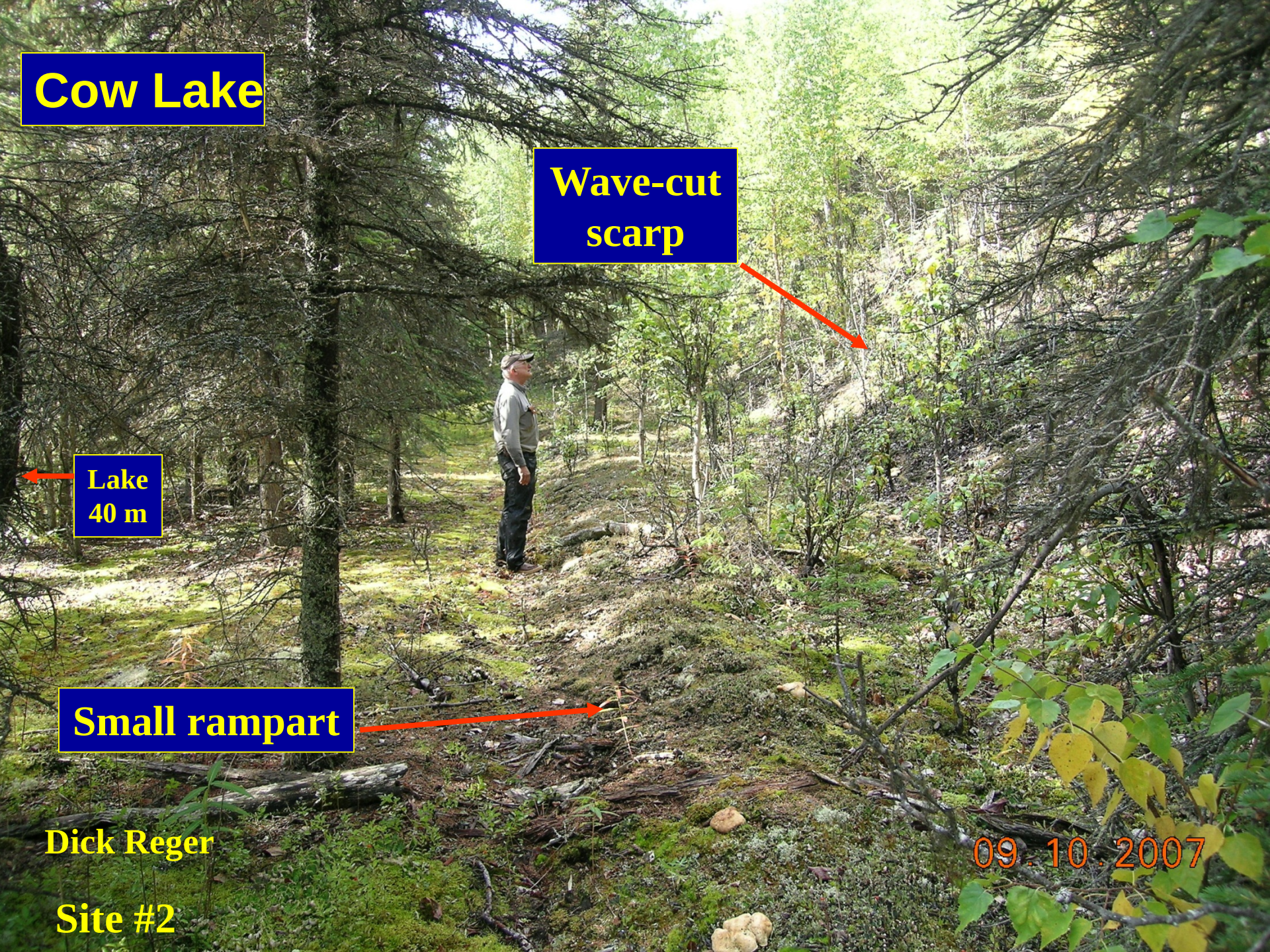
1st Step: Ice freezes and shrinks, cracks form and fill with water which then freezes



2nd Step: Ice expands during warming

Expanding ice bulldozes sediments into shoreline berm

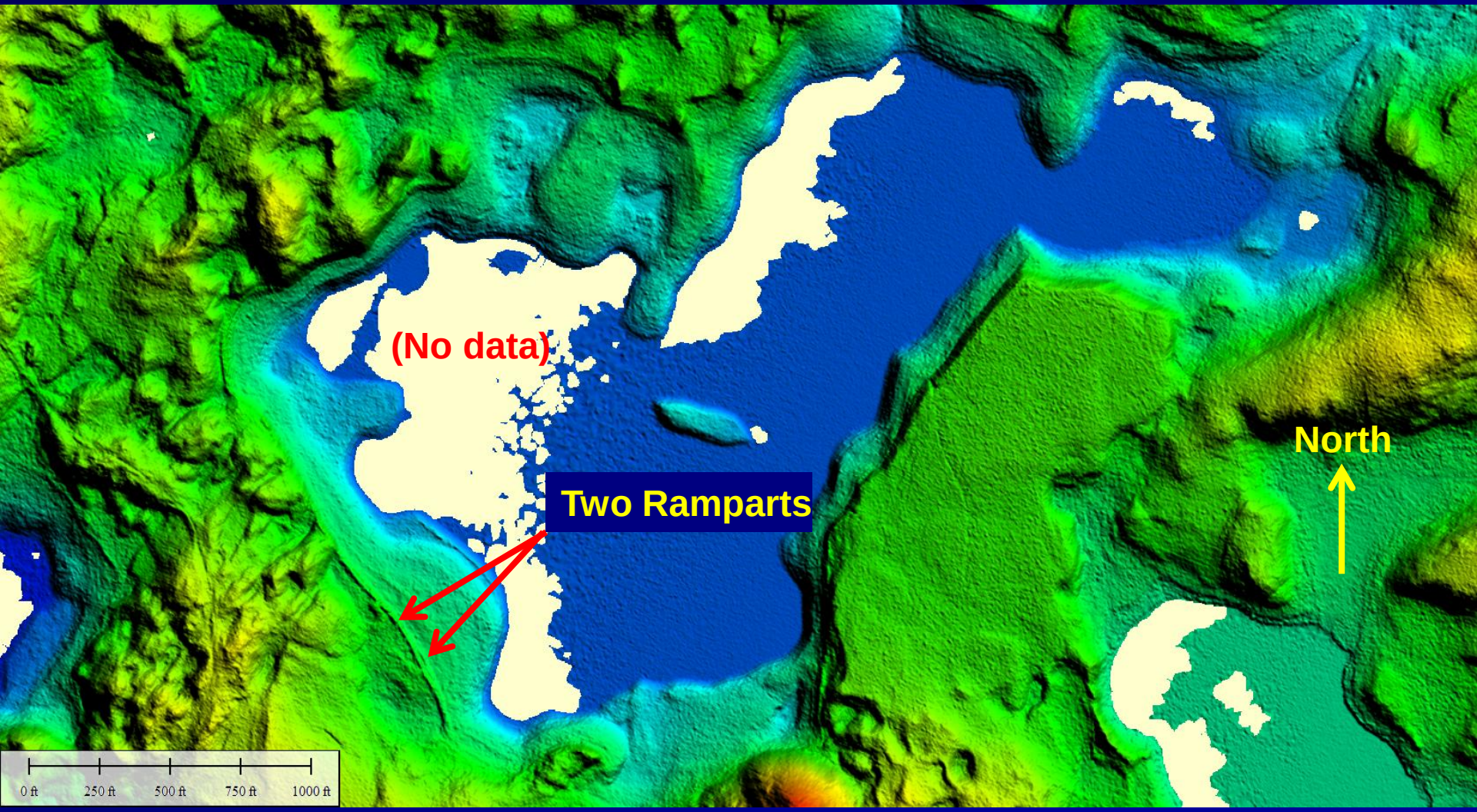

Cow Lake
Large rampart
Lake
70 m
Dick Reger
Site #1
Small rampart
09 . 10 . 2007


Cow Lake
Wave-cut scarp
Lake 40 m
Small rampart
Dick Reger
09 . 10 . 2007
Site #2

Bare-earth LiDAR reveals ice-shoved ramparts (ISR's) and old shoreline scarps with remarkable clarity.

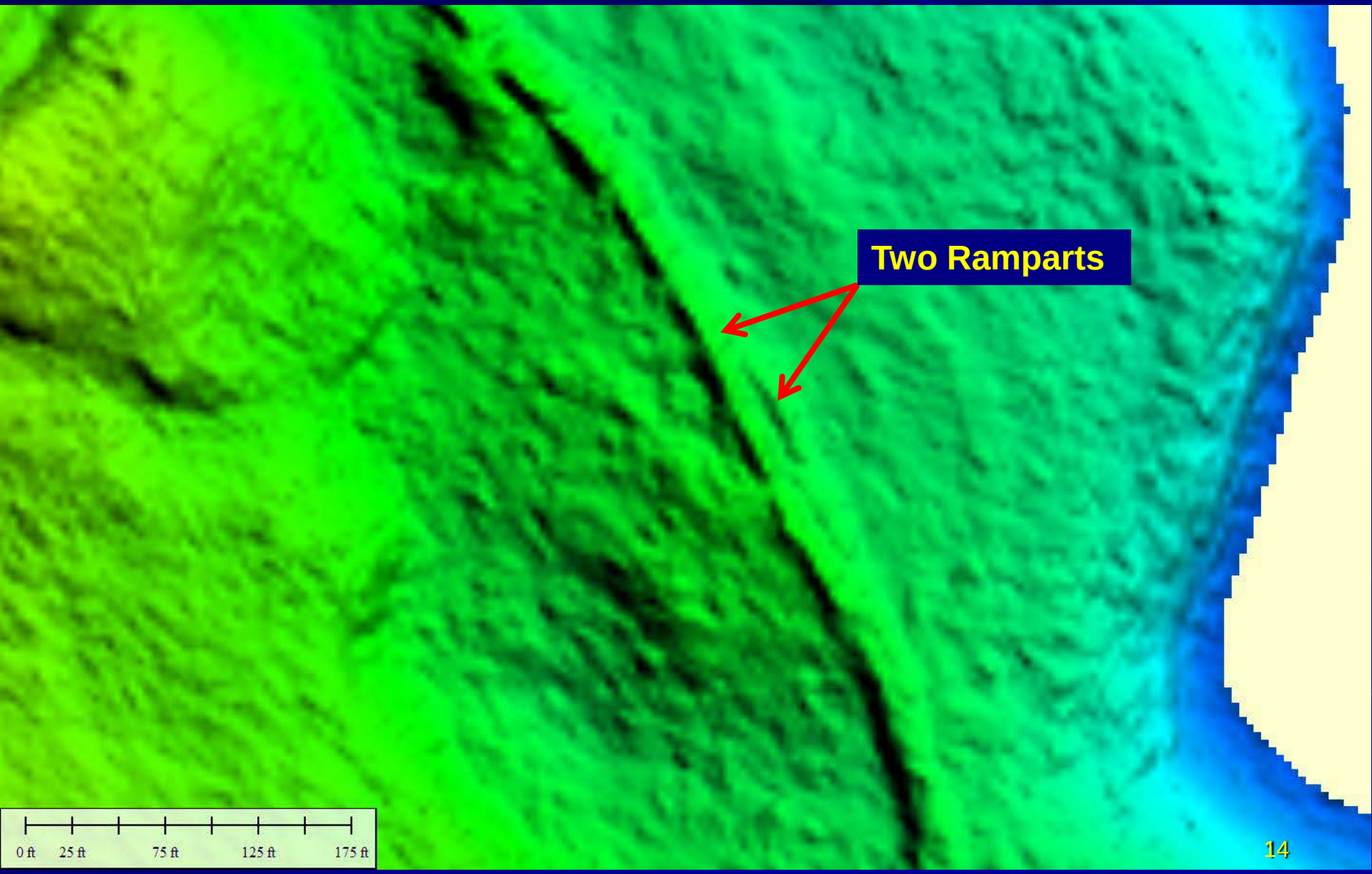
Global Mapper software allows easy exploration of the LiDAR landscape.

Cow Lake Bare-Earth LiDAR

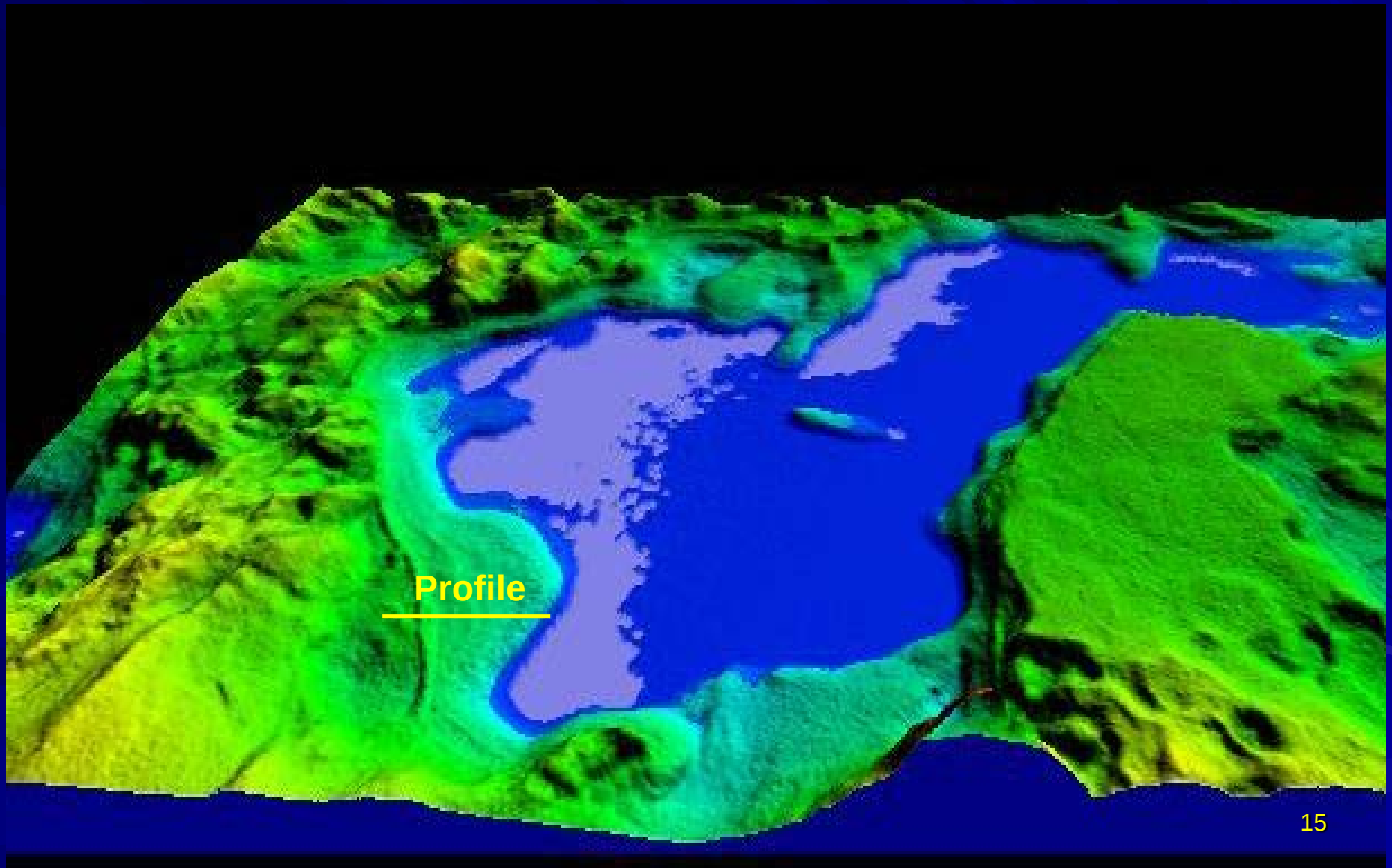


Cow Lake fits the wind-drive ice pan model, with ramparts on the Southwest shore

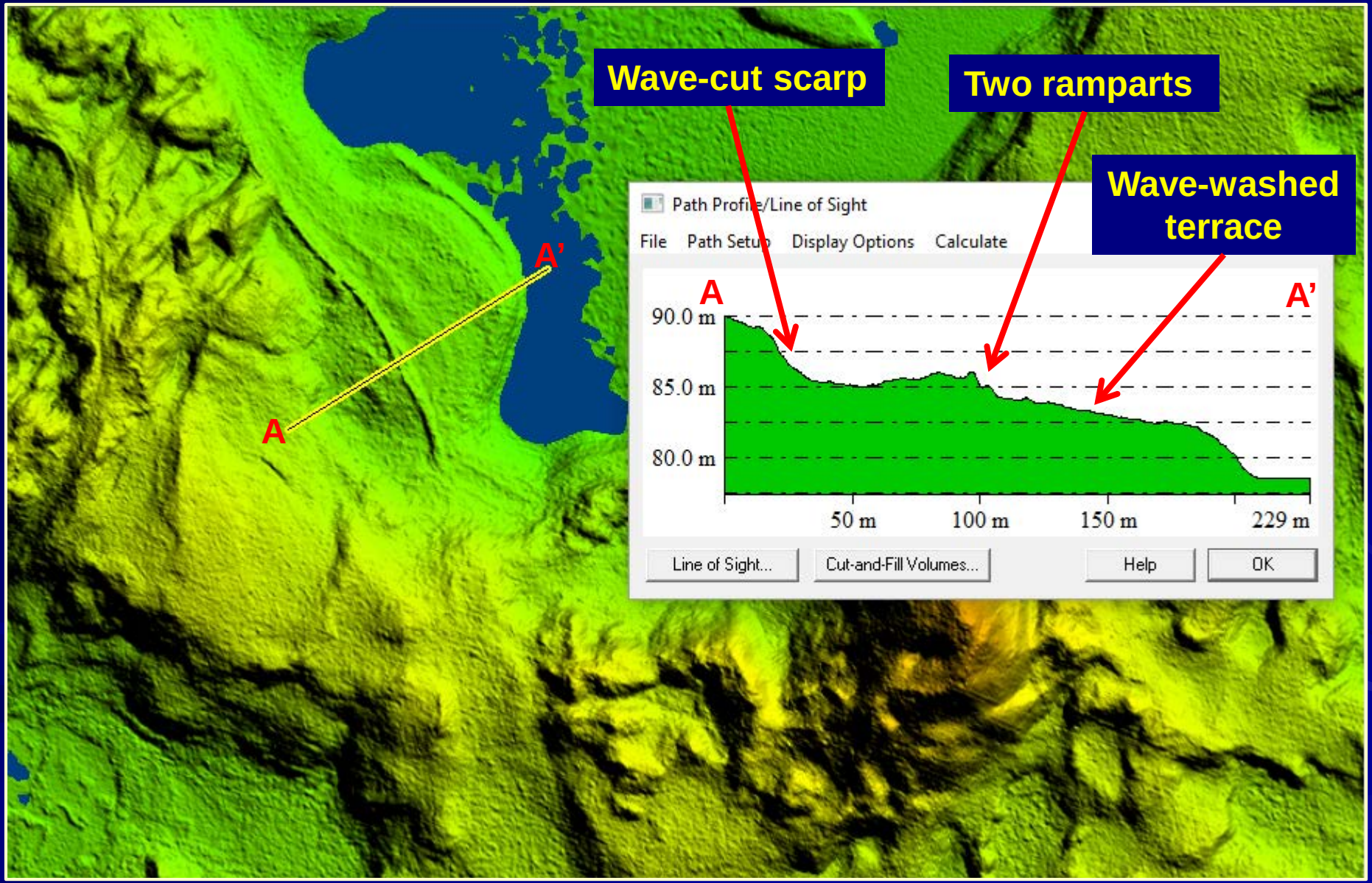
Cow Lake detail

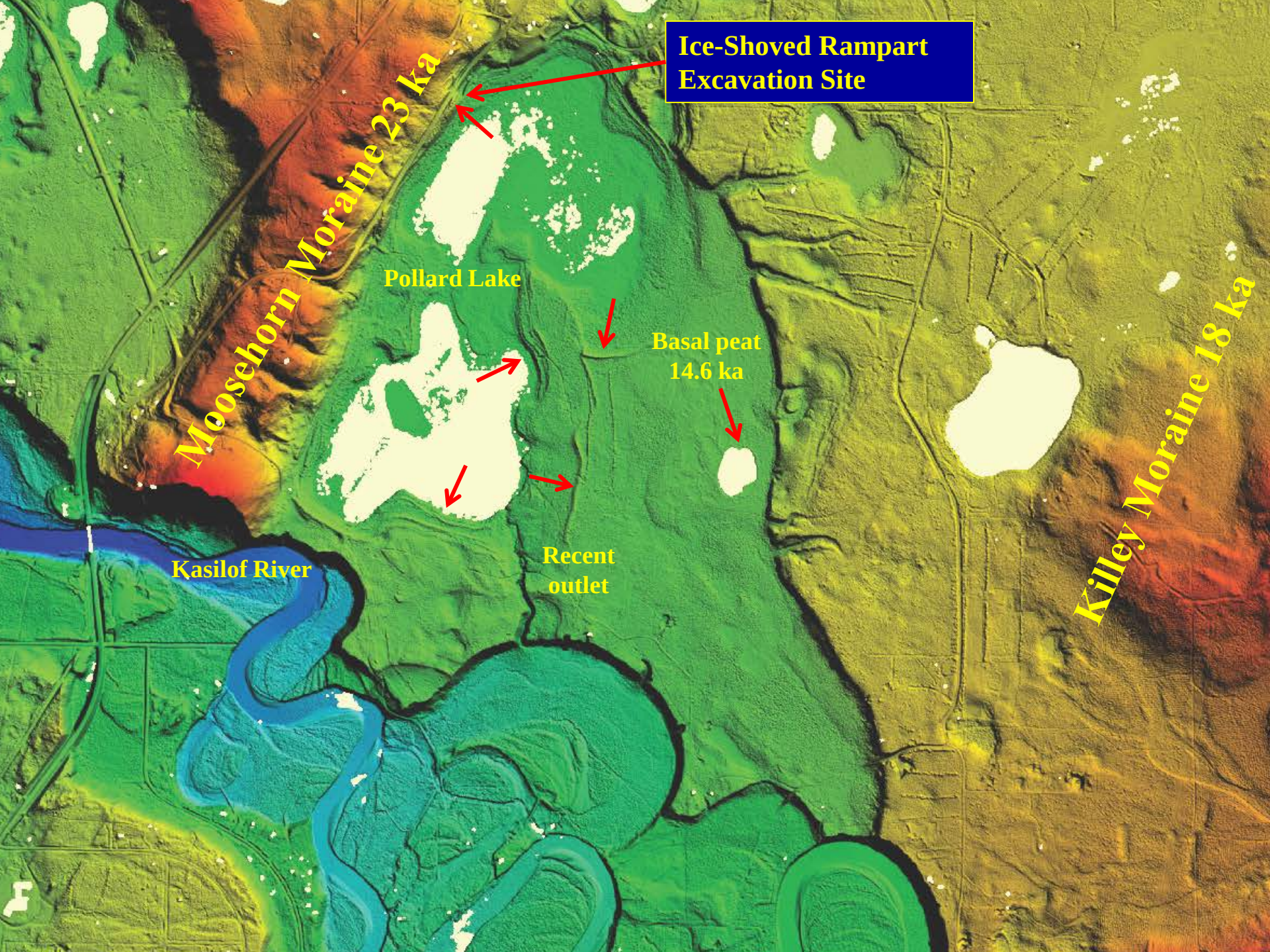


Cow Lake – 3-D LiDAR View from South

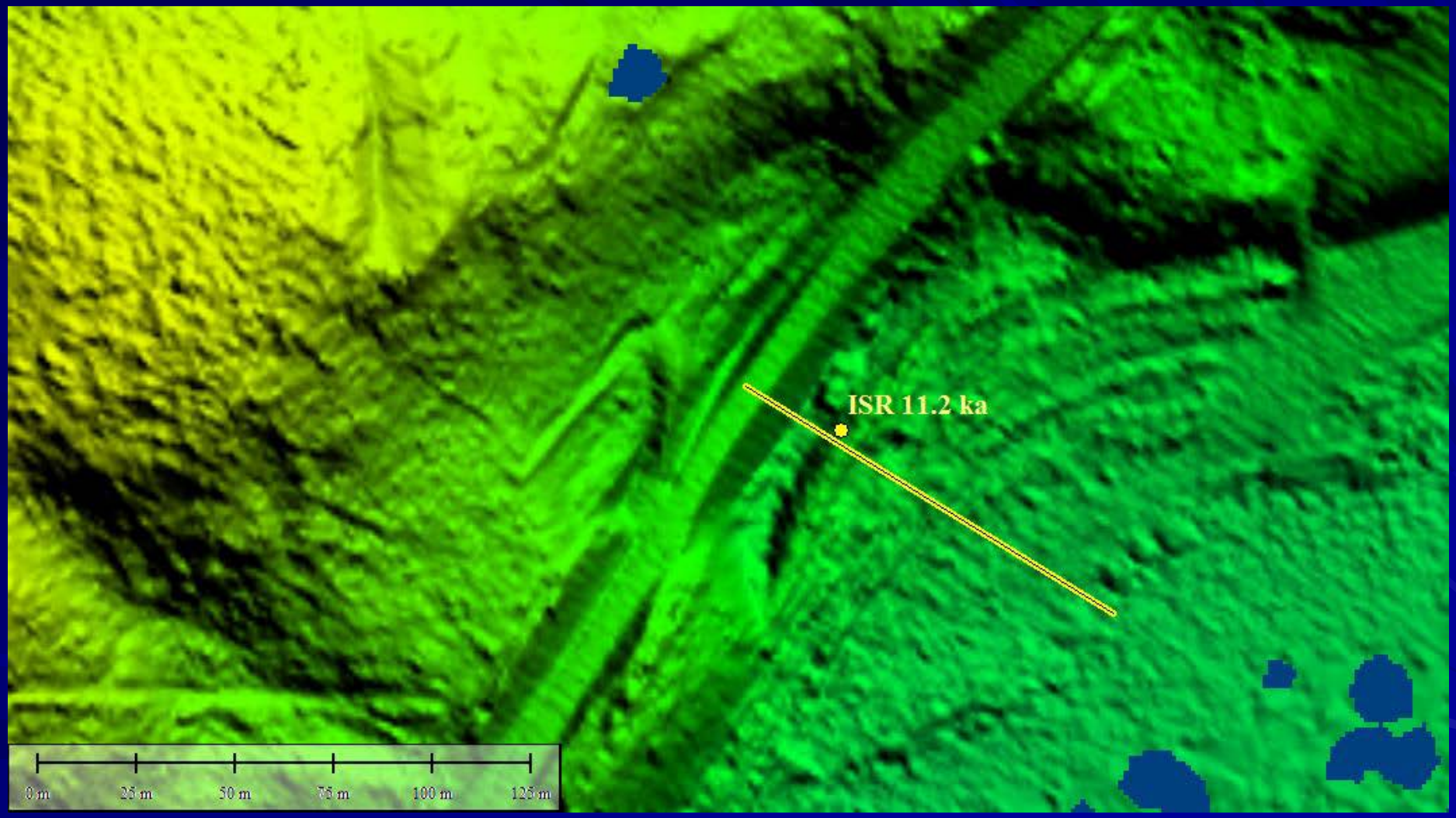


Cow Lake LiDAR Profile




Ice-Shoved Rampart
Excavation Site
Moosehorn Moraine 23 ka
Pollard Lake
Basal peat
14.6 ka
Kasilof River
Recent
outlet
Killey Moraine 18 ka

ISR detail

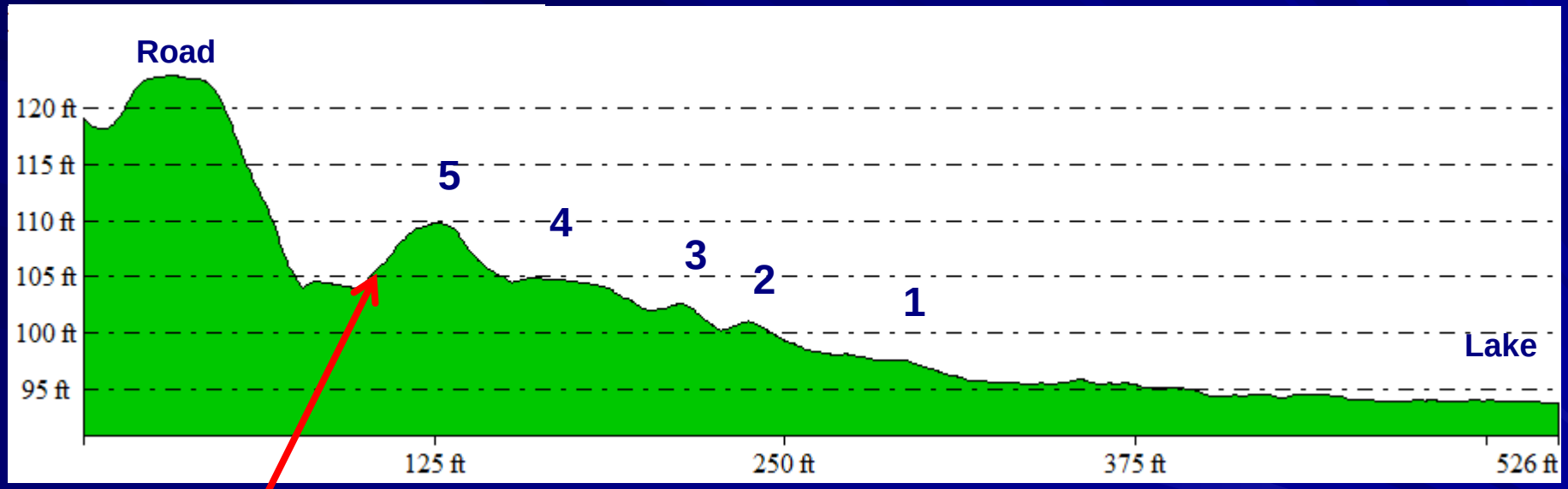


Pollard Lake

Pollard Lake Ice-Shoved Ramparts

NW

SE



Vertical Exaggeration 3.7x

Excavation Site

Pollard Lake - 2010

Toby Burke and Dick Reger

Pollard Lake - 2011

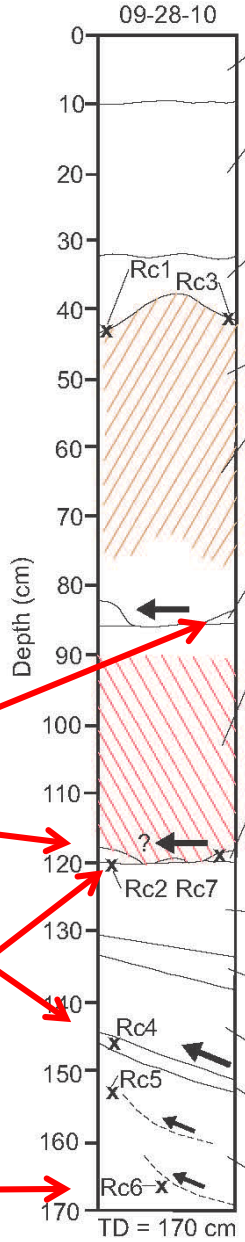
Dick Reger and Toby Burke

Pollard Lake Rampart Soil Profile

Buried Forest Soils

Rc2 - 11,213 cal years BP

Rc6 - 10,254 cal years BP



Organic mat with trace silt (loess); 8 to 16 cm thick; numerous roots and plant fragments; abrupt lower contact

Unit 4; interlayered loess and thin tephras with scattered, frost-jacked pebbles in lower third of unit; 0 - 28 cm thick; loess is very fine sand with some silt; light yellowish brown (10YR6/4); lower contact gently irregular and abrupt

Complex of thin Holocene tephras; silt and fine sand; 3 - 10 cm thick; lower contact sharp; radiocarbon samples Rc1 and Rc3 beneath lowest tephra; tephras mottled grayish brown (10YR5/2) (50 %), very pale brown (10YR7/4) (40 %), and brownish yellow (10YR6/6) (10 %)

Bw soil profile

Unit 3; massive pebbly medium to coarse sand; 40 - 49 cm thick; polymictic subangular to subrounded pebbles up to 8 cm diameter are scattered through upper 10 - 12 cm of unit; most of unit weathered to yellowish red (5YR4/6) Bw horizon that gradually transitions downward to a grayish brown (2.5Y5/2) Cox layer; thrust unit

Forest soil C; silt and fine sand; 0 - 3 cm thick; upper and lower contacts abrupt; very pale brown (10YR7/4)

Unit 2; massive medium to coarse nearshore lake sand with numerous subangular to subrounded pebbles up to 2 cm diameter, particularly lower in the layer; 33 - 35 cm thick; mottled very dusky red (10YR2.5/2) (80 %) and dark brown (10YR3/3) (20 %) (heavy groundwater staining); staining is heaviest near base of layer; probable thrust unit

Forest soil B; silt with trace fine sand, scattered wood fragments; 0 - 3 cm thick; contacts sharp; dark grayish brown (10YR4/2); radiocarbon sample Rc2 isdisseminated charcoal at base of layer (possible *Equisetum* contamination); radiocarbon sample Rc7 is wood from layer

Unit 1; nearshore lake sediments; > 53 cm thick; beds of fine to coarse sand 12 to 22 cm thick, locally crossbedded, separated by thin beds of granule gravels

Unit 1d; upper medium to coarse sand with scattered small pebbles; generally horizontally bedded, locally crossbedded; uniform dark yellowish brown (10YR3/4) (light groundwater staining)

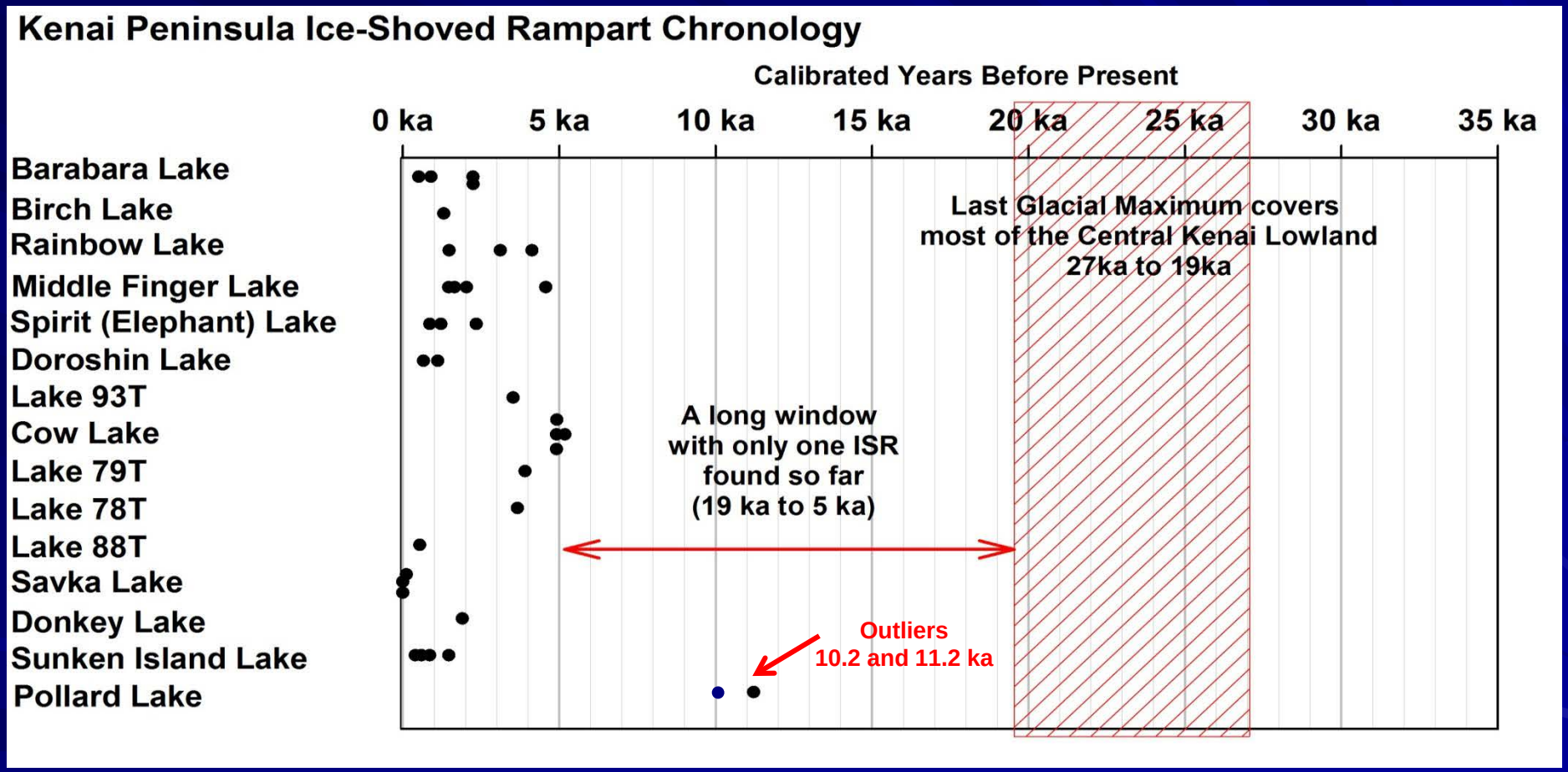
Unit 1c; massive granule gravel; polymictic angular to subangular pebbles up to 8 mm diameter; upper and lower contacts sharply planar

Unit 1b; fine to coarse sand stained dark reddish brown (5YR3/3) in 13-cm long by 0.5-cm wide vertical stripes along former roots

Forest soil A; silt with trace fine sand, scattered wood fragemtns; 2-3 cm thick; contacts sharp; Rc4 sample is wood

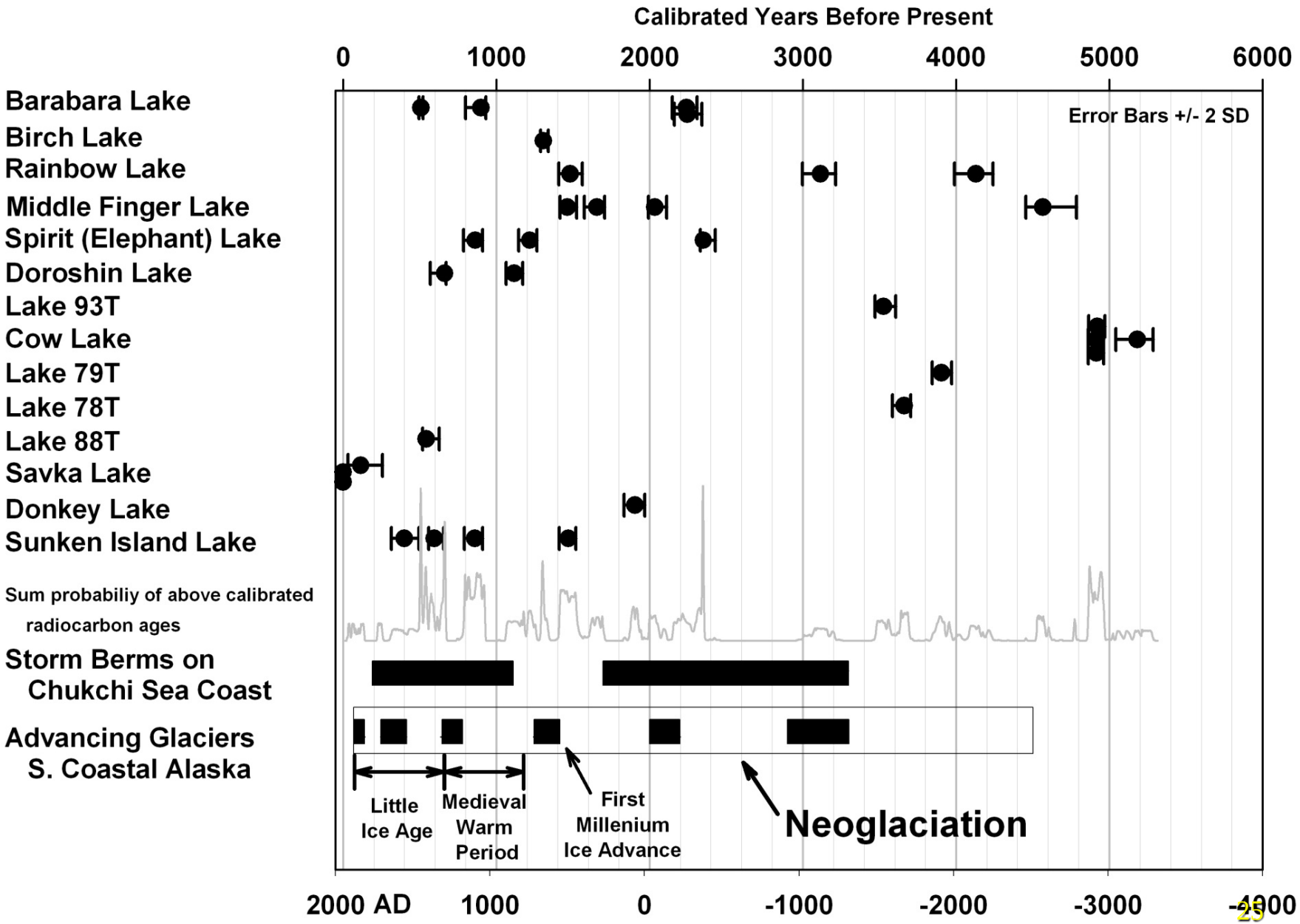
Unit 1a; lower unweathered gray (5Y5/1) fine sand and gray (5Y6/1) coarse sand; contains two minor thrust units; Rc5 is wood beneath upper minor thrust; Rc6 is wood beneath lower minor thrust

Puzzle: What is different about the climate of the last 5000 years?

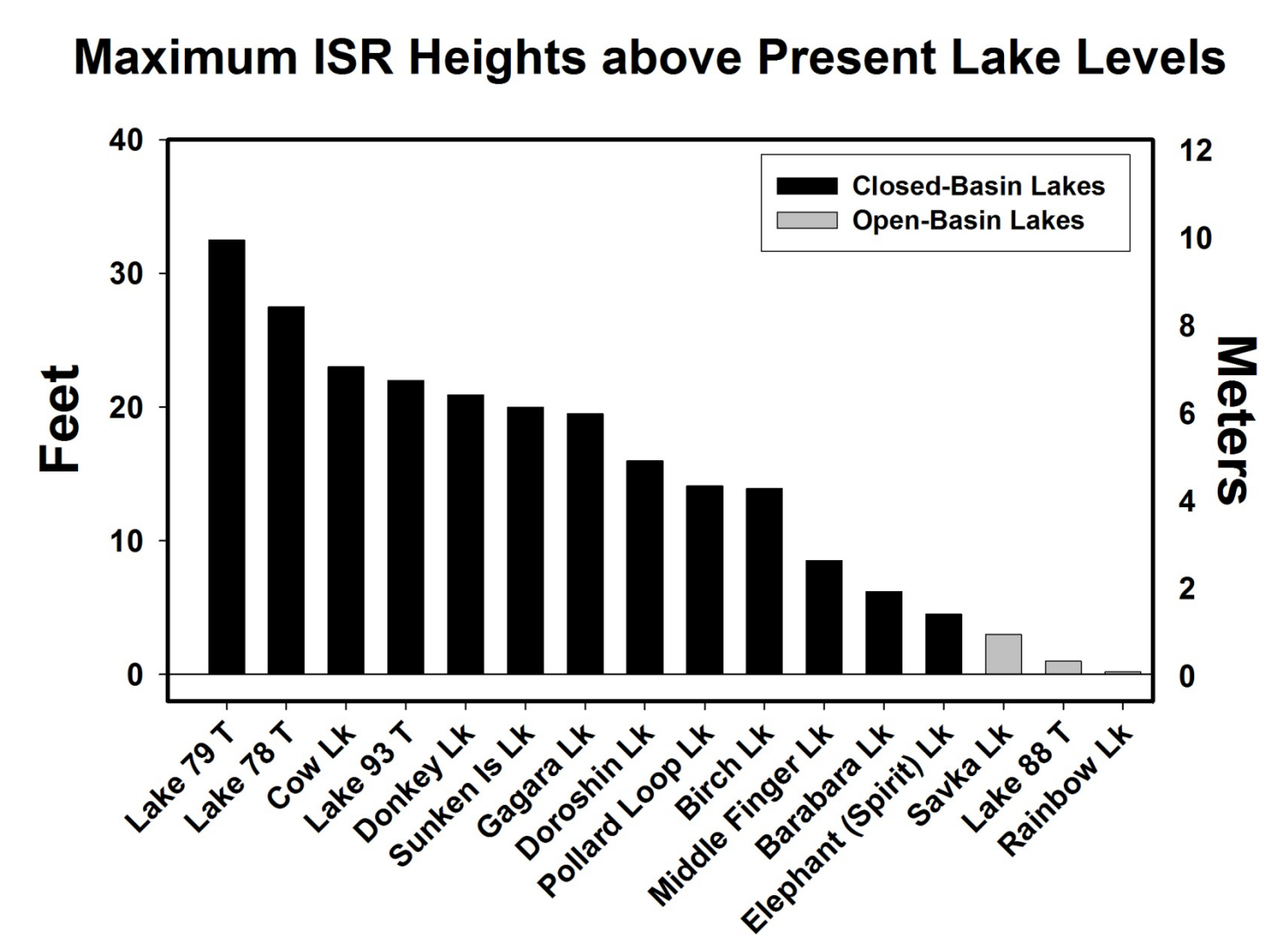


Higher lake levels – Yes
Colder winters – Probably
Stronger spring winds - Unknown

Detail


Calibrated Years Before Present
0
1000
2000
3000
4000
5000
6000
Barabara Lake
Birch Lake
Rainbow Lake
Middle Finger Lake
Spirit (Elephant) Lake
Doroshin Lake
Lake 93T
Cow Lake
Lake 79T
Lake 78T
Lake 88T
Savka Lake
Donkey Lake
Sunken Island Lake
Error Bars +/- 2 SD
Sum probabiliy of above calibrated radiocarbon ages
Storm Berms on Chukchi Sea Coast
Advancing Glaciers S. Coastal Alaska
Little Ice Age
Medieval Warm Period
First Millenium Ice Advance
Neoglaciation
2000 AD
1000
0
-1000
-2000
-3000
-4000

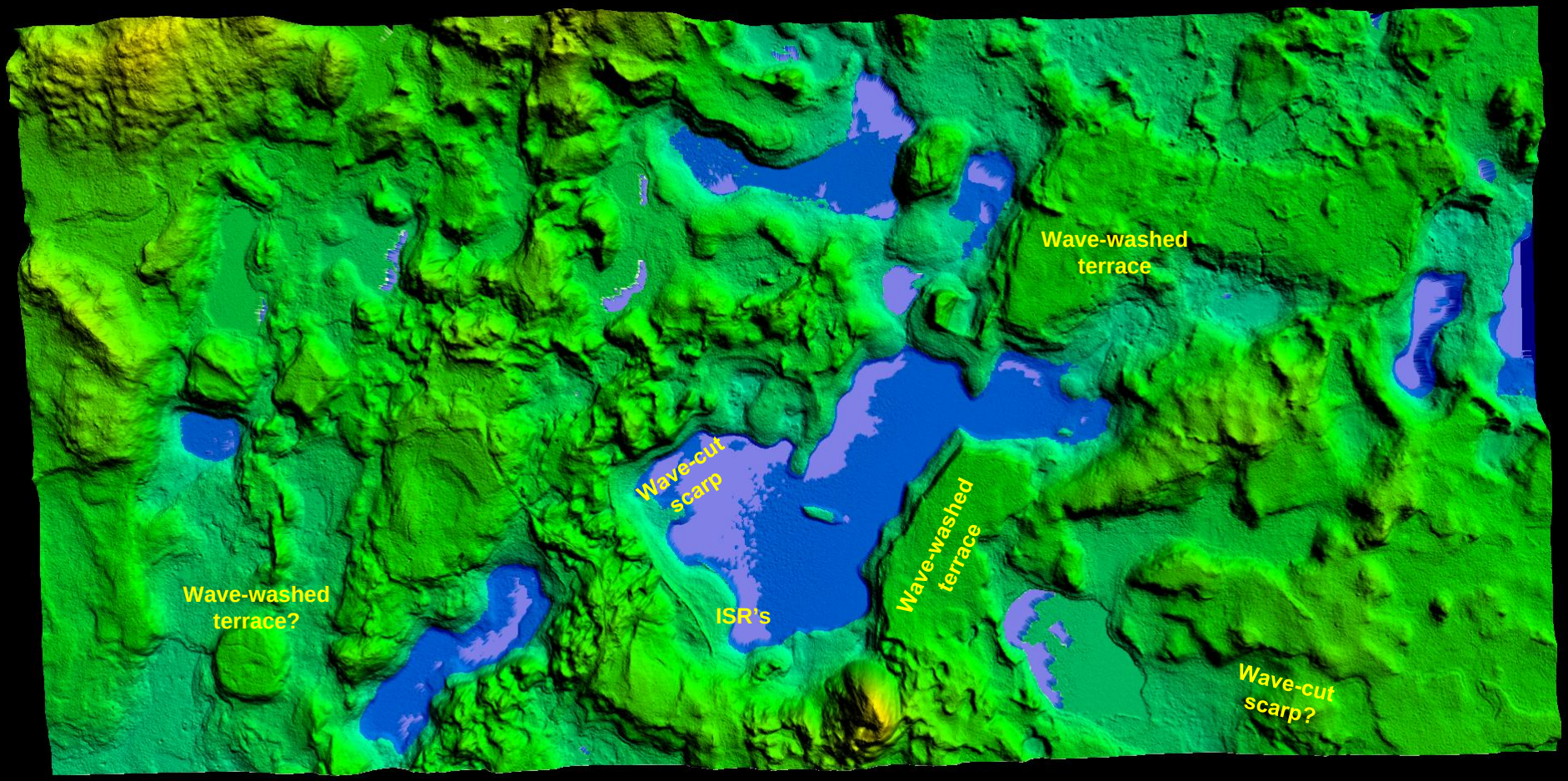
Many of these ramparts were formed when lakes were much fuller, i.e., a wetter climate



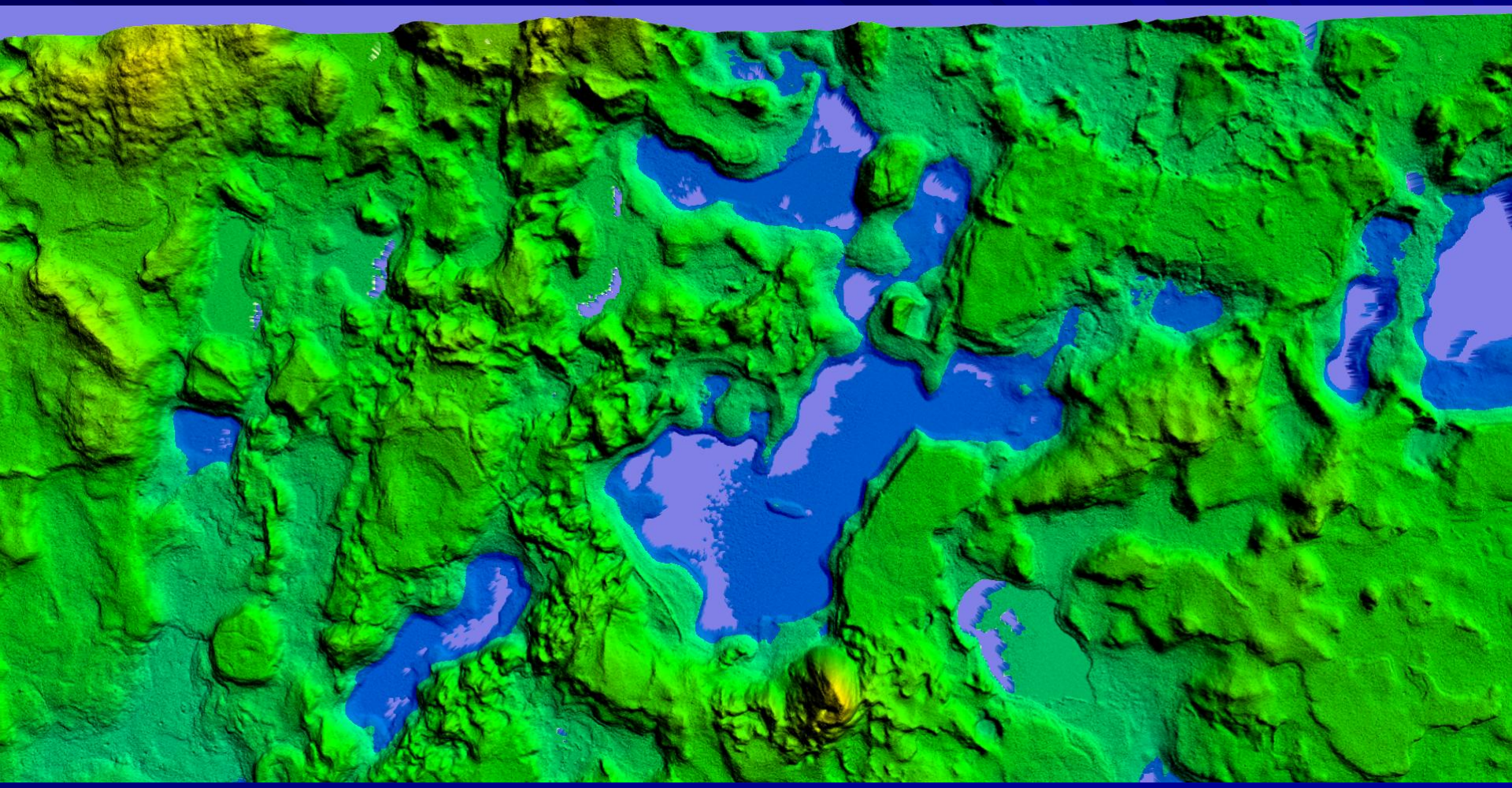
Wave-cut Scarps (Shorelines)

- When did they form?
- Erosion features are hard to date!
- We begin with a LiDAR inventory of closed-basin lakes
- Then we date “satellite fen” peats lying within the old shorelines
- Finally, we reconstruct paleo lake levels

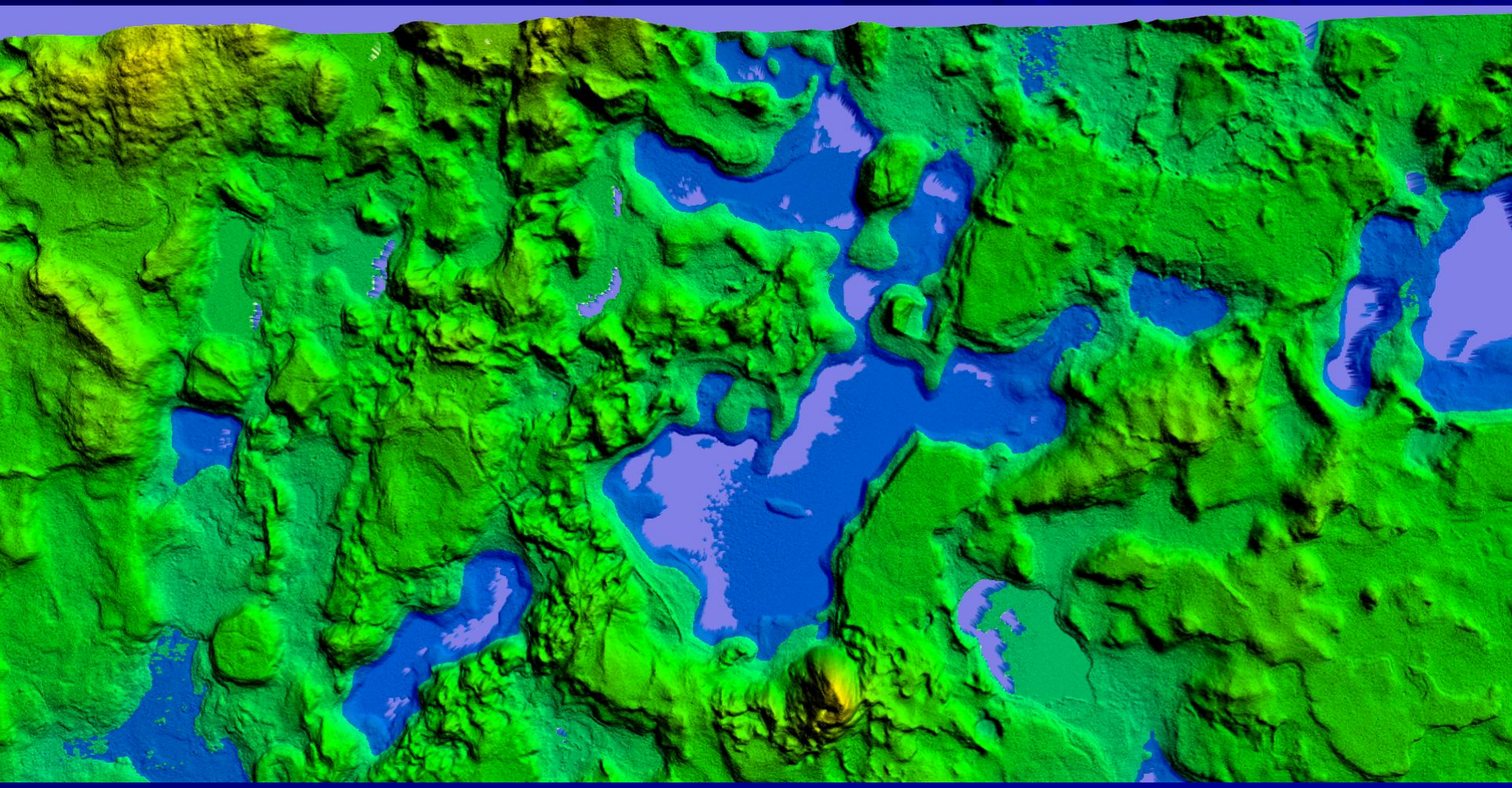
Cow Lake



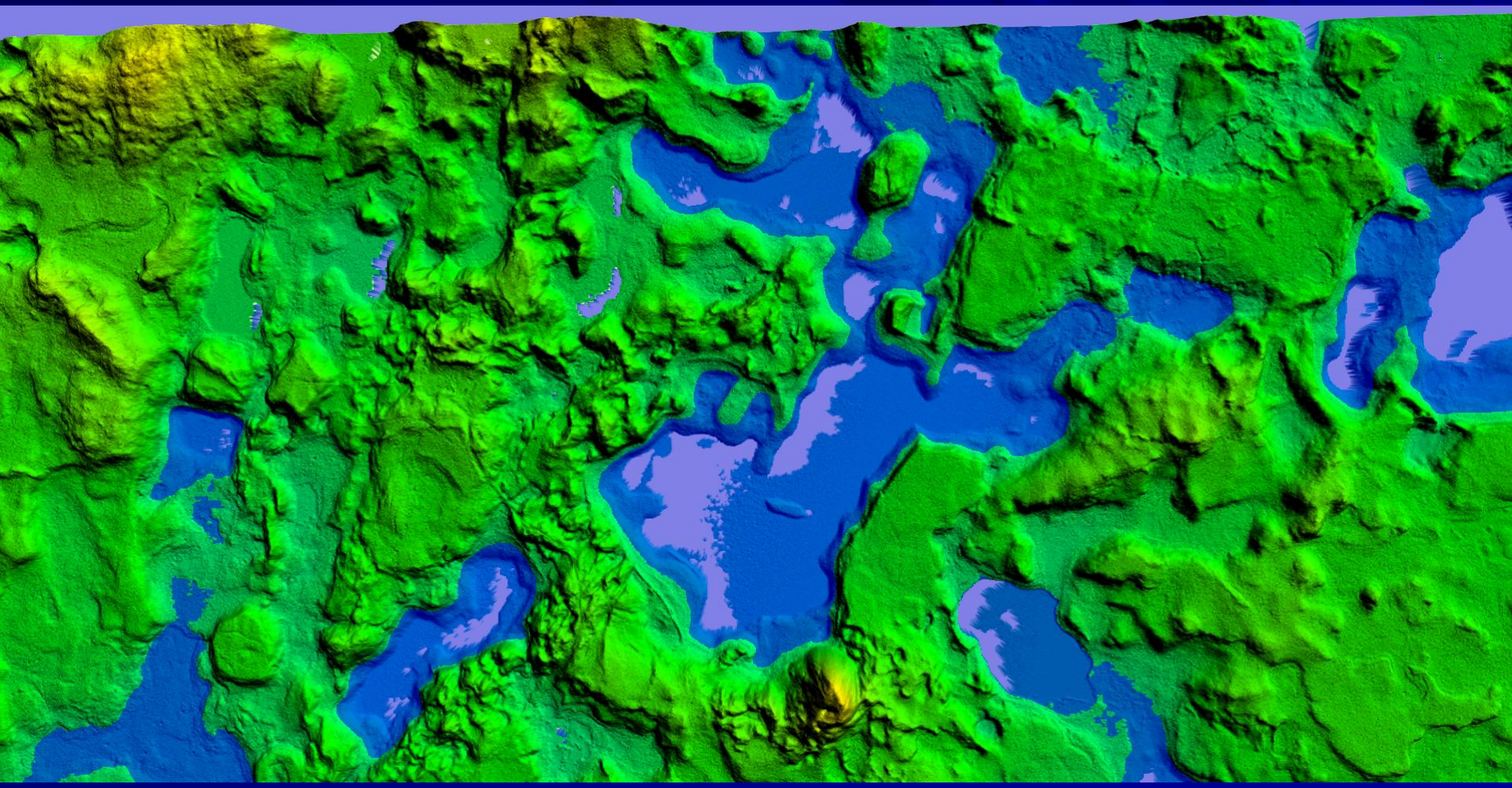
Lake level 80 m



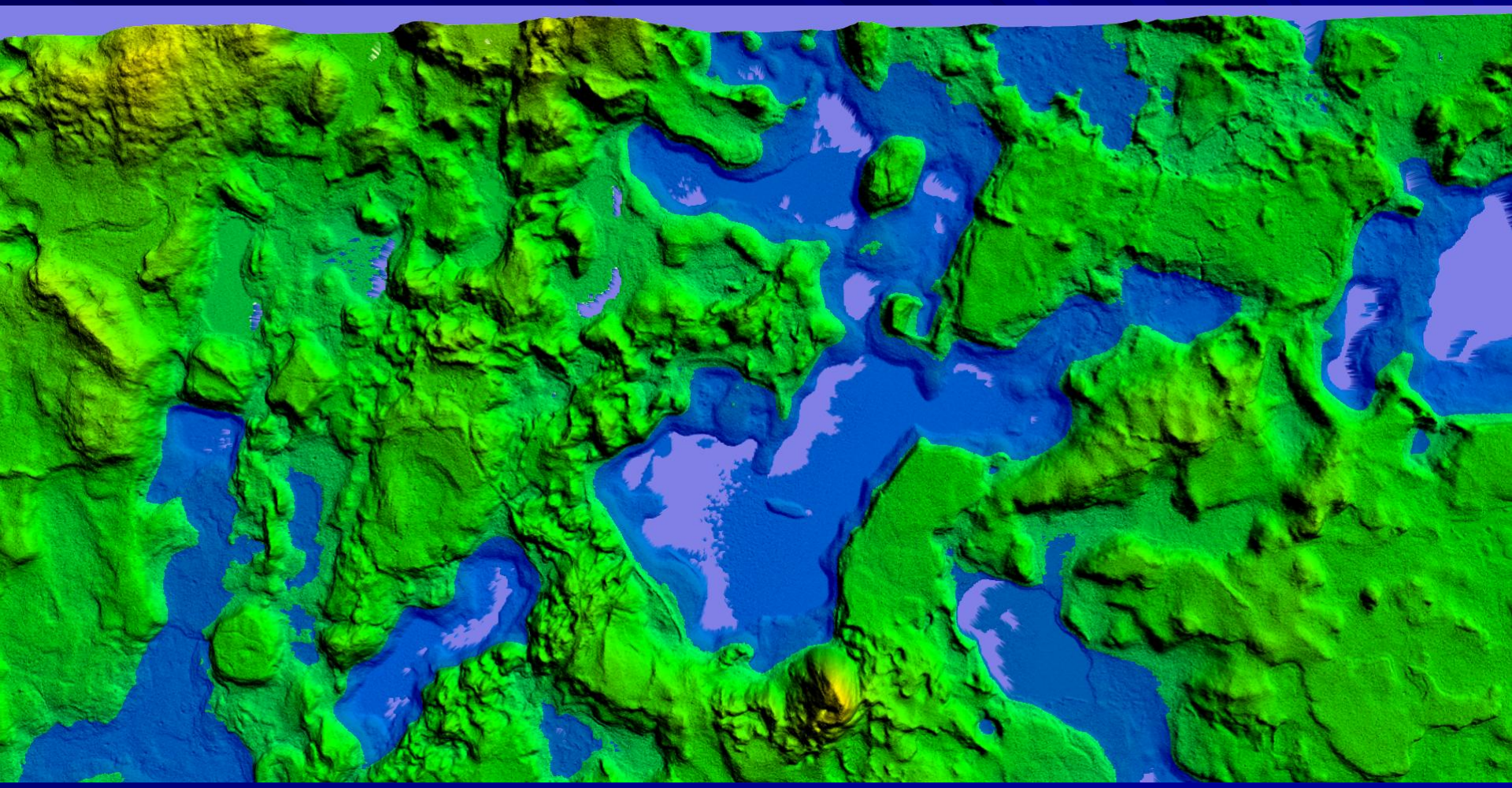
Lake level 81 m



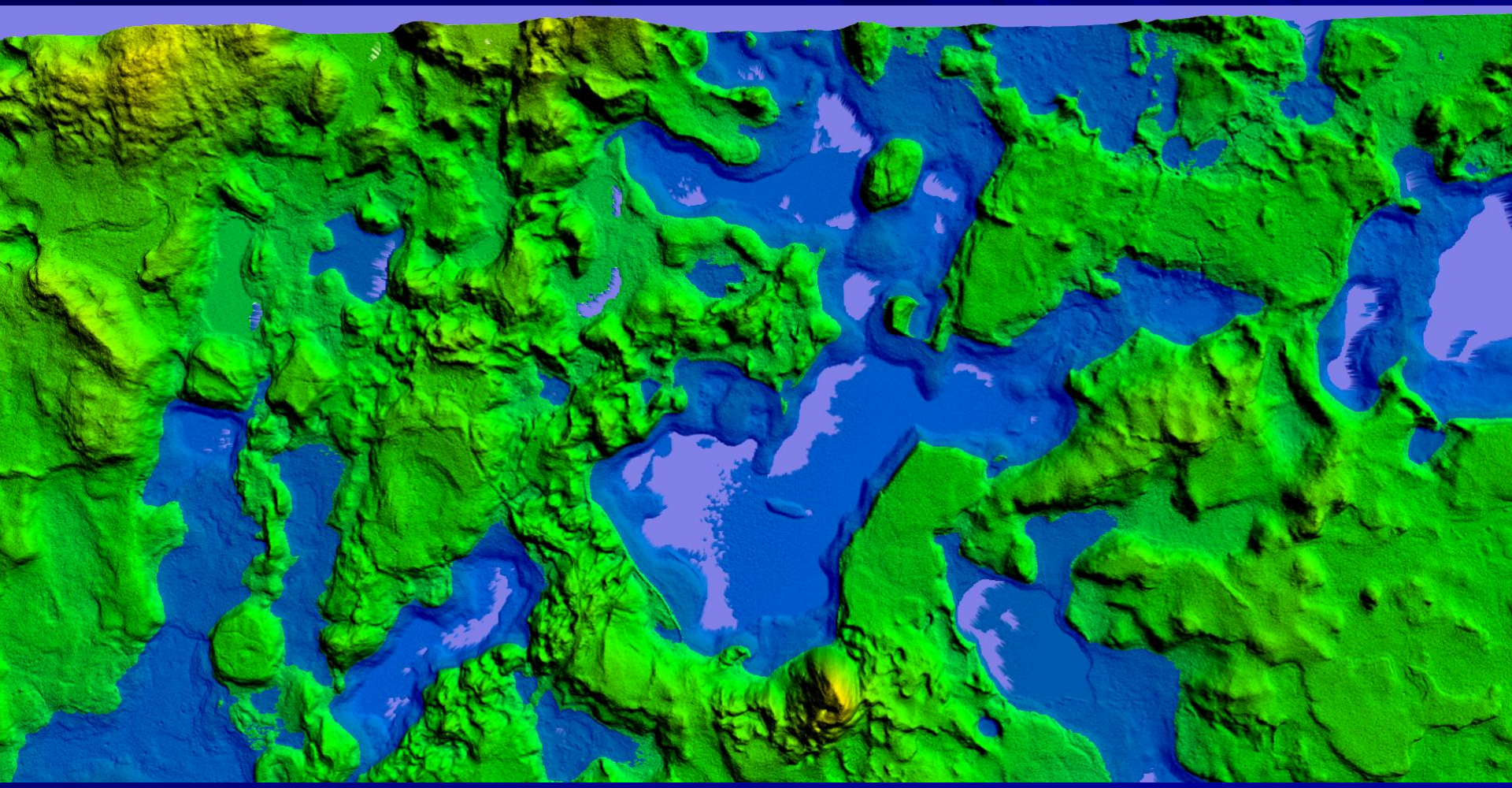
Lake level 82 m



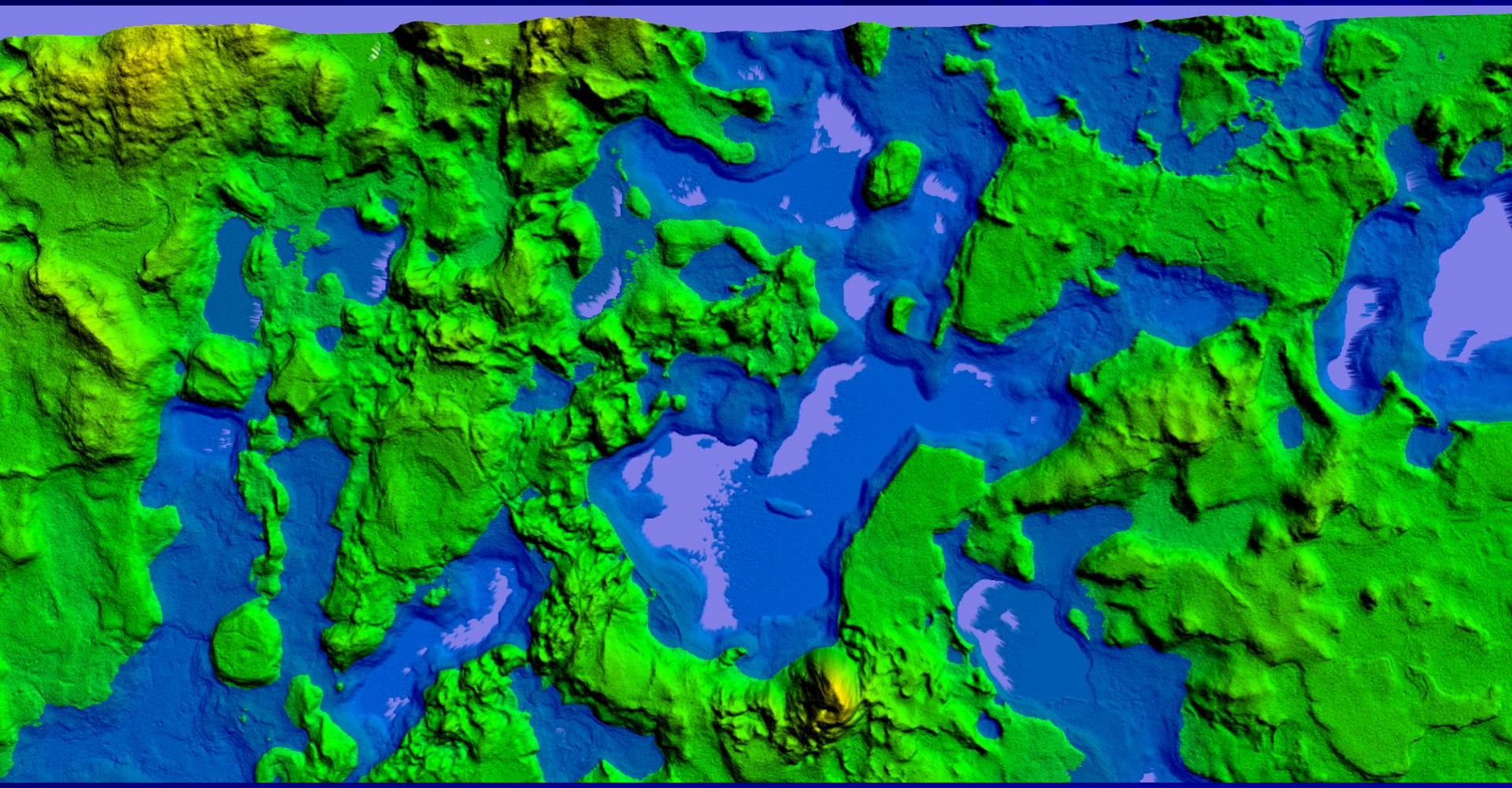
Lake level 83 m



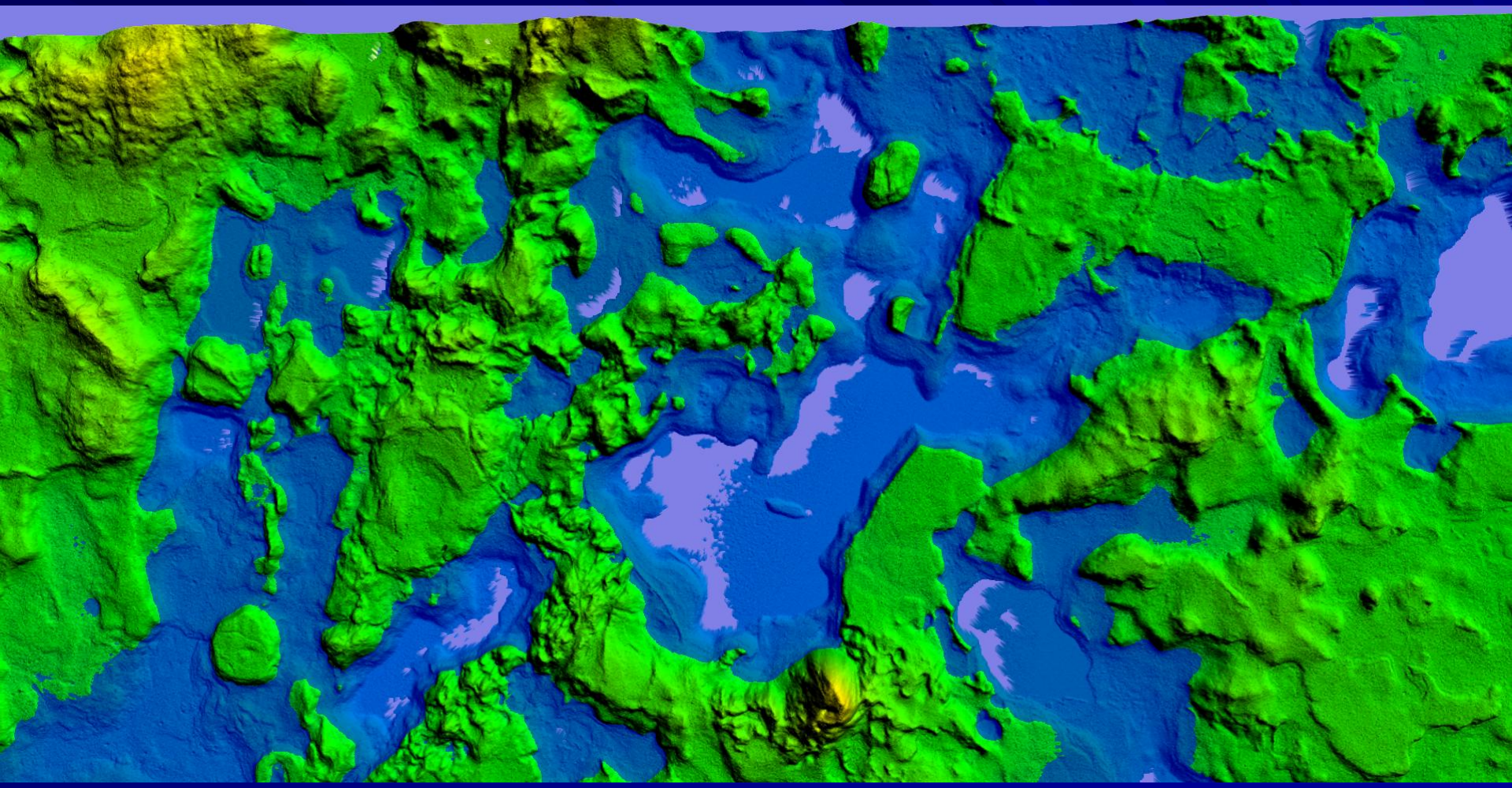
Lake level 84 m (water is at base of wave-cut scarps)



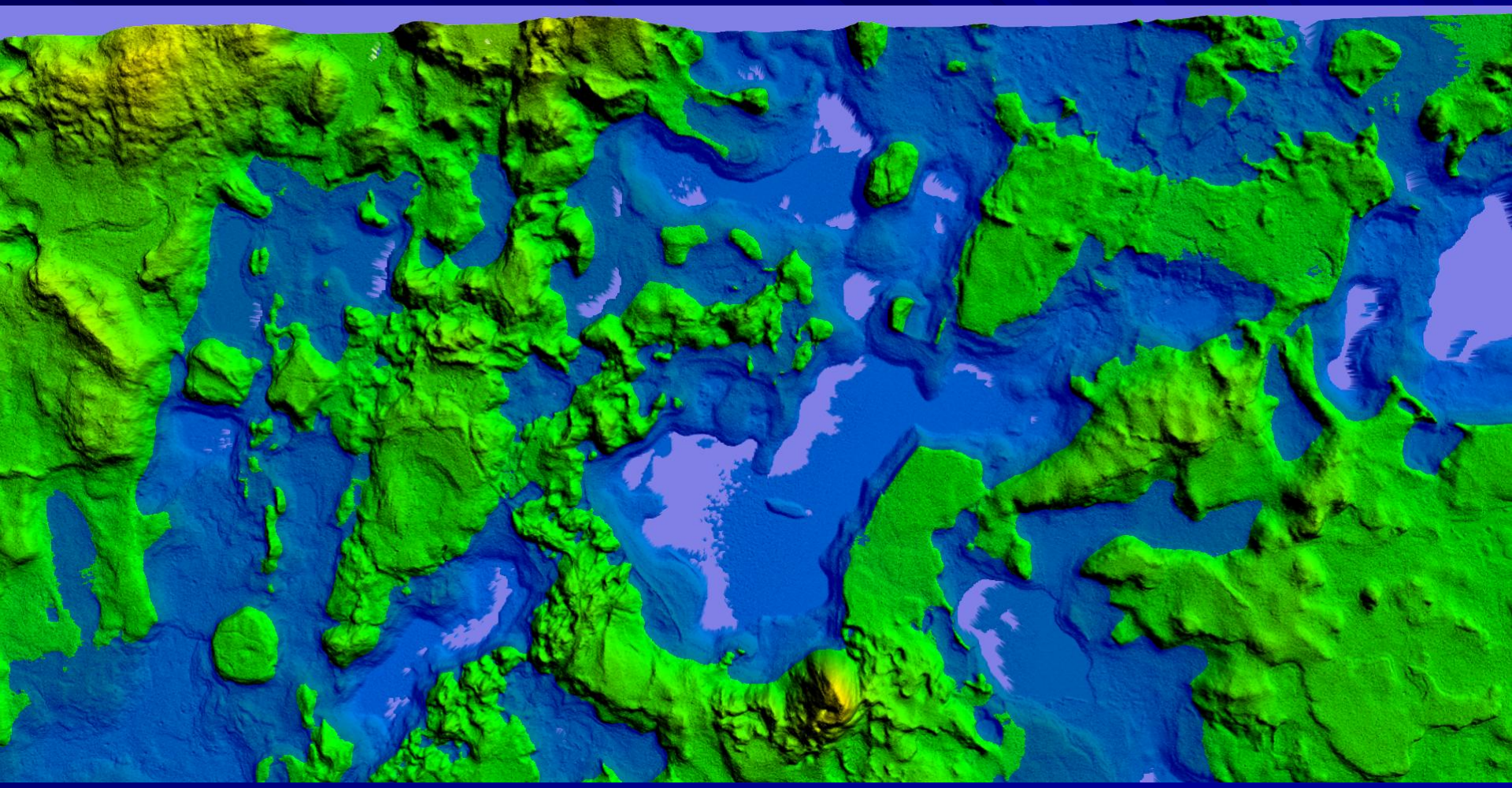
Lake level 85 m



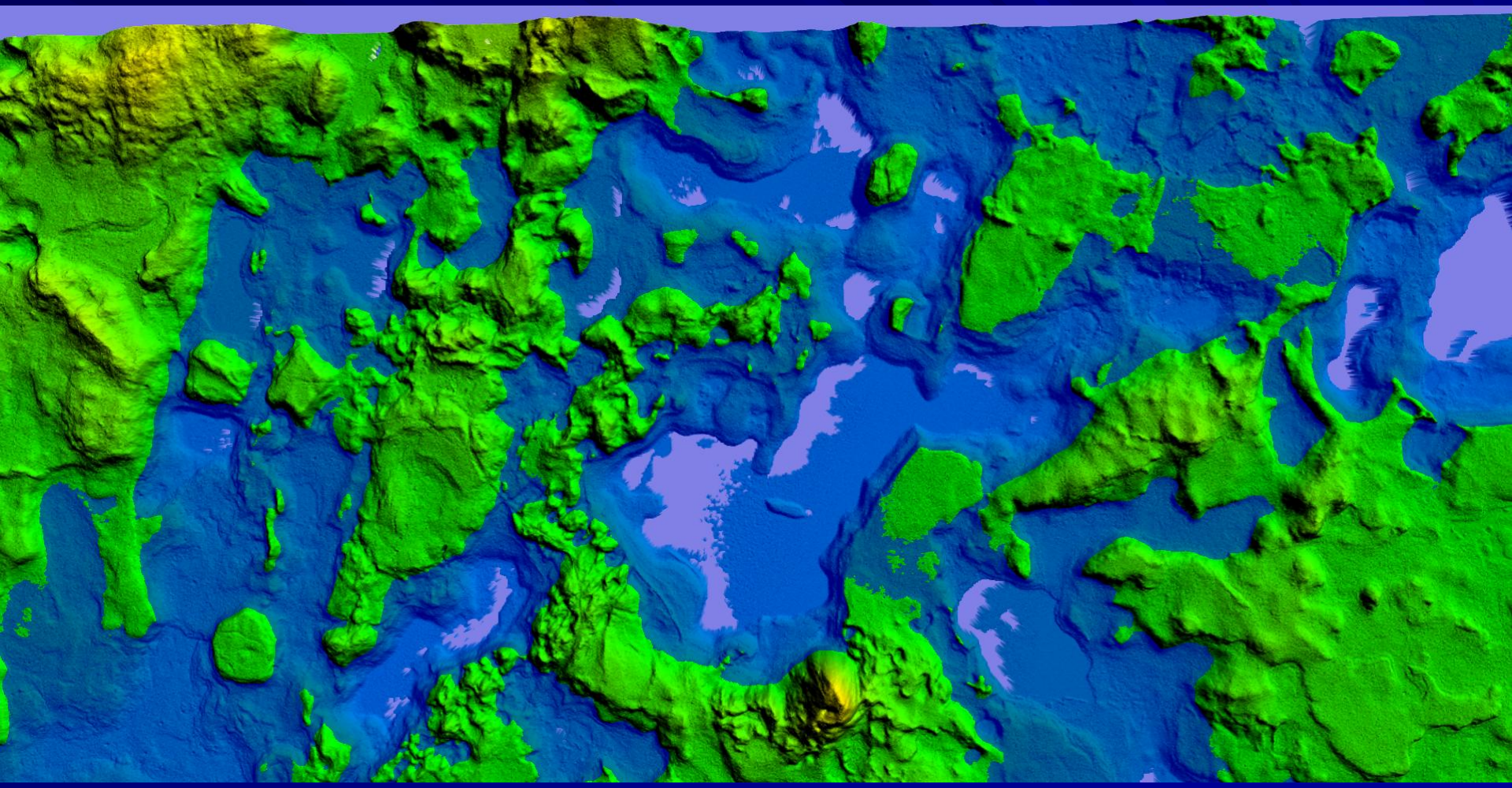
Lake level 86 m



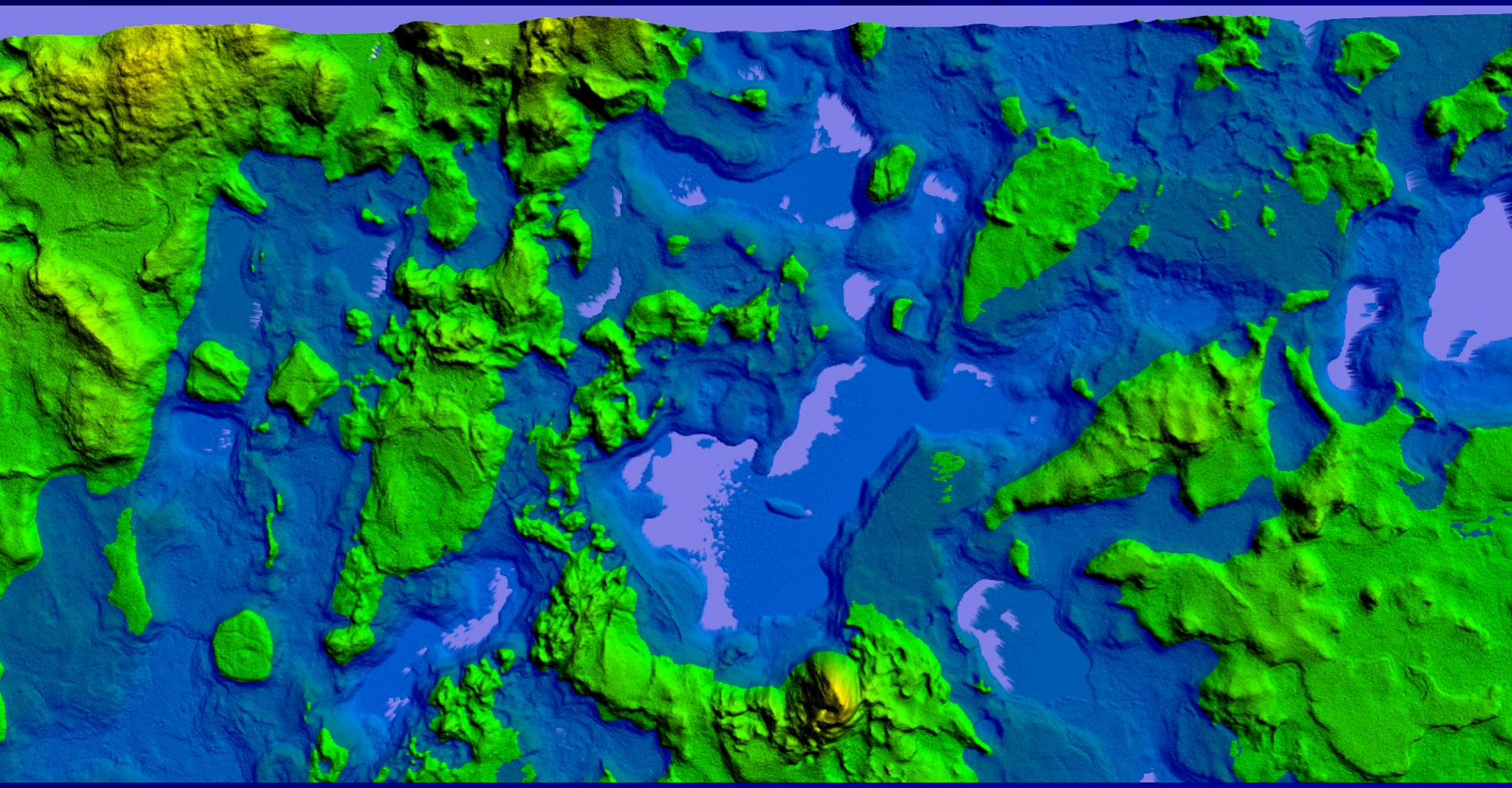
Lake level 87 m



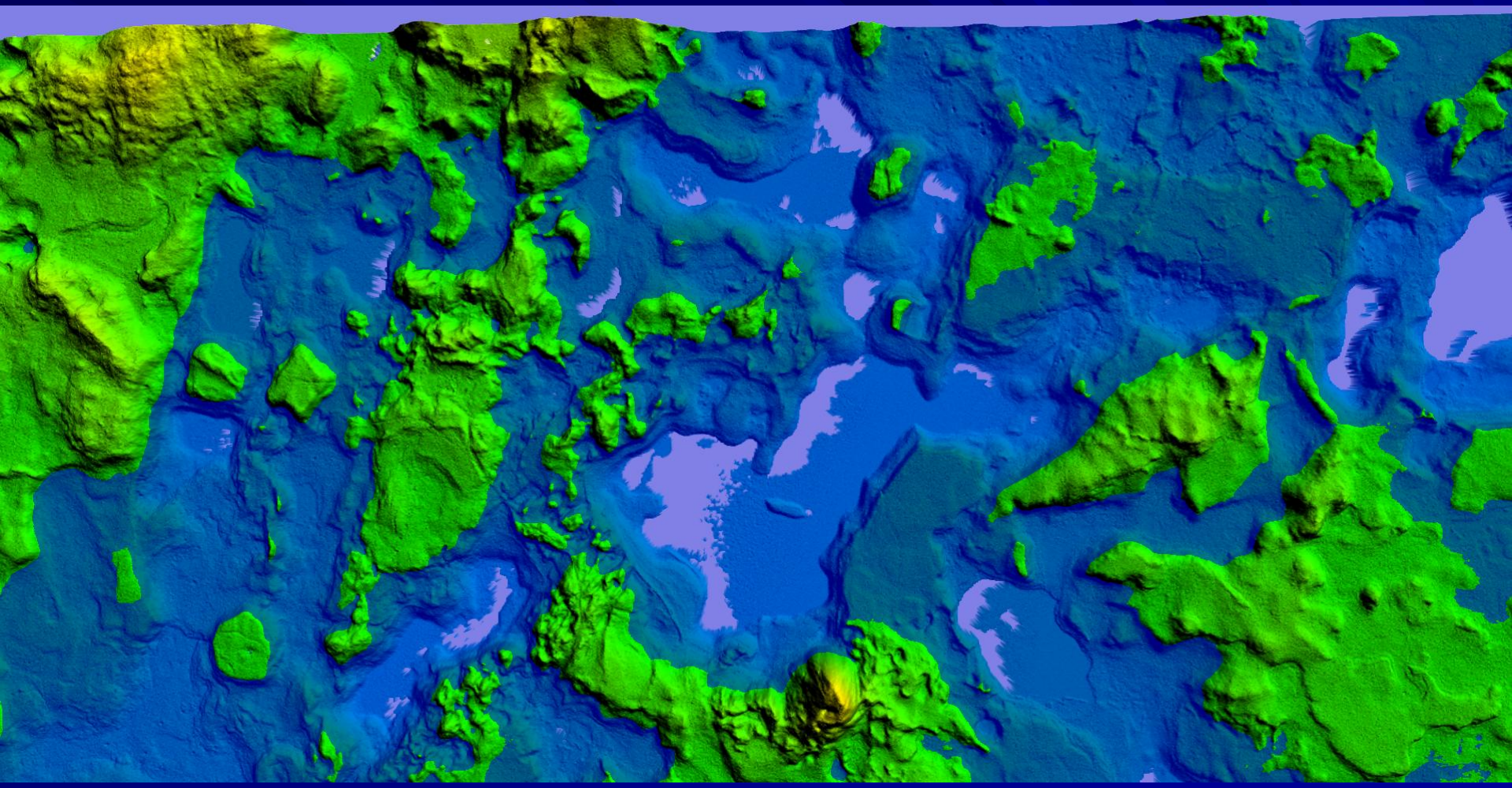
Lake level 88 m



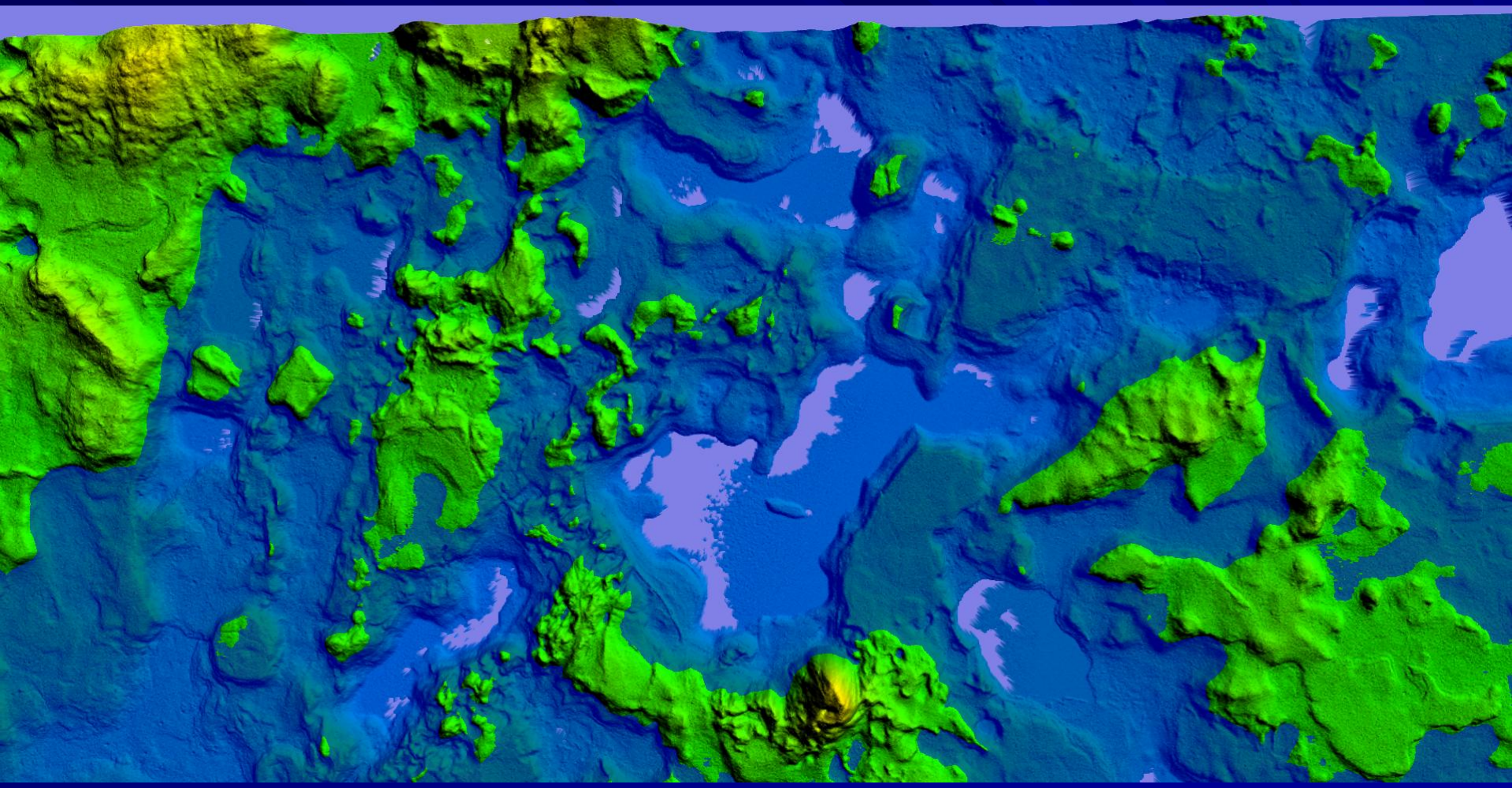
Lake level 89 m



Lake level 90 m (highest water?, ~12 m above lake level)

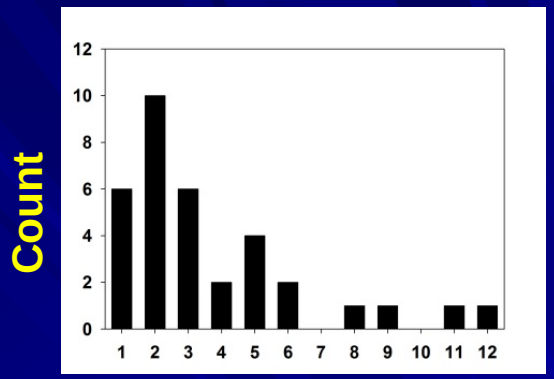


Lake level 91 m

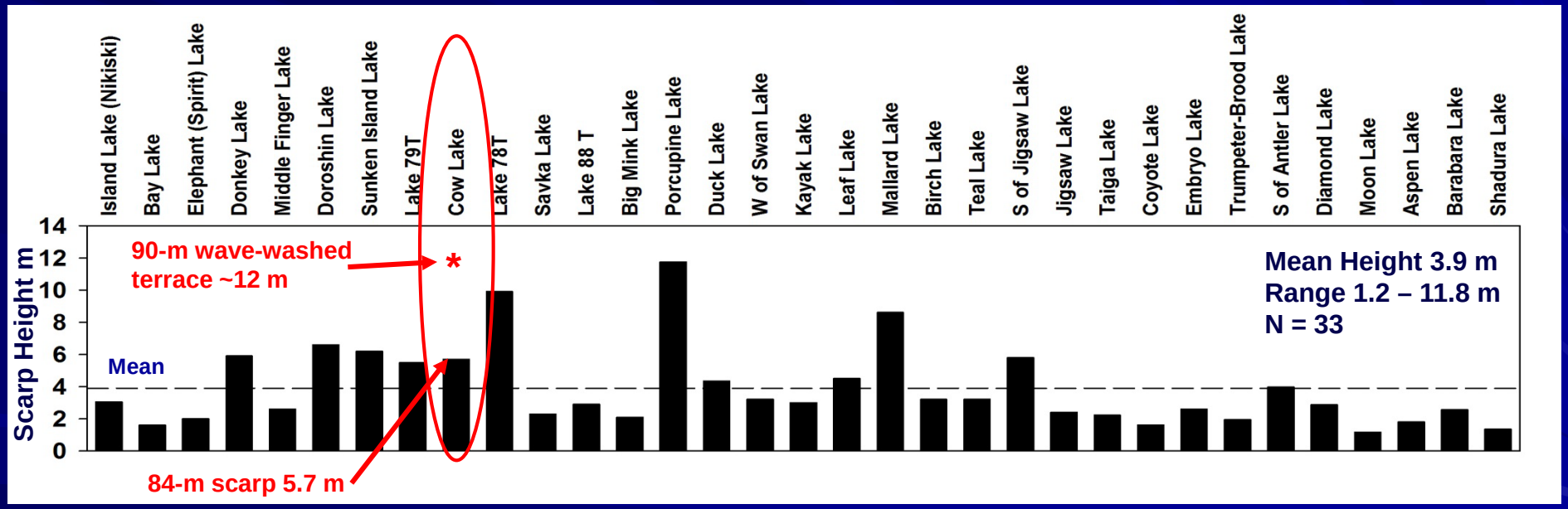


Lake level 92 m

Height of Wave-cut Scarps Above Modern Lake Levels



1-m Height Classes

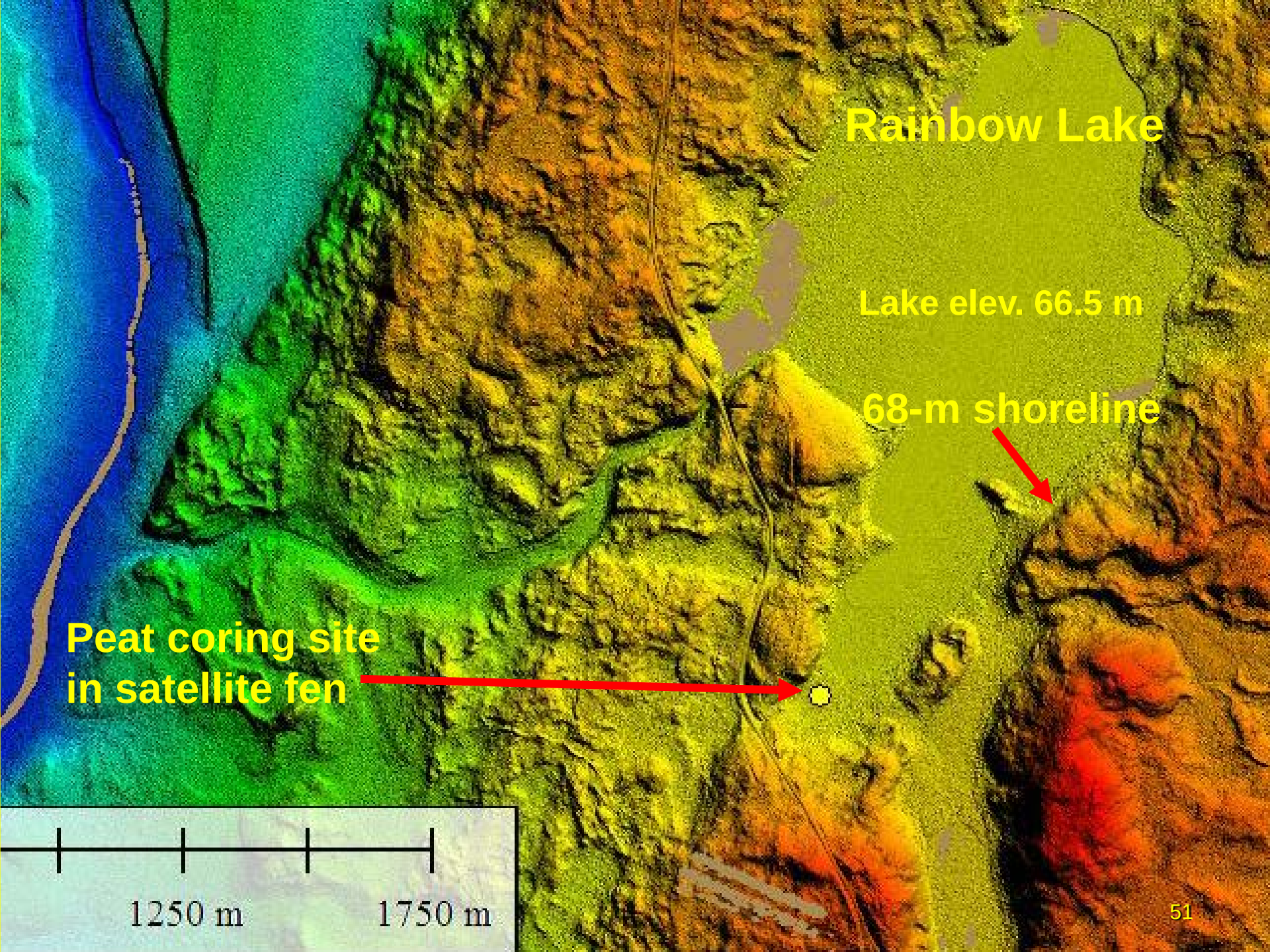


Closed-basin Lakes (100%)

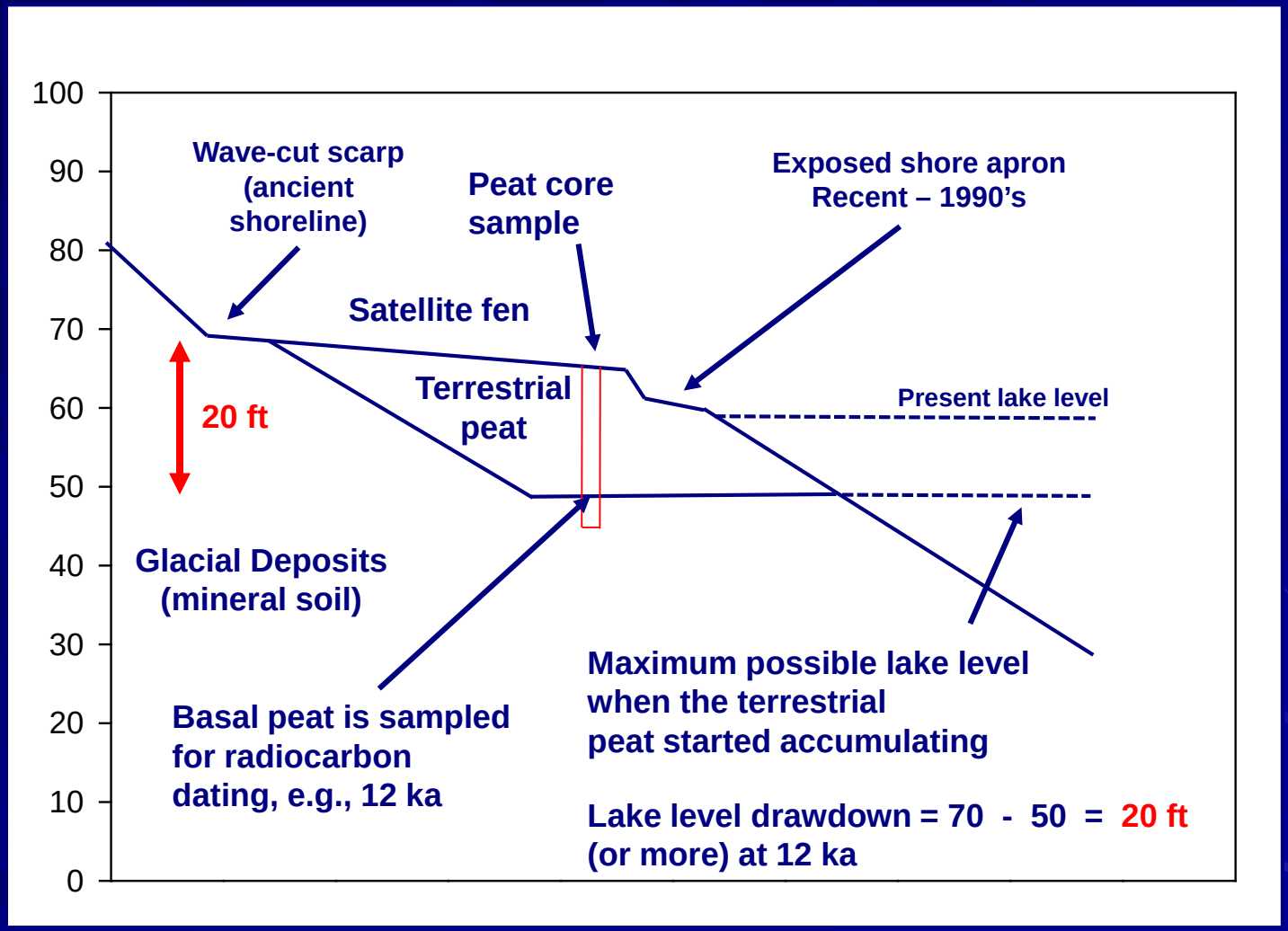
How to date these scarp??

Satellite fen peats will give *minimum* ages

But fen peats can also reveal paleo lake levels

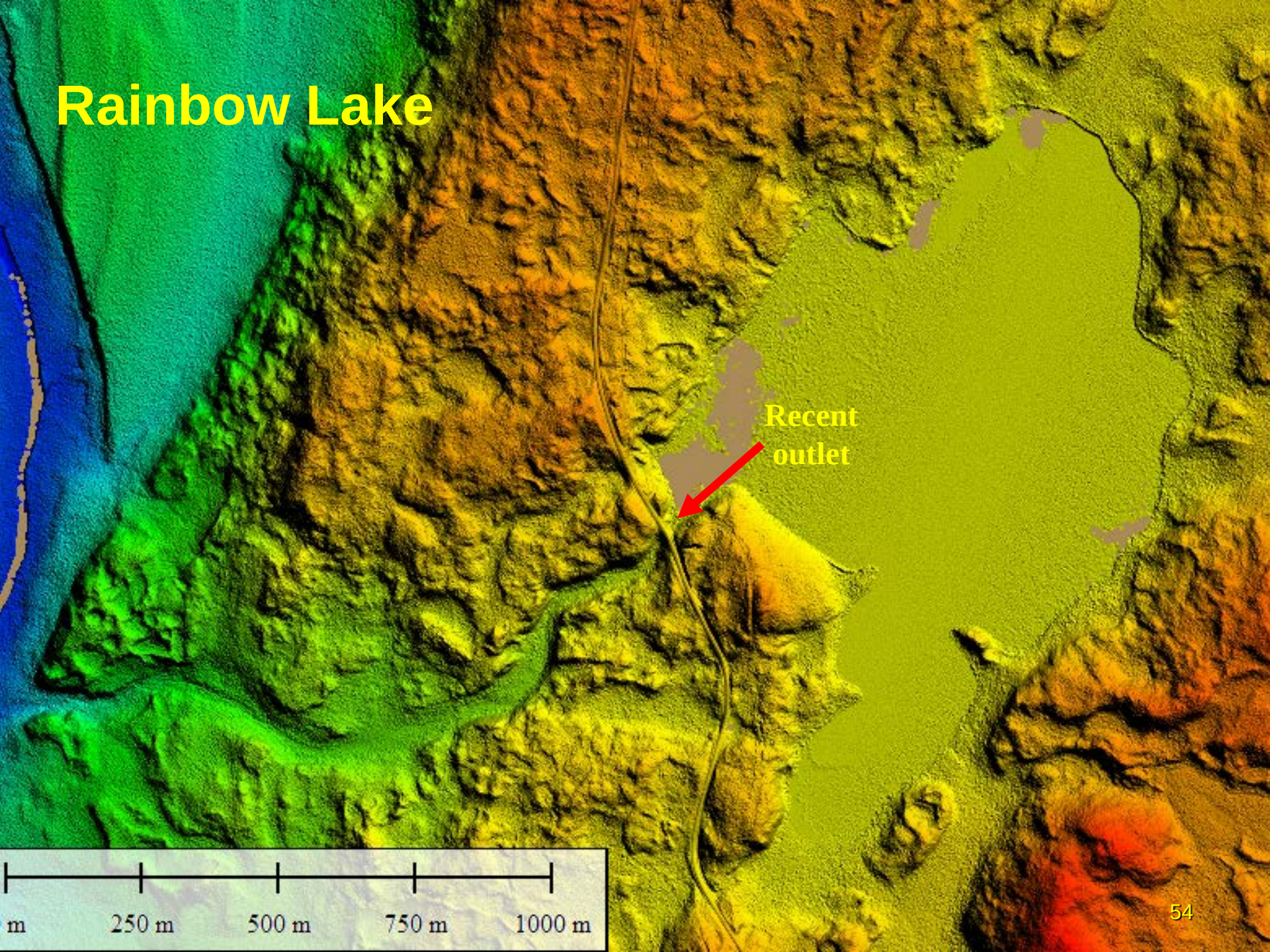

Rainbow Lake
Lake elev. 66.5 m
68-m shoreline
Peat coring site
in satellite fen
1250 m
1750 m

“Satellite fen” concept for dating paleo lake levels

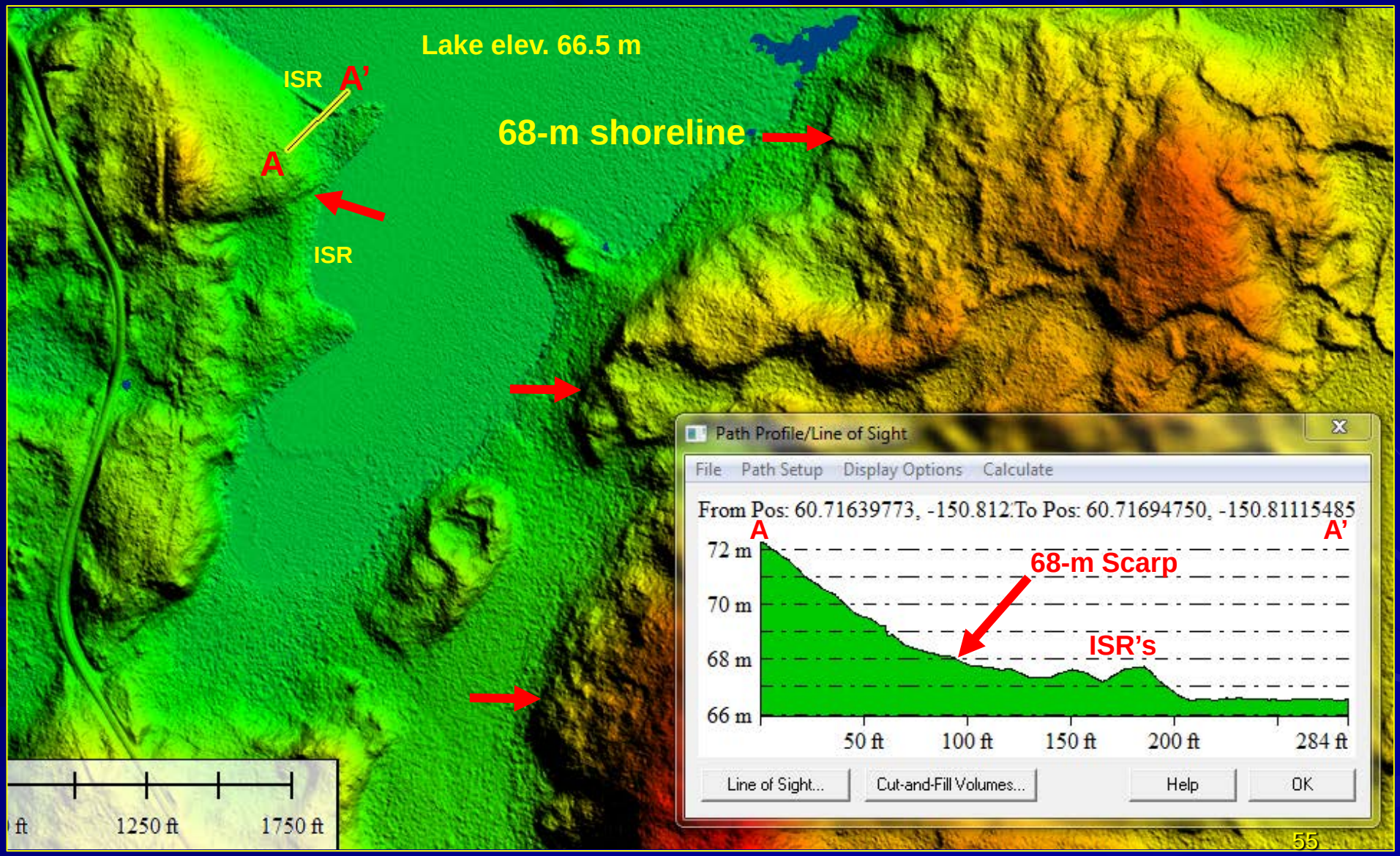


Rainbow Lake

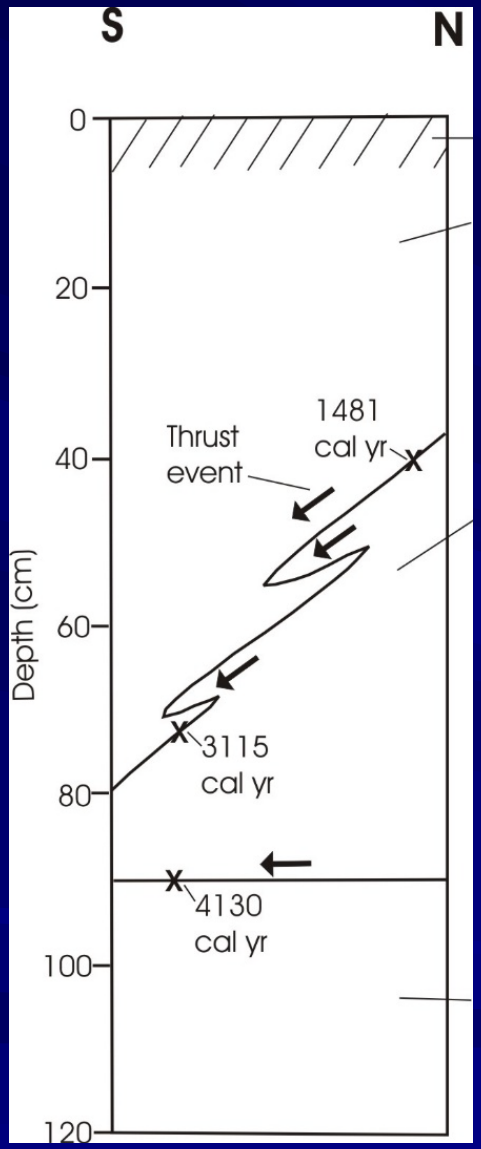
Rainbow Lake



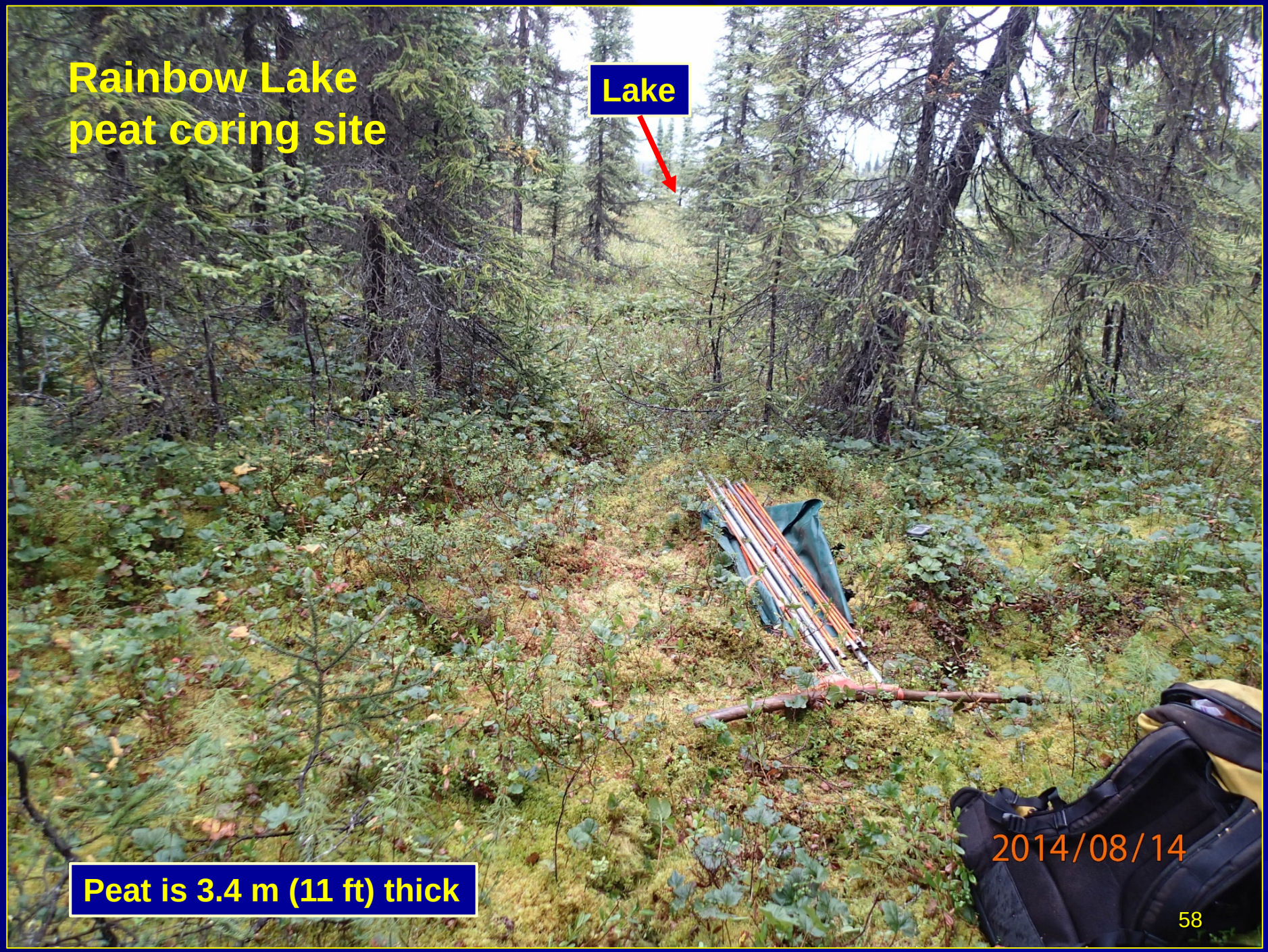
Rainbow Lake

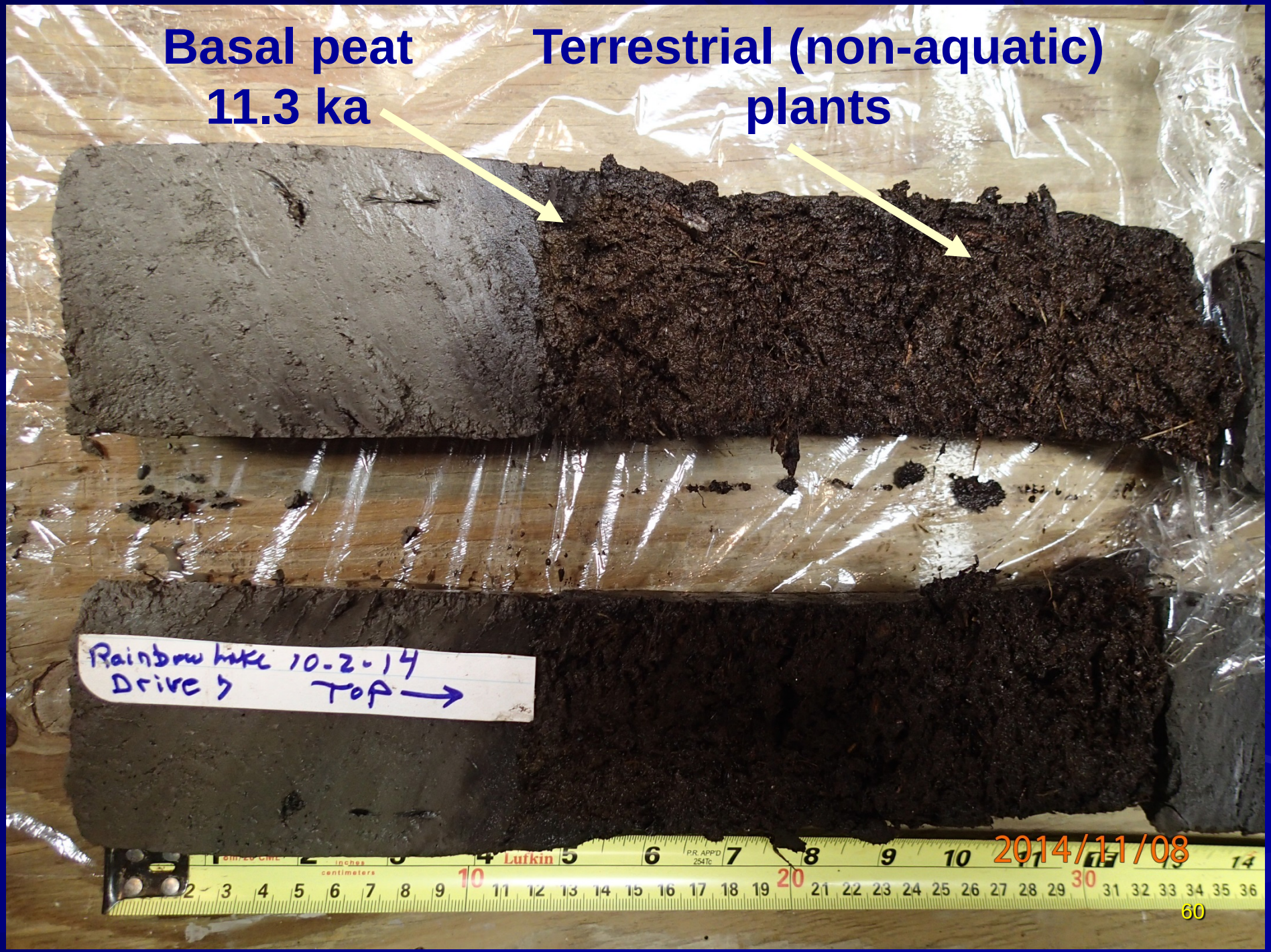


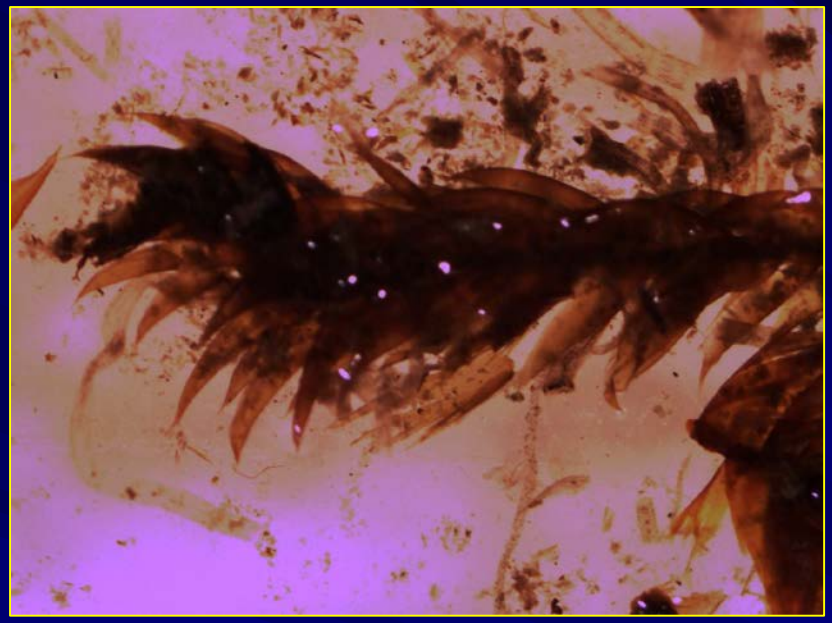
Ice-shoved rampart



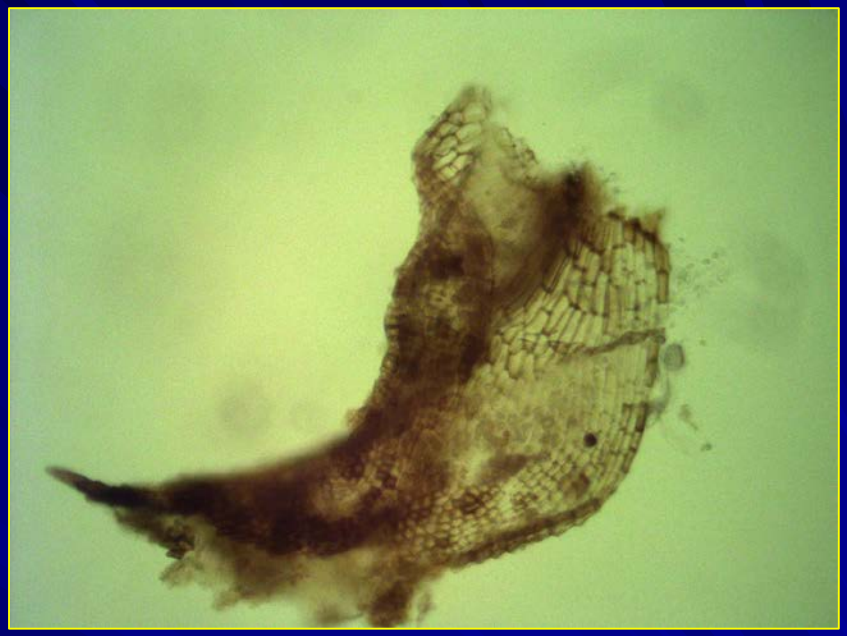
Rainbow Lake


Rainbow Lake
peat coring site
Lake
2014/08/14
Peat is 3.4 m (11 ft) thick

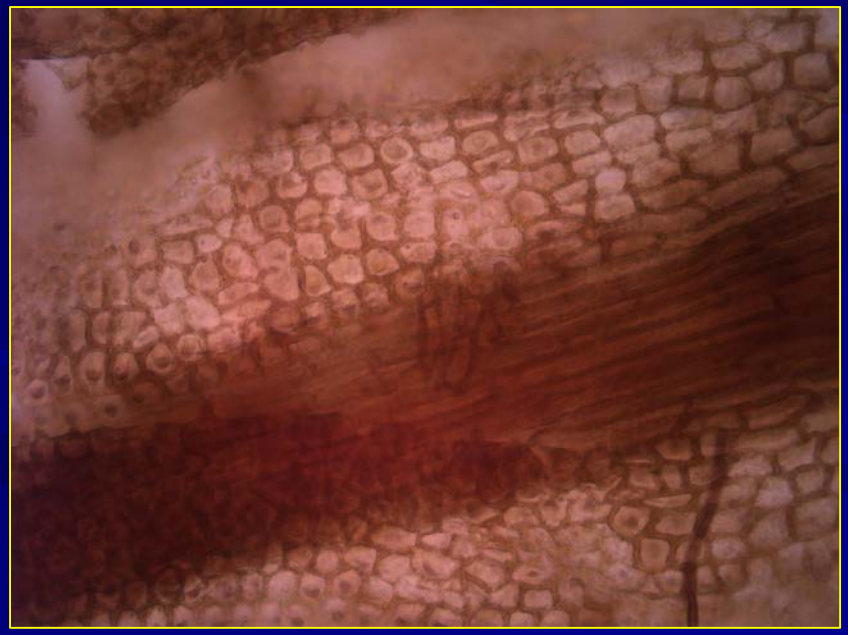

Basal peat
11.3 ka
Terrestrial (non-aquatic)
plants
Rainbow Lake 10-2-14
Drive 7 Top →
2014/11/08



***Scorpidium* leafy stem 20x**

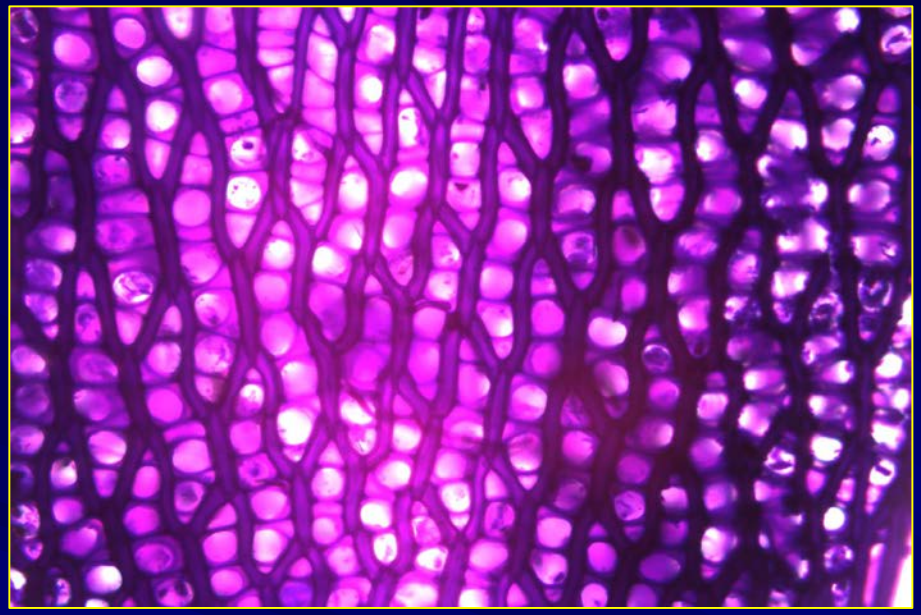


***Paludella squarrosa* leaf 200x**



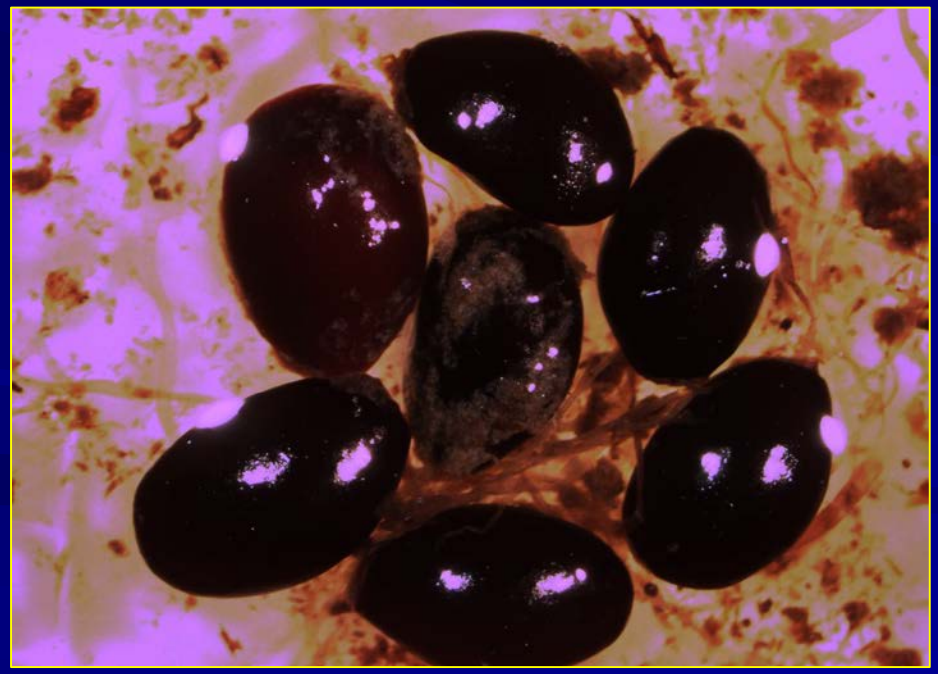
***Aulacomnium palustre* leaf 400x**

***Drepanocladus* leafy stem 40x**

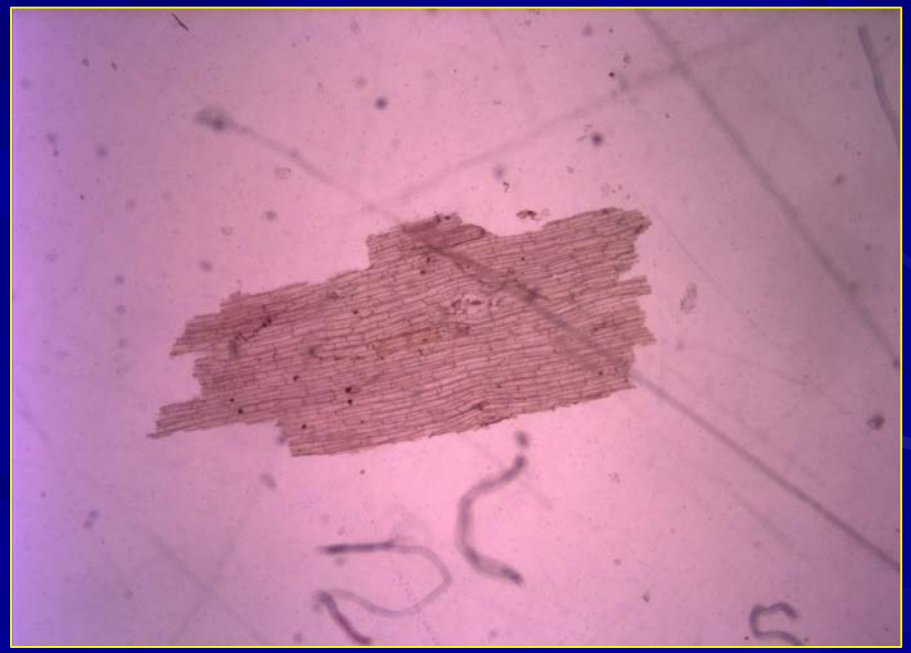


Sphagnum girgensohnii branch leaf 400x

Sphagnum girgensohnii stem leaf 100x

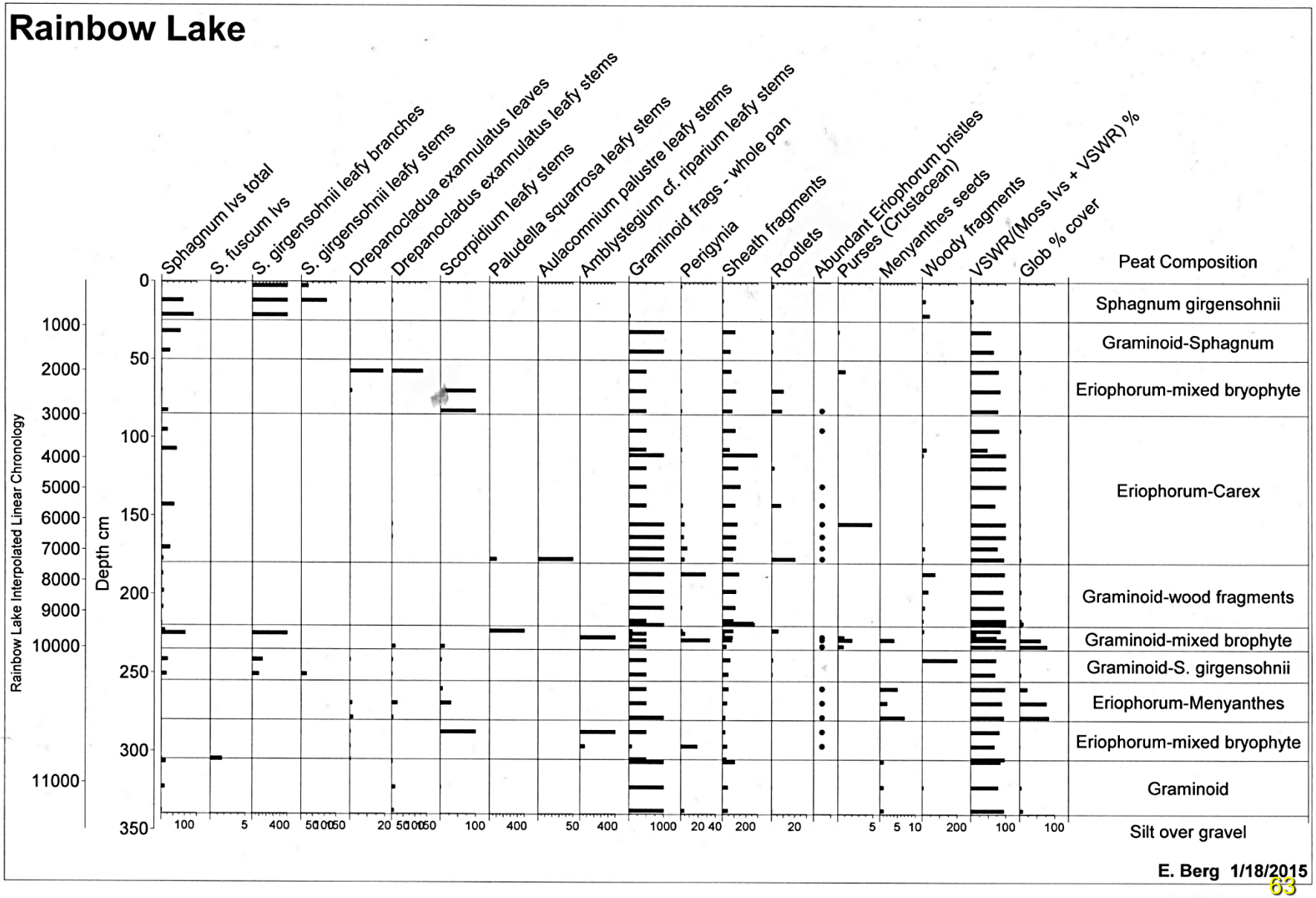


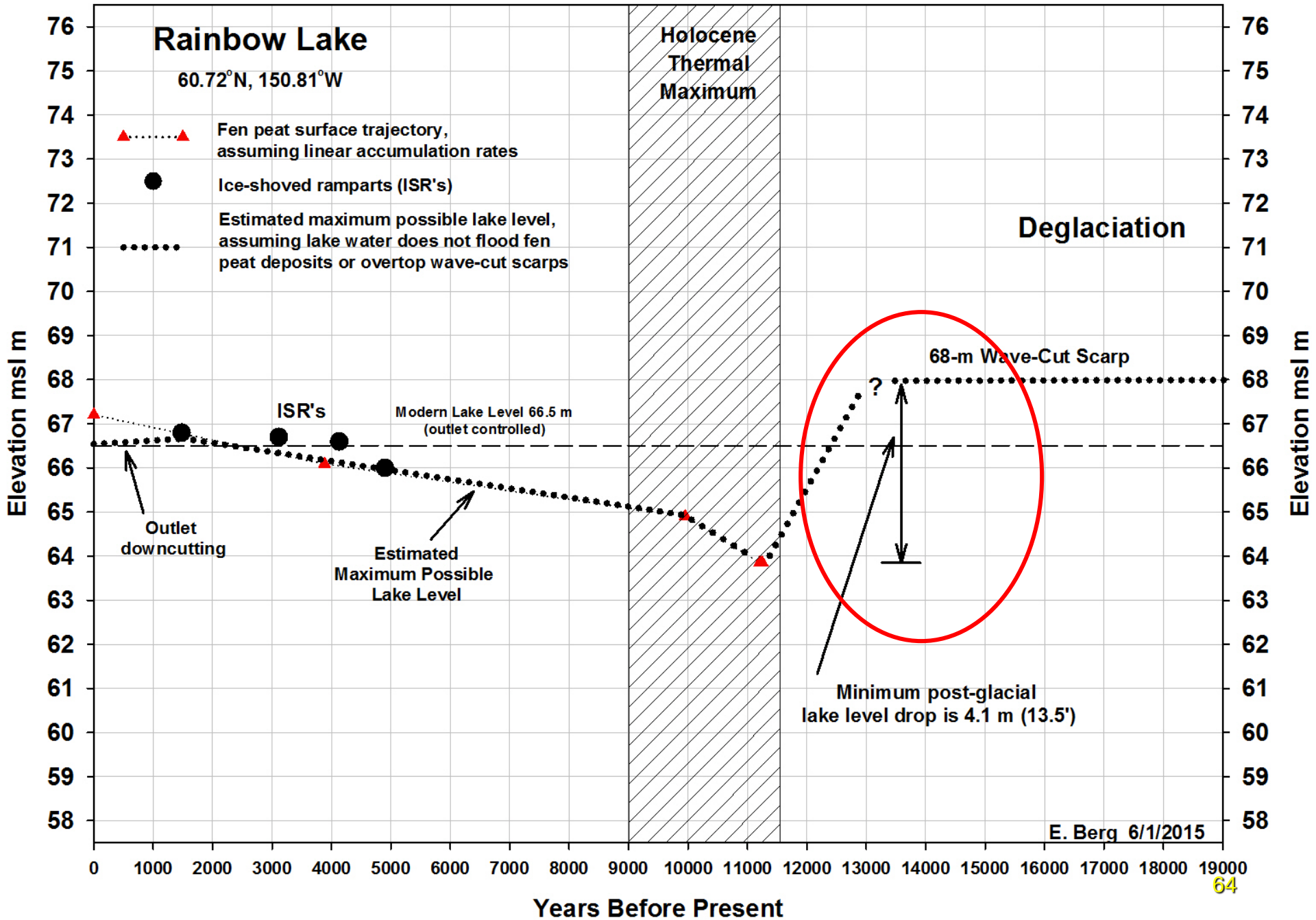
Menyanthes trifoliata seeds (5x3 mm) 7x



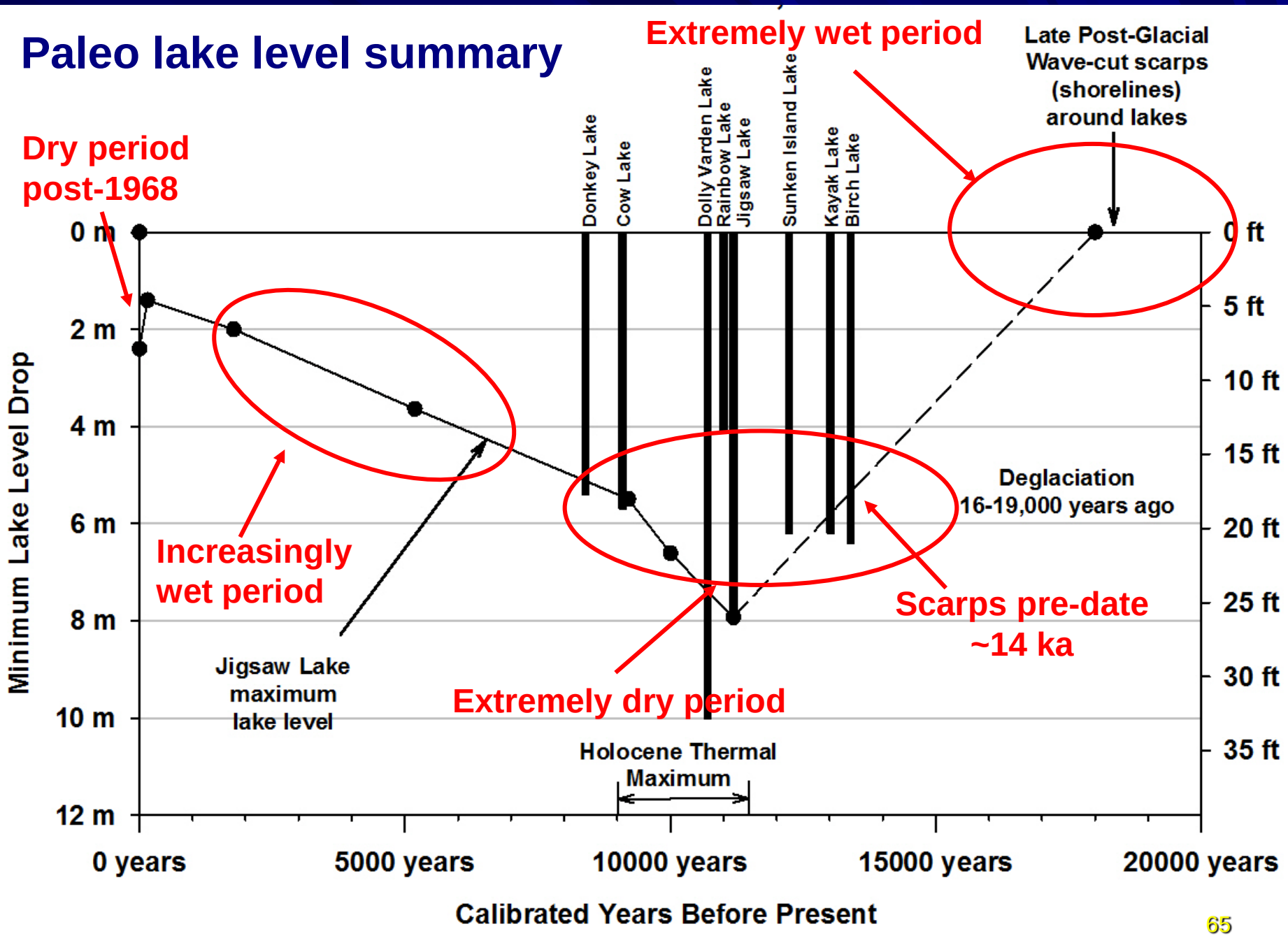
Eriophorum leaf epidermis 40x

Macrofossil Diagram



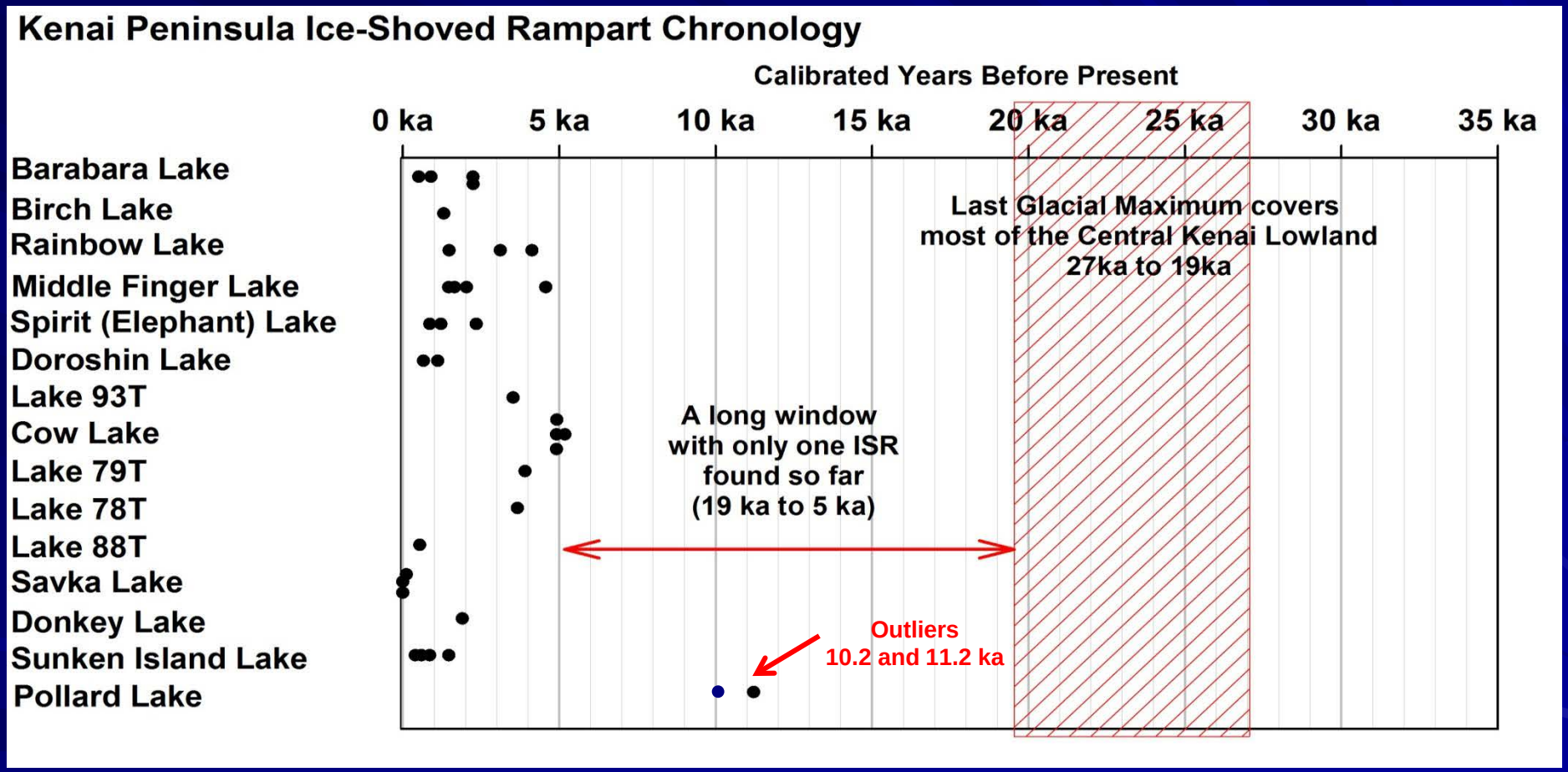

Rainbow Lake
60.72°N, 150.81°W
Fen peat surface trajectory, assuming linear accumulation rates
Ice-shoved ramparts (ISR's)
Estimated maximum possible lake level, assuming lake water does not flood fen peat deposits or overtop wave-cut scarps
Holocene Thermal Maximum
Deglaciation
68-m Wave-Cut Scarp
?
ISR's
Modern Lake Level 66.5 m (outlet controlled)
Outlet downcutting
Estimated Maximum Possible Lake Level
Minimum post-glacial lake level drop is 4.1 m (13.5')
E. Berg 6/1/2015
Elevation msl m
Years Before Present
76
75
74
73
72
71
70
69
68
67
66
65
64
63
62
61
60
59
58
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000

Paleo lake level summary

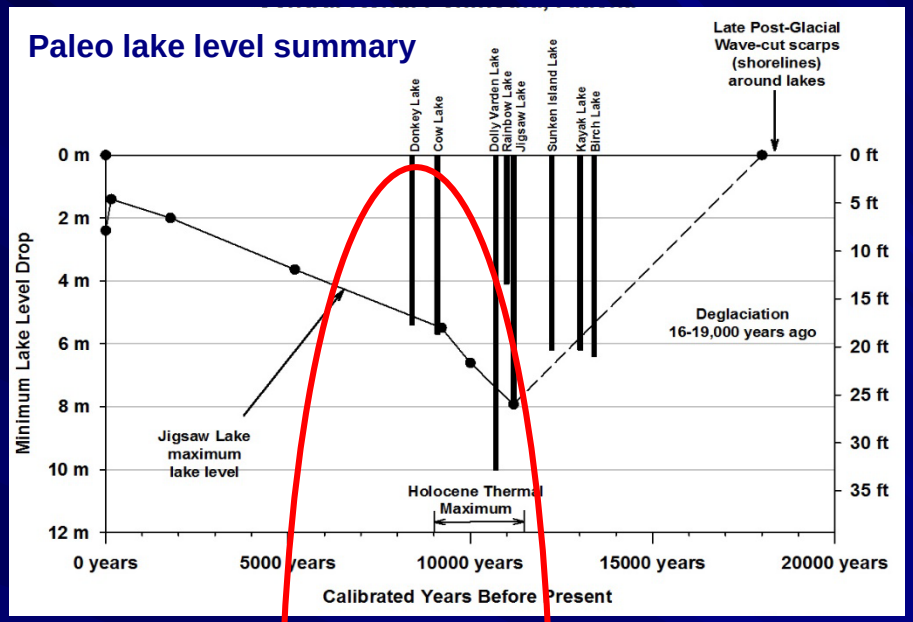


(Repeat)

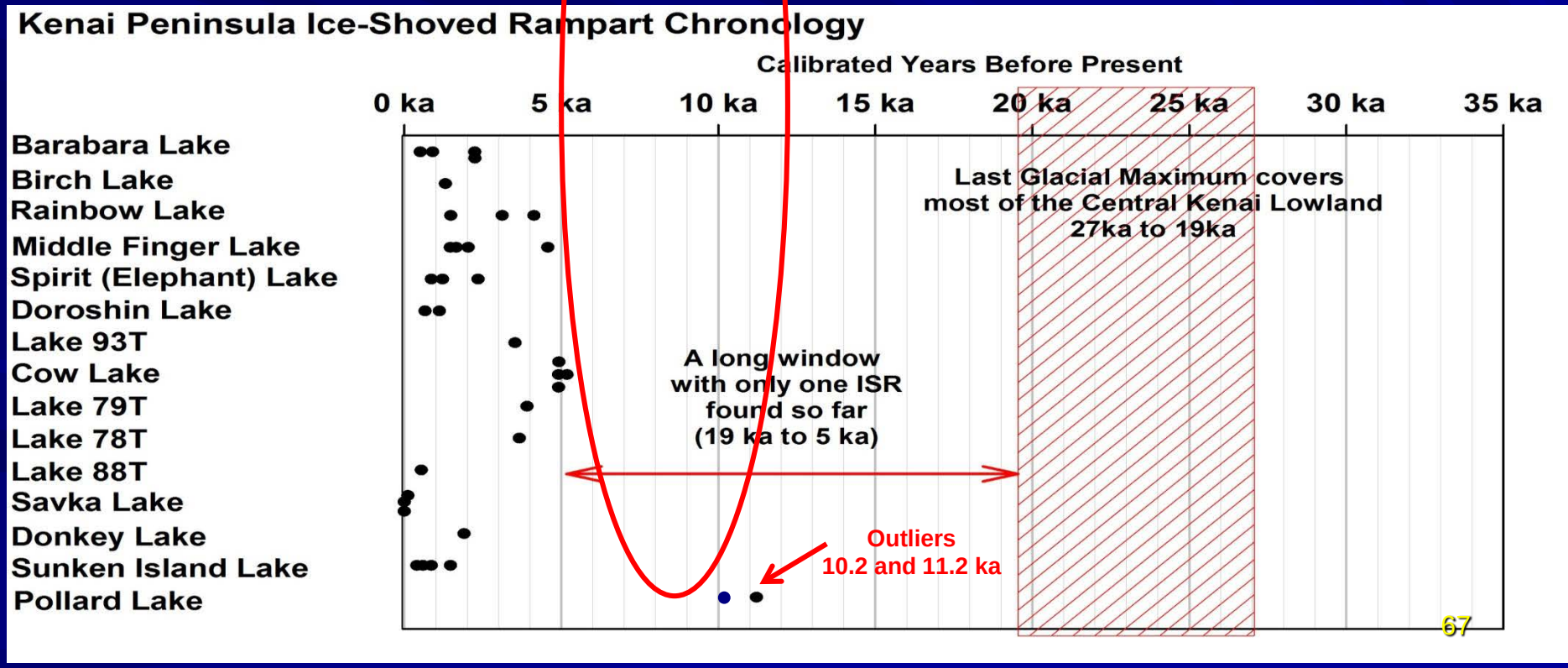
Puzzle: What is different about the climate of the last 5000 years?



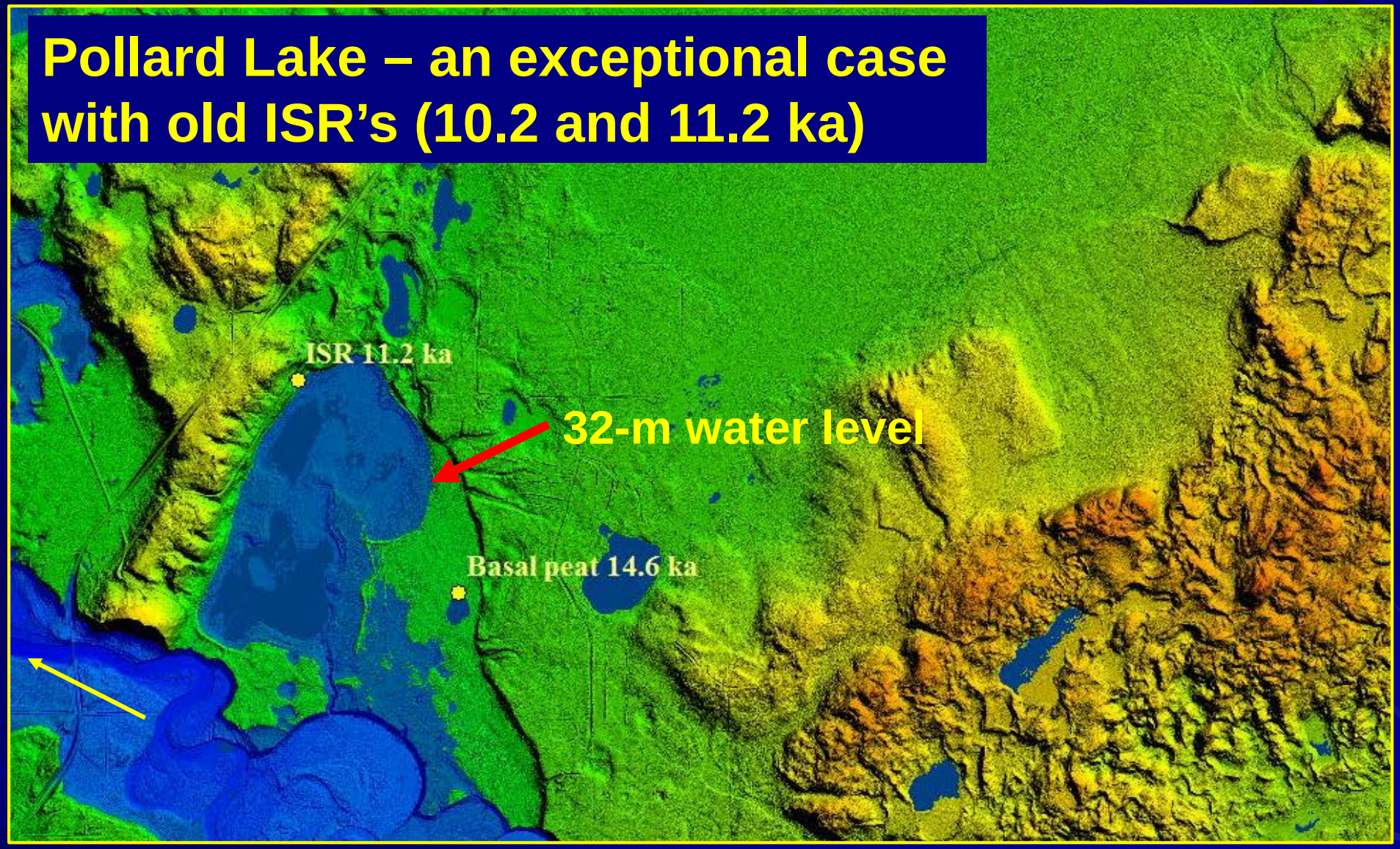
Higher lake levels – Yes
Colder winters – Probably
Stronger spring winds - Unknown



Possible answer: Rising lake levels have erased the pre-5 ka ISR's.



Pollard Lake – an exceptional case with old ISR's (10.2 and 11.2 ka)



High water was created by impoundments of the Kasilof River. Cause unknown.

The End