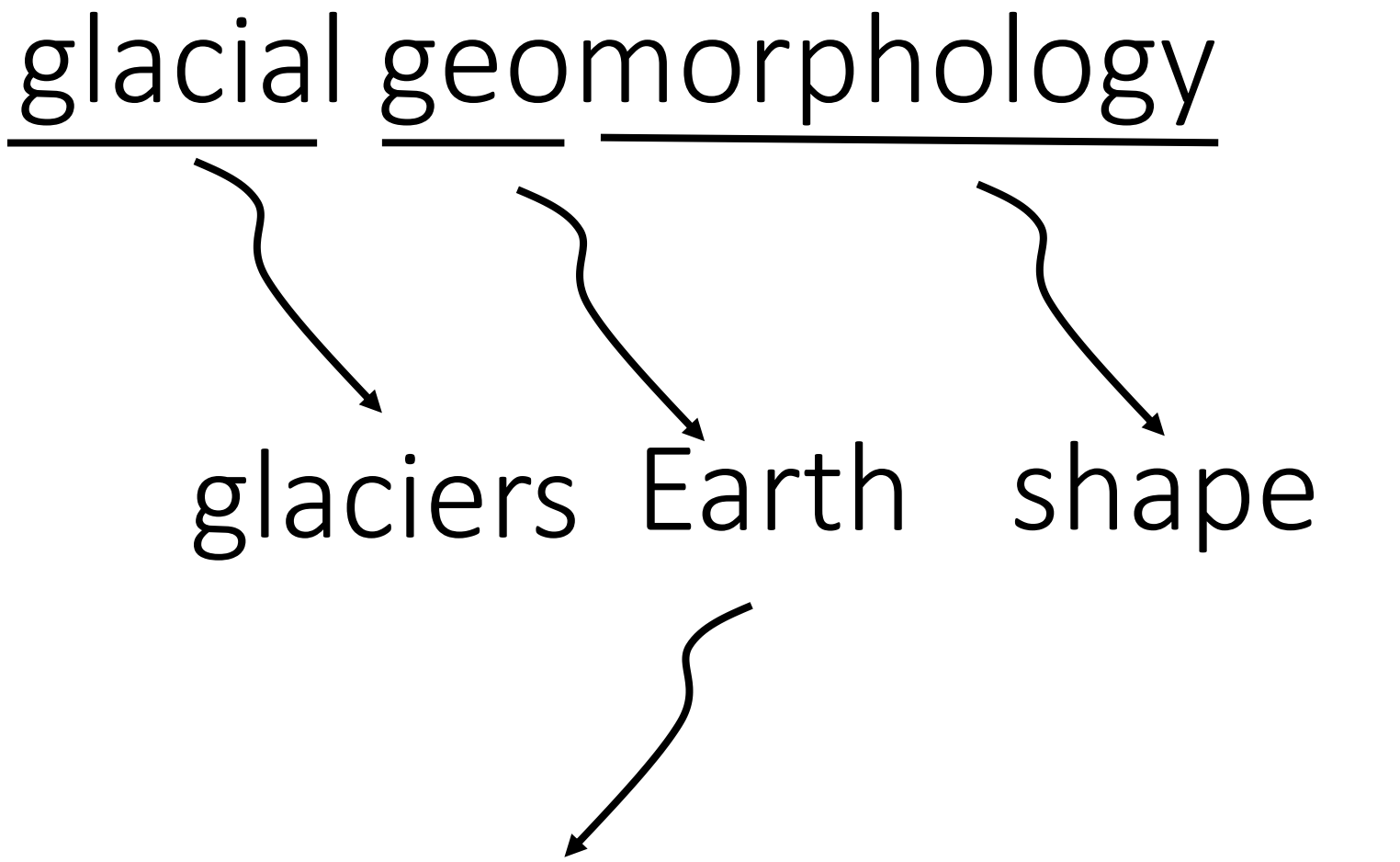
glacial geomorphology

Lecture 01

Skaftafelljokull (glacier)


glacial geomorphology
glaciers
Earth
shape
how glaciers shape the earth

goals of the course

for you to able to recognize signs of glaciation in the world's landforms

for you to be able to connect these landforms to the glacial processes that formed then

for you to be able to make inferences about climate conditions in the past

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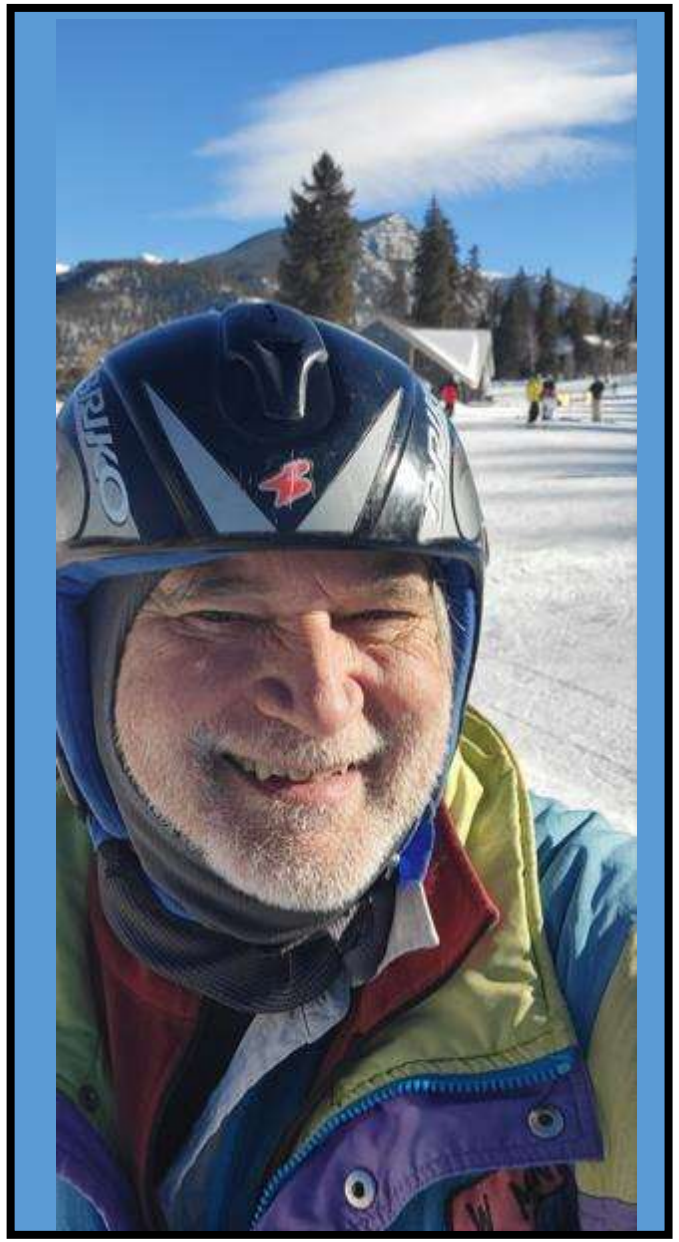
for you to able to recognize signs of glaciation in the world's landforms

for you to be able to connect these landforms to the glacial processes that formed them

for you to be able to make inferences about climate conditions in the past

Anyone want to propose any additional goals?

Teaching Staff



Bill Menke, (he/him), Instructor
MENKE@LDEO.COLUMBIA.EDU

Caitlin Locke (she/her), T.A.
CD2477@COLUMBIA.EDU

please review my policies on grading and other student matters

www.ldeo.columbia.edu/~menke/www_users_menke/gradingpolicy.html

Format of Class

Tuesdays: Lecture with some discussion
Thursdays: In-class group projects

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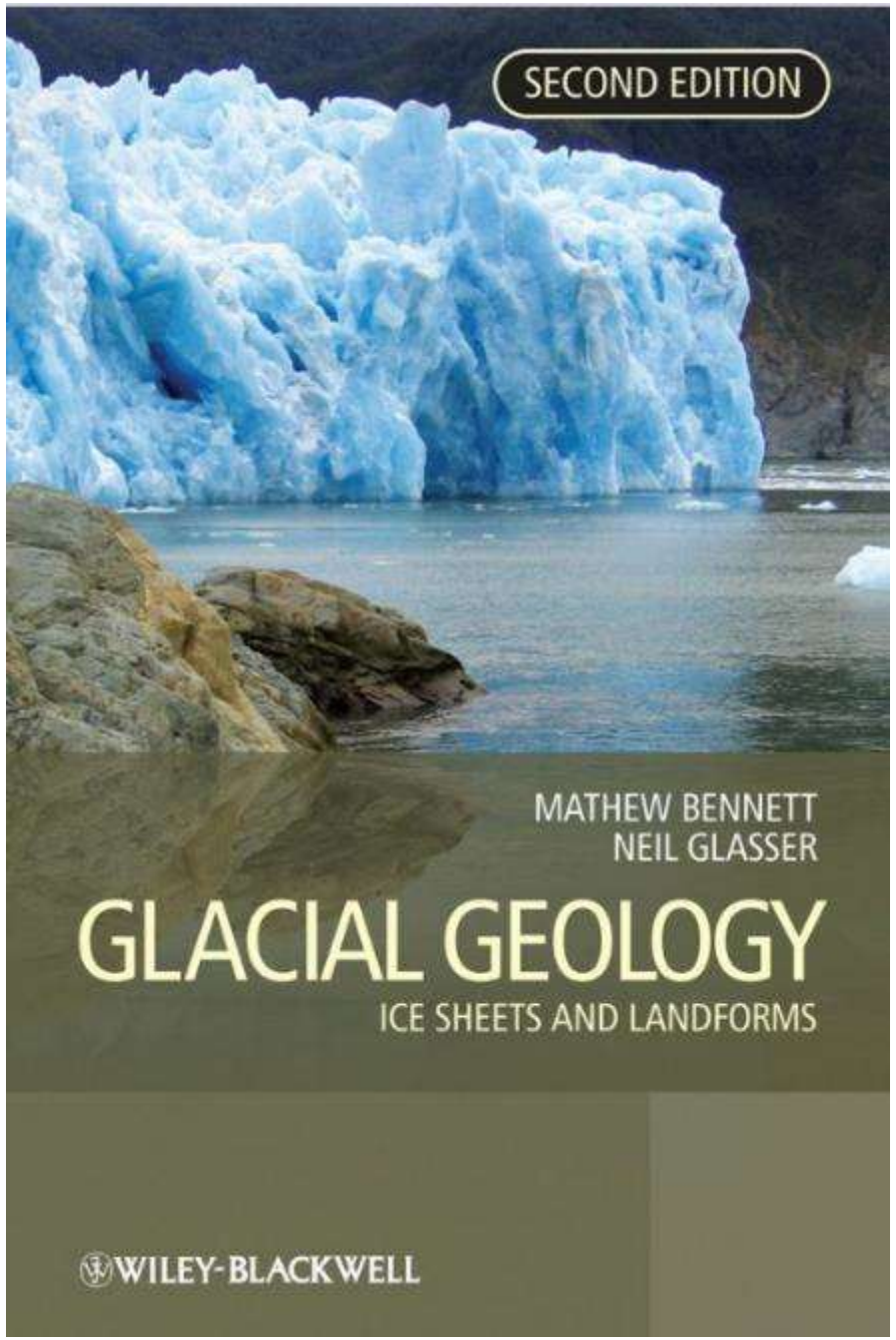
Tuesdays: Lecture with some discussion
Thursdays: In-class group projects

In Class Participation Required



Weekly readings
from the textbook

Assessment

Weekly:
Individual Project Report
(2/3 of grade)

End of Term:
Individual Term Paper
Glacial Geomorphology of the [region] and its implications
(1/3 of grade)

Assessment

Weekly:
Individual Project Report
(2/3 of grade)

End of Term:
Individual Term Paper
Glacial Geomorphology of the [region] and its implications
(1/3 of grade)

Regions pre-approved by me; no duplicates allowed, FCFS
10 minute in class presentations April 29 – May 1
PDF posted to Courseworks by 11:59 PM May 16, 2025

Assessment

Weekly:
Individual Project Report
(2/3 of grade)

Rubric
on Courseworks

End of Term:
Individual Term Paper
Glacial Geomorphology of the [region] and its implications
(1/3 of grade)

Rubric
on Courseworks

Collaboration

Encouraged
however
collaborations must be declared
and
all submitted writing must be your own

Mostly a “qualitative” course

But next Thursday (1/30) we will use Python-based glacial flow simulations. So please install Python on your Notebook computers (using instructions and with help of TA).

Why is Glacial Geomorphology Important?

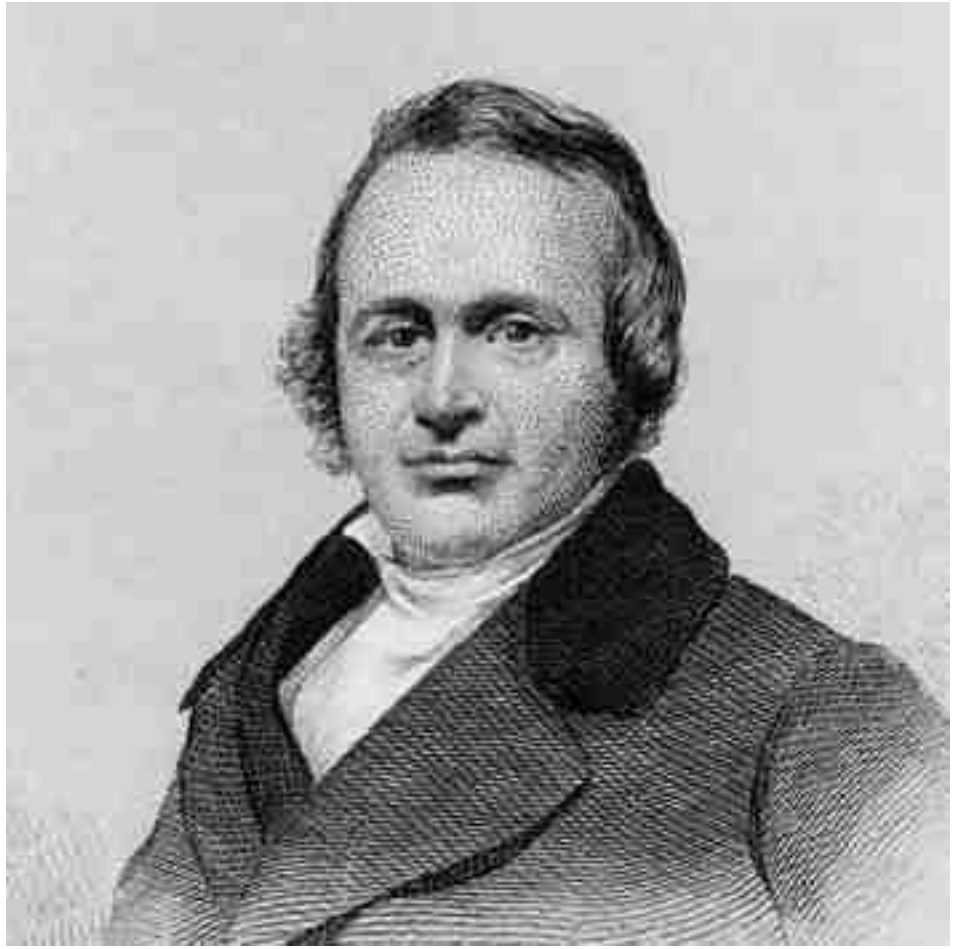
Why is it important to you?

lets make a list

The Discovery of the Ice Age

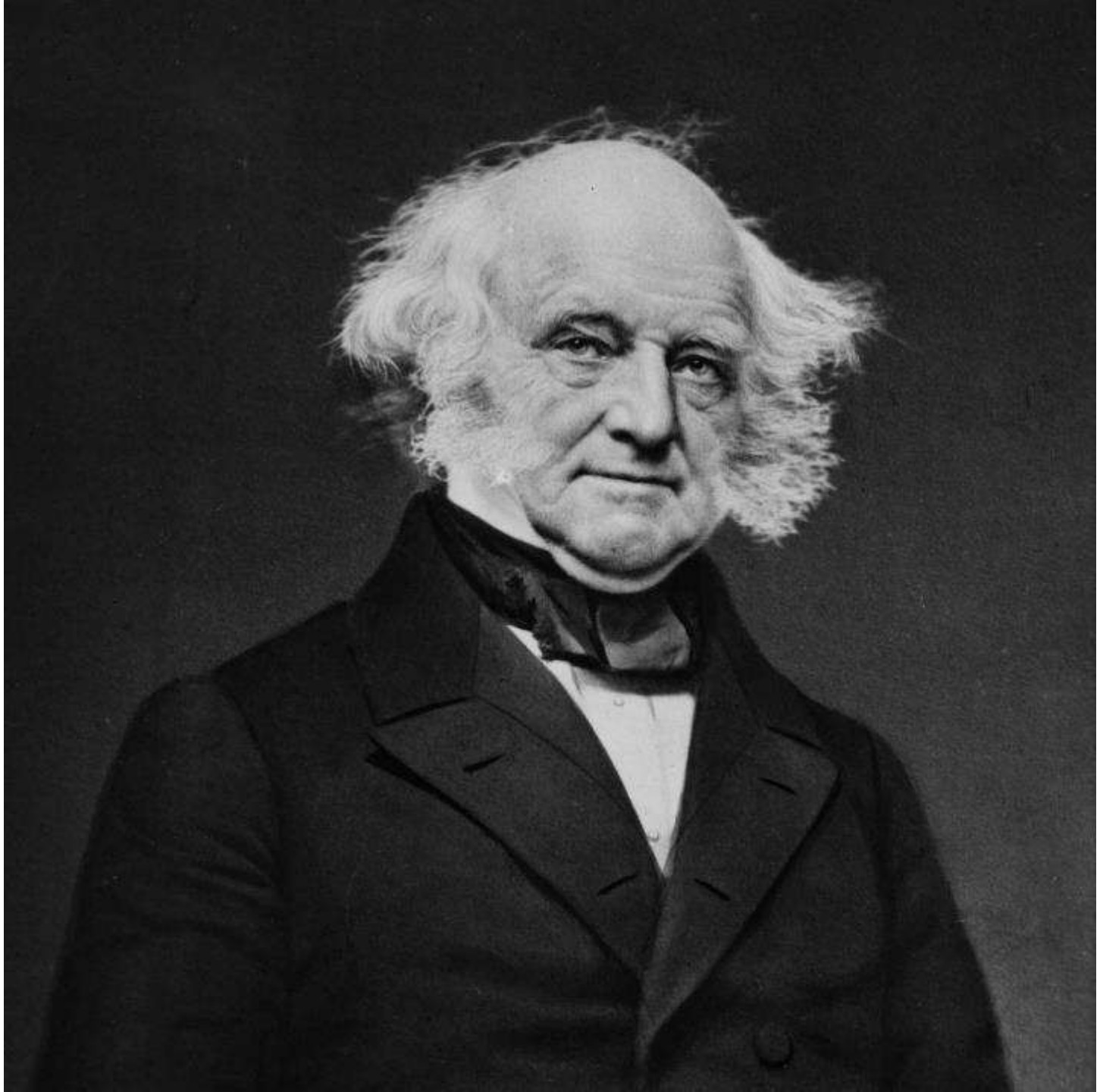
1837

Swiss naturalist Louis Agassis speaks at Swiss sachet of Natural Sciences. Replaces talk on fossil fishes with one proposing an 'ice age' in Europe and North America.



Louis Agassis

Who was US President in 1837?



Martin Van Buren

8th President of the United States

“There is a power in public opinion in this country—and I thank God for it: for it is the most honest and best of all powers".

Why 1837 ?

What Precursory Knowledge was necessary ?

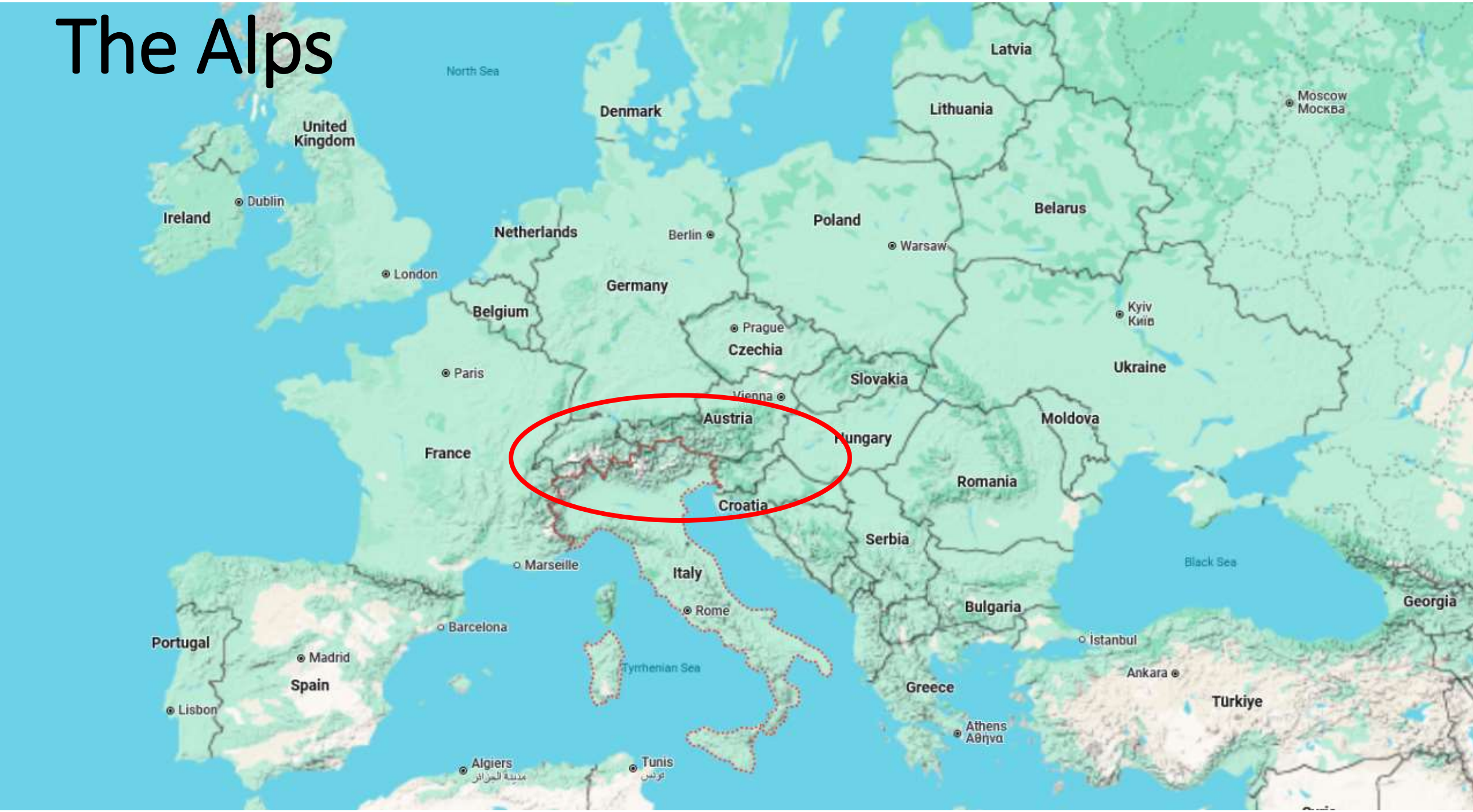
What Cultural Factors were important ?

Suppose you were living in 19th Century

London
Paris
Vienna
Rome

where would you go to see a glacier?

The Alps


North Sea
Denmark
United Kingdom
Ireland
Dublin
London
Netherlands
Berlin
Germany
Belgium
Paris
France
Prague
Czechia
Vienna
Austria
Slovakia
Hungary
Poland
Warsaw
Latvia
Lithuania
Belarus
Moscow
Москва
Kyiv
Київ
Ukraine
Moldova
Romania
Croatia
Serbia
Bulgaria
Black Sea
Georgia
Marseille
Italy
Rome
Barcelona
Portugal
Madrid
Spain
Lisbon
Tyrrhenian Sea
Istanbul
Ankara
Türkiye
Greece
Athens
Αθήνα
Algiers
مدينة الجزائر
Tunis
تونس

The Alps

here’s a glacier

and how long would the trip take?

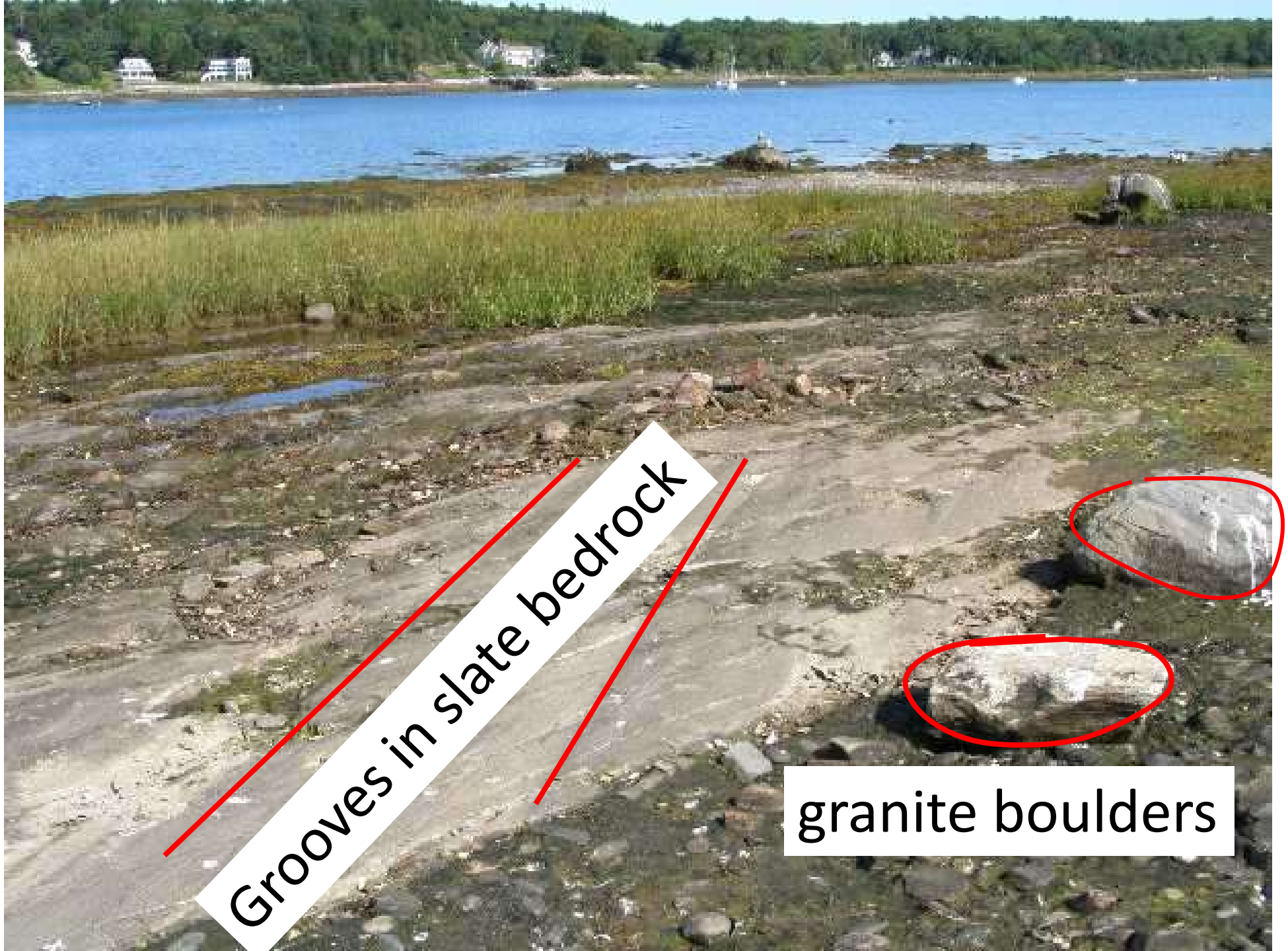
and how safe would the trip be?

1815, Jean-Pierre Perraudin, Swiss Mountaineer.

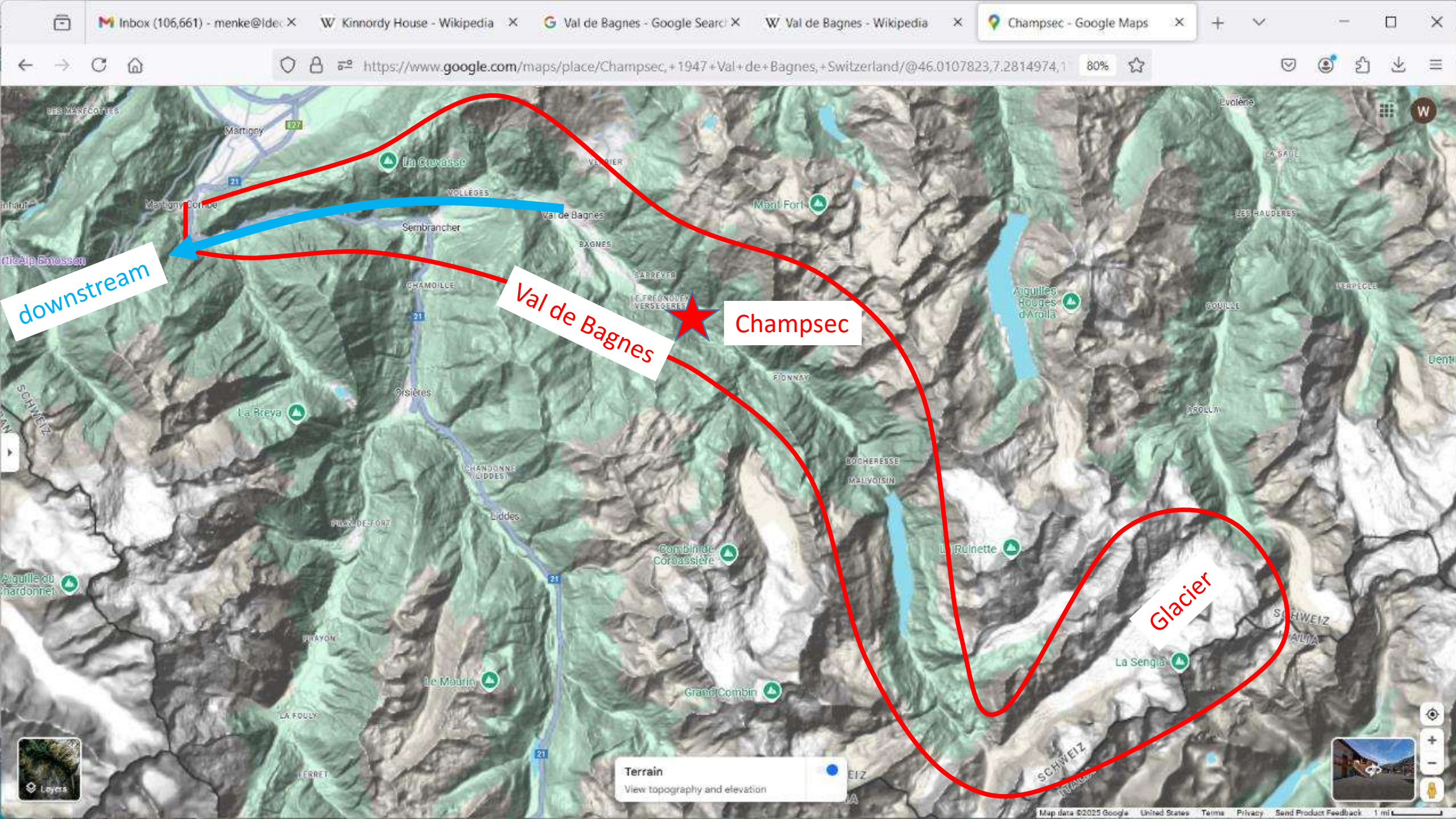
"Having long ago observed marks and scars occurring on hard rocks which do not weather, I finally decided, after going near the glaciers, that they had been made by the pressure or weight of these masses, at which I find traces as least as far as Champsec. This makes me think that glaciers filled in the past the entire Val de Bagnes, and I am ready to demonstrate this fact to incredulous people by the obvious proof of comparing these marks with those uncovered by glaciers at present."

1815, Jean De Charpentier, Swiss naturalist.

"Although Perraudin extended his glacier only [24 miles beyond its limit to Martigny], because he himself probably had never been beyond that town, and although I agreed with him on the improbability of transporting erratic boulders by water, I nevertheless found his hypothesis so extraordinary and even so extravagant that I considered it as not worth examining or even considering."


Grooves in slate bedrock
granite boulders

Val de Bagnes


downstream
Val de Bagnes
Champsec
Glacier

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https://www.google.com/maps/place/Champsec,+1947+Val+de+Bagnes,+Switzerland/@46.0107823,7.2814974,1 80%


LES MARECOTTES
Martigny
La Crevasse
VERBIER
Martigny-Combe
VOLLEGES
Val de Bagnes
Sembrancher
Mont Fort
BAGNES
Evolène
LA SAGE
LES HAUDERES
CHAMOILLE
Trient
Aiguilles Rouges d'Arolla
COUILLE
FIONNAY
Orsières
La Breya
AROLLA
BOCHERESSE
MAUVOISIN
CHANDONNE (LIDDES)
Liddes
PRAZ-DE-FORT
Combin de Corbassière
La Ruinette
Aiguille du Chardonnet
SCHWEIZ
ITALIA
La Sengla
Le Mourin
Grand Combin
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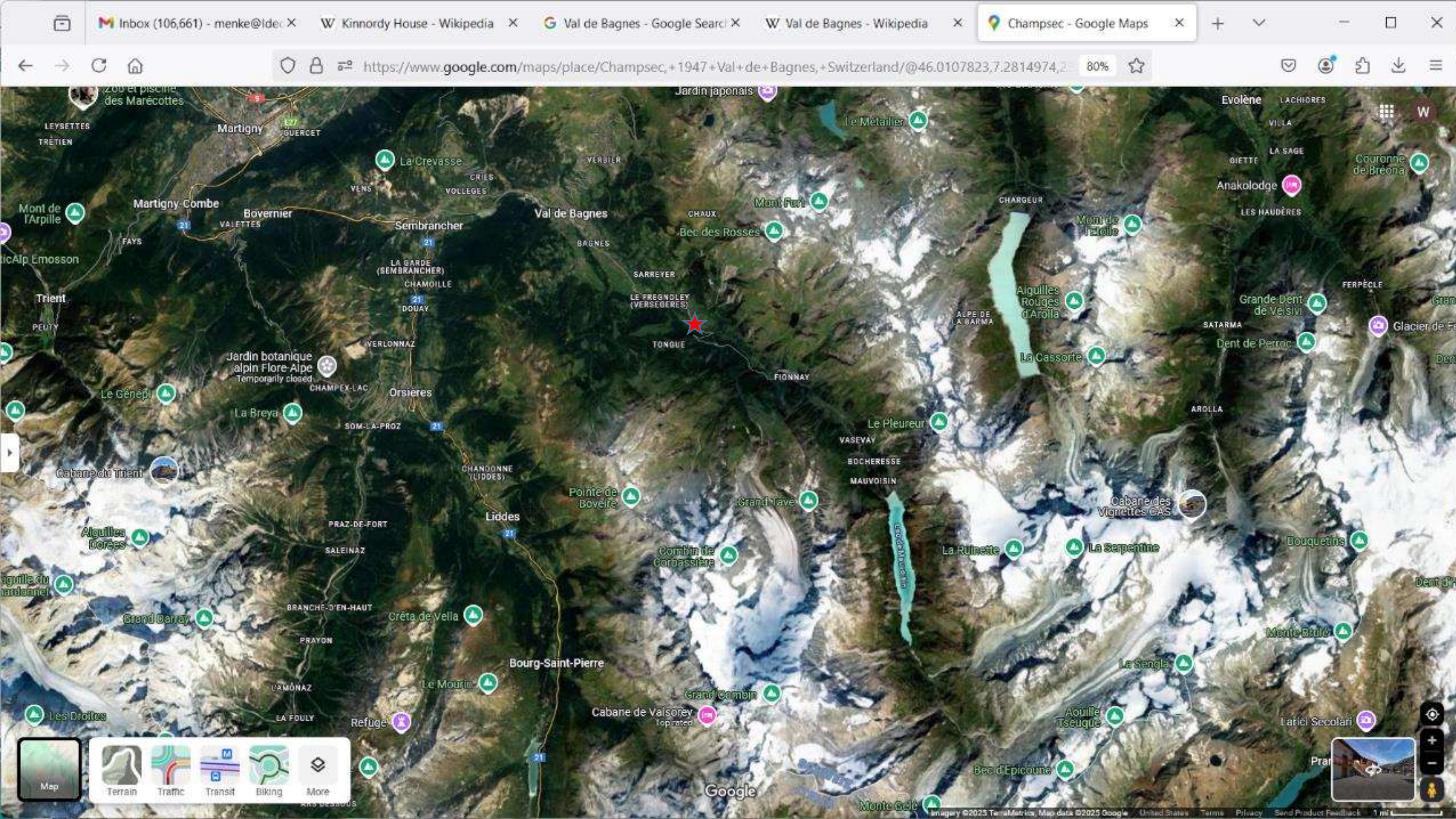
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Martigny
Martigny-Combe
Bovernier
Sembrancher
Val de Bagnes
Mont de l'Arpille
Trient
Jardin botanique alpin Flore-Alpe
Temporarily closed
Orsières
Le Génépi
La Breya
Cabane du Trient
Liddes
Grand Darray
Bourg-Saint-Pierre
Le Mourin
Cabane de Valsorey
Top rated
Refuge
Les Droites
Aiguilles Dorées
Pointe de Boveire
Grand Tavé
Combin de Corbassière
Mont Fort
Bec des Rosses
Le Métailler
Jardin japonais
Evolène
Anakolodge
Couronne de Bréona
Aiguilles Rouges d'Arolla
La Cassorte
Le Pleureur
Grande Dent de Veisivi
Dent de Perroc
Glacier de Fa
Cabane des Vignettes CAS
La Serpentine
La Ruinette
Bouquetins
Mont Brûlé
La Sengla
Aouille Tseuque
Mont Gelé
Bec d'Epicoune
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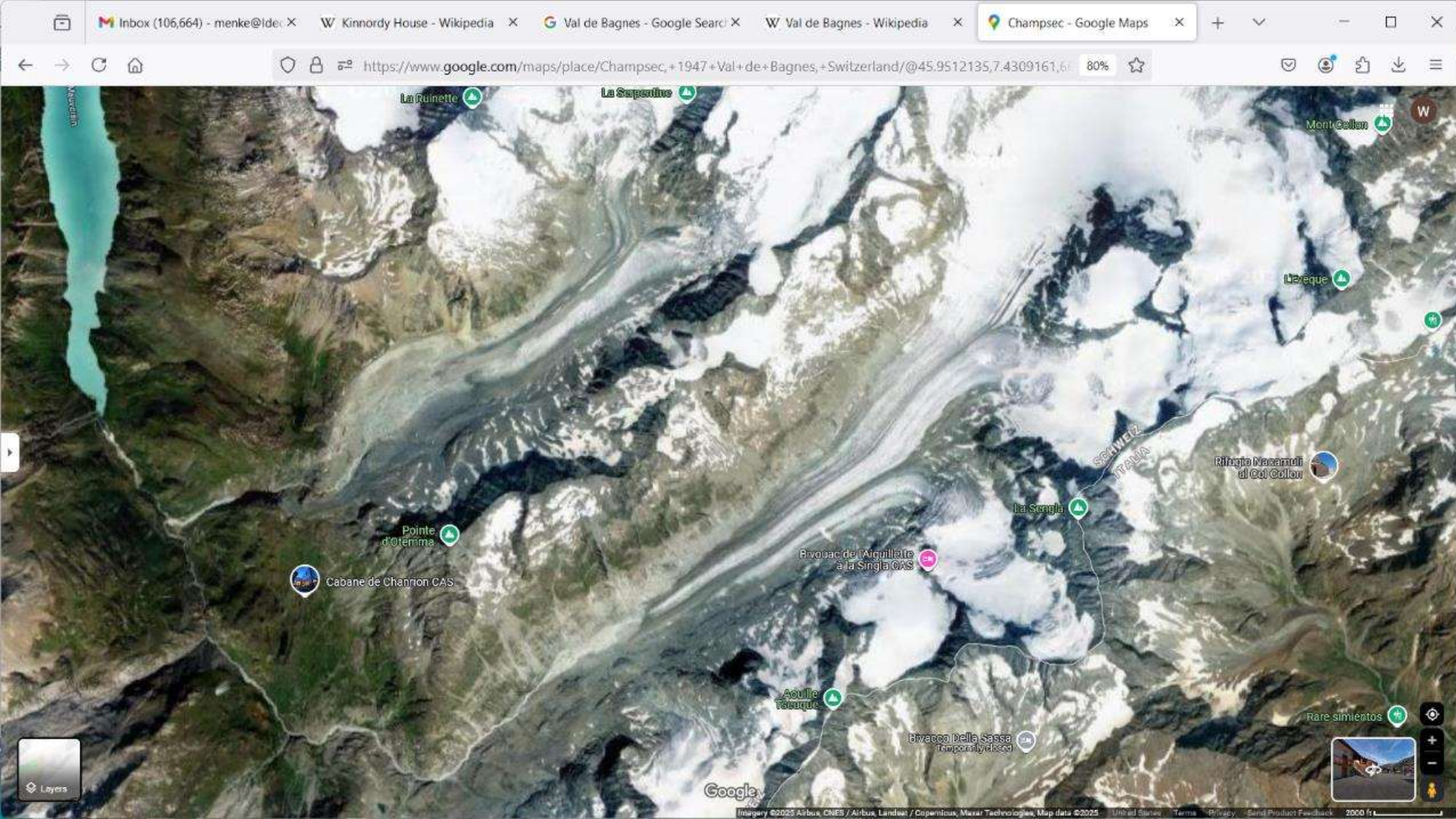
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La Ruinette
La Serpentine
Mont Gelon
Lidèque
SCHWEIZ
ITALIA
Rifugio Nacamuli al Col Collon
La Sengla
Pointe d'Otemma
Bivouac de l'Aiguillette à la Sengla CAS
Cabane de Chanrion CAS
Aouille Tessuque
Bivacco Della Sassa
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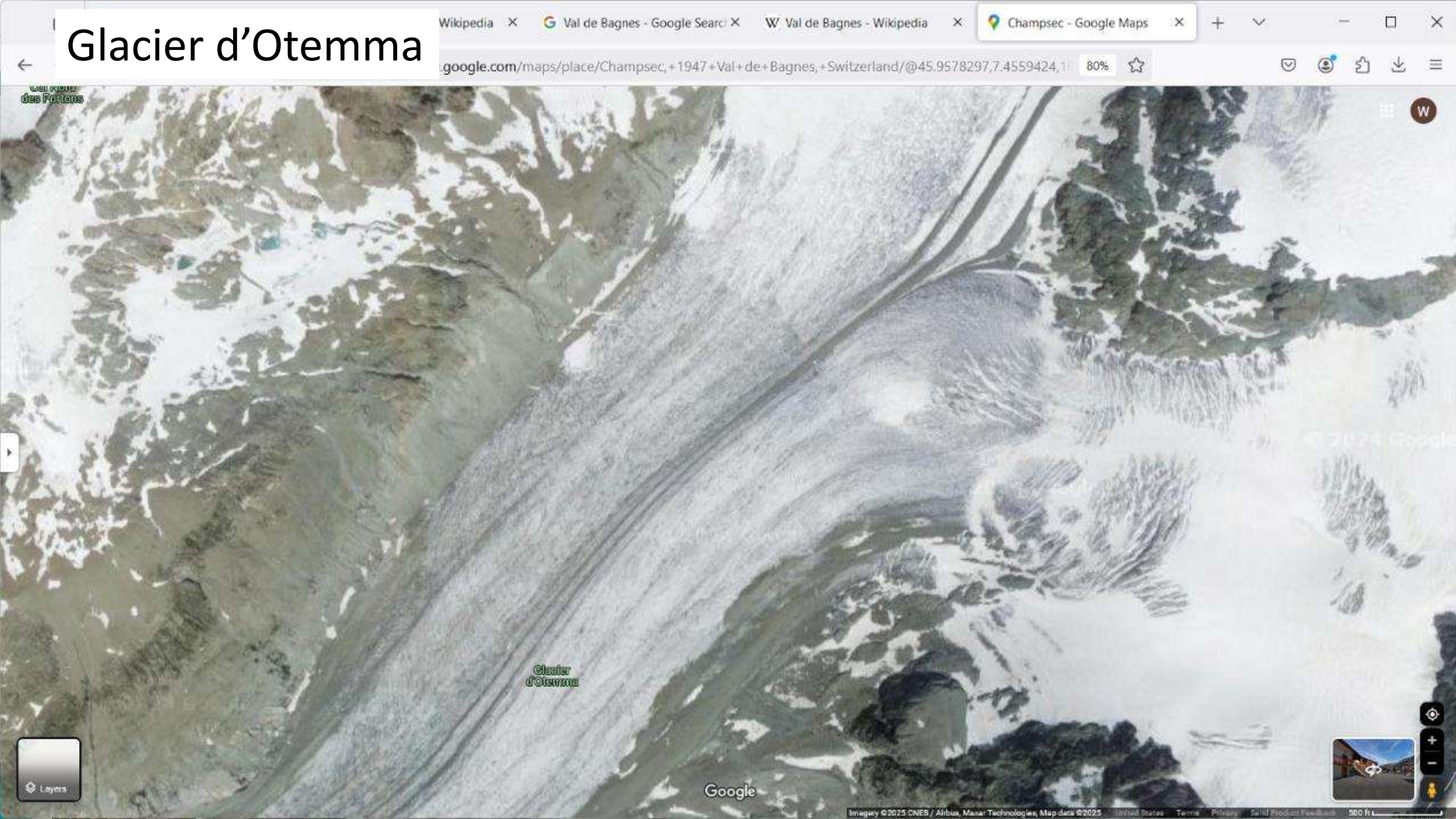
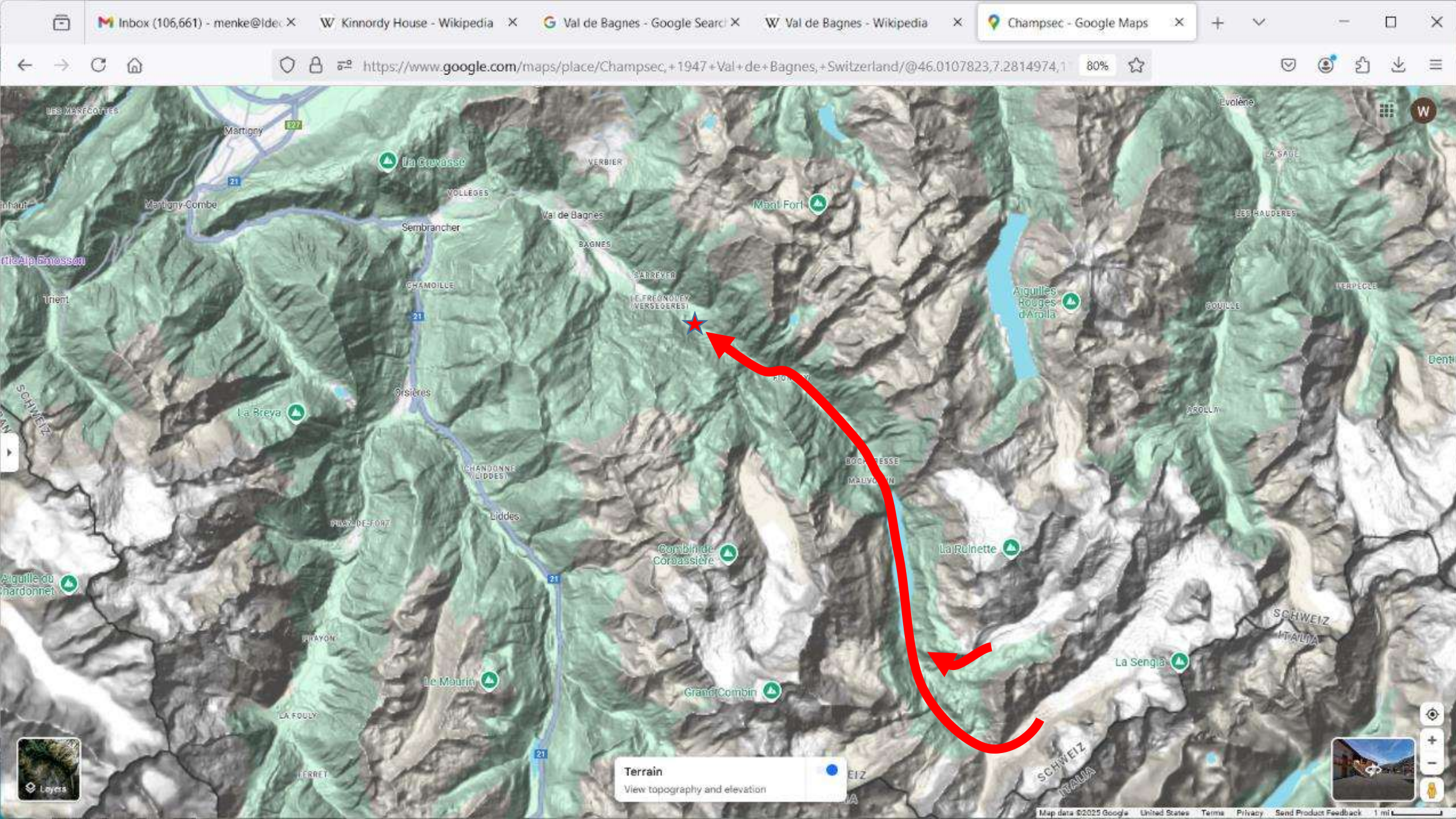
Glacier d’Otemma

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Martigny
La Garrasse
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Sembrancher
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Liddes
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La Rosablanche
La Ruinette
La Sengla
Le Mauvoisin
Grand Combin
Aiguille du Chardonnet
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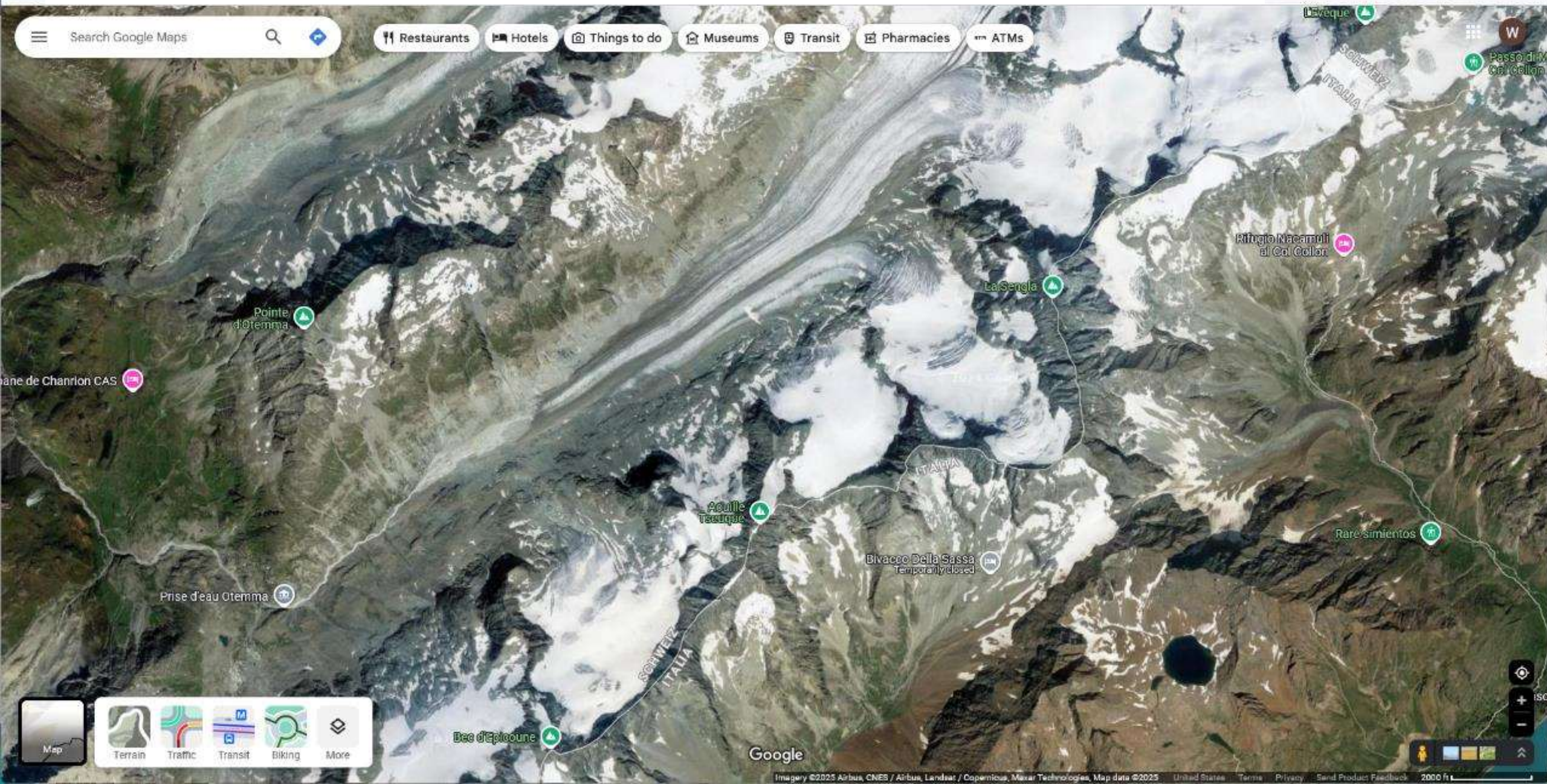
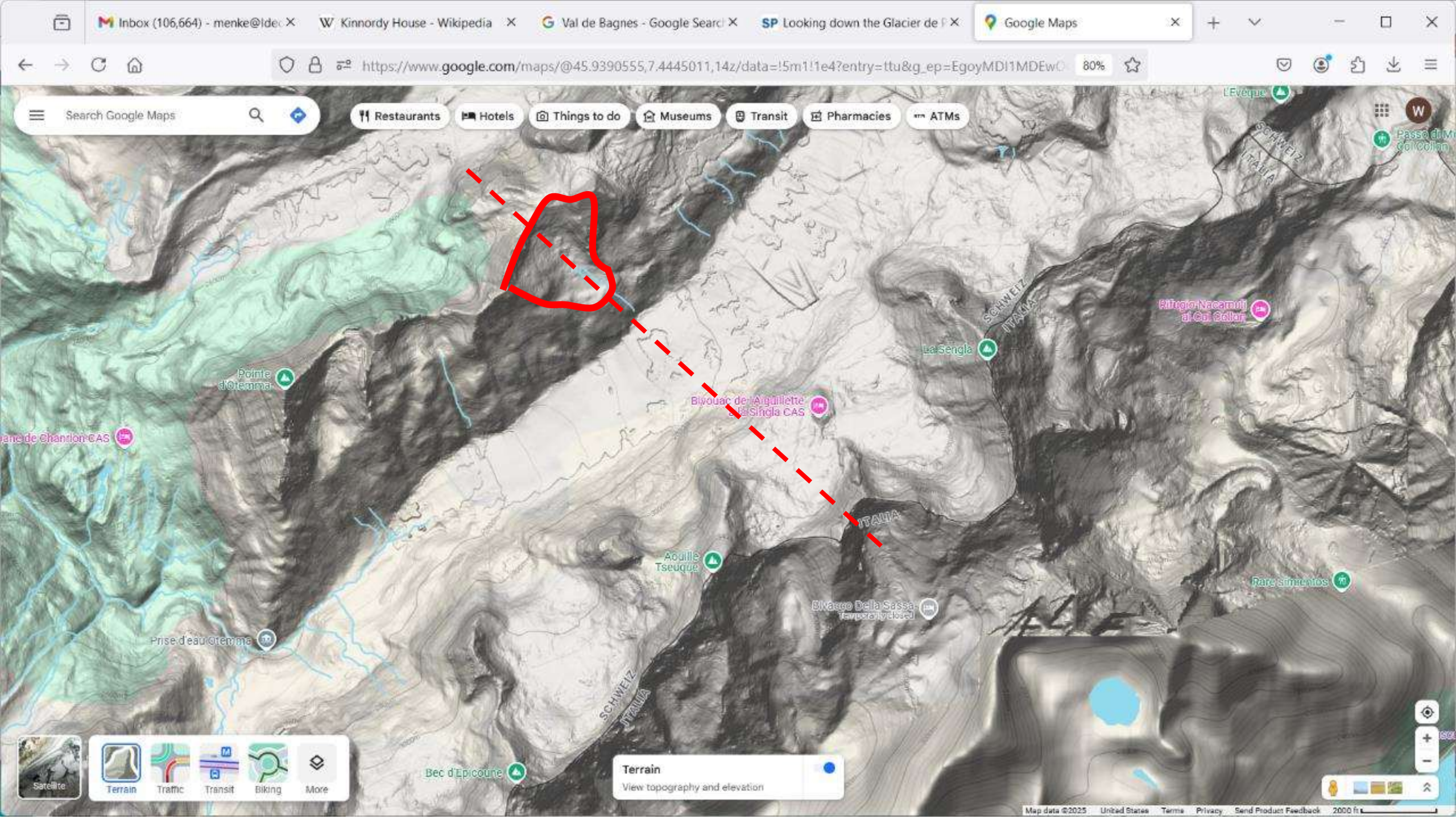
Glacier

Evidence for the Ice Age here. Do you see it?



Evidence for the Ice Age here. Do you see it?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Looking down the Glacier de P
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Museums
Transit
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ATMs
SCHWEIZ
ITALIA
La Sengla
Pointe d'Otemma
Bivouac de l'Aiguillette de la Singla CAS
Aiguille Tseuque
Prise d'eau Otemma
Bec d'Epicoune
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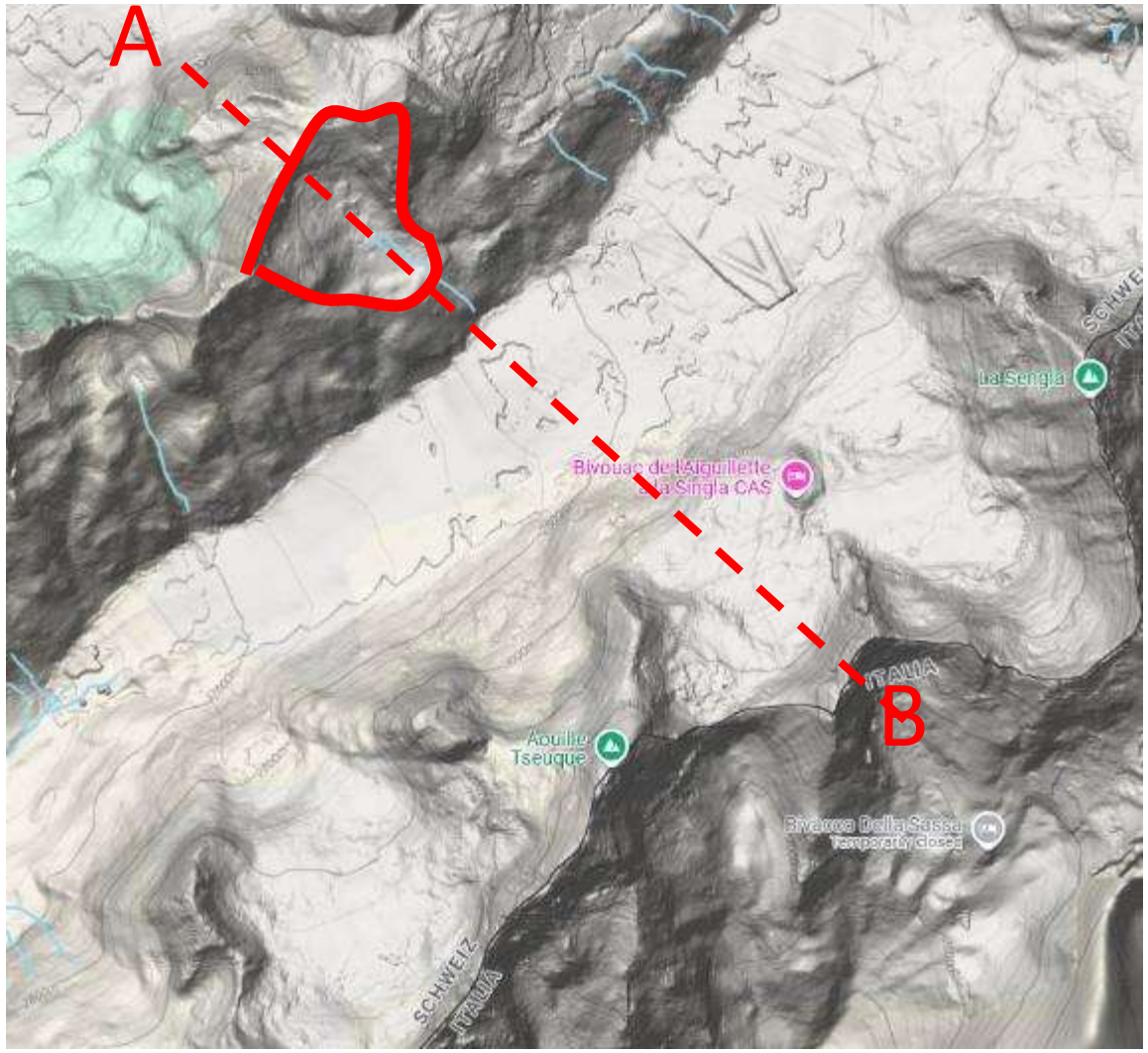
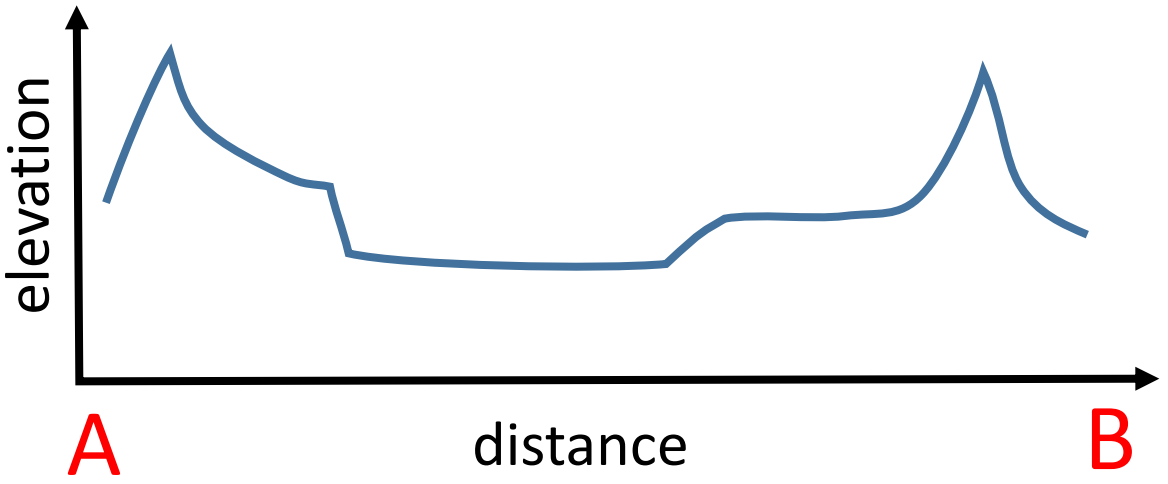
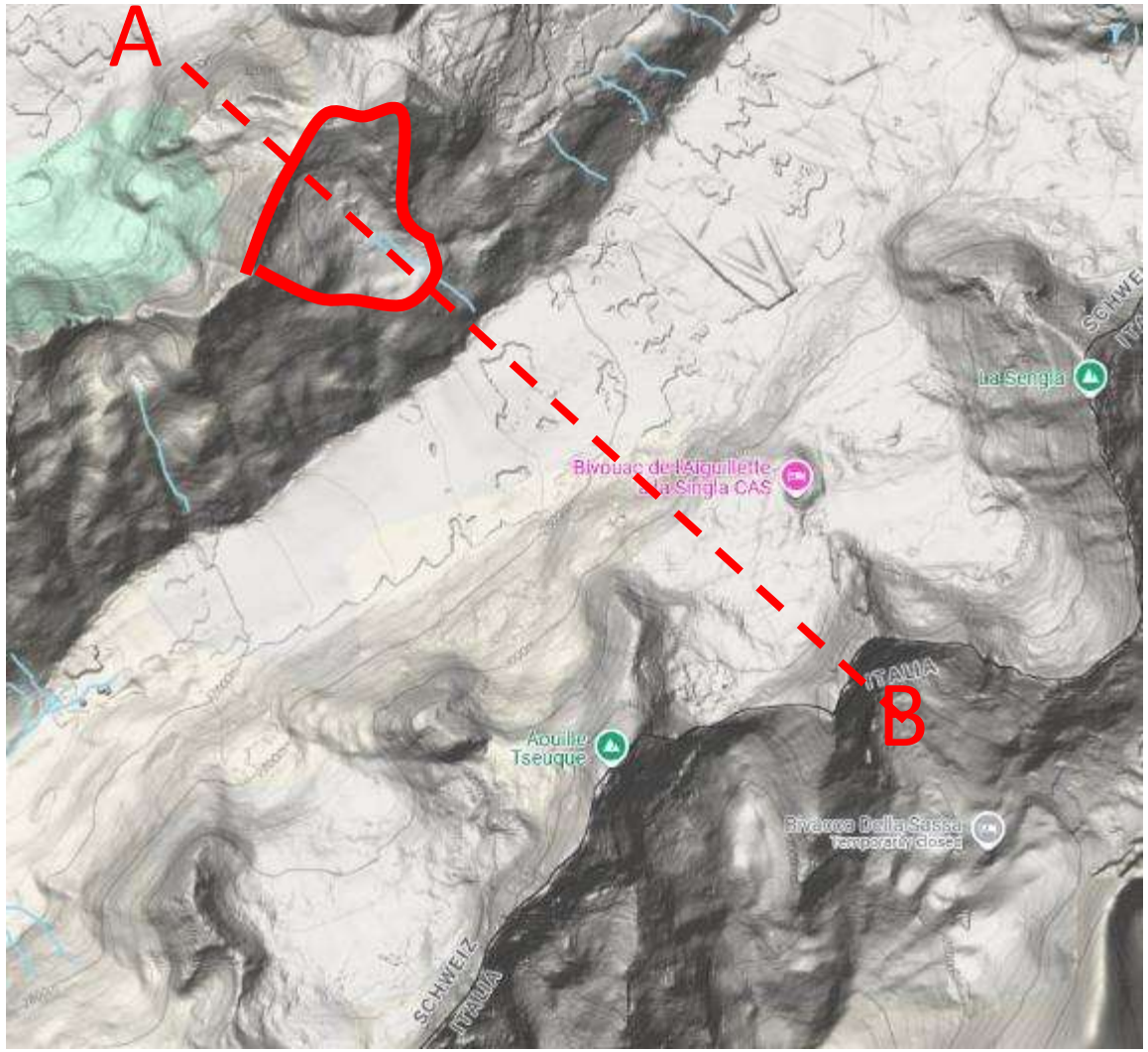
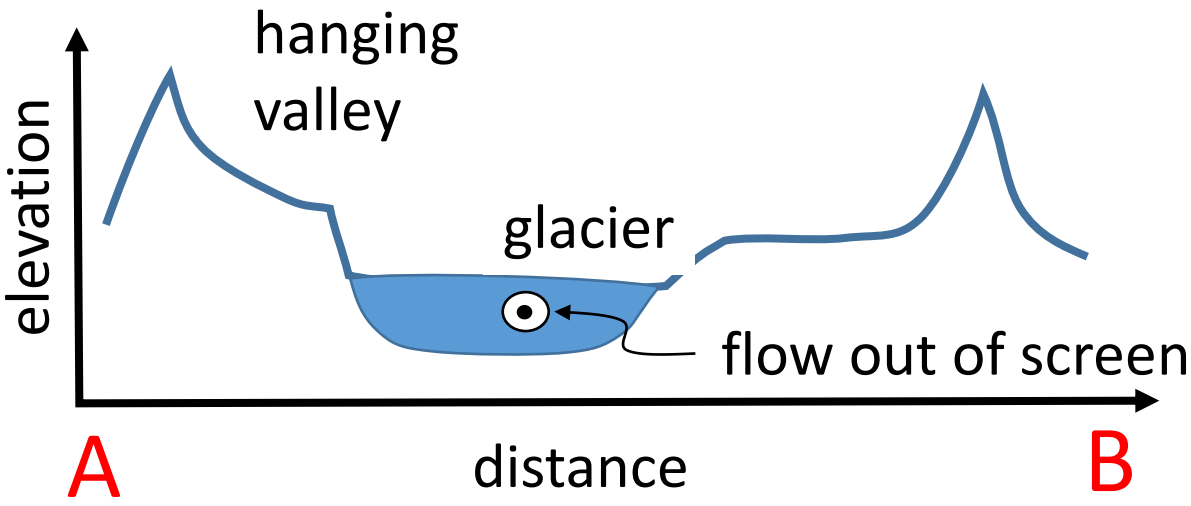
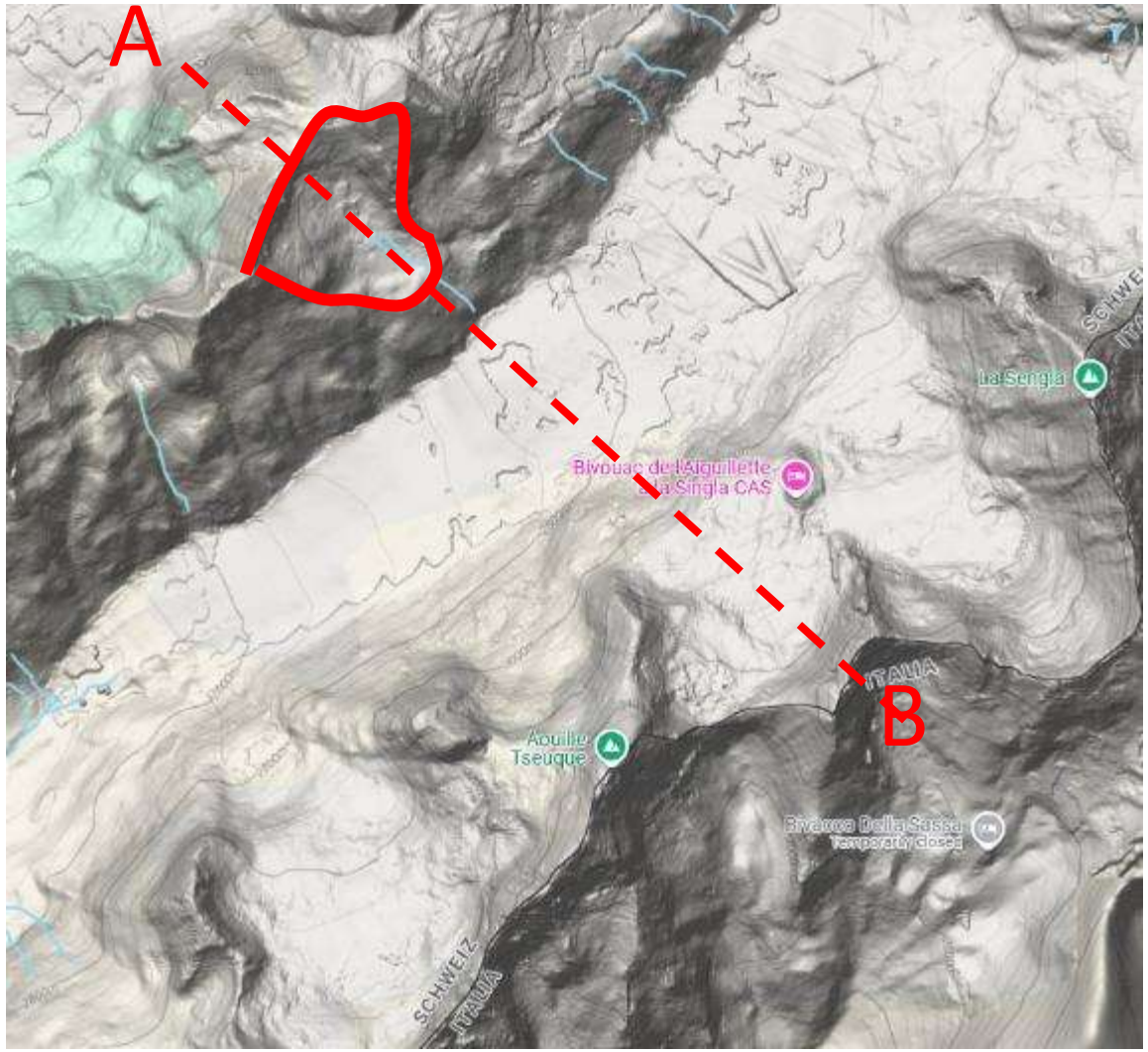

A
B
La Sengla
Bivouac de l'Aiguillette
La Sengla CAS
Aouille
Tseuque
ITALIA
SCHWEIZ
ITALIA


elevation
A
distance
B

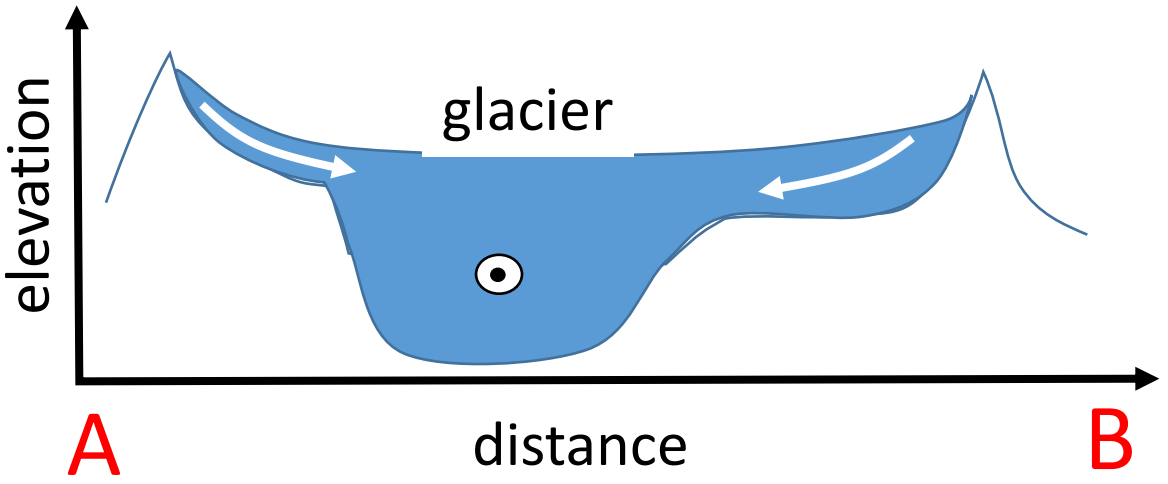

A
B
La Sengla
Bivouac de l'Aiguillette
La Sengla CAS
Aouille
Tseuque
ITALIA
SCHWEIZ
ITALIA

Now


hanging
valley
glacier
flow out of screen
elevation
A
distance
B



During the Ice Age



1821-1833, Ignace Venetz, highway engineer, studies glaciers, characterizes their movements.

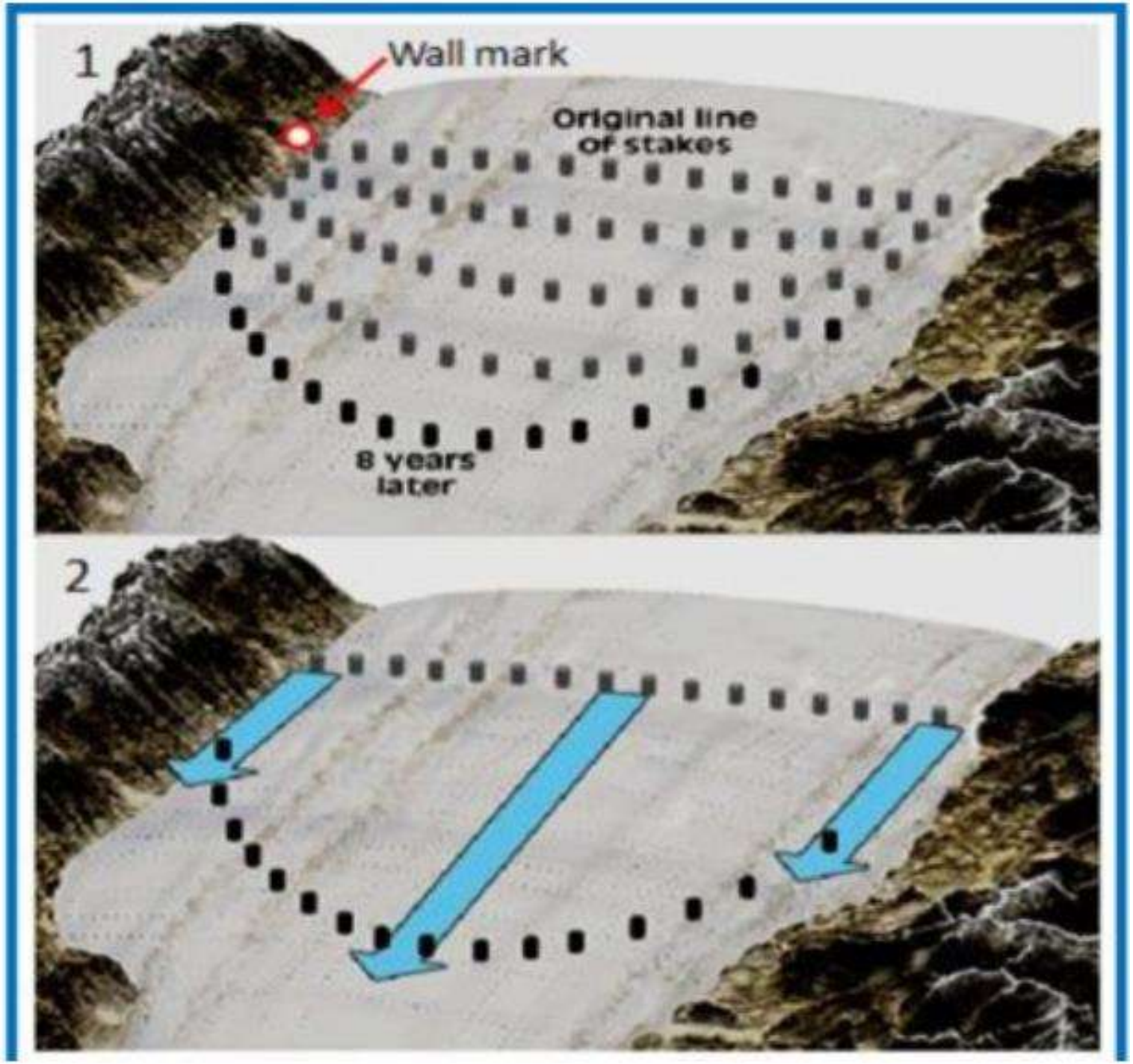
Can you see a glacier move?

have *you* ever seen a glacier move?

time lapse of glacial movement

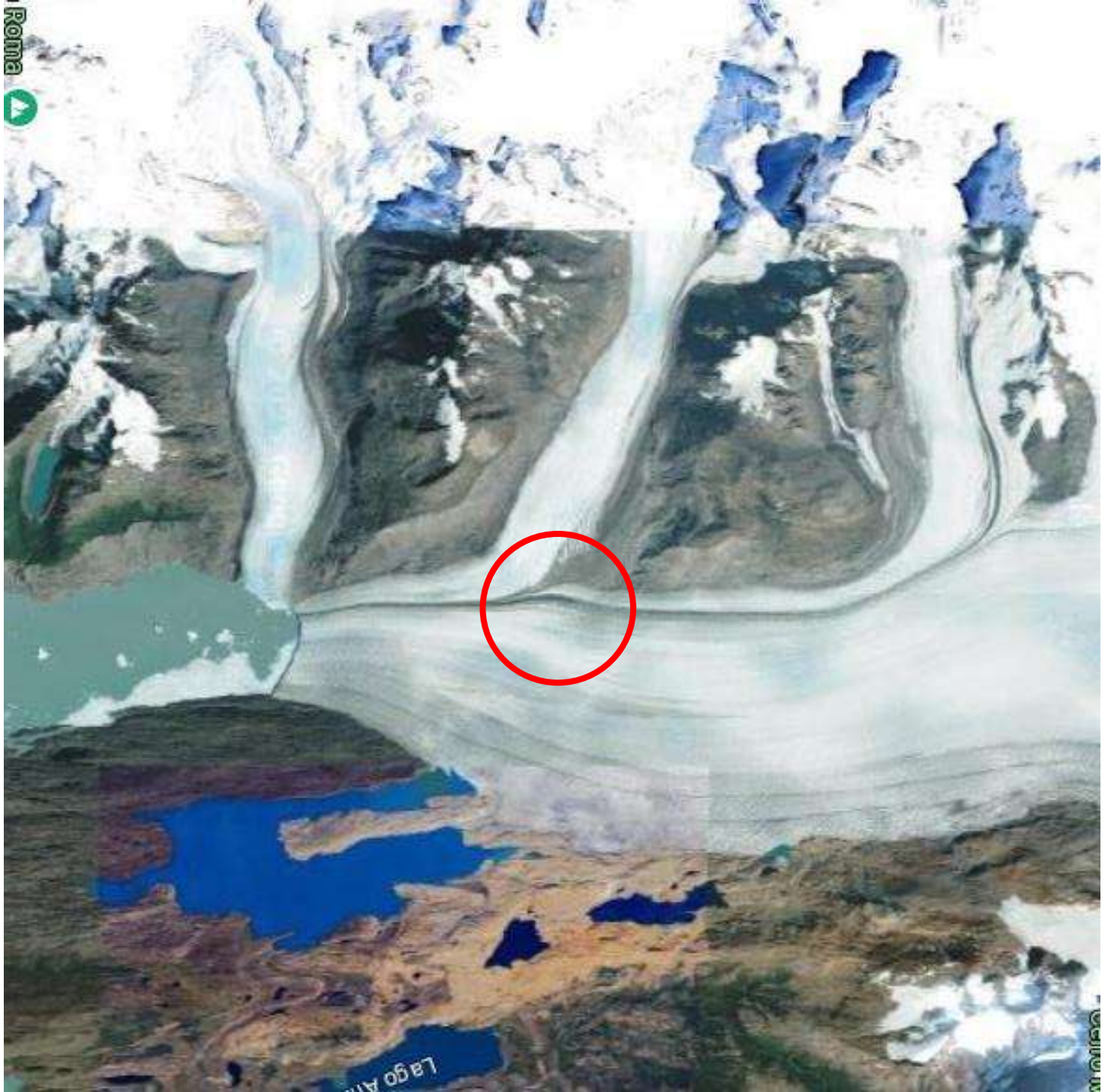
https://www.youtube.com/watch?v=hRhnLtFZxso

Venetz used a line of stakes



Indirect evidence of moving ice.

What's happening here?



Close-up

1829, De Charpentier systematically characterizes evidence of glaciation.

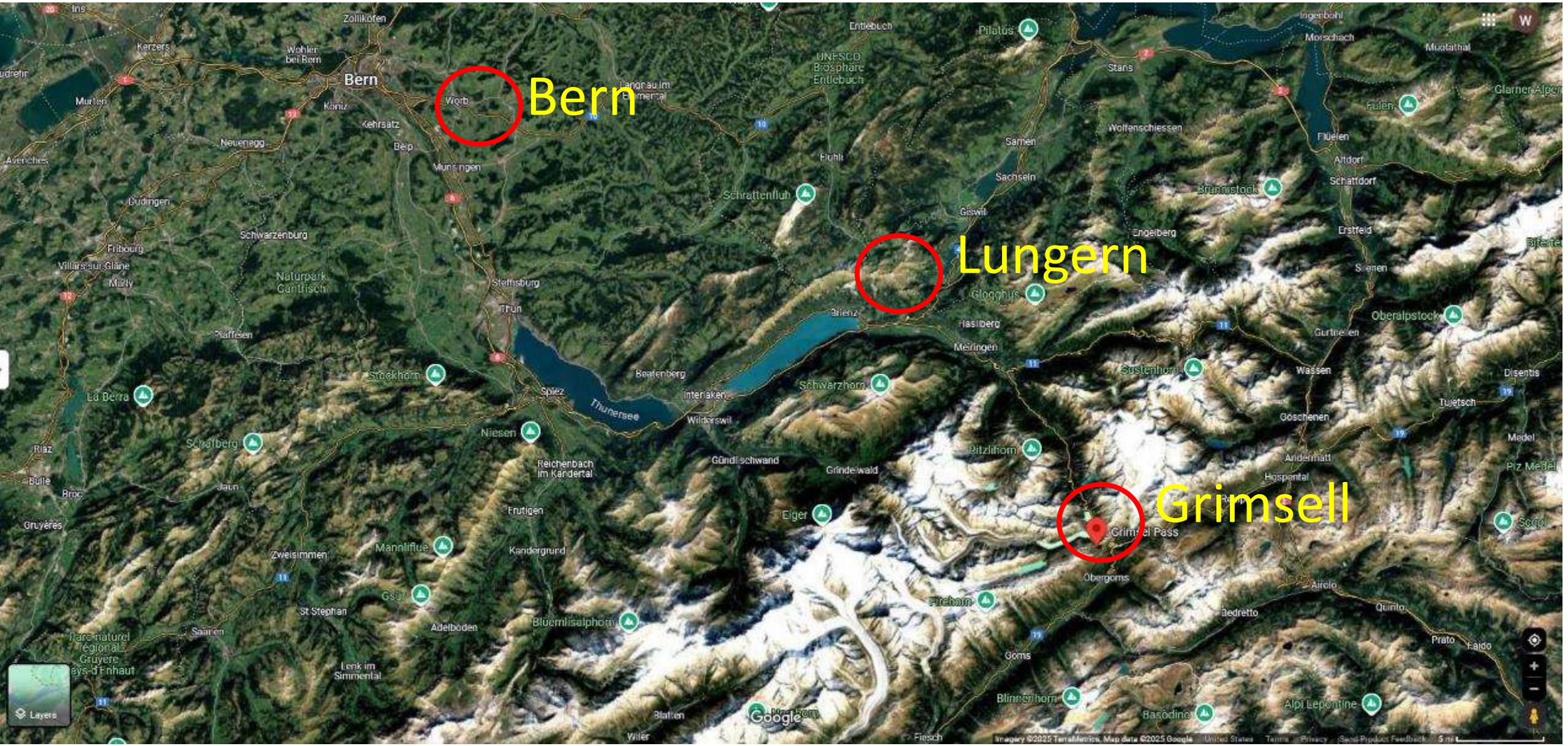
1834, De Charpentier.

Traveling through the valley of Hasli and Lungern, I met on the Brunig road a woodcutter from Meiringen. We talked and walked for a while. As I was examining a large boulder of Grimsel granite, lying next to the path, he said: 'There are many stones of that kind around here, but they come from far away, from the Grimsel, because they consist of Geisberger [granite] and the mountains of this vicinity are not made of it.

When I asked him how he thought that these stones had reached their location, he answered without hesitation, 'The Grimsel glacier transported and deposited them on both sides of the valley, because that glacier extended in the past as far as the town of Bern, indeed water could not deposit them at such an elevation above the valley bottom, without filling the lakes.

This good old man would never have dreamed that I was carrying in my pocket a manuscript in favor of his hypothesis. He was greatly astonished when he saw how pleased I was by his geological explanation, and when I gave him some money to drink to the memory of ancient Grimsel glacier and to the preservation of the the Brunig boulders.


Bern
Lungern
Grimsell
Nesthorn
Google


Bern
Lungern
Grimsell
Bern
Wohler bei Bern
Zollikofen
Kerzers
Murten
Kehrsatz
Neuenegg
Gurbrü
Schwarzenburg
Fribourg
Villars-sur-Glâne
Marly
Naturpark Gantrisch
Stockhorn
La Berra
Schafberg
Riaz
Bulle
Broc
Gruyères
Jaun
Zweisimmen
Saanen
Parc naturel régional Gruyère Pays-d'Enhaut
Lenk im Simmental
St Stephan
Adelboden
Gsteig
Mannlifluh
Bluemlisalphorn
Kandergrund
Frutigen
Reichenbach im Kandertal
Niesen
Spiez
Thunersee
Beatenberg
Interlaken
Wilderswil
Gündlischwand
Grindelwald
Eiger
Schwarzhorn
Ritzlihorn
Titlis
Engelberg
Brunnistock
Stans
Wolfenschiessen
Sarnen
Sachseln
Giswil
Flühli
Schrattenfluh
Entlebuch
Pilatus
Meiringen
Hasliberg
Brienz
Glogghüs
Susenhorn
Oberalpstock
Andermatt
Hospental
Goschenen
Wassen
Tujetsch
Disentis
Grimsel Pass
Obergoms
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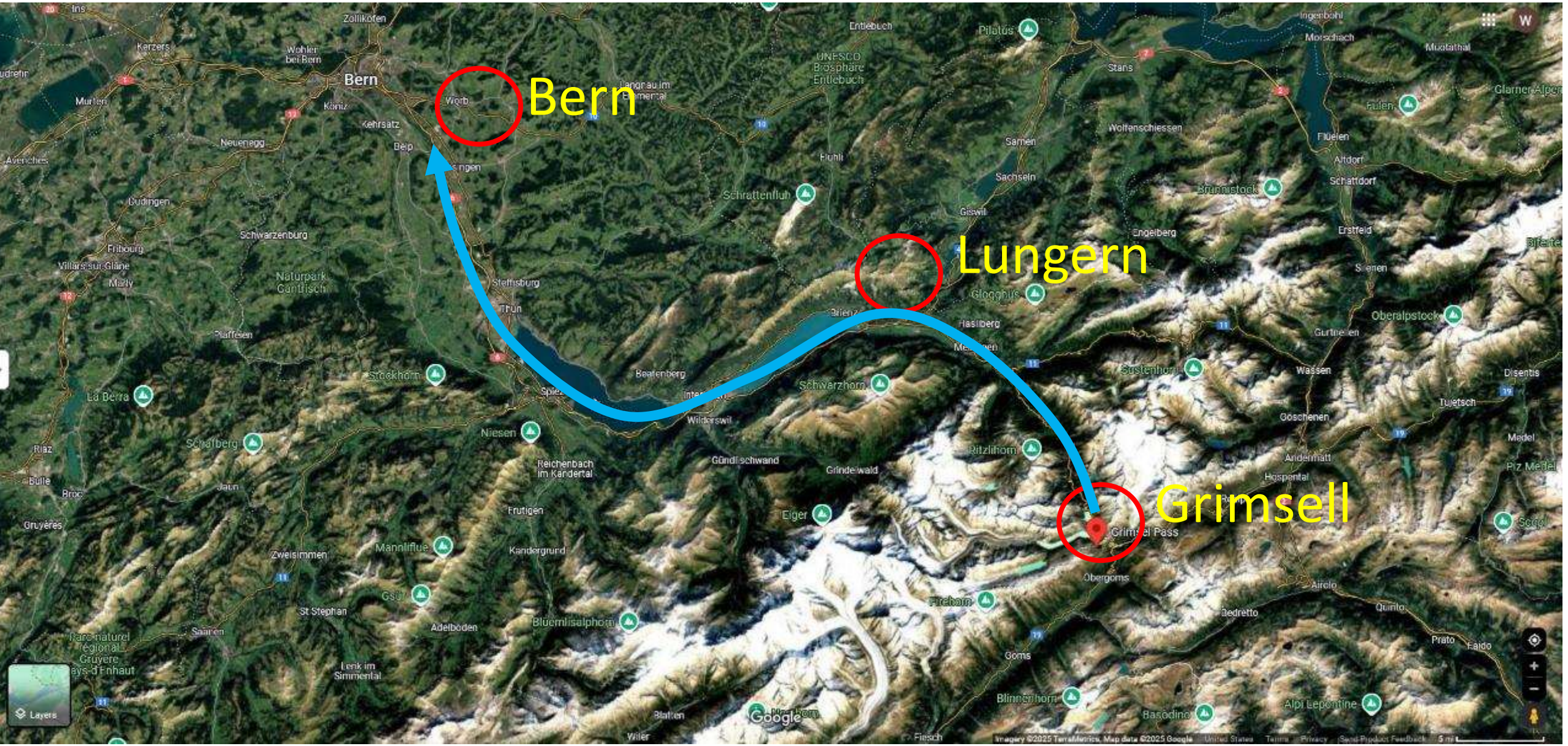
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Villars-sur-Glâne
Naturpark Gantrisch
Steffisburg
Thun
Stockhorn
La Berra
Schallberg
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Saanen
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Lenk im Simmental
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Gündlischwand
Grindelwald
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Schwarzhorn
Blüemlisalphorn
Entlebuch
UNESCO Biosphäre Entlebuch
Pilatus
Stans
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Flühli
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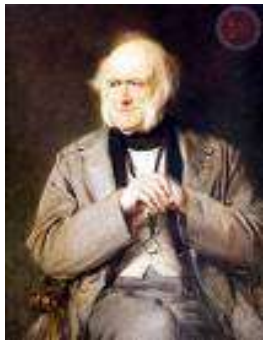
Wolfenschiessen
Engelberg
Hasliberg
Glogghüs
Ritzlihorn
Titlis
Brunnistock
Flüelen
Altdorf
Schattdorf
Erstfeld
Seelisberg
Oberalpstock
Gurtnellen
Wassen
Sustenhorn
Göschenen
Andermatt
Hospental
Tujetsch
Disentis
Medel
Piz Medel
Scopi
Obergoms
Airolo
Quinto
Prato
Faido
Piz Blas
Goms
Blinnenhorn
Basodino
Alpi Lepontine
Layers

1833, Charles Lyell, English geologist & author of *Principles of Geology*. Recognition of 'erratic boulders' (or 'erratics') as geological enigma. Charles Lyell published ice rafting theory of erratics, transport occurred during Noah's flood.



Lyell

1833, Rev. William Buckland, British geologist, recognizes a sea level problem with ice rafting theory. Where did all the water come from?

Buckland

1834, Louis Agassiz hears de Charpentier's talk, but not impressed with it.

1836, Agassiz visits de Charpentier, ostensibly to study fossil fishes. Becomes acquainted with evidence of extensive past glaciation.

1837, Agassiz speaks at Swiss sachet of Natural Sciences. Replaces talk on fossil fishes with one proposing an 'ice age' in Europe and North America. Met with complete disbelief.

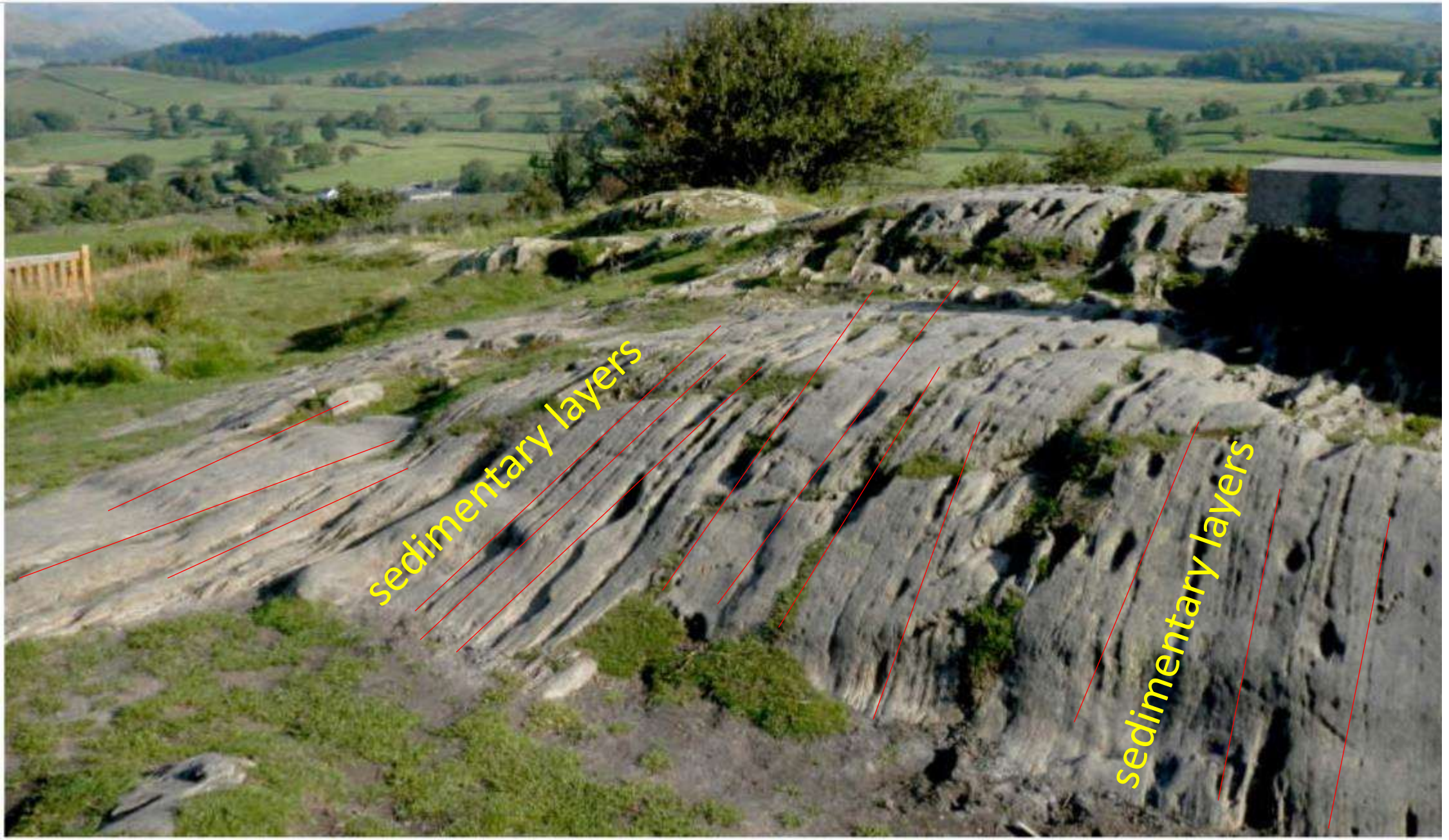
Charpientier

1838, Buckland visits Agassiz in Alps, sees glaciers, but is unconvinced that they were once larger.

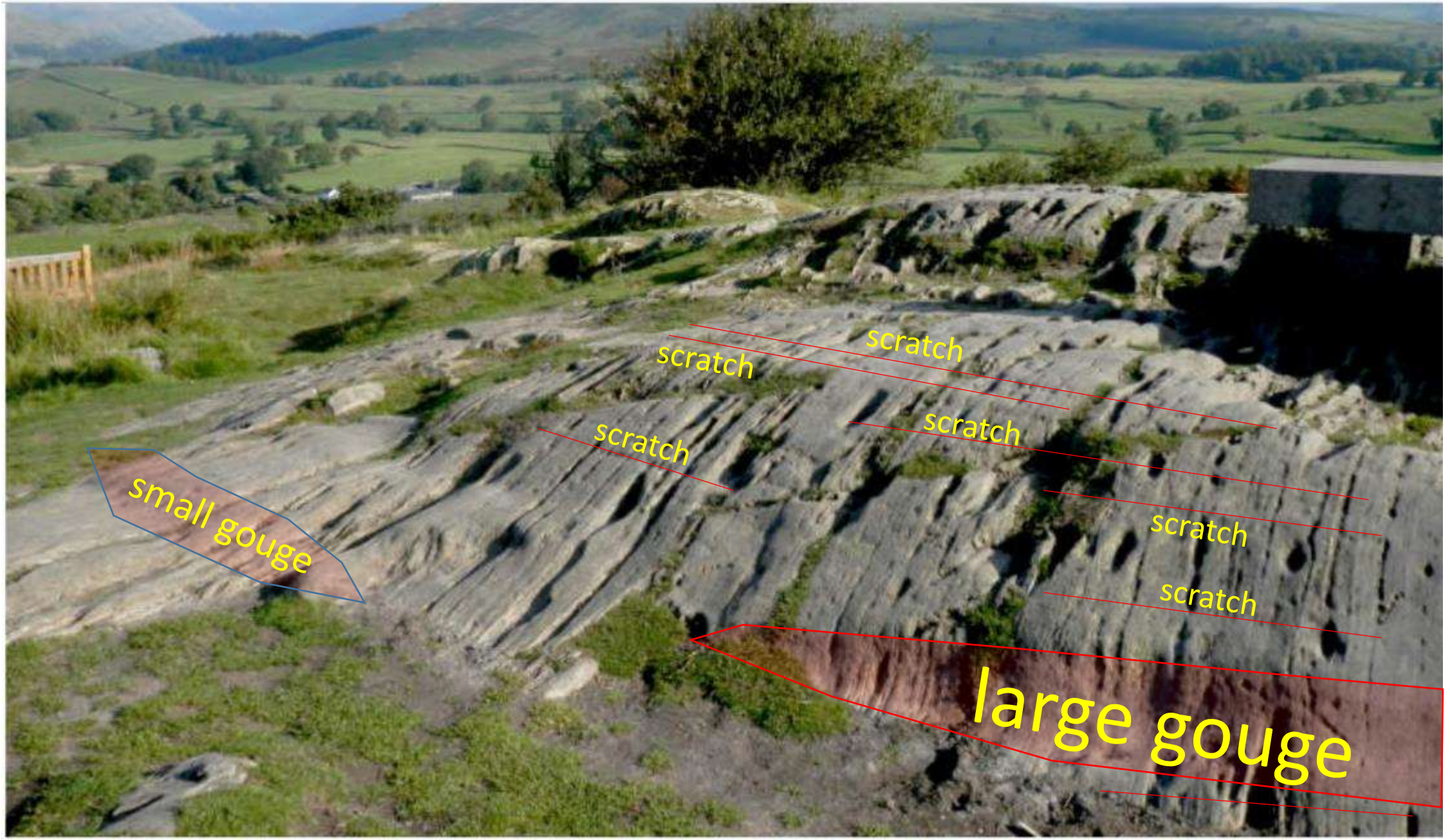
1840, Agassiz published Study on Glaciers, which includes theory of the ice age

1840, Agassiz visits Buckland, shows him **evidence of glaciation in England**.

Rock ledge (shale with glacial scratches) atop Orrest Head (hill)



Rock ledge (shale with glacial scratches) atop Orrest Head (hill)



Rock ledge (shale with glacial scratches) atop Orrest Head (hill)

1840, Buckland convinces Lyell.

“Lyell has adopted your theory in toto!! On my showing him a beautiful cluster of moraines within **two miles of his father's house [in Scotland]**, he instantly accepted it, as solving a host of difficulties which have all his life embarrassed him.”


Lyell's father's house
Tarbert
Leverburgh
Ullapool
Dornoch
Tain
Gairloch
Lossiemouth
Buckie
Banff
Fraserburgh
Elgin
Duntulm
Staffin
Dingwall
Nairn
Forres
Keith
Turriff
Peterhead
North Uist
Inverness
Isle of Benbecula
Dunvegan
Portree
Applecross
Dufftown
Huntly
Ellon
Oldmeldrum
Inverurie
Plockton
Kyle of Lochalsh
Skye
Aviemore
Daliburgh
Lochboisdale
Fort Augustus
Westhill
Aberdeen
Kingussie
Cairngorms National Park
Ballater
Banchory
Armadale
Mallaig
Ardmhor
Castlebay
Stonehaven
Vatersay
Fort William
Pitlochry
Kinnoull Hill
Acharacle
Glencoe
Forfar
Tobermory
Aberfeldy
Blairgowrie and Rattray
Arbroath
Carnoustie
Isle of Mull
Oban
Dundee
Perth
Fionnphort
St Andrews
Glenrothes
Stirling
Kirkcaldy
Dunfermline
North Berwick
Dunbar
Loch Lomond & The Trossachs National Park
Falkirk
Edinburgh
Livingston
Paisley
Glasgow
Eyemouth
Berwick-upon-Tweed
Kilchoman
Islay
Kilmarnock
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Lyell's father's house
Auchronie
Glenesk
Glensaugh
Auchenblae
Fordoun
Fettercairn
The Burn
Clova
Glenclova
Spittal of Glenshee
Glenshee
Croftmore
Old Blair
Blair Atholl
Dalnaglar Castle
Straloch
Enochdhu
Killiecrankie
Kirkton of Glenisla
Kirkmichael
Glenprosen
Edzell
Luthermuir
Stracathro
St Cyrus
Little Brechin
Brechin
Hillside
Cortachy
Memus
Tannadice
Finavon
Montrose
Pitlochry
Kilry
Bridgend of Lintrathen
Colin McSmith Home Electricals Kirriemuir
Lunanhead
Forfar
Friockheim
Inverkeilor
Letham
Grandtully
Ballinluig
Logierait
Aberfeldy
Alyth
Dunkeld
Birnam
Tay Forest Park
Blairgowrie and Rattray
Meigle
Clunie
Caputh
Murthly
Letham Grange
Auchmithie
St Vigeans
Arbroath
Elliot
Monikie
Tealing
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Kinnordy Estates
Colin M Smith Home Electricals Kirriemuir
Auchronie
Glenesk
Glensaugh
Auchenblae
Fordoun
Fettercairn
The Burn
Clova
Spittal of Glenshee
Glenshee
Croftmore
Old Blair
Blair Atholl
Dalnaglar Castle
Straloch
Enochdhu
Killiecrankie
Kirkton of Glenisla
Kirkmichael
Glenprosen
Edzell
Luthermuir
Stracathro
St Cyrus
Little Brechin
Brechin
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Tannadice
Finavon
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How well did Agassiz do in proving a

Global Ice Age ?

What attributes does a

Global Ice Age Have

Global

Contemporaneous

What technologies were available in the 1840’s to address them?

Global … relatively easy

Contemporaneous … much harder

1846, Agassiz visits North America:

"I sprang on the shore [at Halifax] and started at a brisk pace for the heights above the landing.... I was met by the familiar signs, the polished surfaces, the furrows and scratches, the line engravings of the glacier ... and I became convinced that here also this great agent had been at work."


Halifax
New York
Lebel-sur-Quévillon
Gaspe
Corner Brook
Saguenay
Rimouski
Percé
Stephenville
Rouyn-Noranda
Carleton-sur-mer
La Vérendrye Wildlife Reserve
Laurentides Wildlife Reserve
Riviere-du-Loup
La Malbaie
Bathurst
Channel-Port aux Basques
Edmundston
NEW BRUNSWICK
St Pierre Miquelo
Québec City
Trois Rivières
Summerside
Cape Breton Island
Sydney
Moncton
PRINCE EDWARD ISLAND
Algonquin Provincial Park
Fredericton
Ottawa
Montreal
Sherbrooke
Antigonish
Saint John
Halifax Regional Municipality
MAINE
Bangor
VERMONT
Kingston
Portland
NEW HAMPSHIRE
Rochester
Syracuse
Saratoga Springs
NEW YORK
Buffalo
Albany
MASSACHUSETTS
Boston
Providence
CONNECTICUT
RI
New Haven
Nantucket
Harrisburg
Philadelphia
Layers
Shawinigan
Quebec, Canada
46.640388, -72.643445
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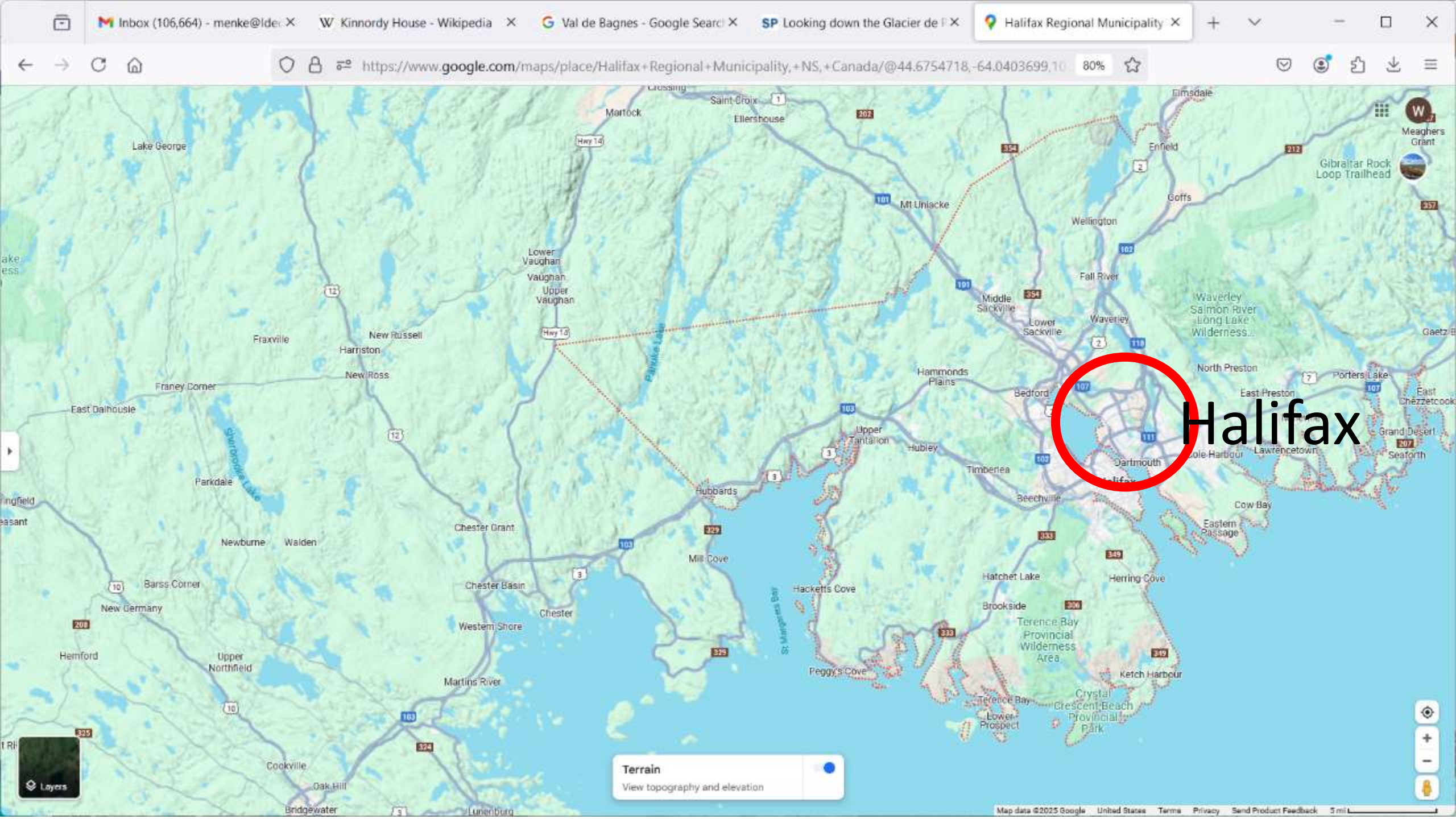
Halifax
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Kinnordy House - Wikipedia
Val de Bagnes - Google Searc
Looking down the Glacier de F
Halifax Regional Municipality
https://www.google.com/maps/place/Halifax+Regional+Municipality,+NS,+Canada/@44.6754718,-64.0403699,10
80%
Martock
Saint Croix
Ellershouse
Elmsdale
Enfield
Meaghers Grant
Gibraltar Rock Loop Trailhead
Lake George
Mt Uniacke
Goffs
Wellington
Lower Vaughan
Vaughan
Upper Vaughan
Fall River
Middle Sackville
Lower Sackville
Waverley
Waverley Salmon River Long Lake Wilderness...
Fraxville
New Russell
Harriston
New Ross
Franey Corner
East Dalhousie
Hammonds Plains
Bedford
North Preston
East Preston
Porters Lake
Upper Tantallon
Hubley
Timberlea
Dartmouth
Lawrencetown
Seaforth
Grand Desert
Parkdale
Hubbards
Beechville
Cow Bay
Eastern Passage
Chester Grant
Newburne
Walden
Mill Cove
Hatchet Lake
Herring Cove
Barss Corner
New Germany
Chester Basin
Chester
Hacketts Cove
Brookside
Terence Bay Provincial Wilderness Area
Western Shore
Hemford
Upper Northfield
Martins River
Peggy's Cove
Ketch Harbour
Terence Bay
Lower Prospect
Crystal Crescent Beach Provincial Park
Cookville
Oak Hill
Bridgewater
Lunenburg
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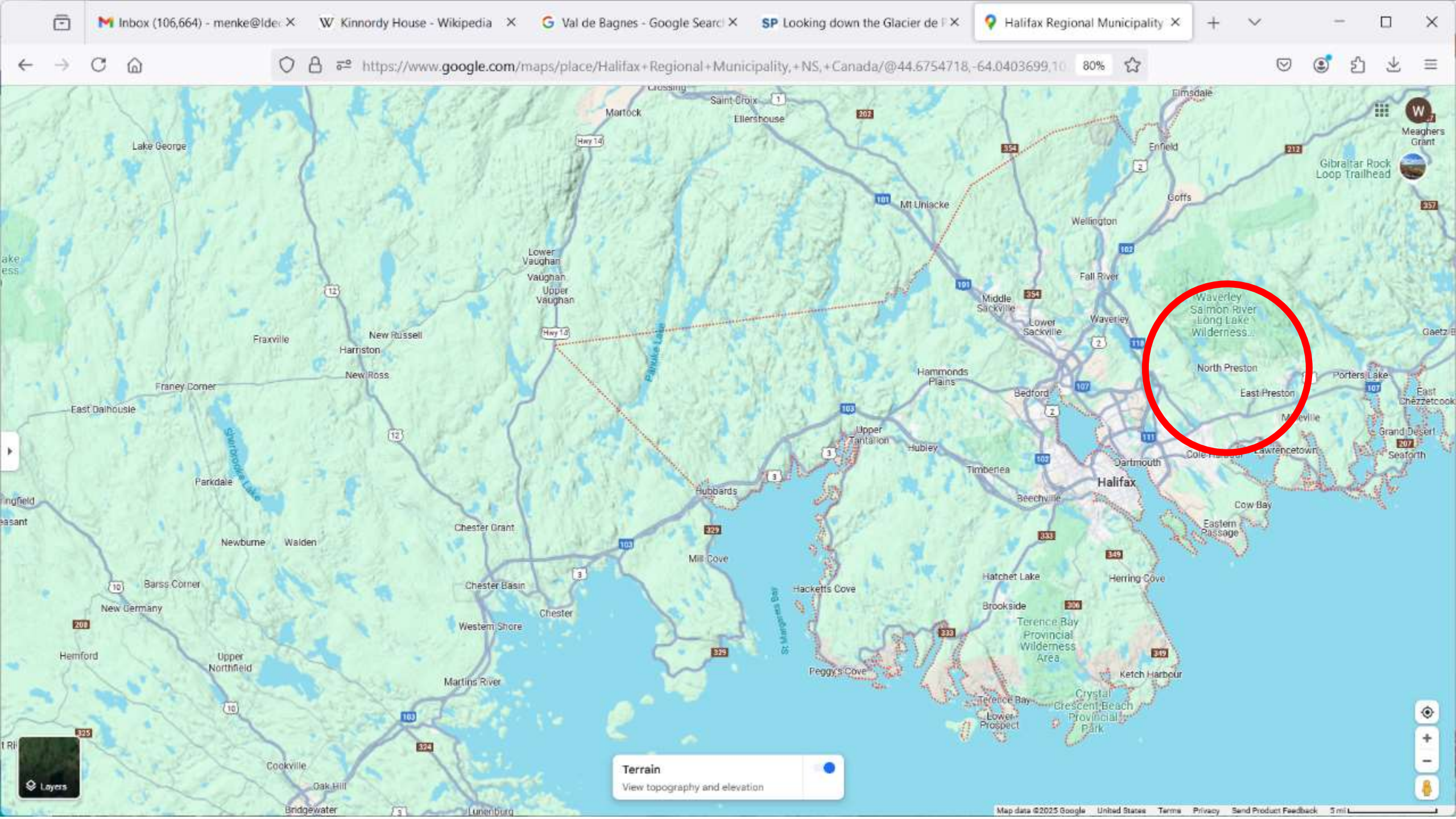
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Timberlea
Dartmouth
Halifax
Lawrencetown
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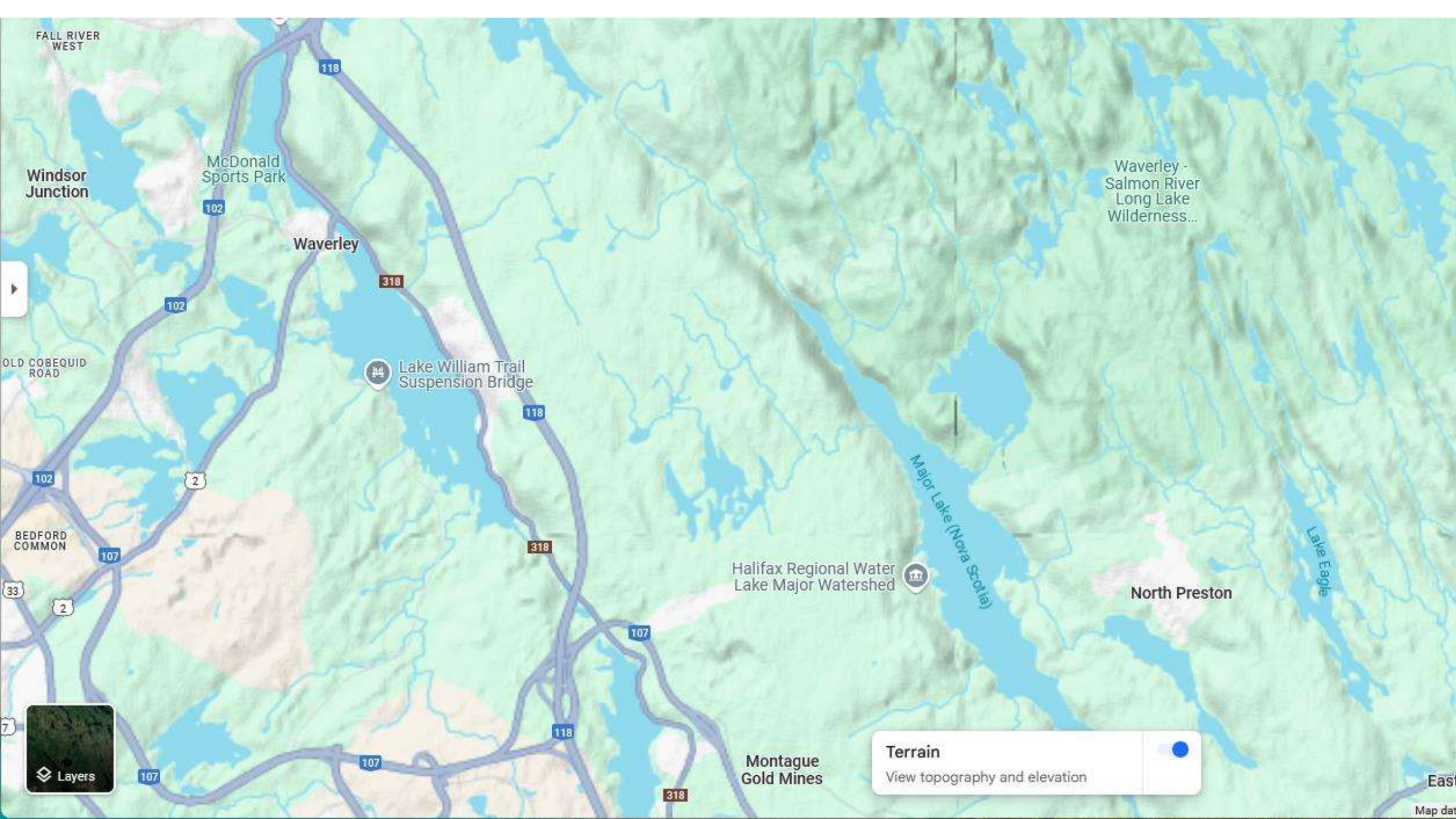
FALL RIVER WEST
Windsor Junction
McDonald Sports Park
Waverley
Waverley - Salmon River Long Lake Wilderness...
OLD COBEQUID ROAD
Lake William Trail Suspension Bridge
BEDFORD COMMON
Halifax Regional Water Lake Major Watershed
Major Lake (Nova Scotia)
Lake Eagle
North Preston
Montague Gold Mines
East
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118
102
318
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107
33


FALL RIVER WEST
Windsor Junction
McDonald Sports Park
Waverley
Waverley - Salmon River Long Lake Wilderness...
Glacial valley
OLD COBEQUID ROAD
Lake William Trail Suspension Bridge
BEDFORD COMMON
Halifax Regional Water Lake Major Watershed
North Preston
Lake Eagle
Montague Gold Mines
Layers
Terrain
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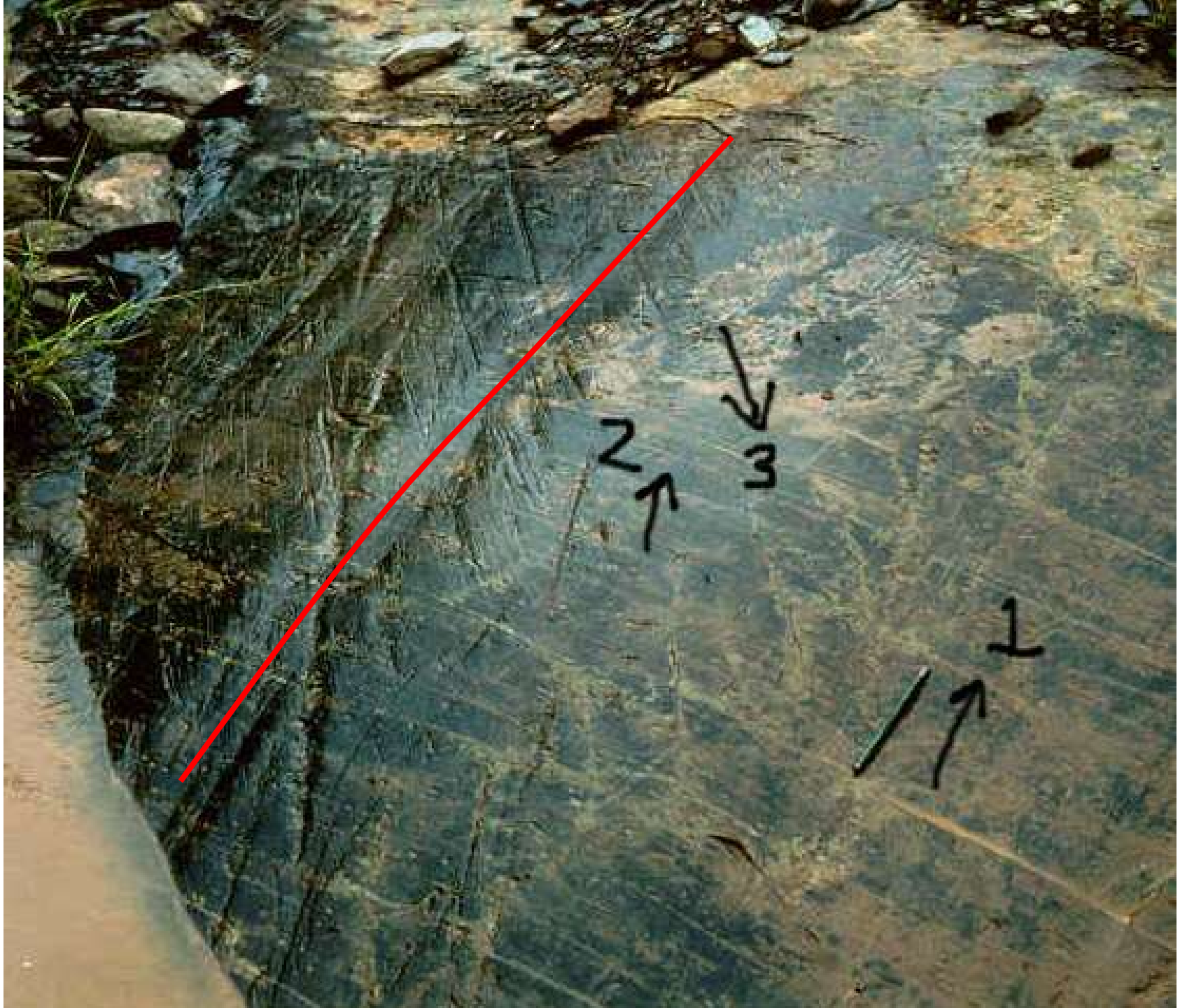
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Global … relatively easy

Contemporaneous … much harder

requires precise dating

Global … relatively easy

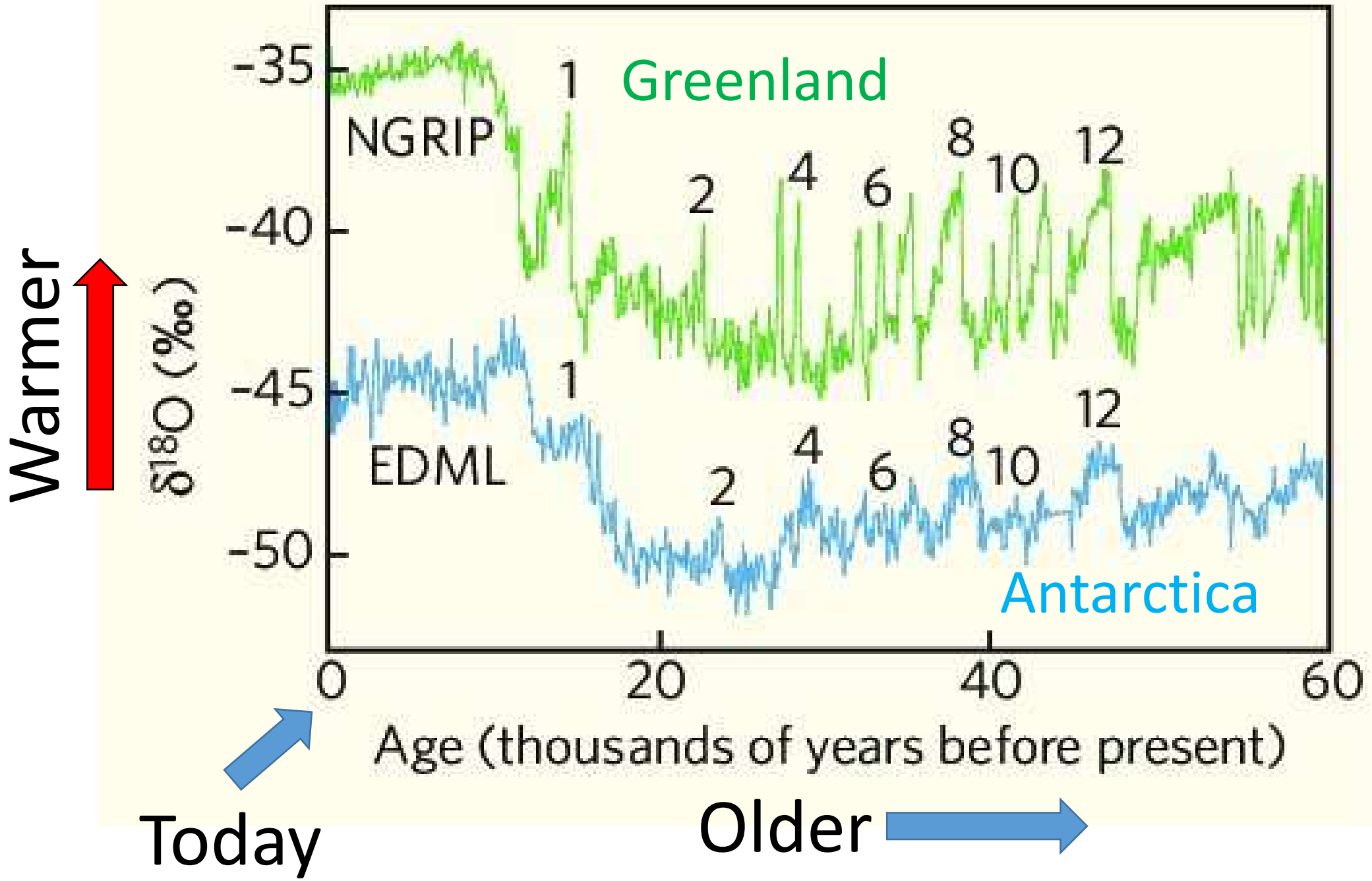
Contemporaneous … much harder

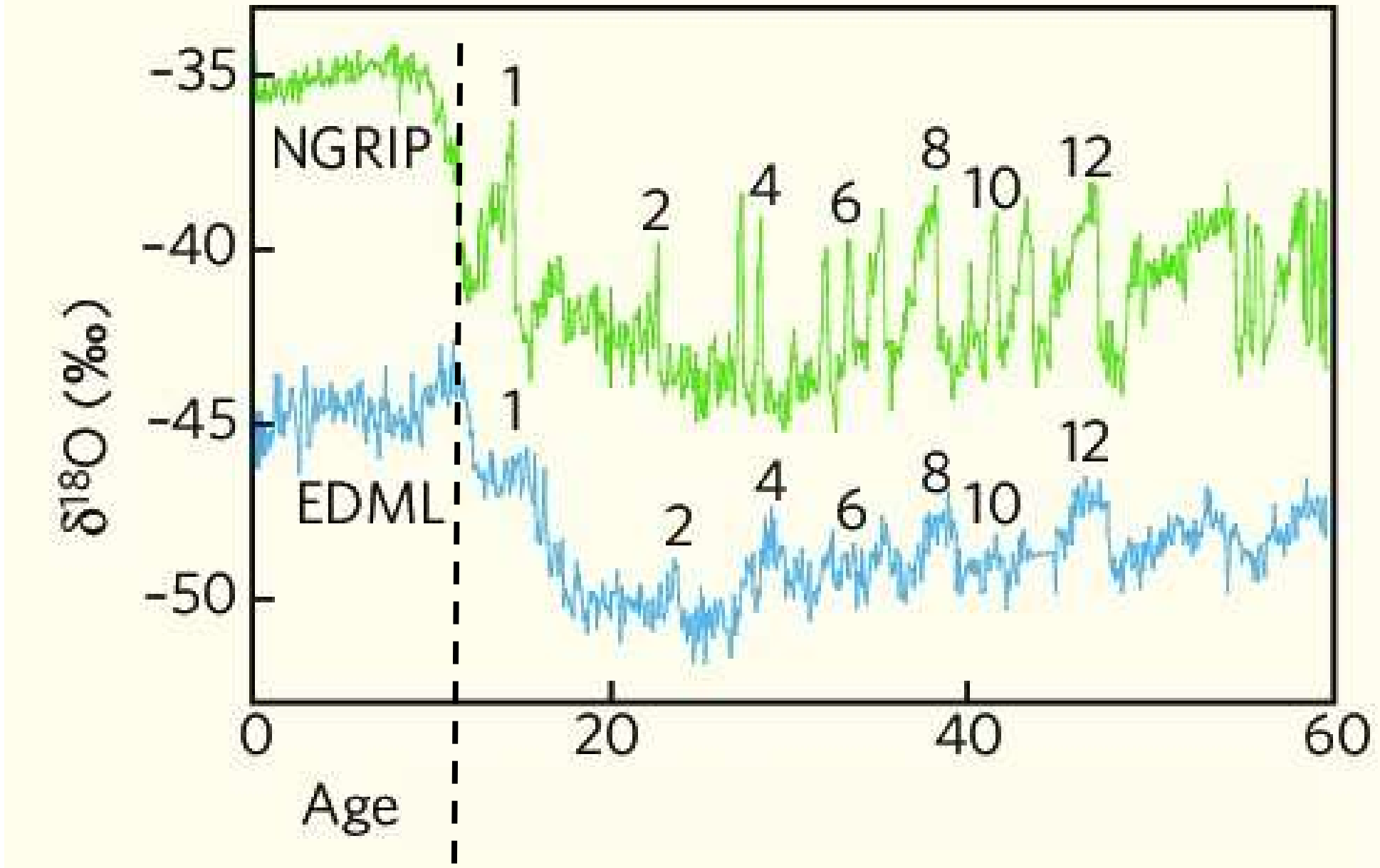
Ice cores … just count annual ice layers

Global … relatively easy

Contemporaneous … much harder

Ice cores … but you have to have a way of estimating the temperature when the ice formed


Warmer
δ18O (‰)
-35
-40
-45
-50
NGRIP
EDML
1
2
4
6
8
10
12
Greenland
Antarctica
0
20
40
60
Age (thousands of years before present)
Today
Older



11.7 end of the Ice Age