M. Chevalier

Pleistocene and Holocene geomorphological transformations in the Valira valleys (SE Pyrenees)

Valentí Turu Michels

Pleistocene in the Pyrenees? Glaciers

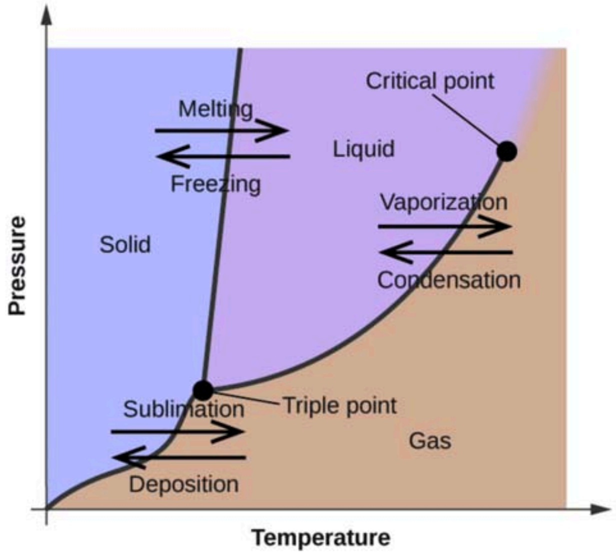
The water ice and glaciers

The melting temperature of water decreases slightly as pressure increases. Water is an unusual substance in this regard.

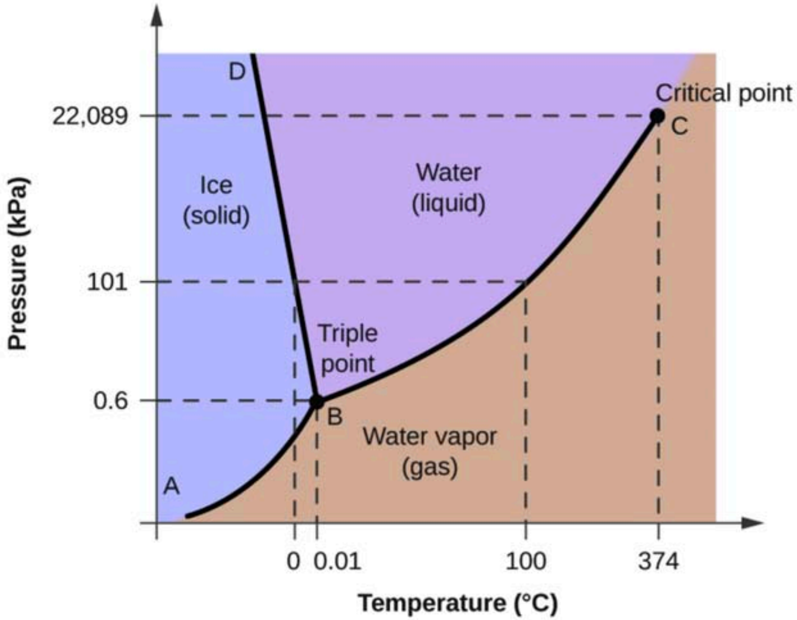
The immense pressures beneath glaciers result in partial melting to produce a layer of water that provides lubrication to assist glacial movement.

This satellite photograph shows the advancing edge of the Perito Moreno glacier in Argentina (credit: NASA)

https://courses.lumenlearning.com/suny-binghamton-chemistry/chapter/phase-diagrams-2/



Any substance

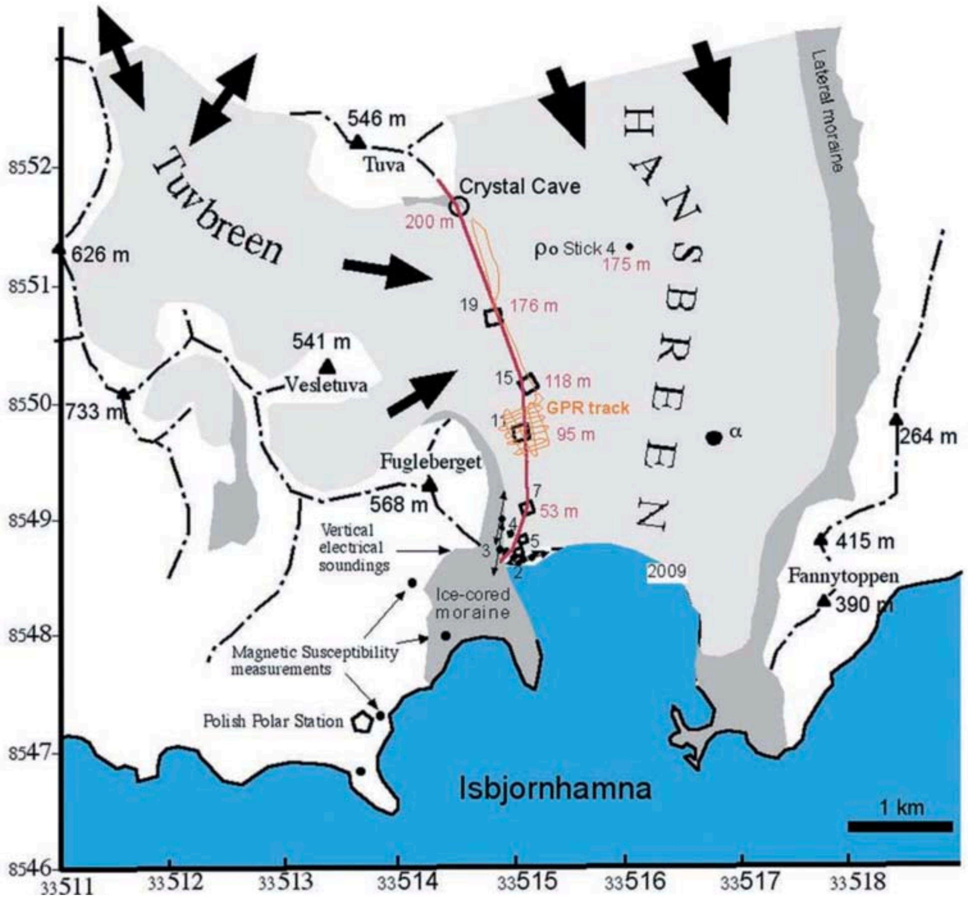


For water only

Architectural structure of a glacier: The Hansbreen glacier case study

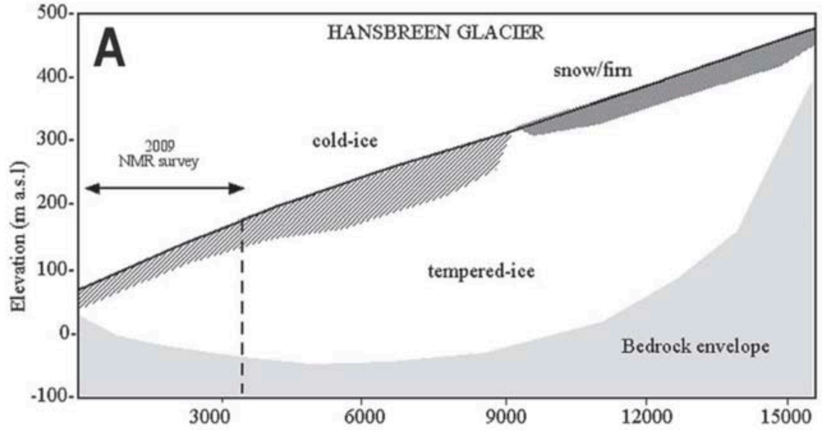
Hansbreen calving ice-cliff, a tidewater grounding glacier at Siedleckivika bay on Hornsund fjord (Spitzbergen), September 2009

Cold and temperate ice

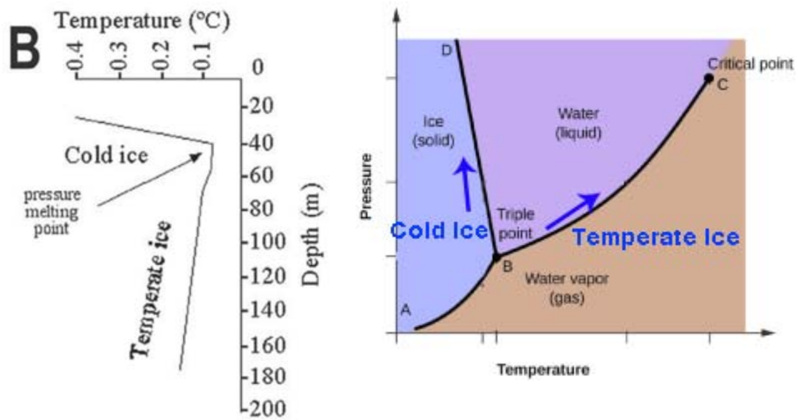


Profile in red and squares MRS stations.

Small black arrows Vertical electrical soundings (VES). Orange brushed lines are the GPR tracks. Pentagon figure show the HRN Polish polar station location. Solid grey and light grey glacial moraines and glacier ice.

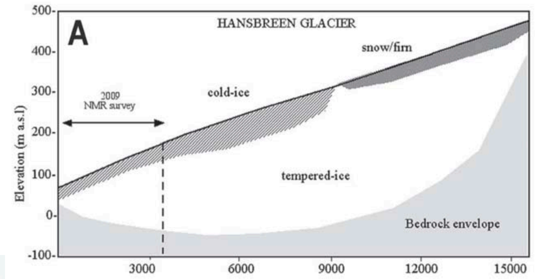


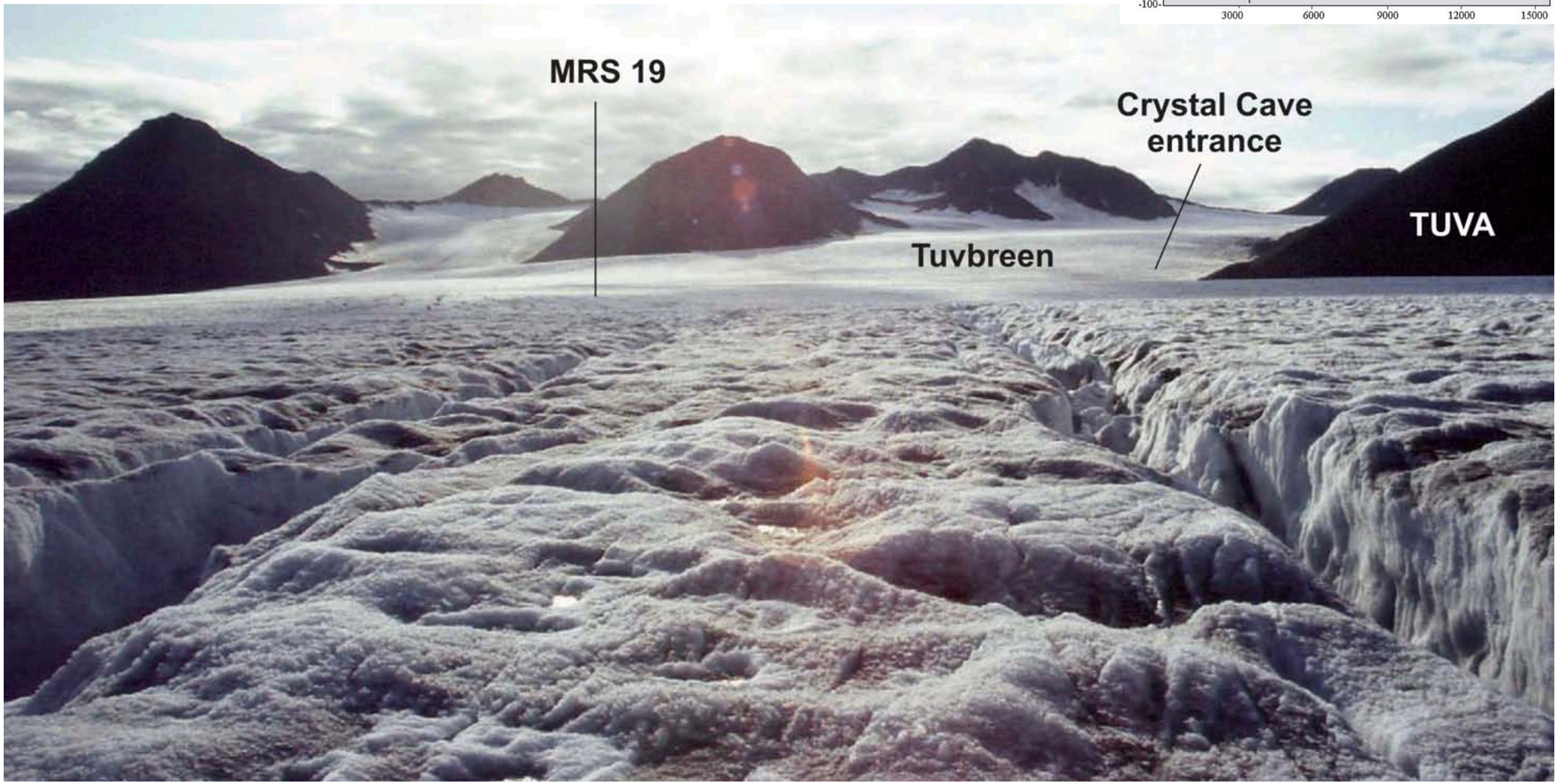
Two main layers form the thermal structure at the ablation zone, cold ice for the uppermost layer and temperate ice below. The increase in temperature with depth is due to the insulating effect of the overlying layer of ice and the increase in pressure with depth, until the PMP (pressure melting point reached here at 40 m depth).



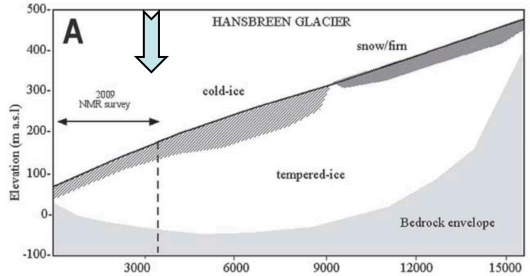
Thermal profile after Jania et al. 1996.
Ice bodies independently work each other

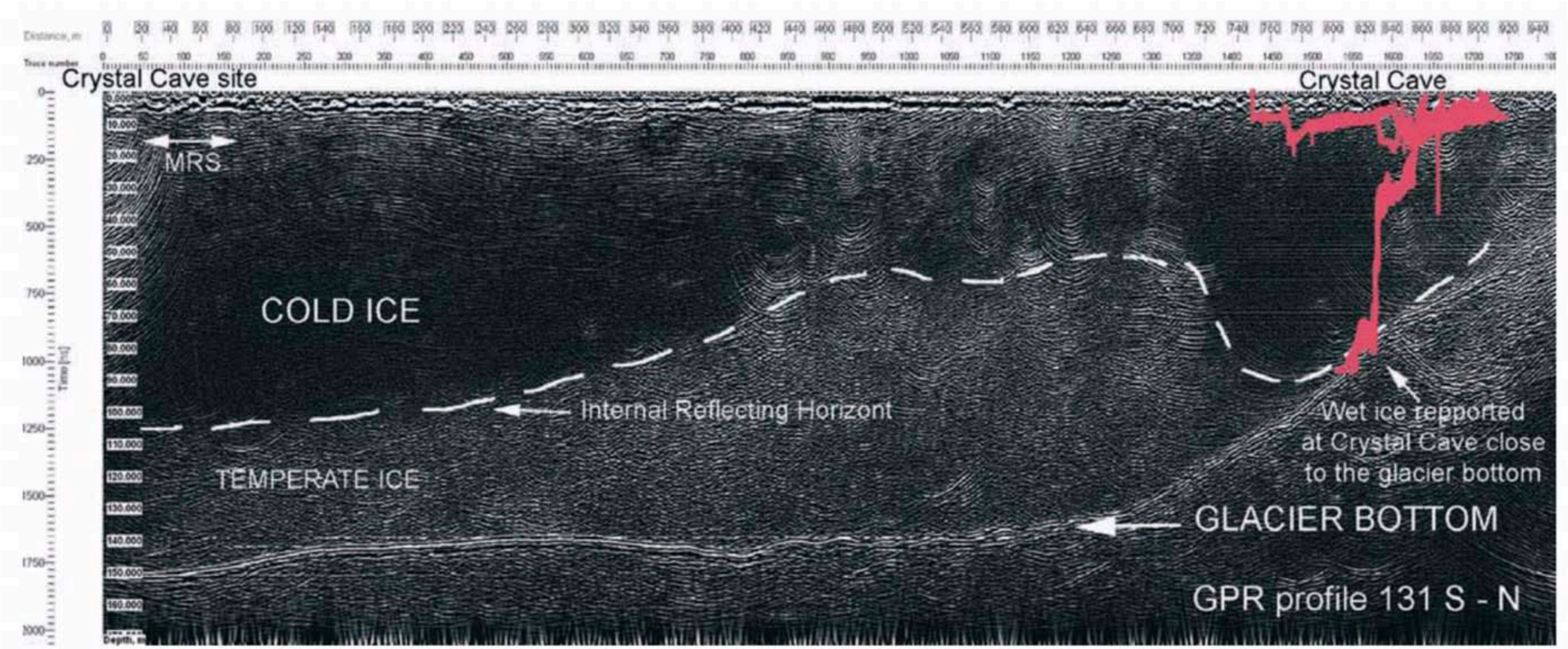
2D Profile


A
HANSBREEN GLACIER
snow/firn
cold-ice
2009
NMR survey
tempered-ice
Bedrock envelope
Elevation (m a.s.l)
500
400
300
200
100
0
-100
3000
6000
9000
12000
15000


MRS 19
Crystal Cave
entrance
Tuvbreen
TUVA

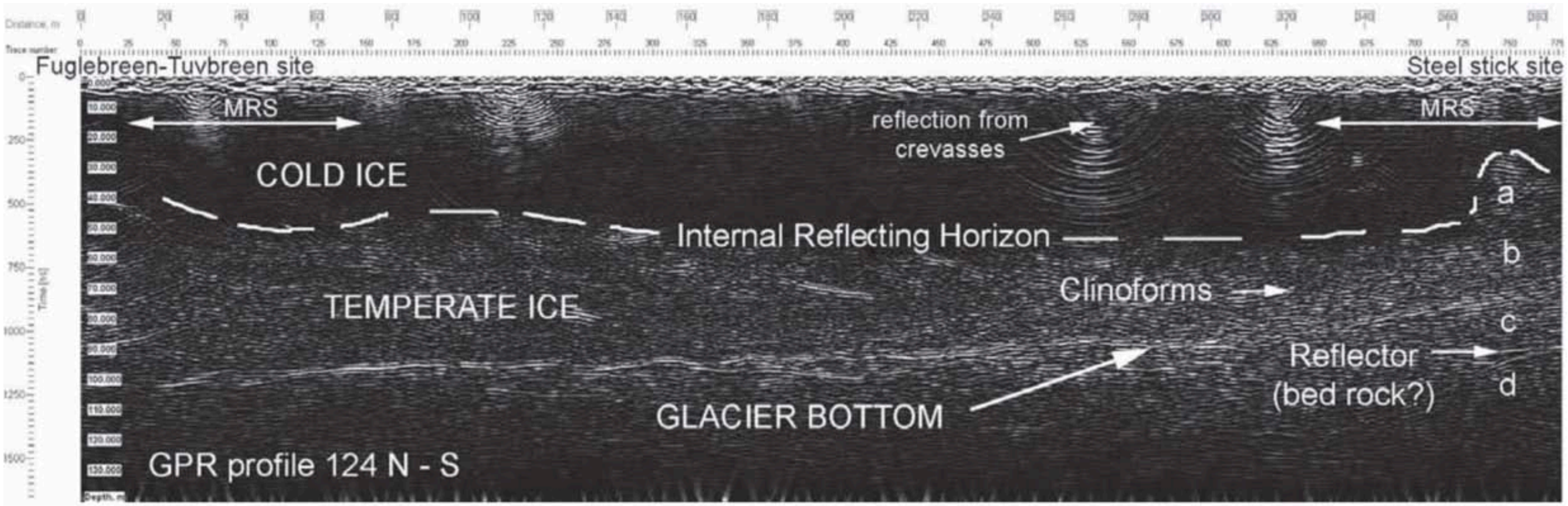
Georadar GPR data



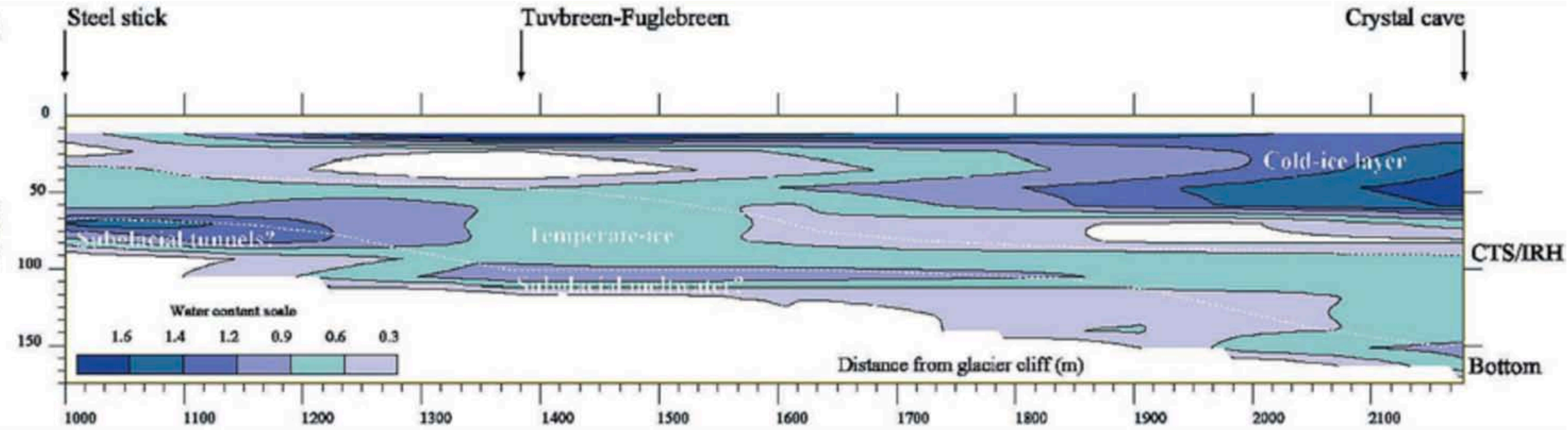


Crystal cave (plotted in red on the GPR profile) is located at the confluence between Tuvbreen and Hansbreen ice streams near to Tuva mountain at the end of the surveyed profile. Here vertical shafts were followed through more than 70 m to subglacial conduit. The presence of wet ice close to the glacier bottom has been reported by Benn et al. (2009). (GPR profile courtesy of Mariusz Grabiec in 2010).

Liquid water on the bottom of the glacier (subglacial drainage channels)



B



Turu (2012)

<u>What is the interest if glaciers?, they are palaeoclimate proxies</u>

Proxy (climate)

15 languages

Article Talk

Read Edit View history Tools

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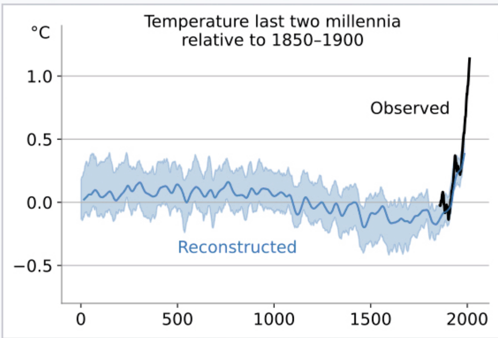
WIKIPEDIA
The Free Encyclopedia

This article is about climatic patterns. For other uses, see Proxy.

In the study of past climates ("paleoclimatology"), **climate proxies** are preserved physical characteristics of the past that stand in for direct meteorological measurements[1] and enable scientists to reconstruct the climatic conditions over a longer fraction of the Earth's history. Reliable global records of climate only began in the 1880s, and proxies provide the only means for scientists to determine climatic patterns before record-keeping began.



Reconstructions of global temperature of the past 2000 years, using composite of different proxy methods

A large number of climate proxies have been studied from a variety of geologic contexts. Examples of proxies include stable isotope measurements from ice cores, growth rates in tree rings, species composition of sub-fossil pollen in lake sediment or foraminifera in ocean sediments, temperature profiles of boreholes, and stable isotopes and mineralogy of corals and carbonate speleothems. In each case, the proxy indicator has been influenced by a particular seasonal climate parameter (e.g., summer temperature or monsoon intensity) at the time in which they were laid down or grew. Interpretation of climate proxies requires a range of ancillary studies, including calibration of the sensitivity of the proxy to climate and cross-verification among proxy indicators.[2]

Proxies can be combined to produce temperature reconstructions longer than the instrumental temperature record and can inform discussions of global warming and climate history. The geographic distribution of proxy records, just like the instrumental record, is not at all uniform, with more records in the northern hemisphere.[3]

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M. Chevalier

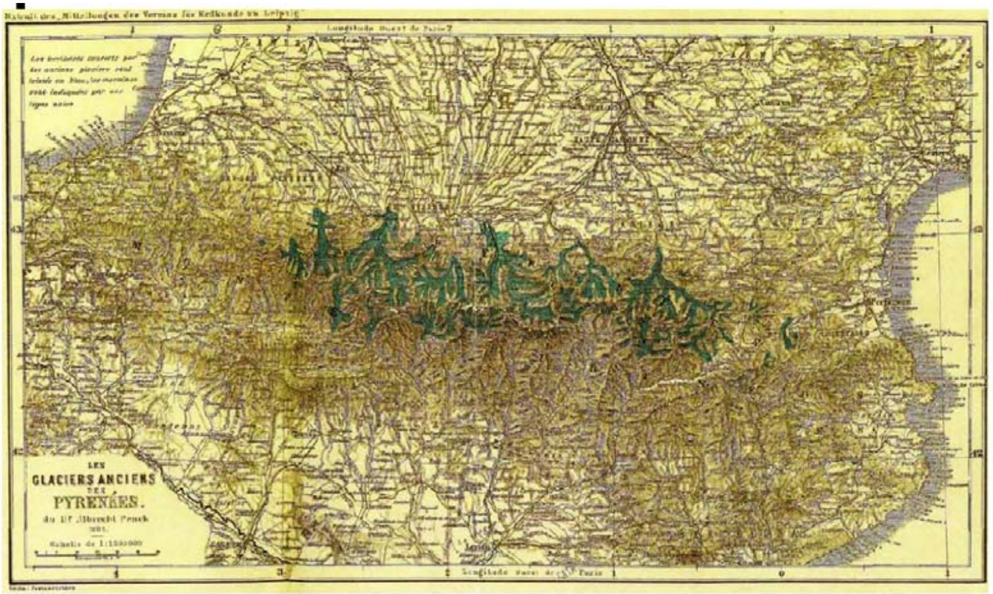
Pleistocene geomorphological transformations in the Valira valleys (SE Pyrenees)

Past and present knowledge in the Pyrenees

The glacial cycles chronology

Valentí Turu Michels

140 years ago



Penck, A.1883.Die Eiszeit in der Pyrenäen. Mitt. Ver. Erdt. Leipzig.

Three unnamed glacial cycles

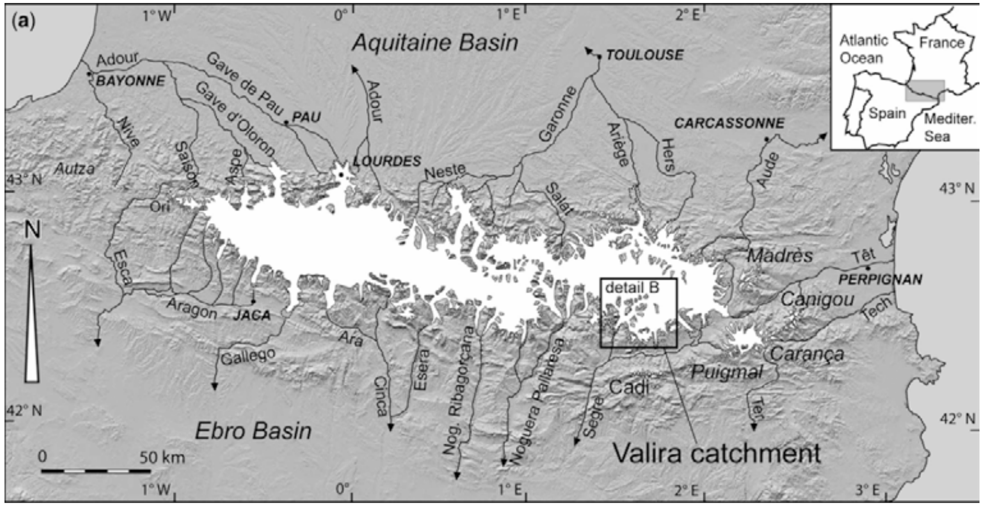
Penck & Brückner (1904)

Würm Riss Mindel Gunz

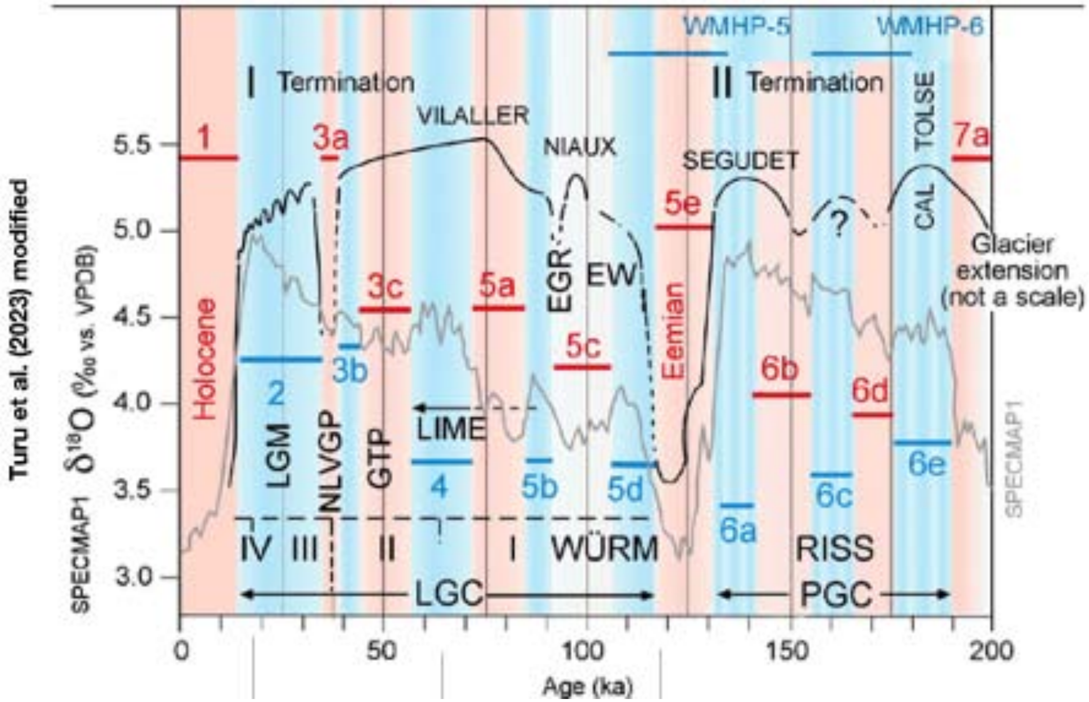
100 ka >200 ka < 1 Ma

(In the Pyrenees)

Nowadays



Calvet et al. (2011)



LGM = Last Glacial Maximum (Global)

CP = MIS 2 in the central Pyrenees

NLVGP = No Large Valley Glacier Period

GTP = Glacial Thinning Period

LIME = Last Ice Maximu Extent

EGR = Early Glacial Recession

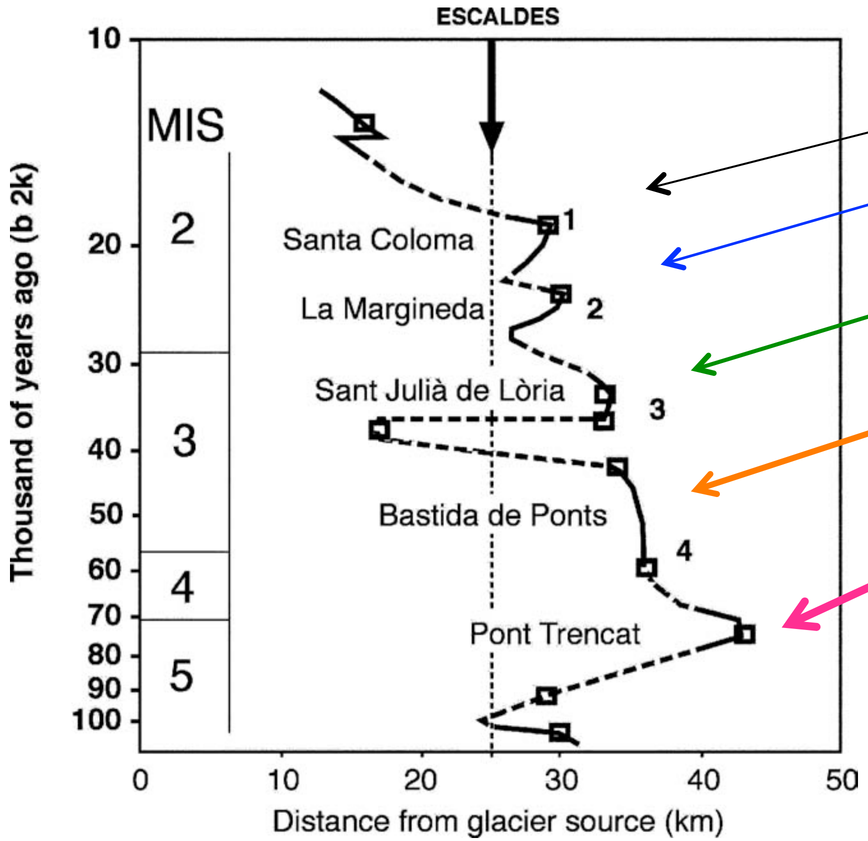
EW = Early Würm

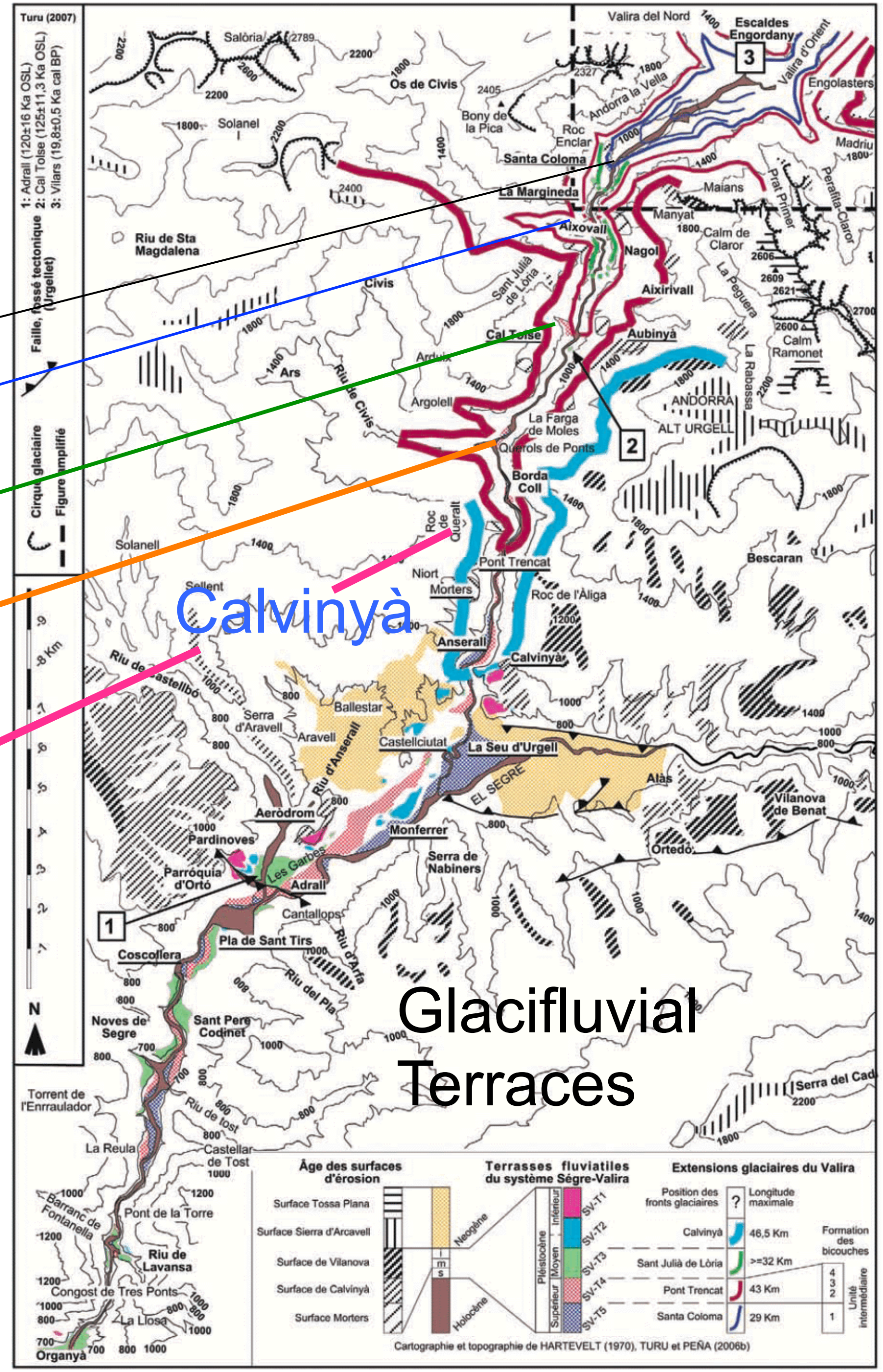
WMHP = Western Mediterranean Humid Periods

LGC = Last Glacial Cycle

PGC = Penultimate Glacial Cycle

The ice extension

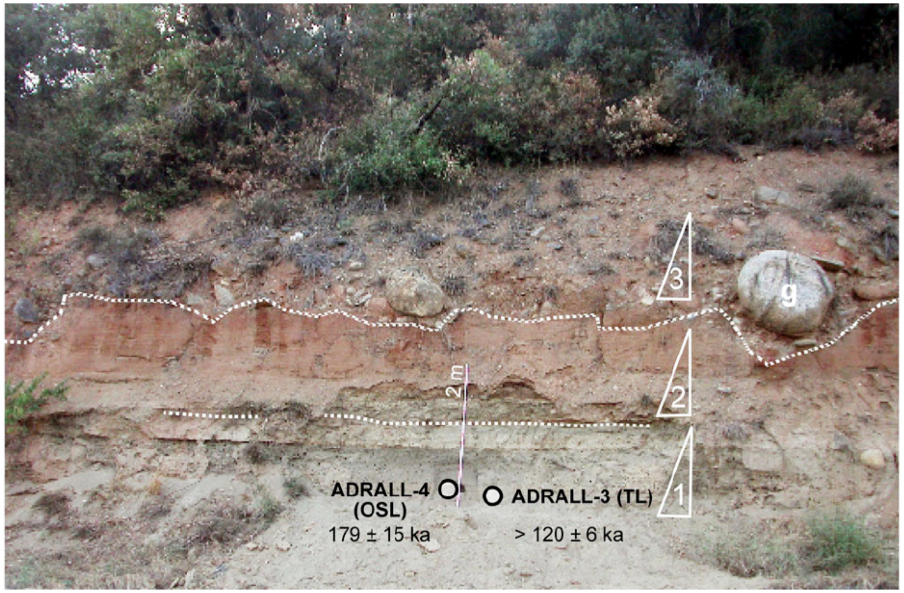


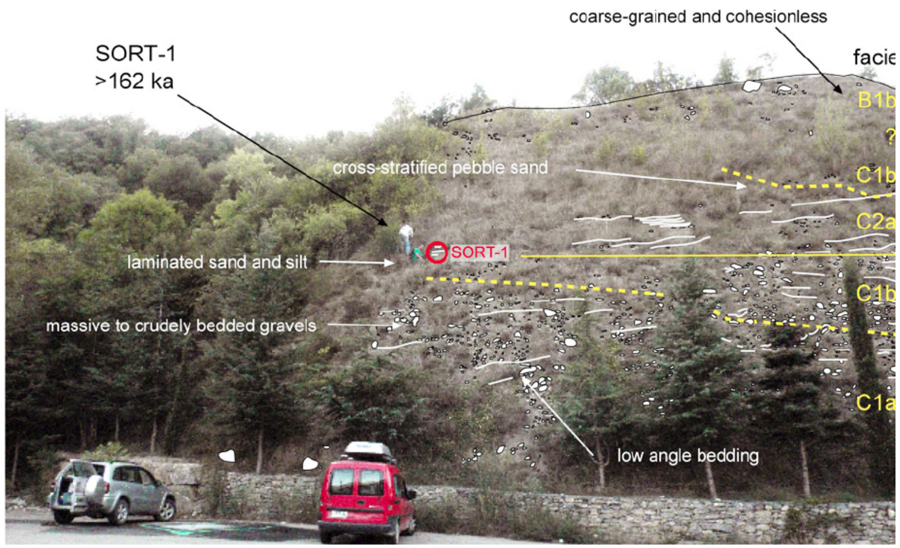


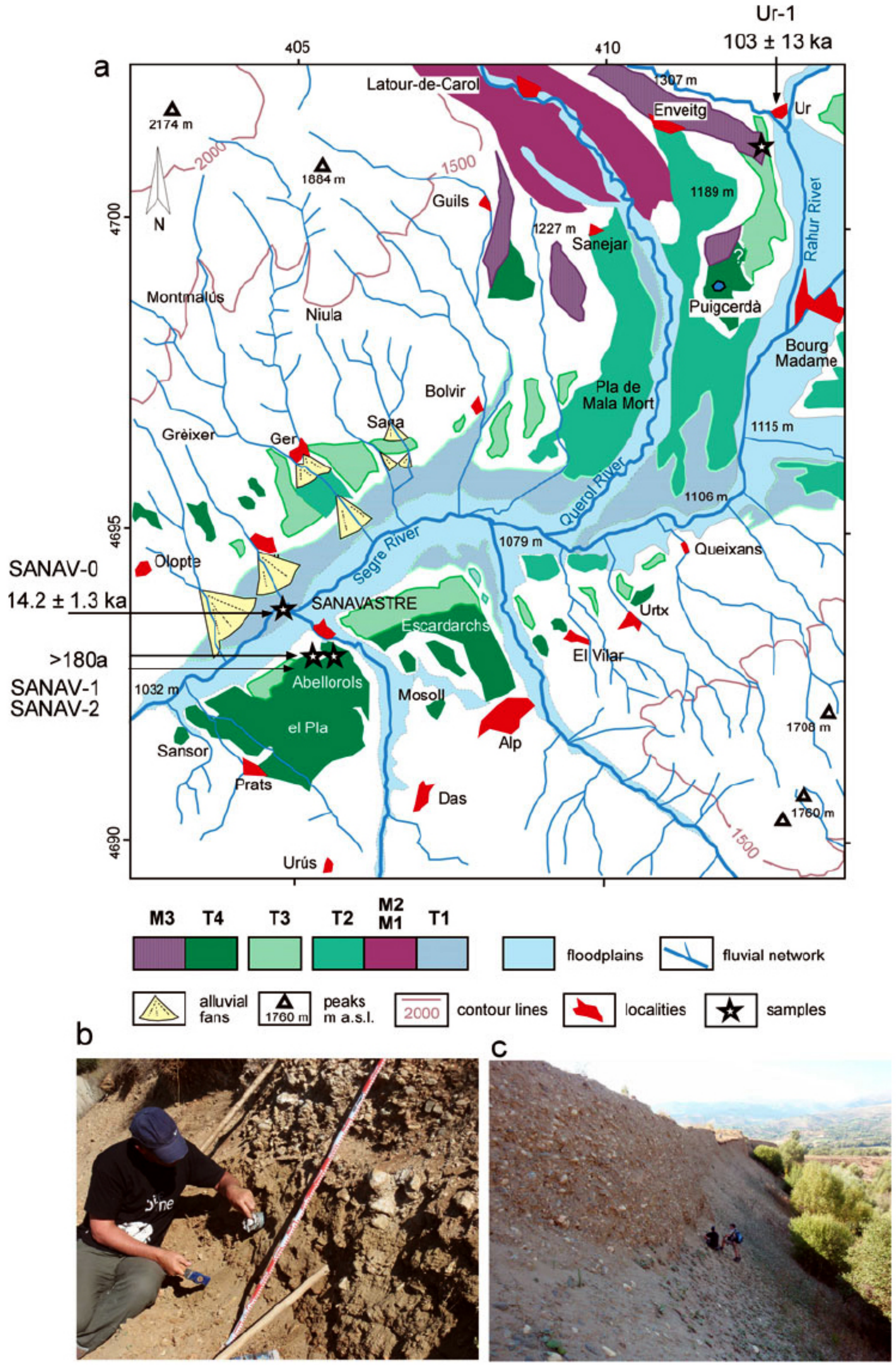
Schematic time-distance diagram showing the known locations of end-moraines from glacier re-advances in the Valira valley.

At each re-advance (1 to 4), a ground moraine (diamicton or till) was by the glacier deposited (Turu et al., 2007; 2017; 2023).

Glacifluvial terraces

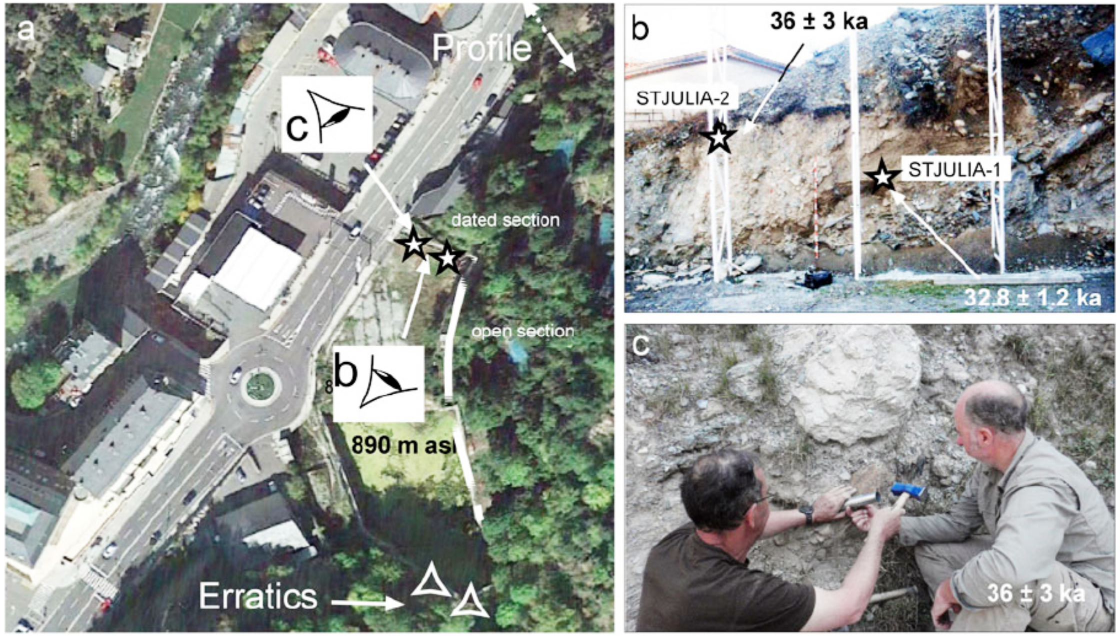


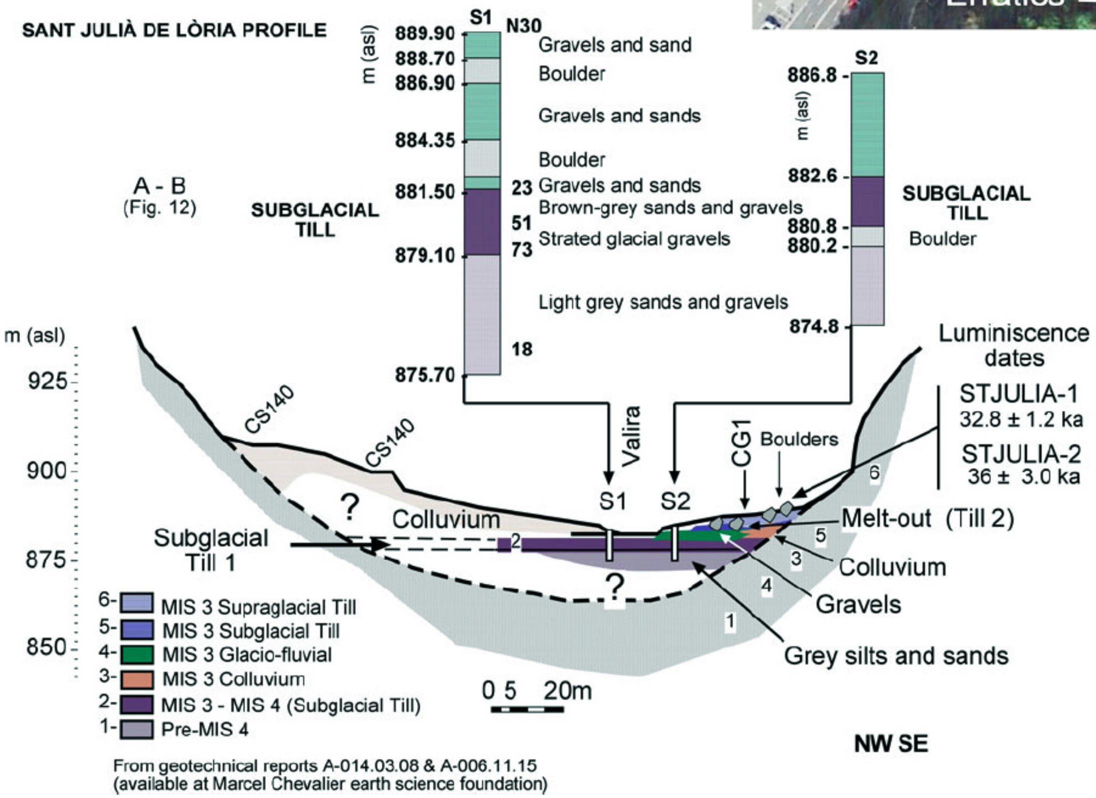




Turu et al. (2023)

End-moraines

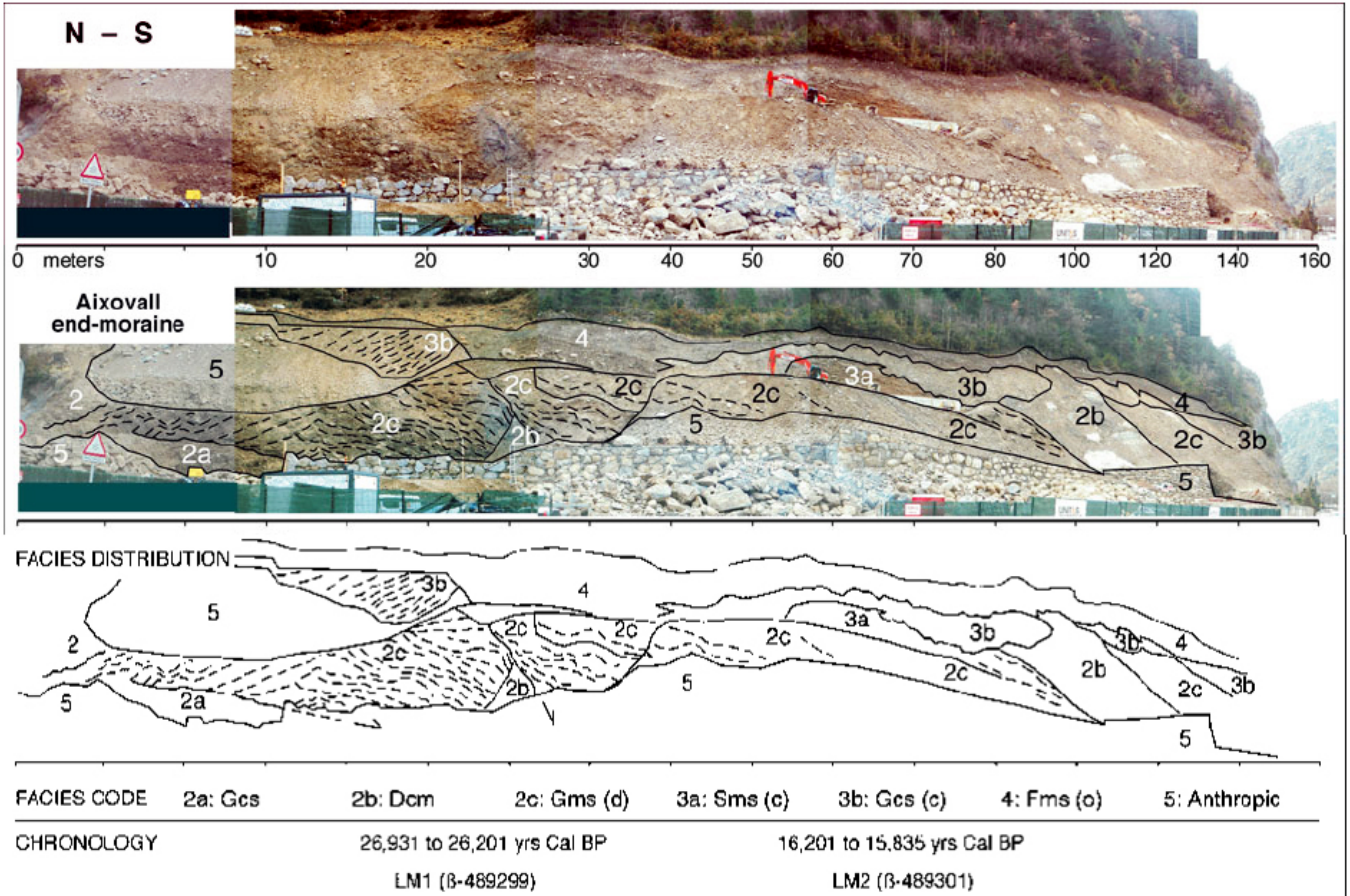




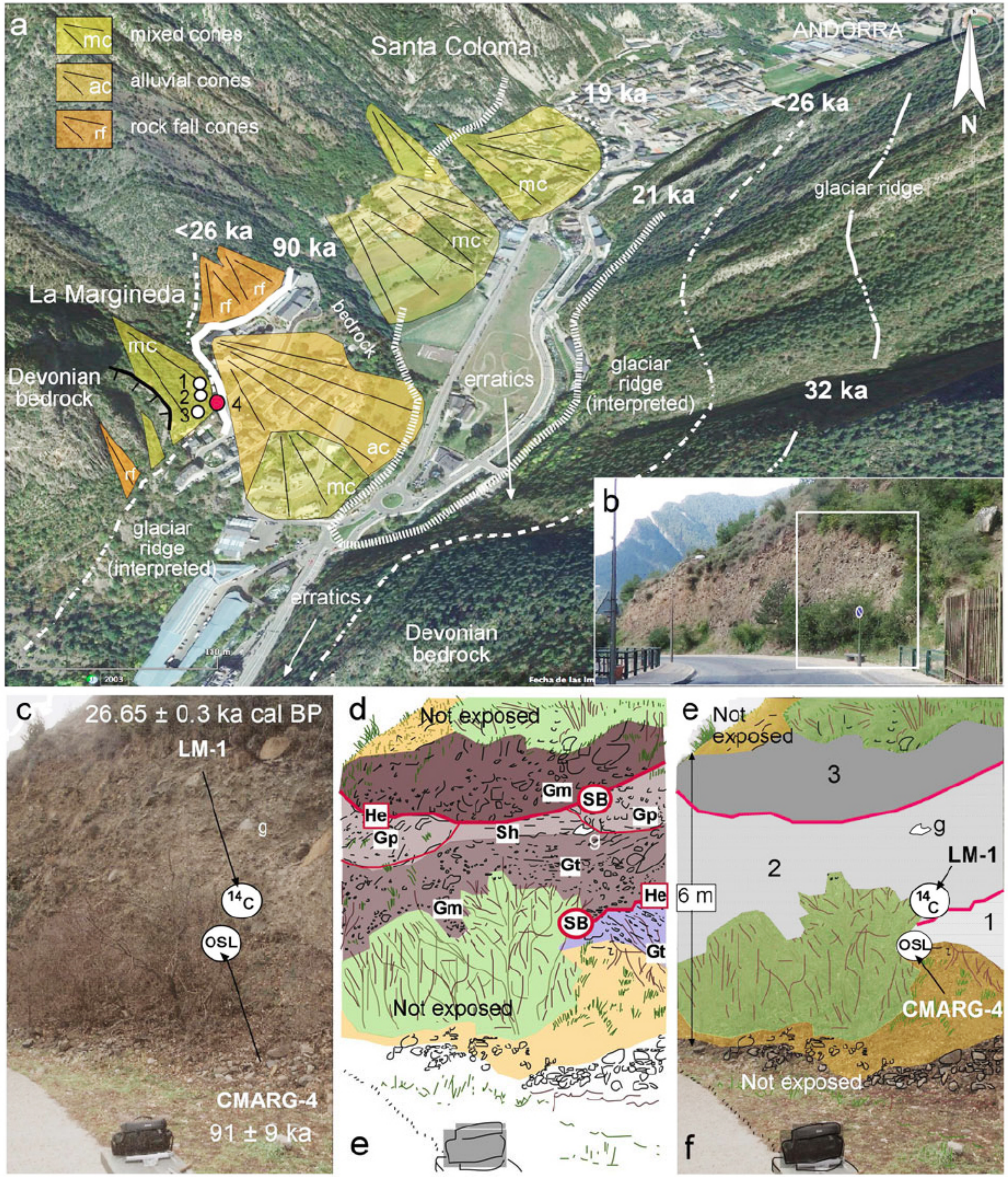
Turu et al. (2023)

End-moraines

Turu et al. (2023)

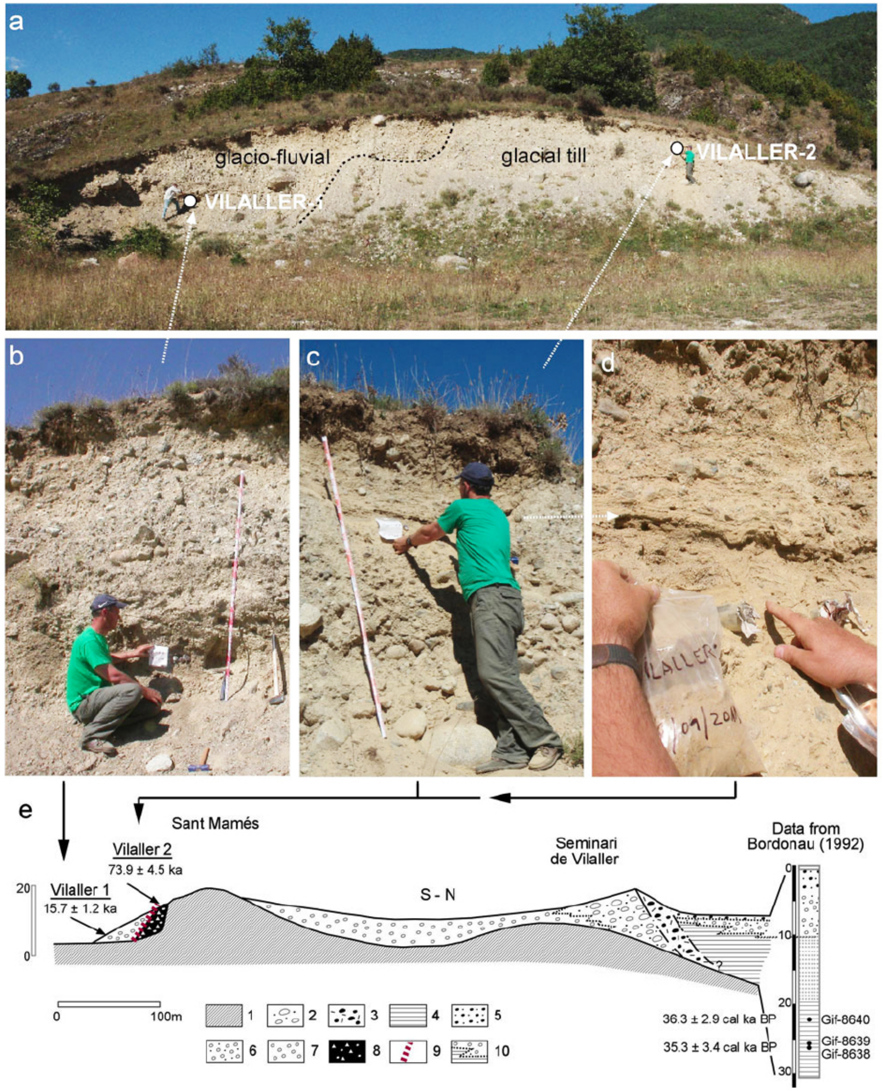


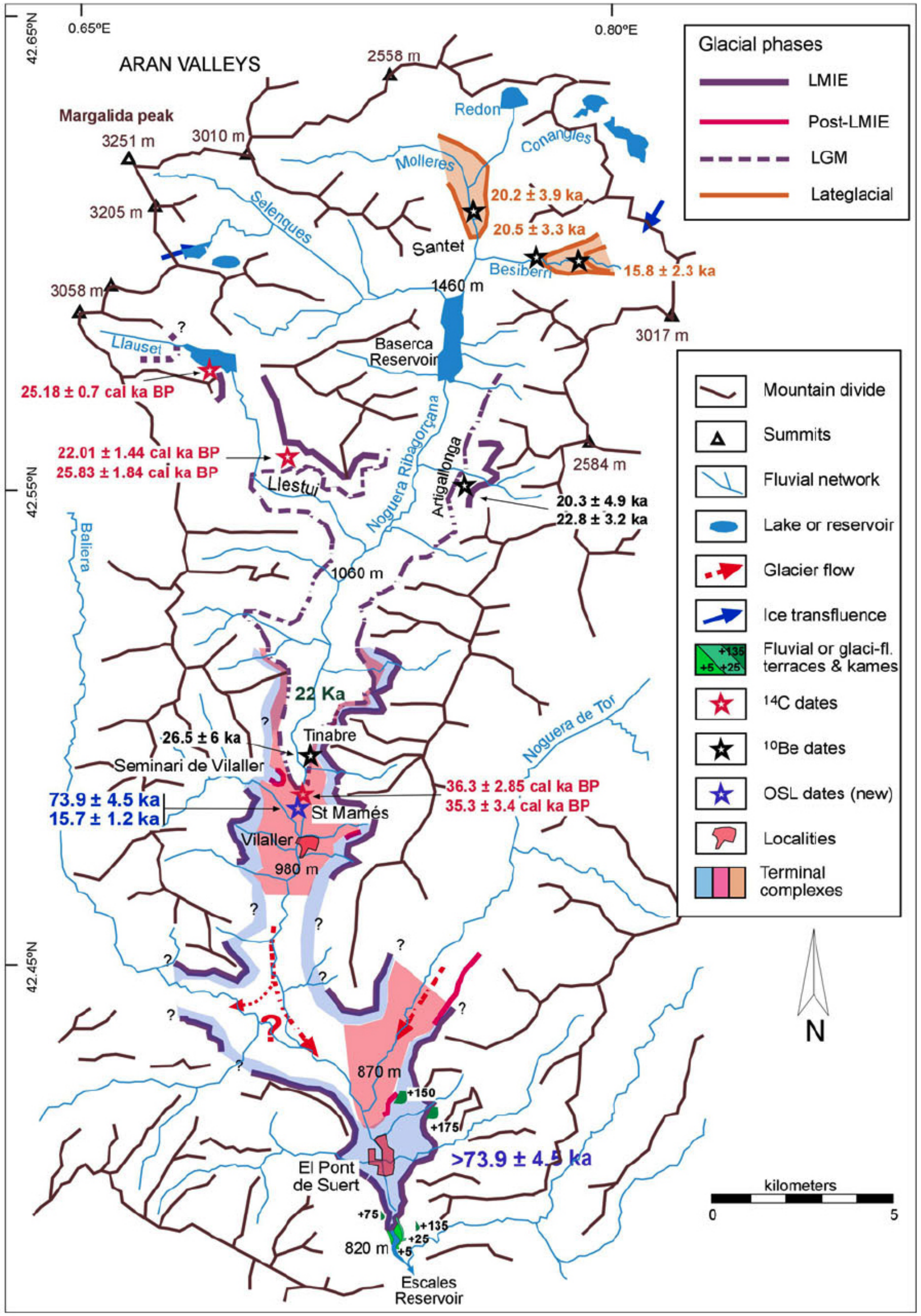
End-moraines and paraglacial



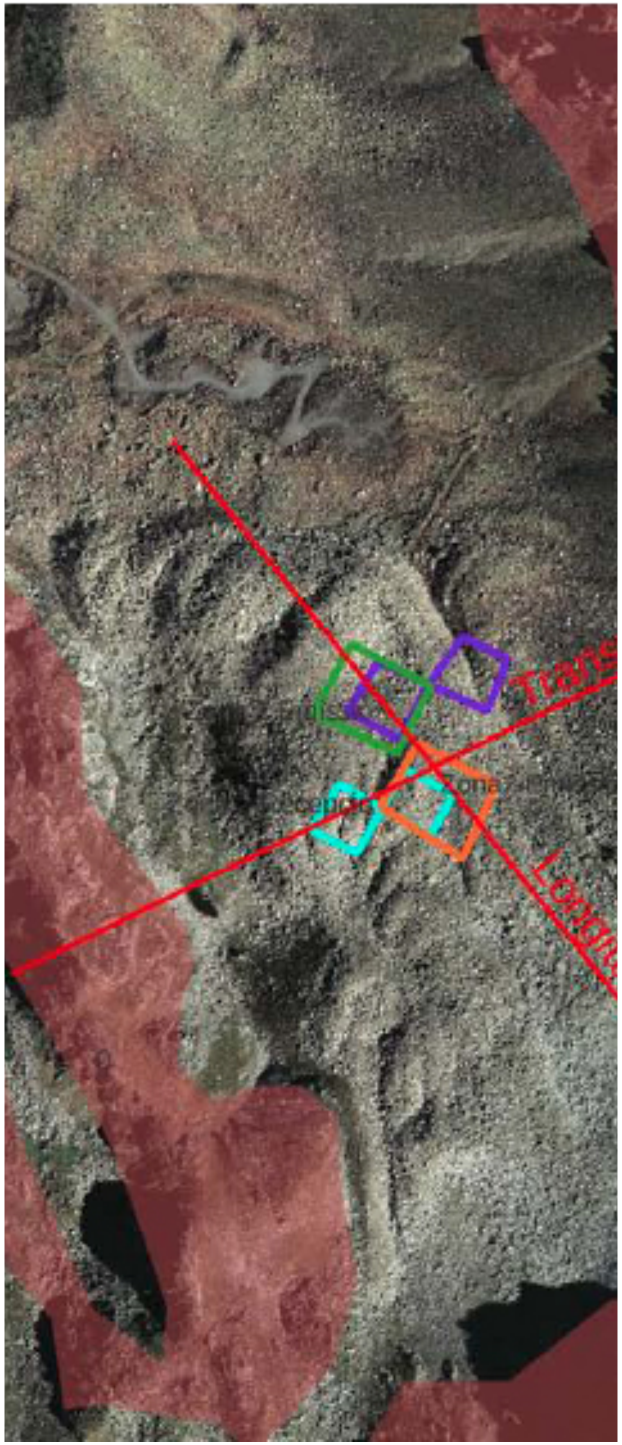
Turu et al. (2023)

Glacifluvial deposits and end-moraines





Turu et al. (2023)



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M. Chevalier

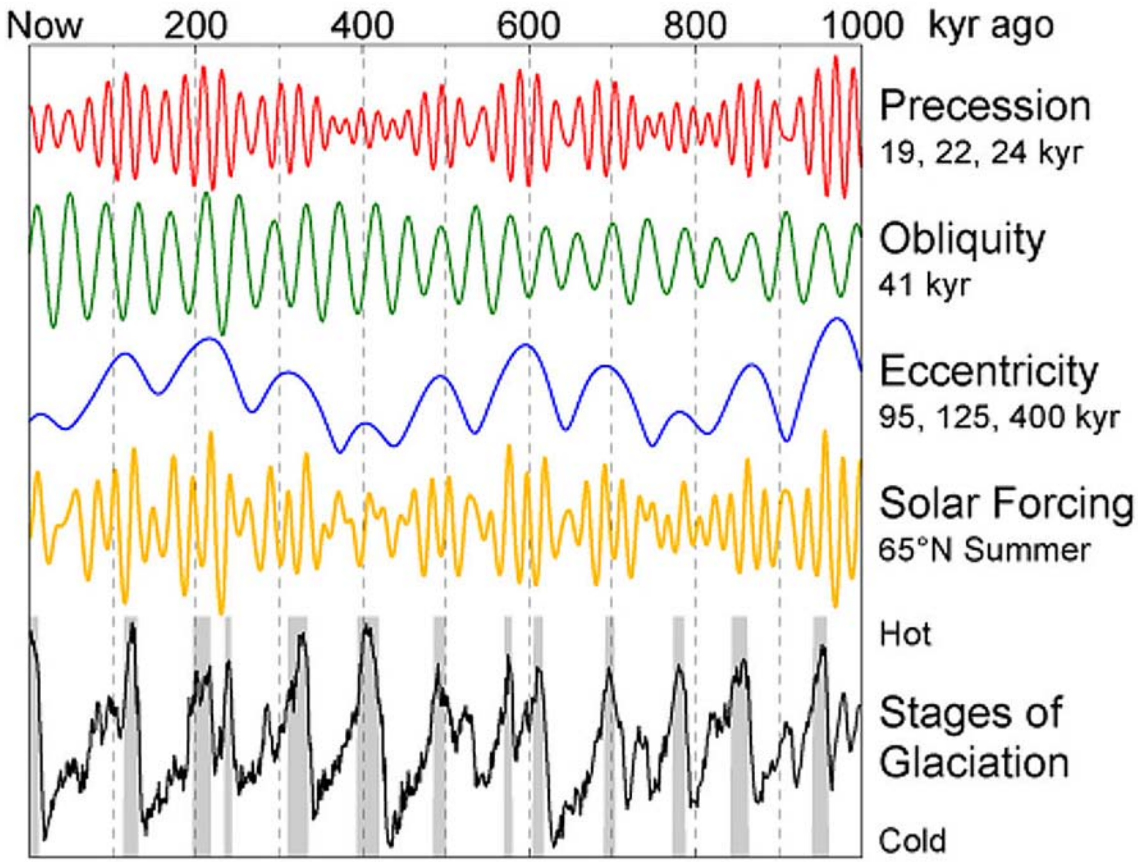
Pleistocene geomorphological transformations in the Valira valleys (SE Pyrenees)

Short note about

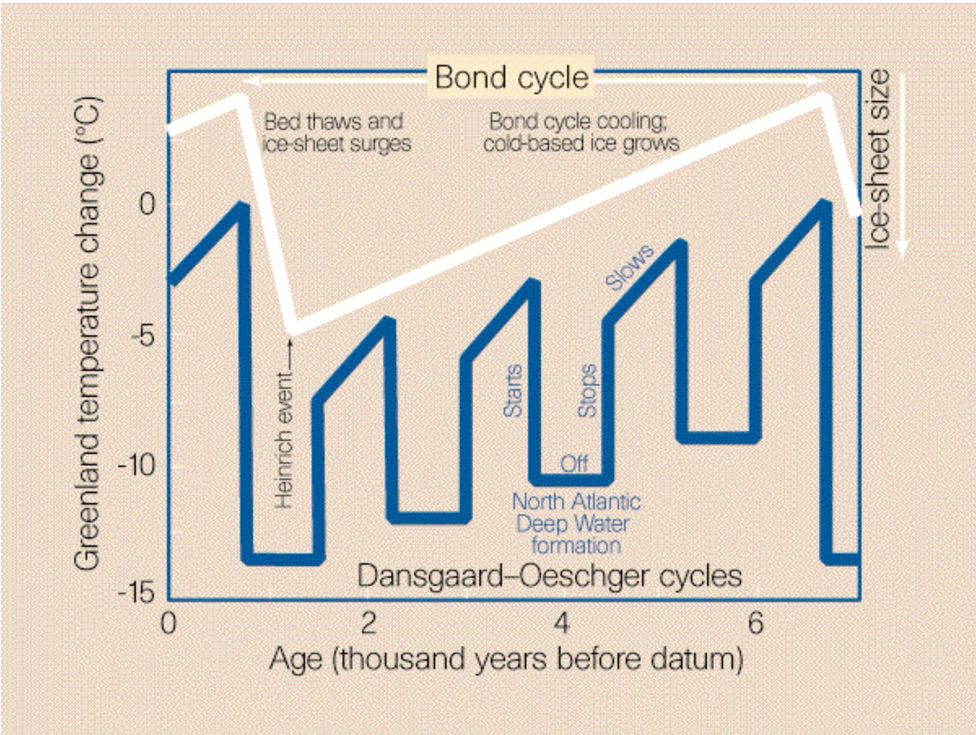
causes of glaciations
and
glacial dynamics

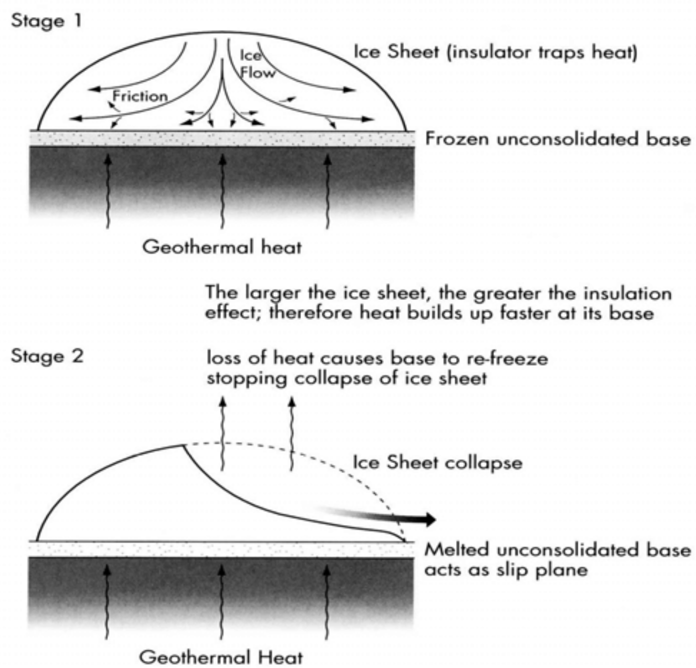
Valentí Turu Michels

Causes: Orbital cycles

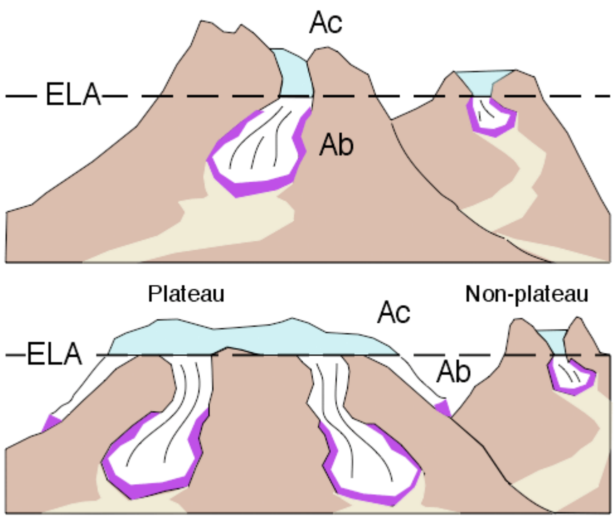


Causes: Sub-orbital cycles

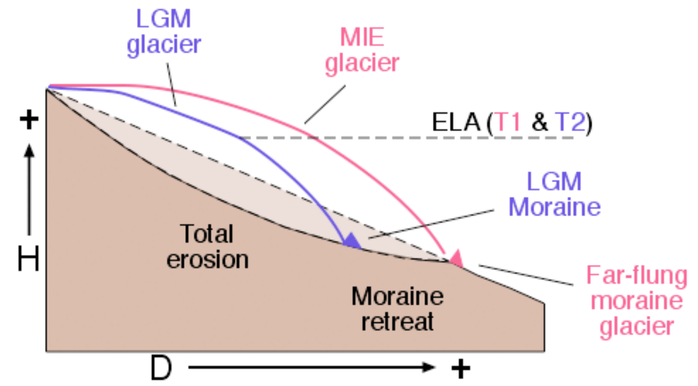


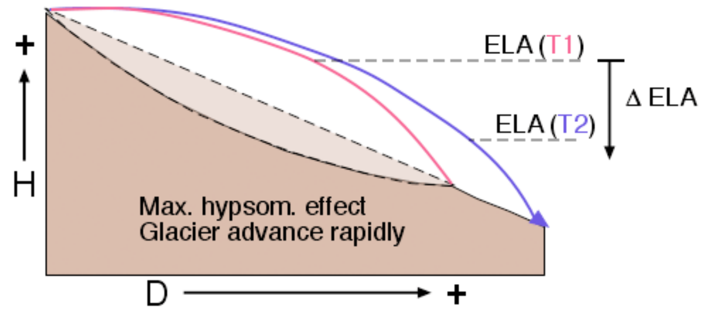


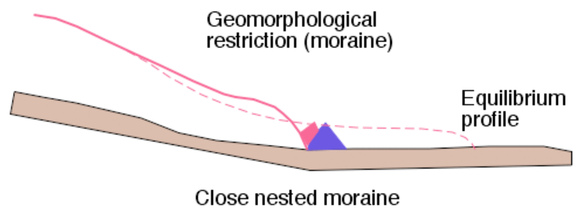
The ELA and extension of end-moraines



Equilibrium line altitude (ELA). The lower topographic limit of multi-annual snow cover is called the snow line or equilibrium line altitude (ELA).







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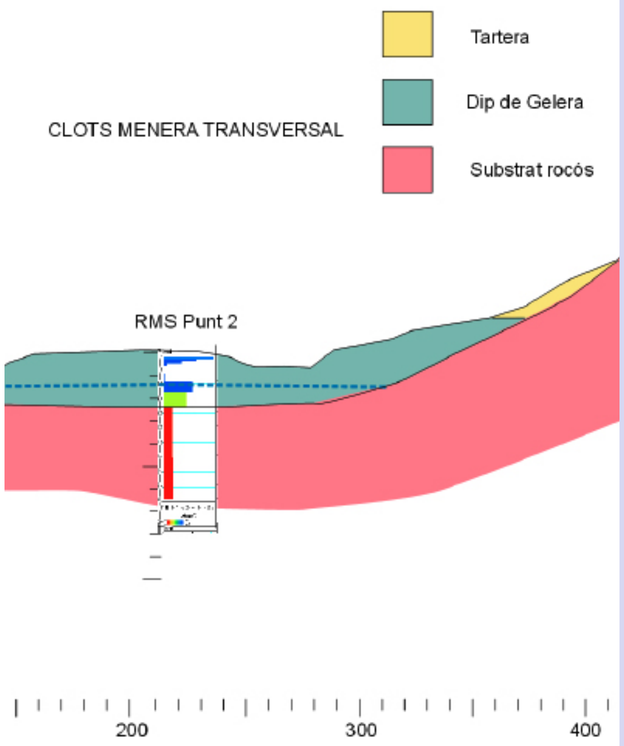
Pleistocene geomorphological transformations in the Valira valleys (SE Pyrenees)

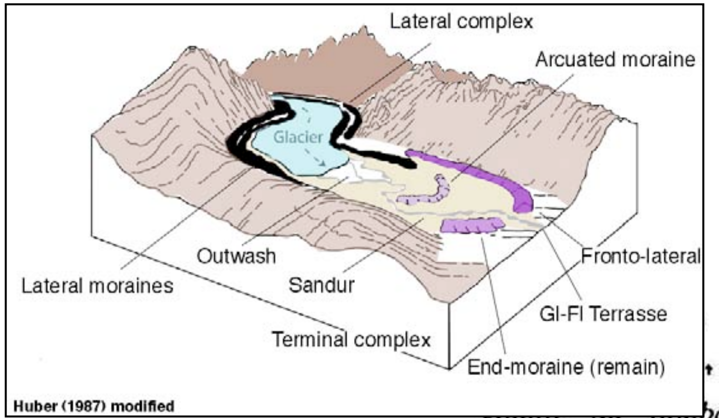


The evidences

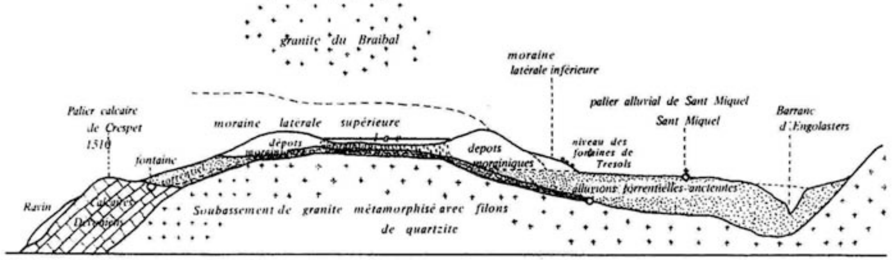
glacial sediments

Valentí Turu Michels

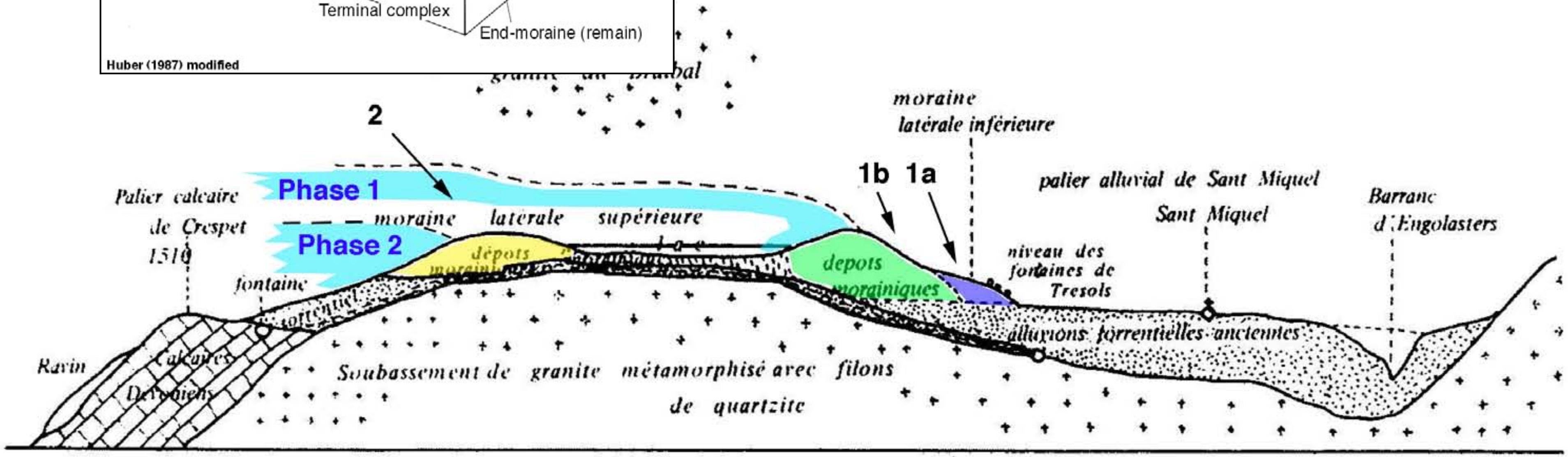
Evidences from the glacial landsystems: The height and extension of the lateral moraines



Huber (1987) modified



Chevalier (1930)



MASSIF D'ENGOLASTERS

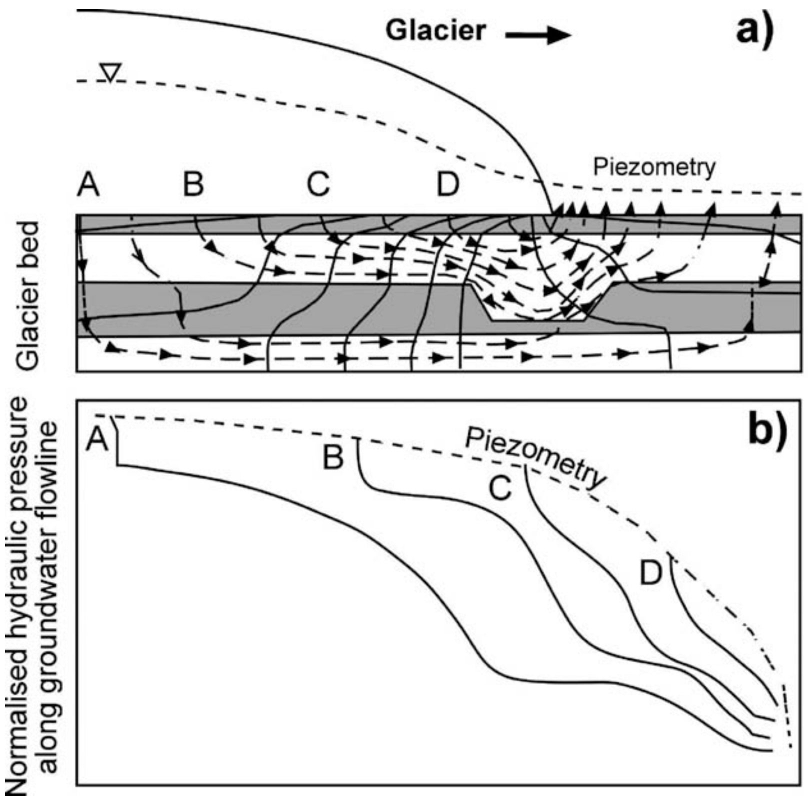
Coupe I. - Profil longitudinal 1: 12.500 -- 1: 10.000

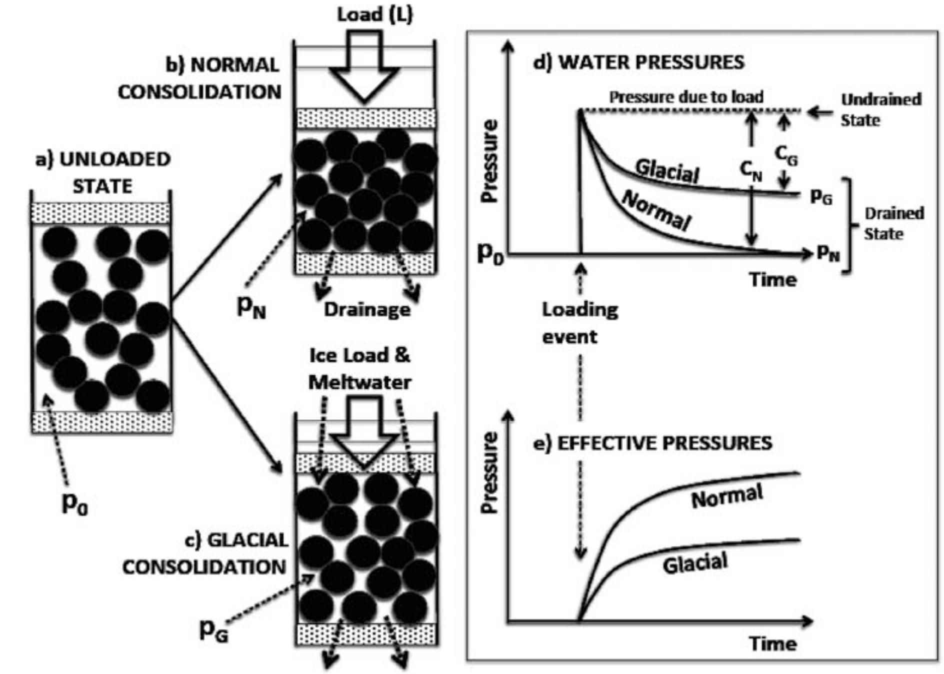
M. Chevalier.

Barcelona, 12 septembre 1930.

NOTA : Aquest tall geològic que ès reproduït a 4/5 parts de l'ori— ginal forma part d'un estudi "Note sur la constitution géologique du lac d'Engolasters (Encamp-Andorra)", inèdit

Evidences of the subglacial drainage imprint in sediments : the glacial consolidation



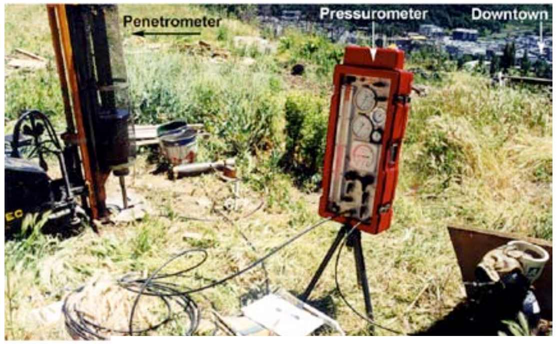


Schematic diagrams based showing a) groundwater flow lines (arrows) and equipotential lines (solid lines) through subglacial strata comprising aquifers and aquitards (mottled), and b) the potential drop along a series of the flowlines in a), with potential gradients changing according to changes in hydraulic conductivity along the flowline. Still on the figure from below, at the bottom right-hand corner shows pressure going to zero as groundwater emerges at the surface beyond the glacier.

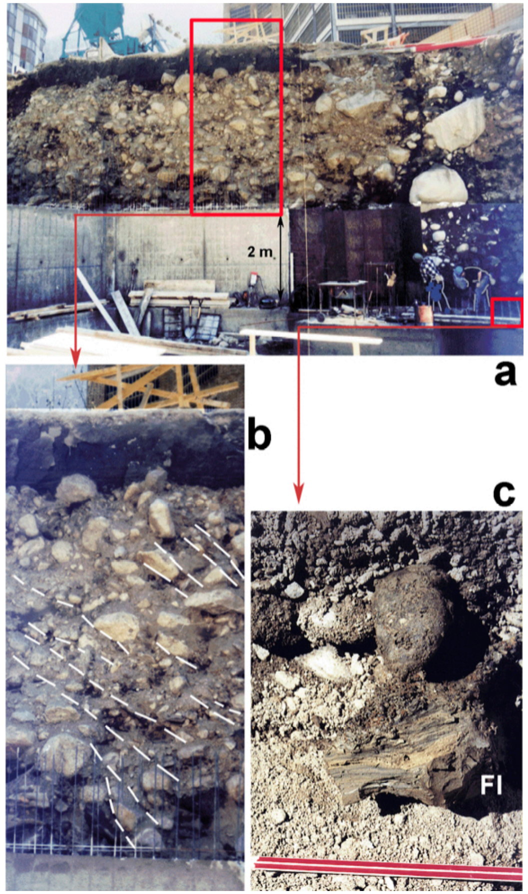
Schematic diagram illustrating a glacial consolidation (Boulton & Dobbie, 1993). a) Unloaded sediment. Initial water pressure = p0. b) Consolidation under a "normal" load. c) Consolidation by a glacier but where the glacier sole also a water source, which maintains a higher water pressure than in b). d) Changes in water pressures as the sediment is loaded. e) Equivalent changes inadequate pressure determined by the changes in water pressure shown in d)..

Methods done in the main Valira valley

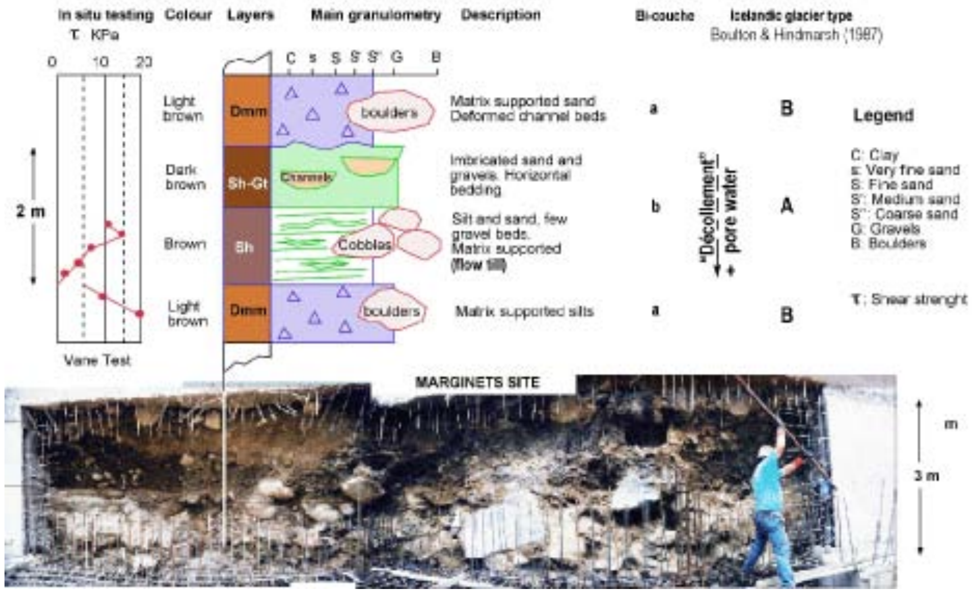
Pumping tests at Av. Meritxell 85



Pressurometer tests at Vilars

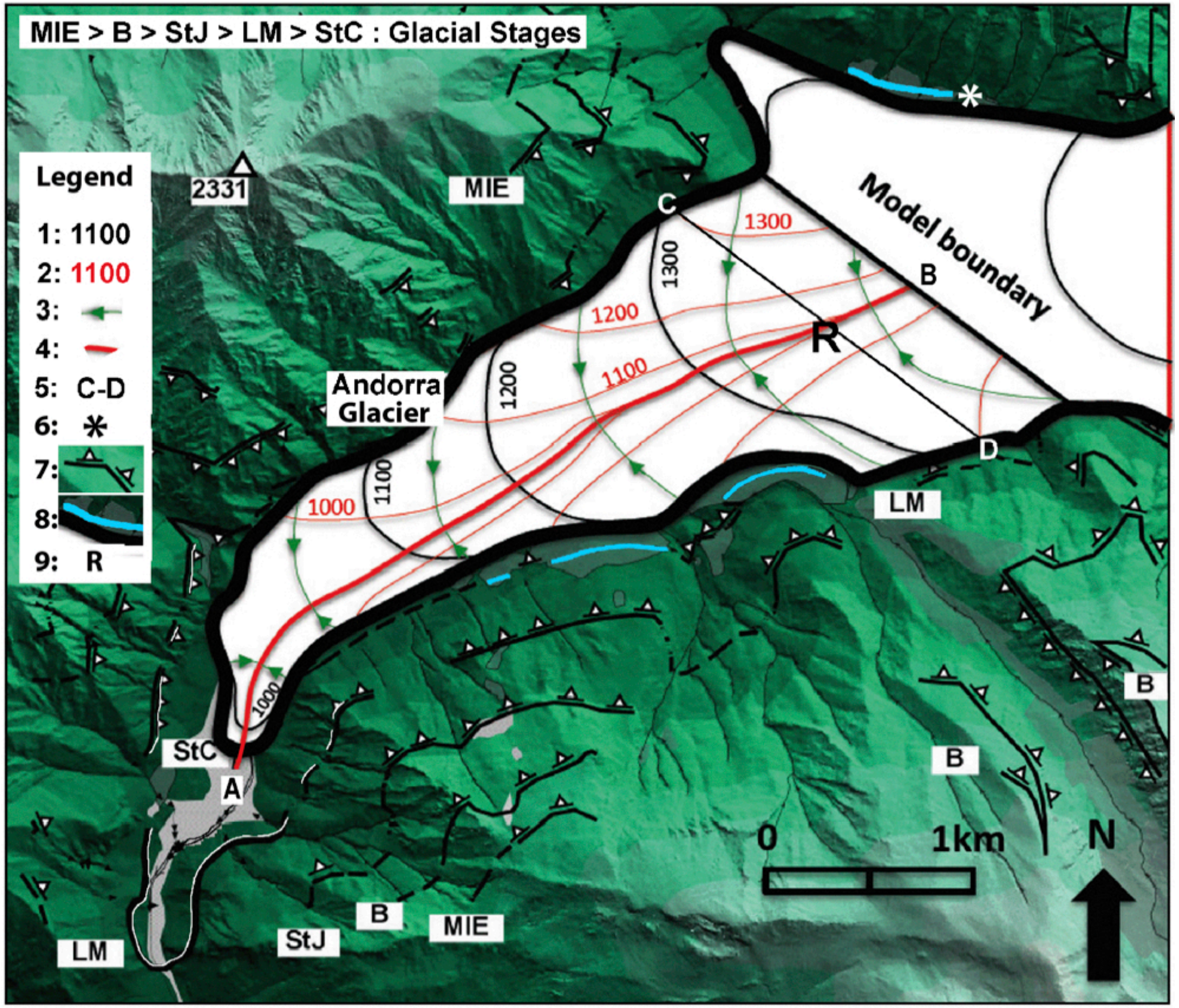


Field descriptions at Av. de les Escoles



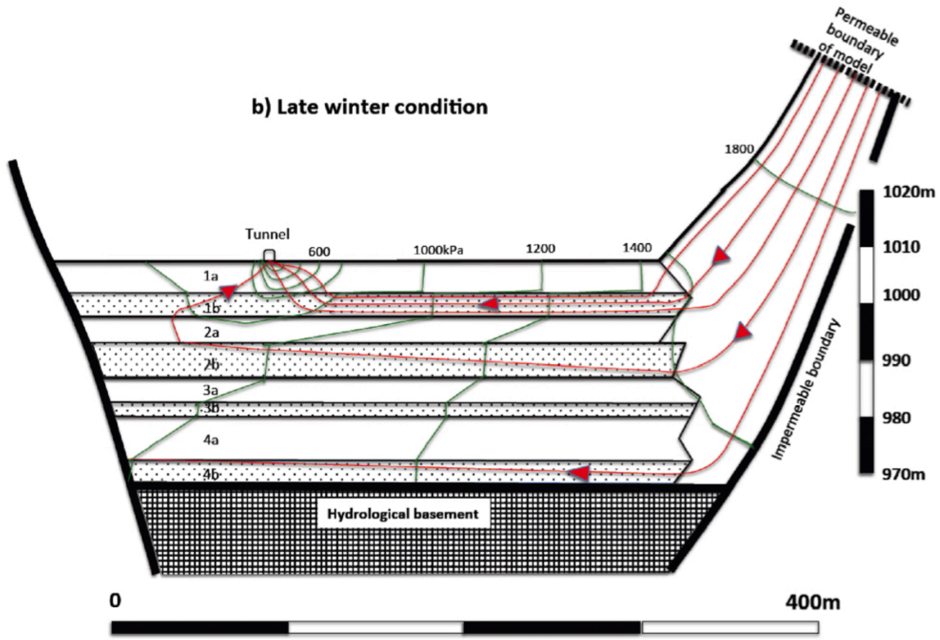
Field descriptions at els Marginets

The conceptual model and numerical modeling for the former Valira glacier of tempered ice

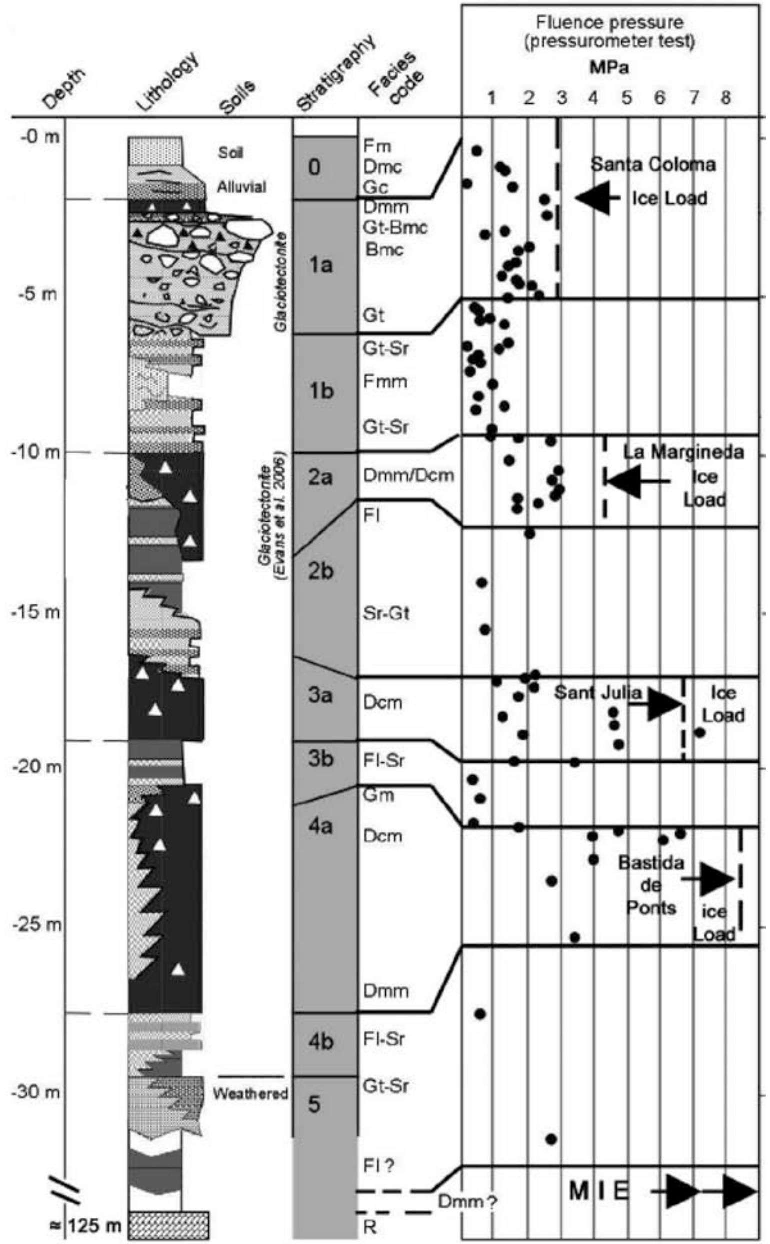


Reconstructed glacier surface topography and modelled groundwater flow for the Santa Coloma re-advance.
(1) Glacier surface contours
(2) Piezometric surface (m a.s.l).
(3) Groundwater flowlines.
(4) R-type tunnel (Turu 2007b).
(5) Profiles A-B and C-D.
(6) AMS Data locality
(7) Simplified geomorphology includes lateral moraines indicating the highest lateral elevations of the glacier surface during the last glacial period maximum ice extent (MIE) and later advance stages, like Bastida del Ponts (B), San Julia (StJ), La Margineda (LM) Santa Coloma (StC).
(8) Moraine ridges.
(9) The study area's location

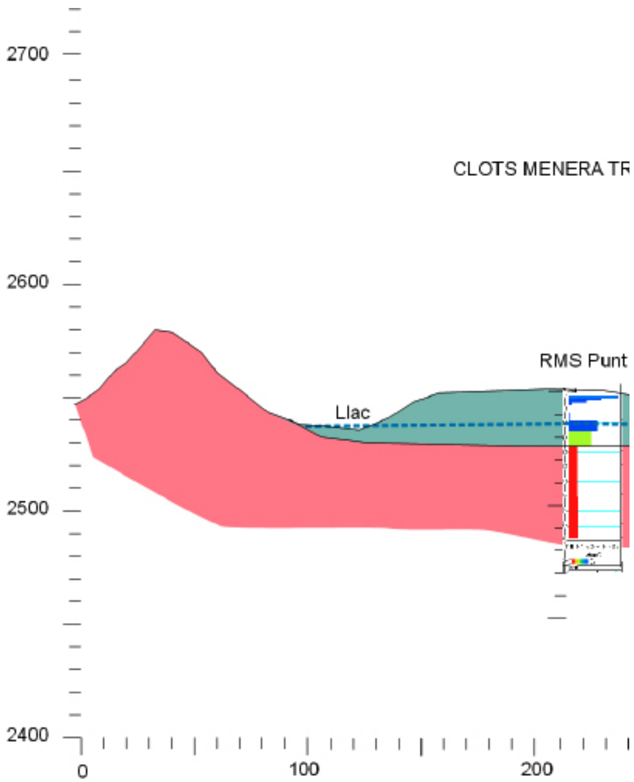
Computed and field data comparison



Computed and measured preconsolidation values fits by using precipitation and temperature at the LGM (last glacial maximum) from Rodes (2008). It would have been **<u>40 ± 20%</u>** less than today and **<u>9ºC ± 1ºC</u>** of mean annual temperature lesser.



Multilayered aquifer



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Pleistocene geomorphological transformations in the Valira valleys (SE Pyrenees)

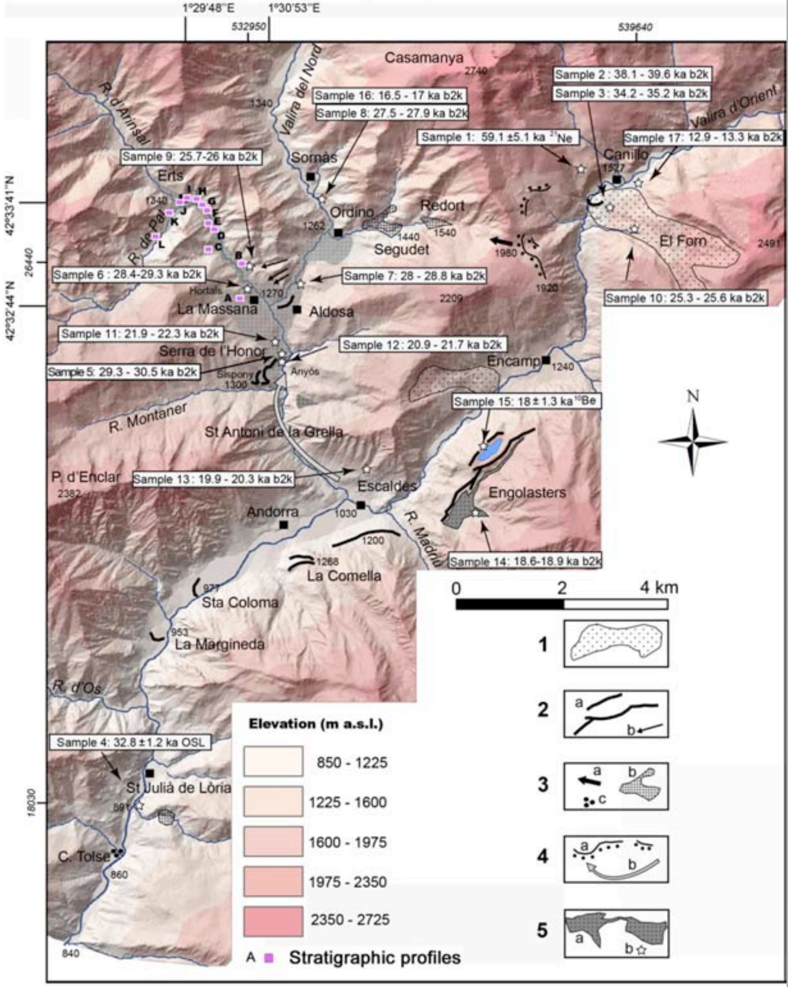
Ice-dammed lakes

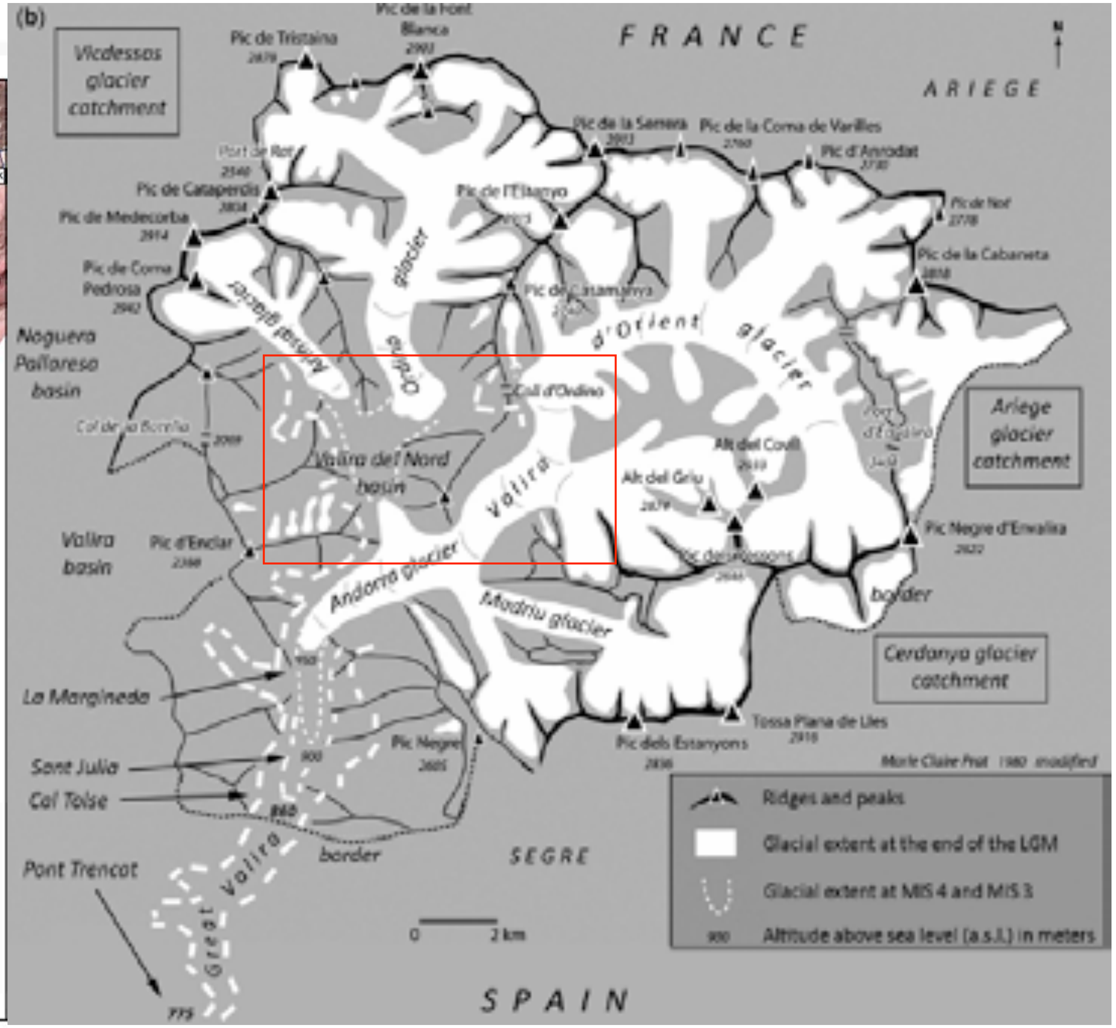
The
La Massana palaeolake

Valentí Turu Michels

PARC ARQUEOLÒGIC MINES DE GAVÀ

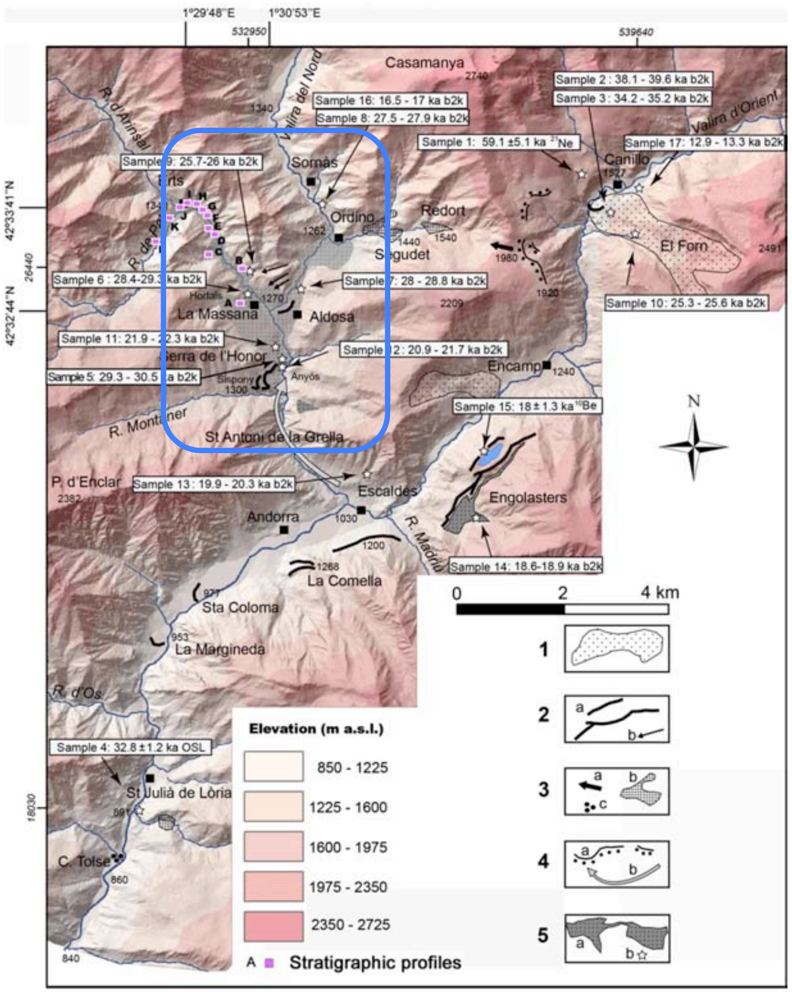
The core of the study

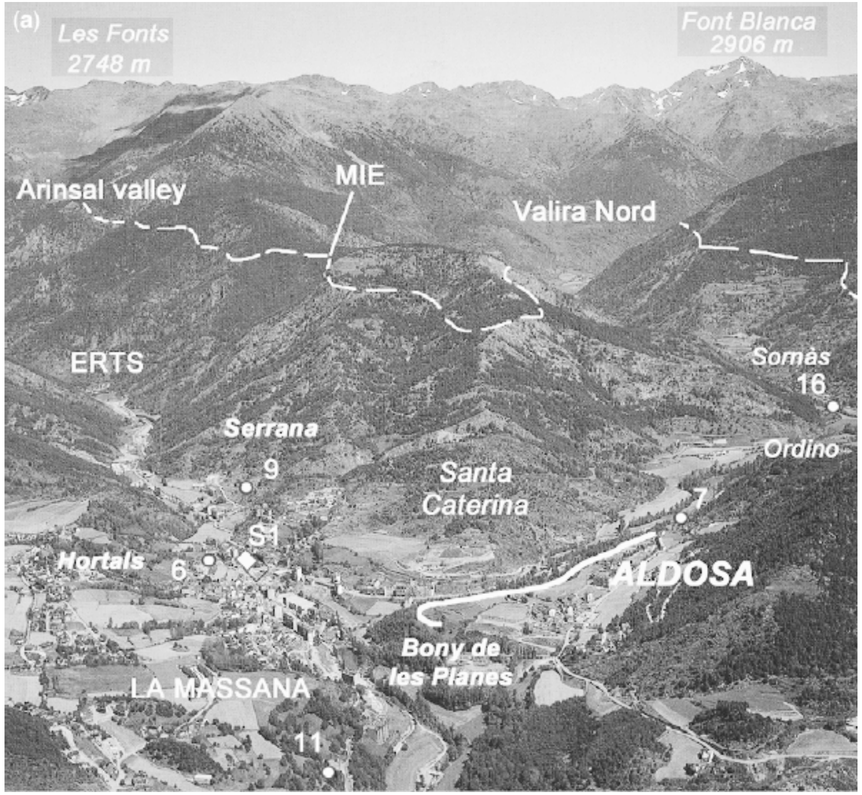




Turu et al. (2016)

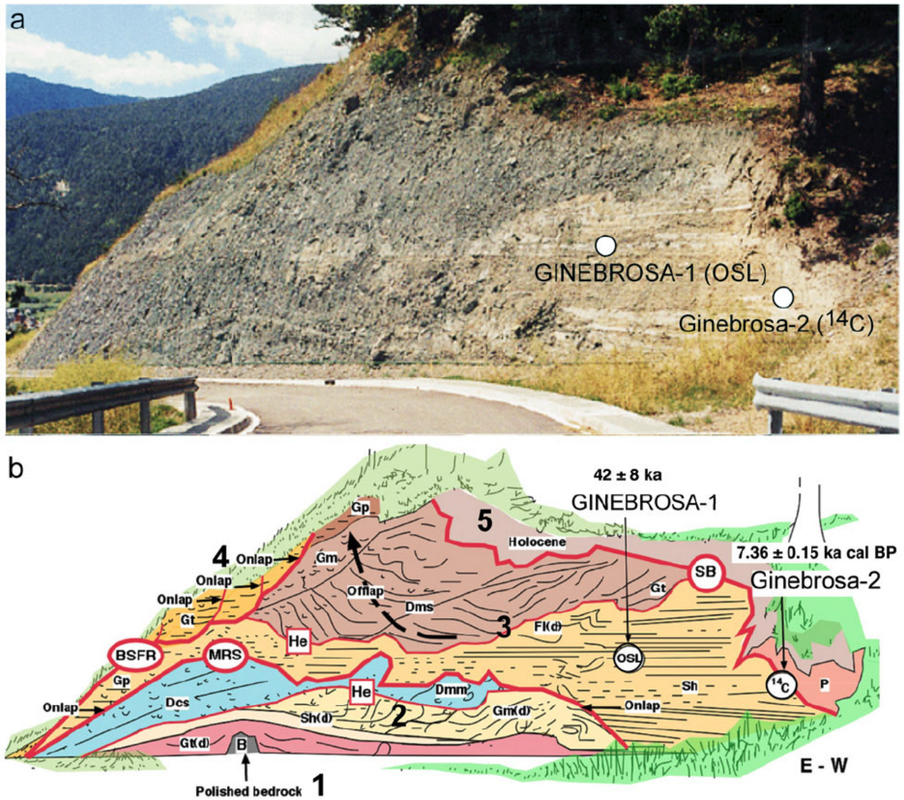
The core of the study area - Valira del Nord basin

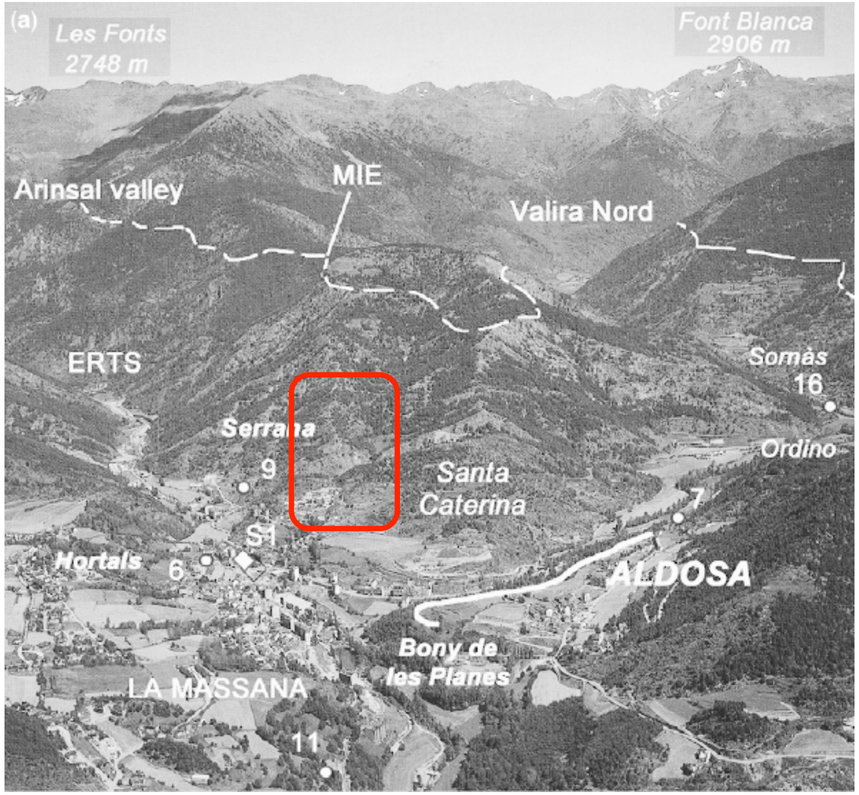




Turu et al. (2016)

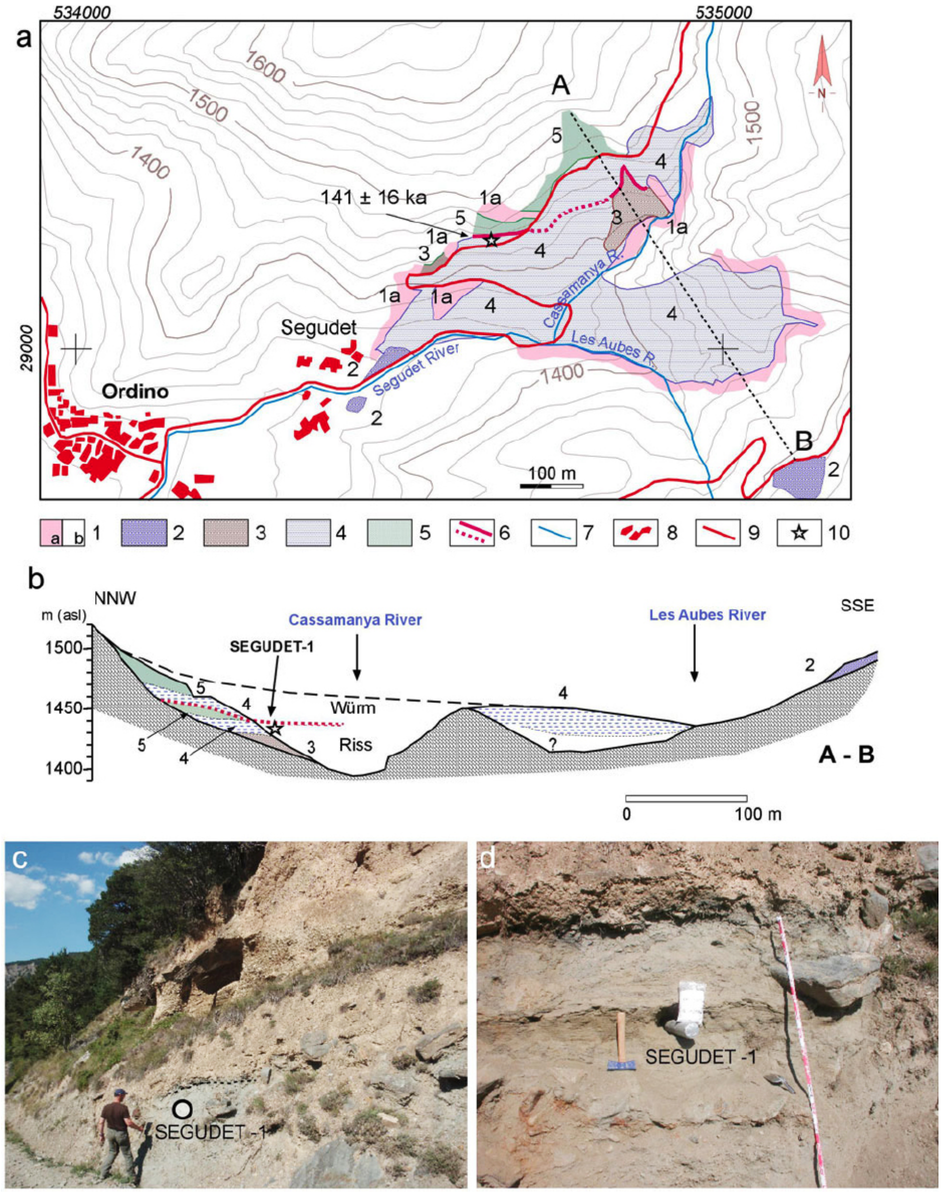
Valira del Nord basin – Lateral kame terraces

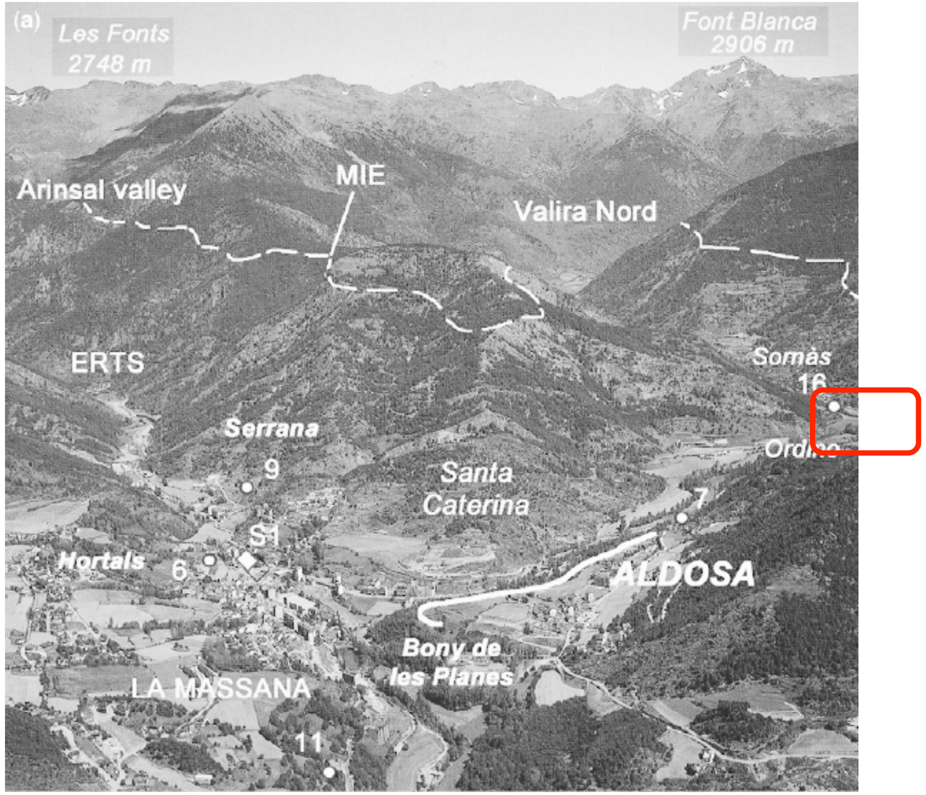




Turu et al. (2023)

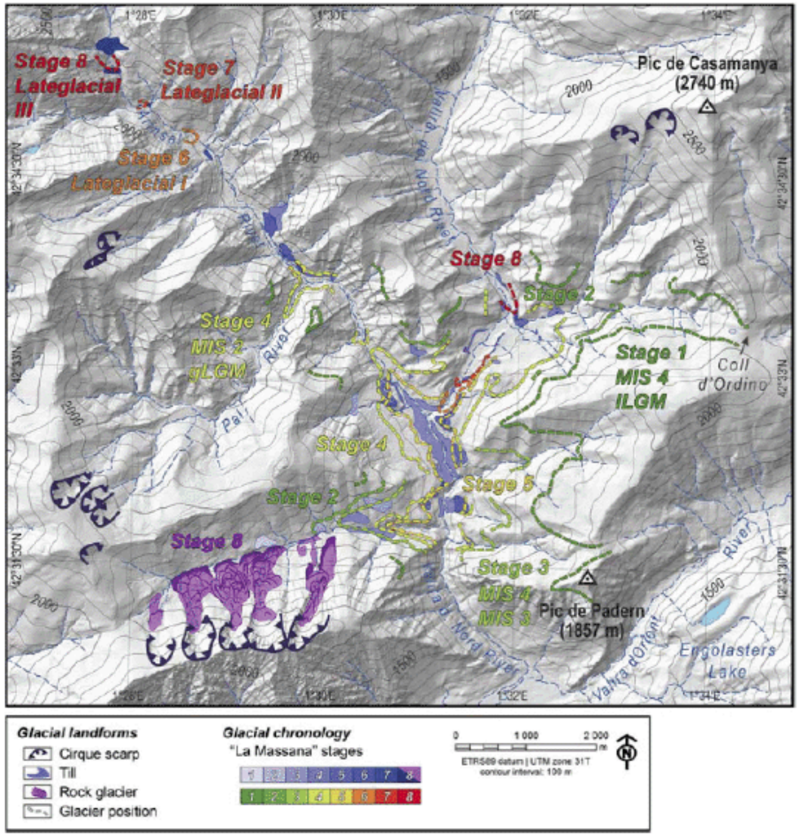
Valira del Nord basin − Lateral kame terraces − at several glaciations

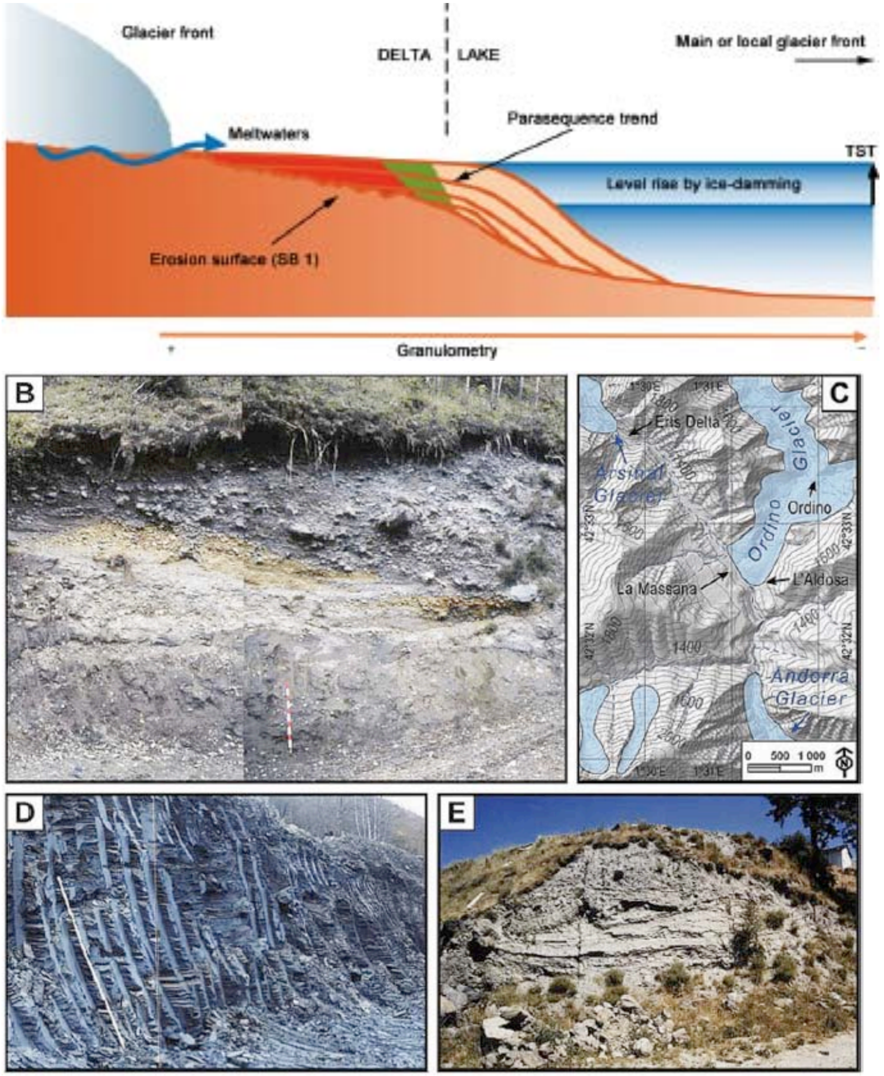




Turu et al. (2023)

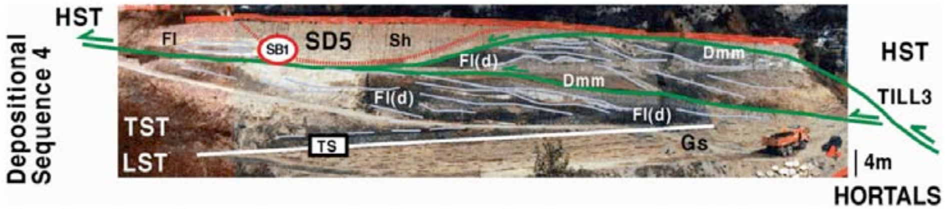
The La Massana palaeolake



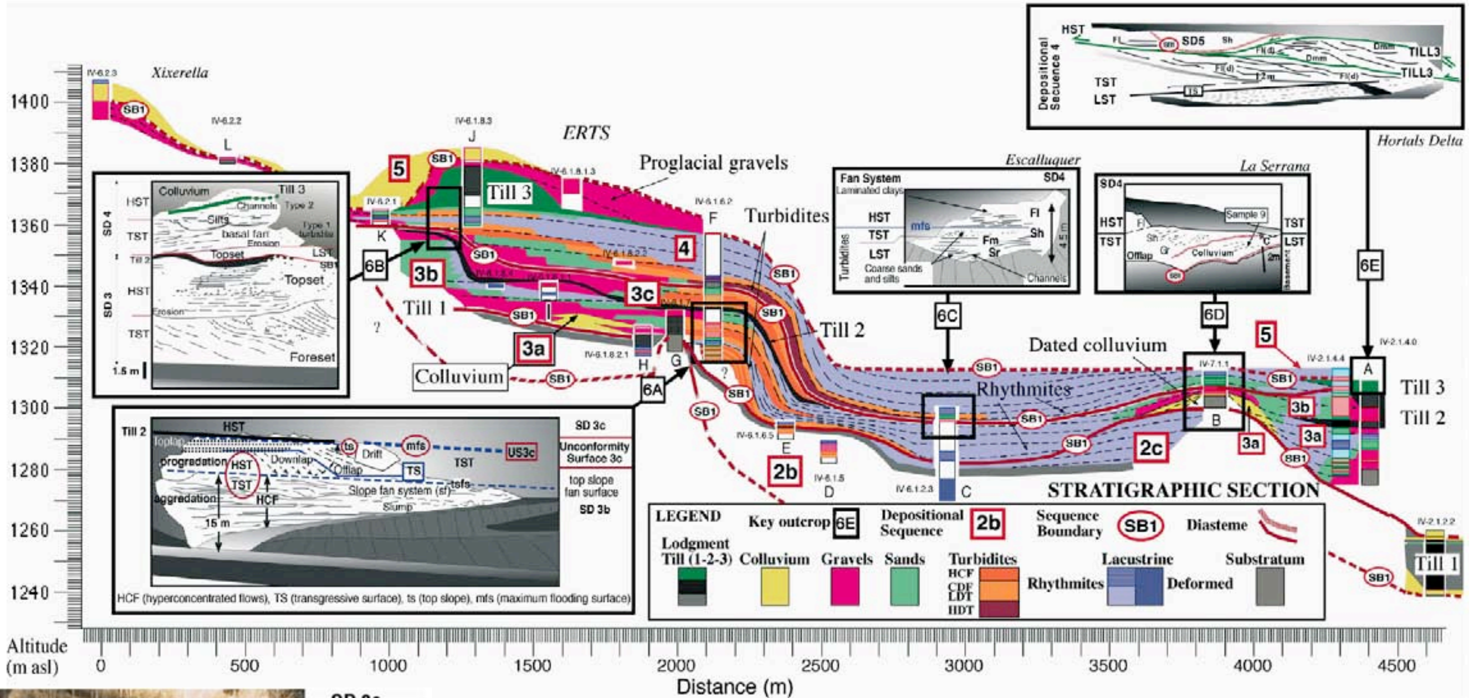


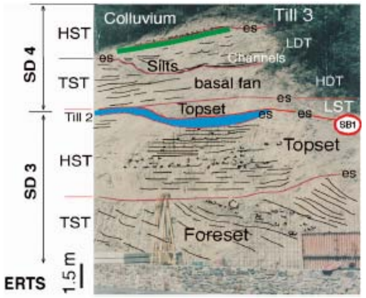
Ventura & Turu (2022)

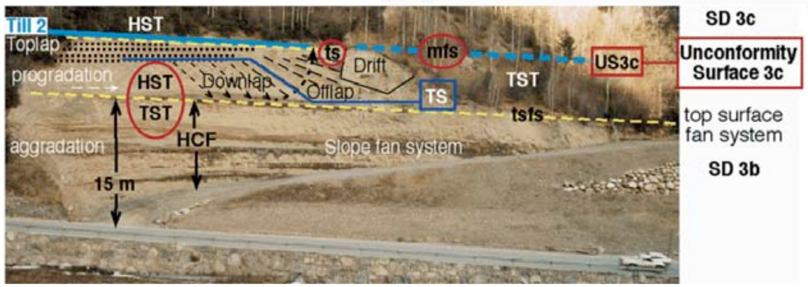
The glacier dynamics recorded at the Erts palaeoDelta

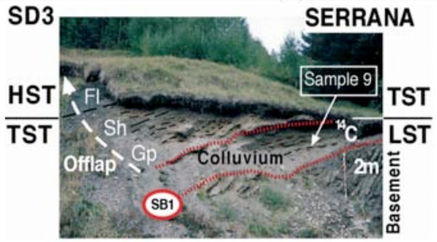


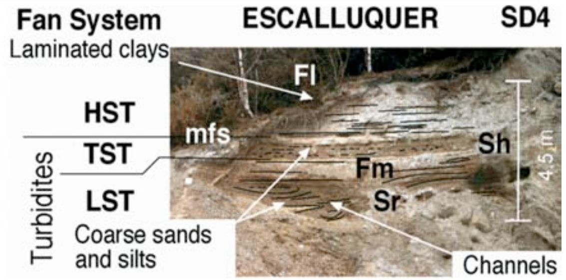
Turu et al. (2016)



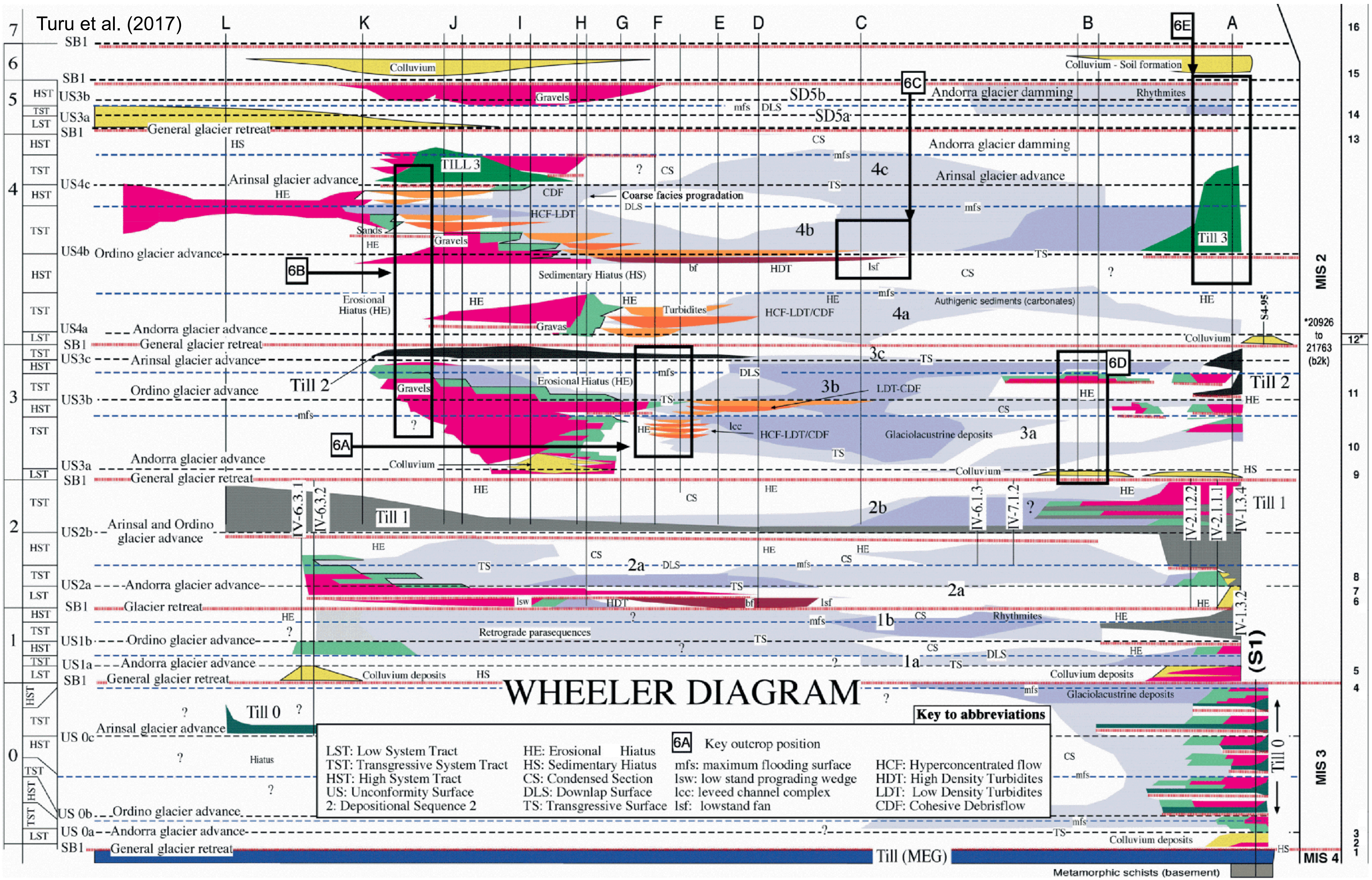




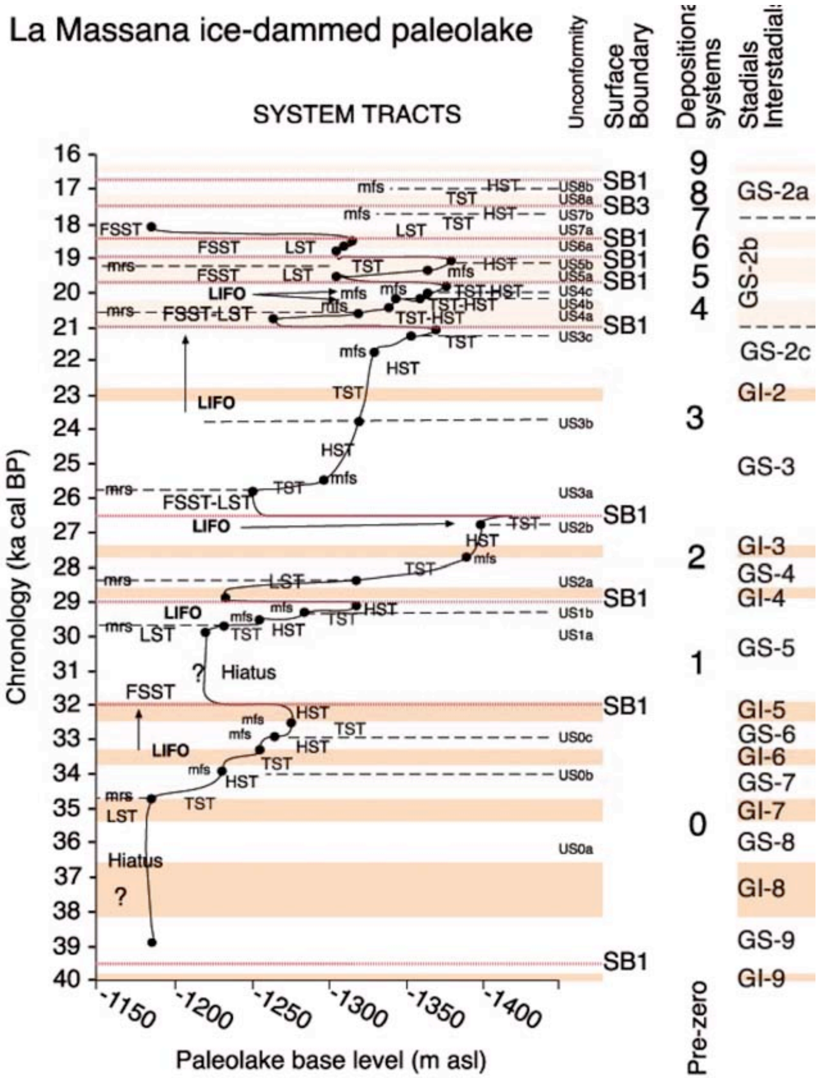




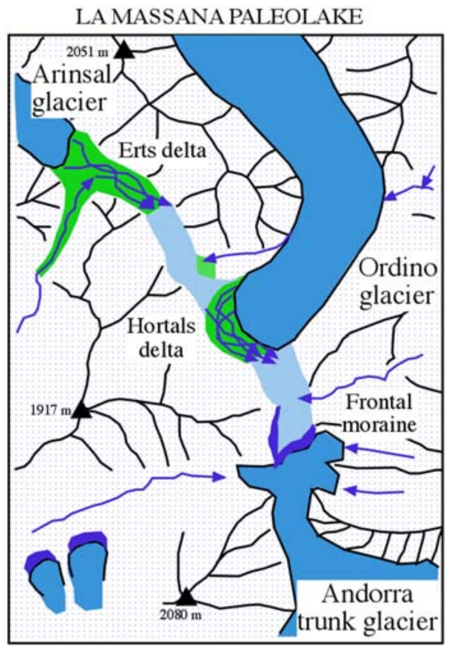
…… from the high resolution MIS 2 record of the Erts paleoDelta



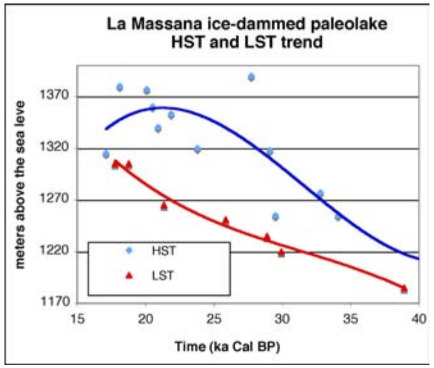
…… Type 1 and 3 discontinuity - unconformity and base level signification



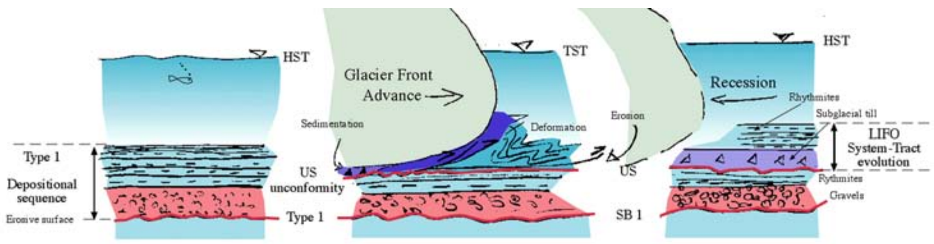
Turu (2018) modified



Turu and Bordonau (1997) modified

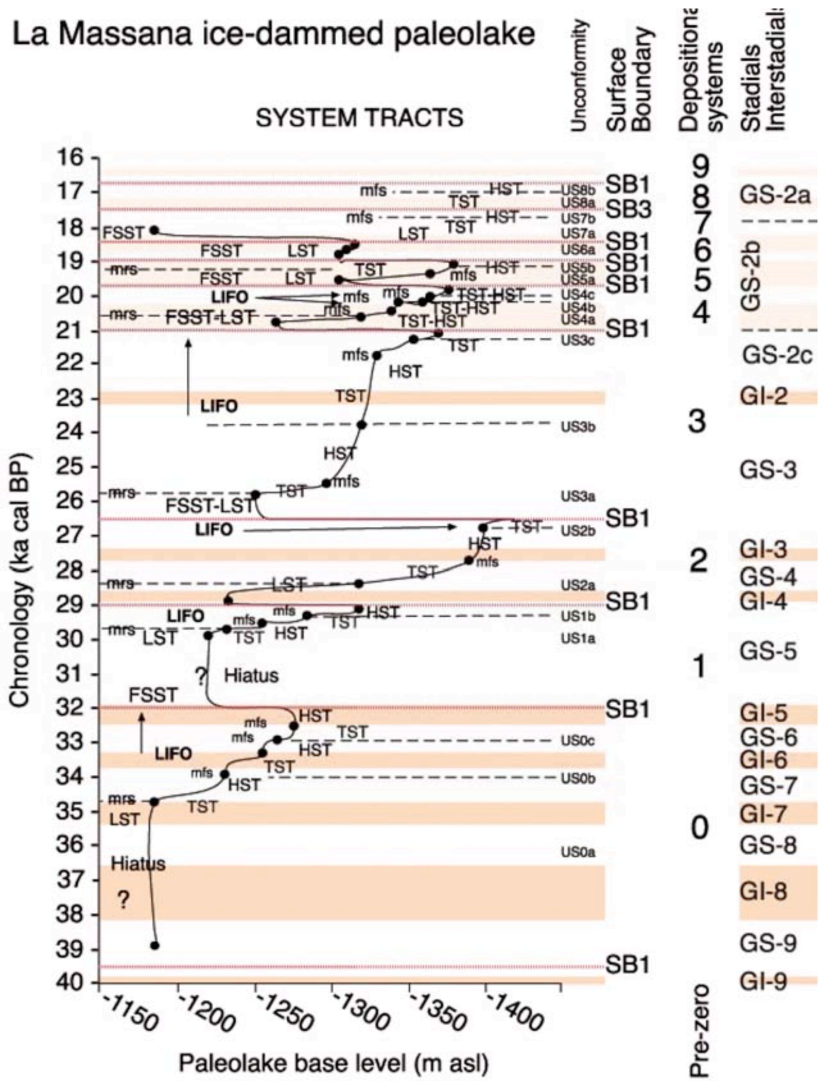


Meltwater overfed glaciers during LGM
Turu (2018)



Turu et al (2018)

…… swiching conditions on the palaeolake during the MIS 3 – MIS 2 transition



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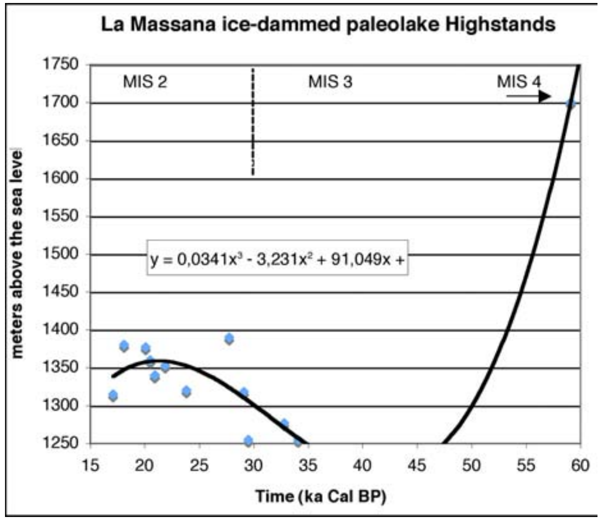
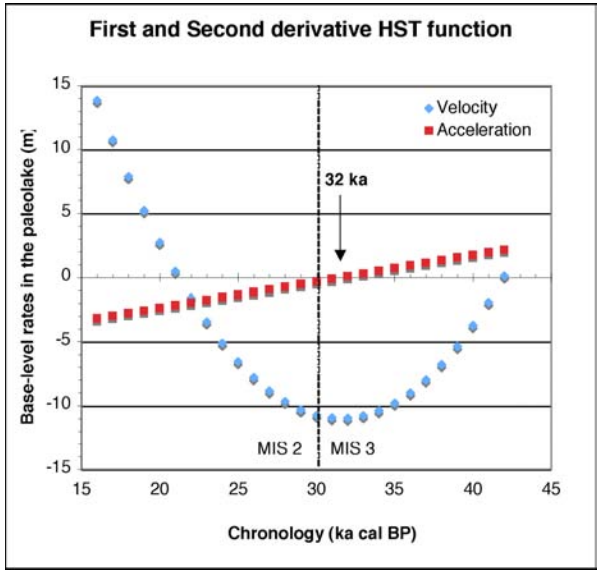
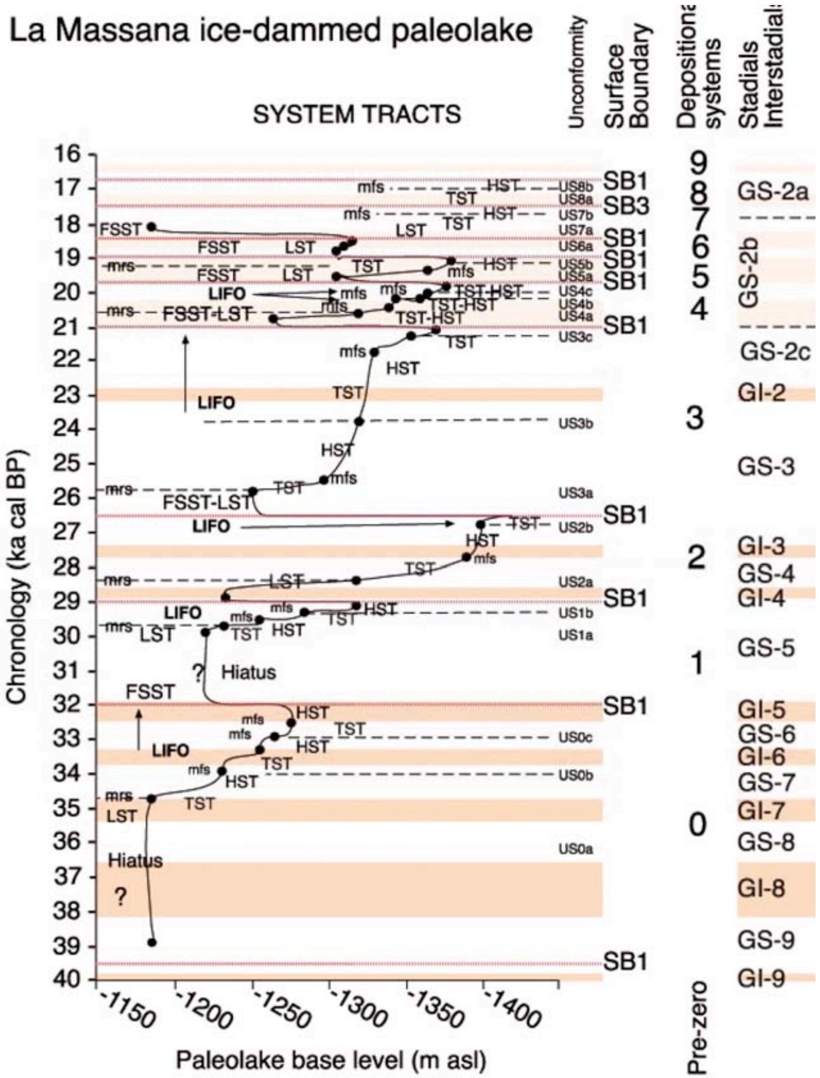


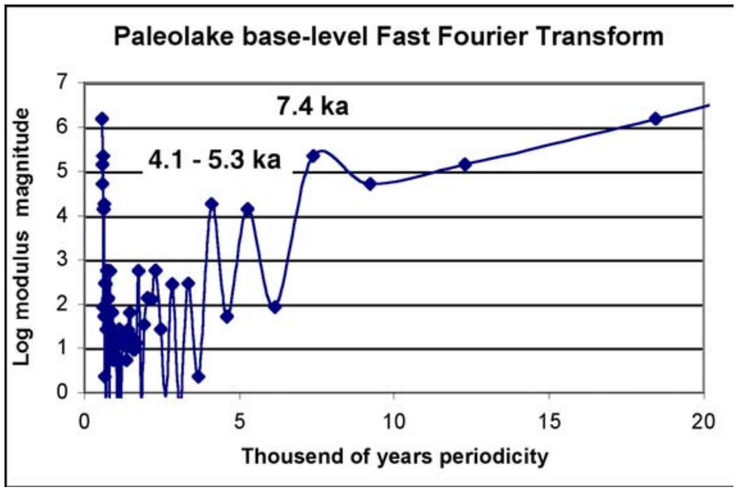


The **Aurignacian** **Gravettian** changeover!

Turu et al (2018)

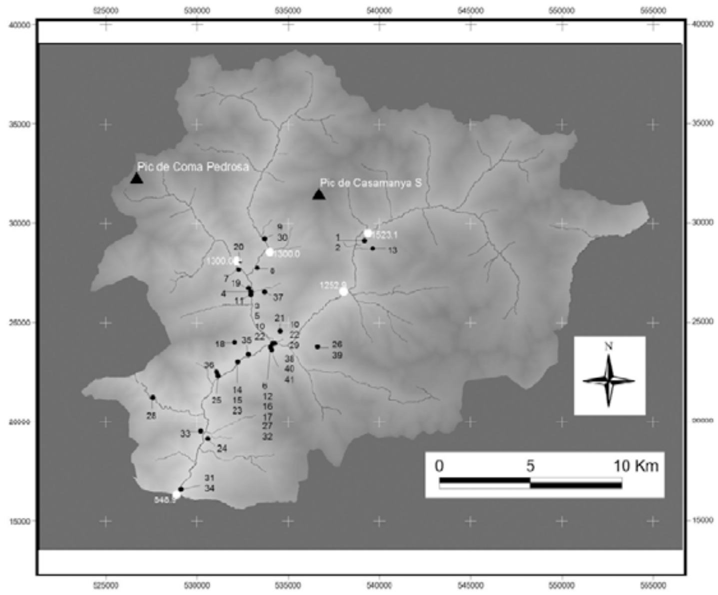
…… FFT reveal sub-Milankovich cycles





Cyclicity within the Henrich events at a frequency aprox. of 7.5 ka, but also …. other

…… the sub-Milankovich cycles palaeoenvironmental signification, the P cycles



Sampled sites from Andorra

P-cycles (4,500 +/- 500 yrs)

A peak of aridity within the 2sigma's range of an AMS date

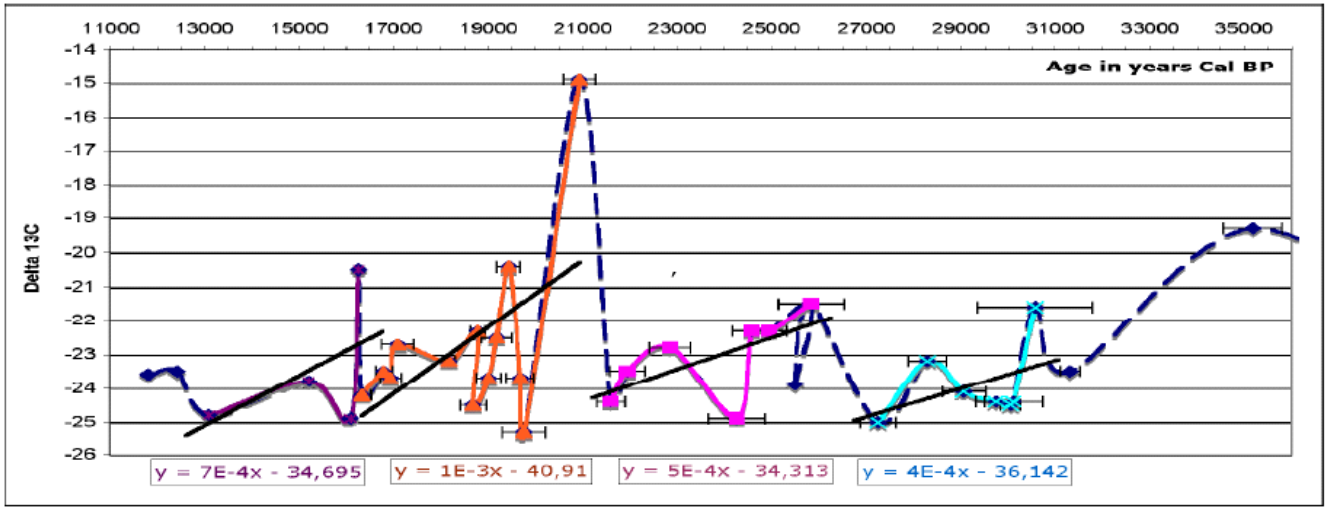
(… in **only +/- 80 yrs !!**)

The way after is a long recovering time of 4500 yrs until the system reach a new relative palaeoenvironmental climax

Quick shifting of depleted δ13C to enhanced values

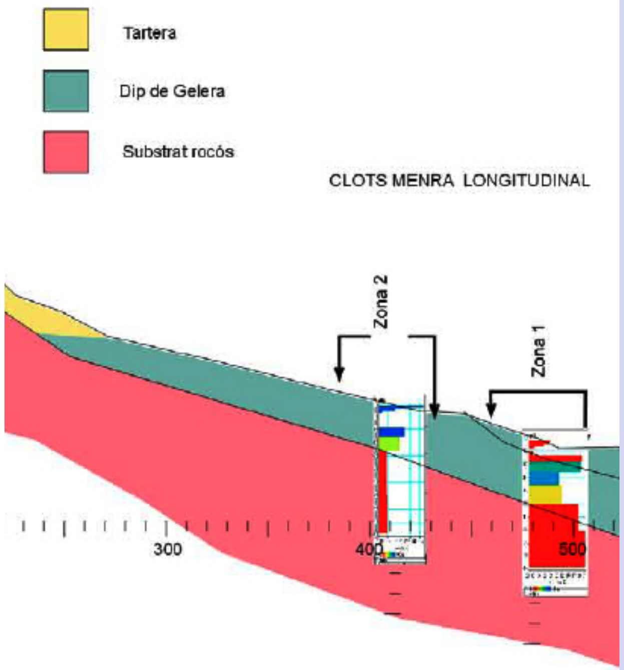
4.5 ± 0.5 ka to recover depleted values of -25‰ (δ13C)

Only bulk organic matter were used in AMS dates



SIMPOSI
PAISATGES HABITATS

PARC ARQUEOLÒGIC MINES DE GAVÀ

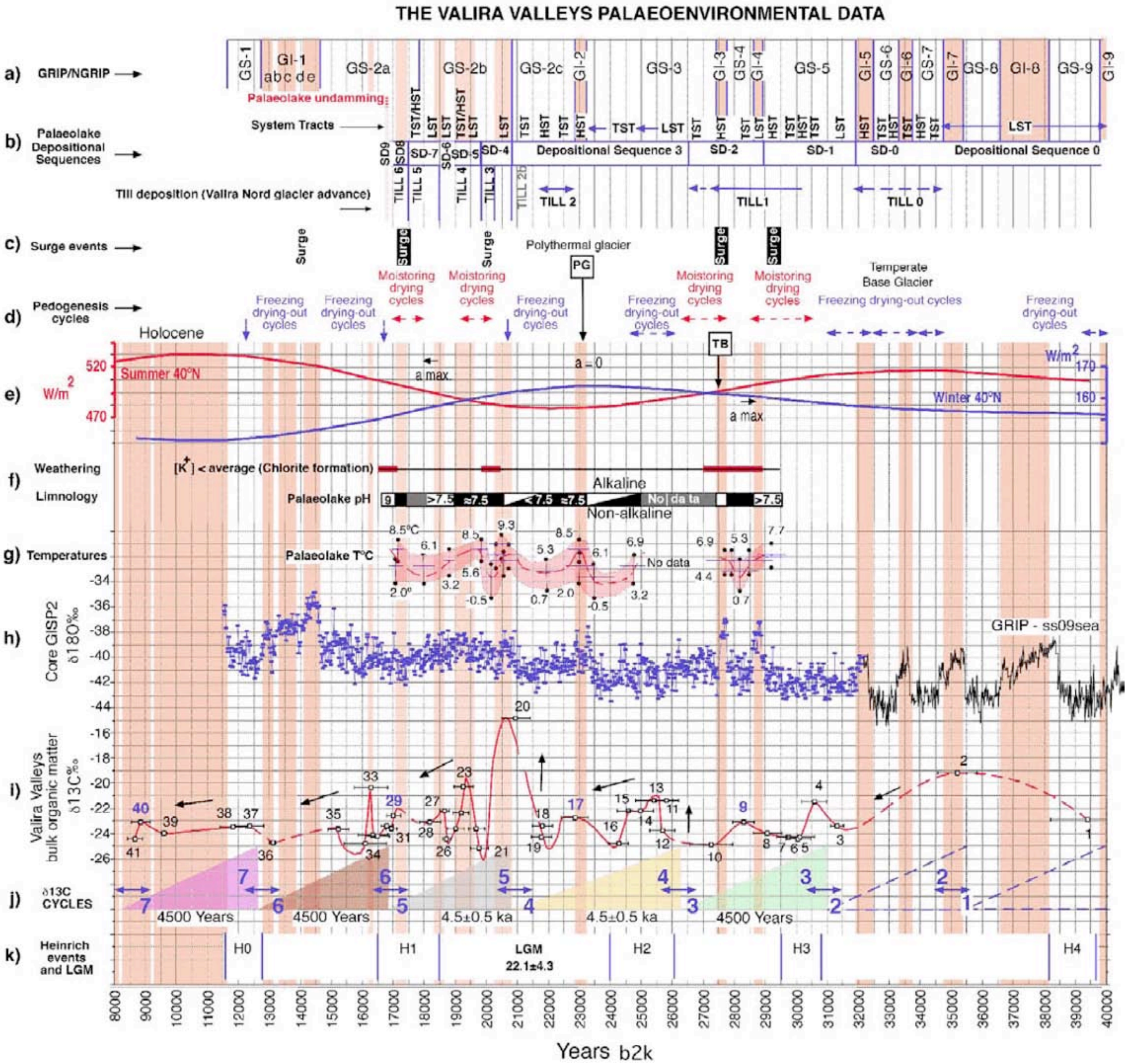


Pleistocene geomorphological transformations in the Valira valleys (SE Pyrenees)

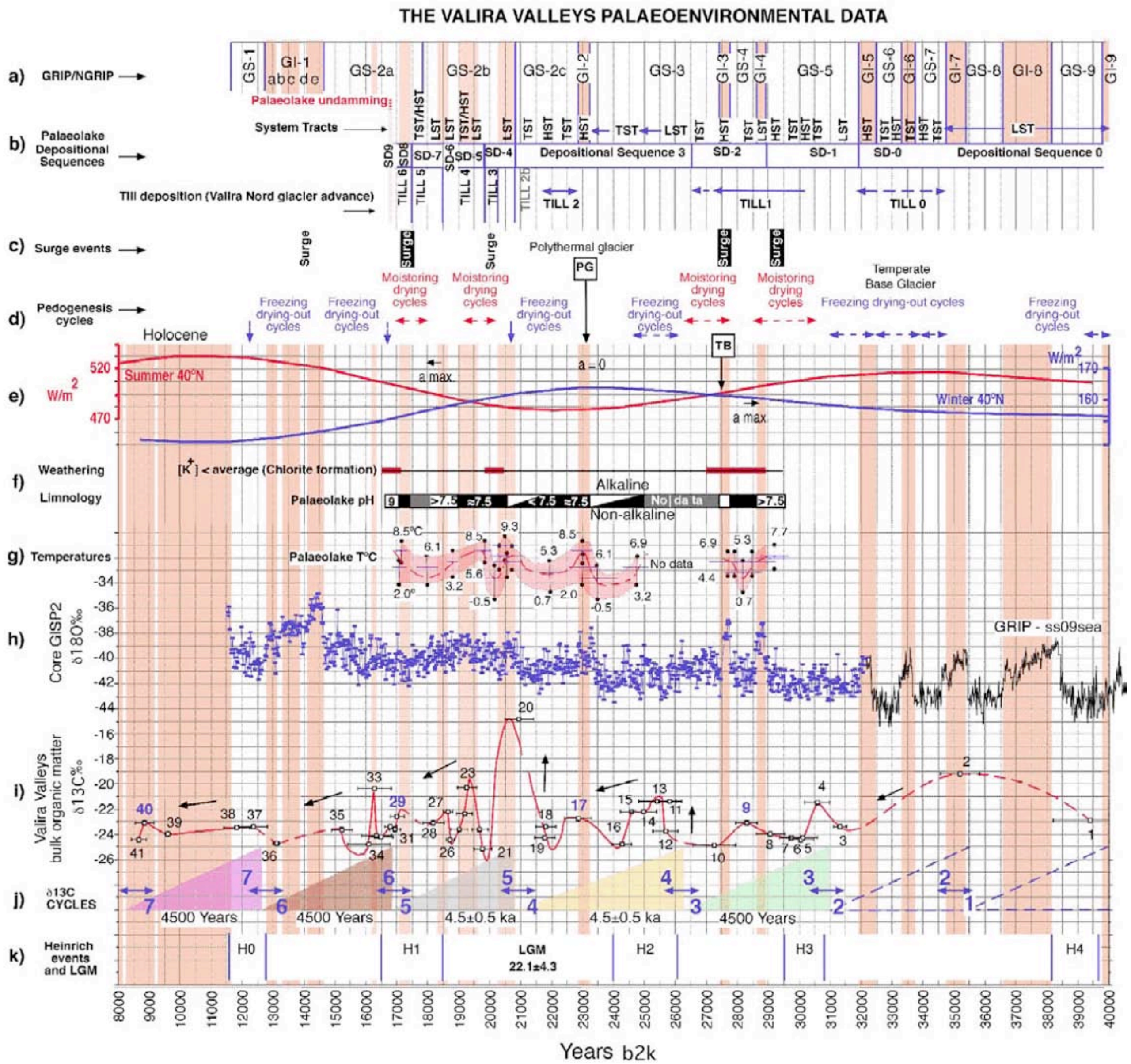
The main chart

Valentí Turu Michels

…… the main palaeoenvironment chart



<u>…… 40.000 to 8.000 yrs ago</u>



Greenland stadials

Stratigraphy

Surges events

Soil weathering

Solar irradiation and the role of “a”

Palaeolimnology

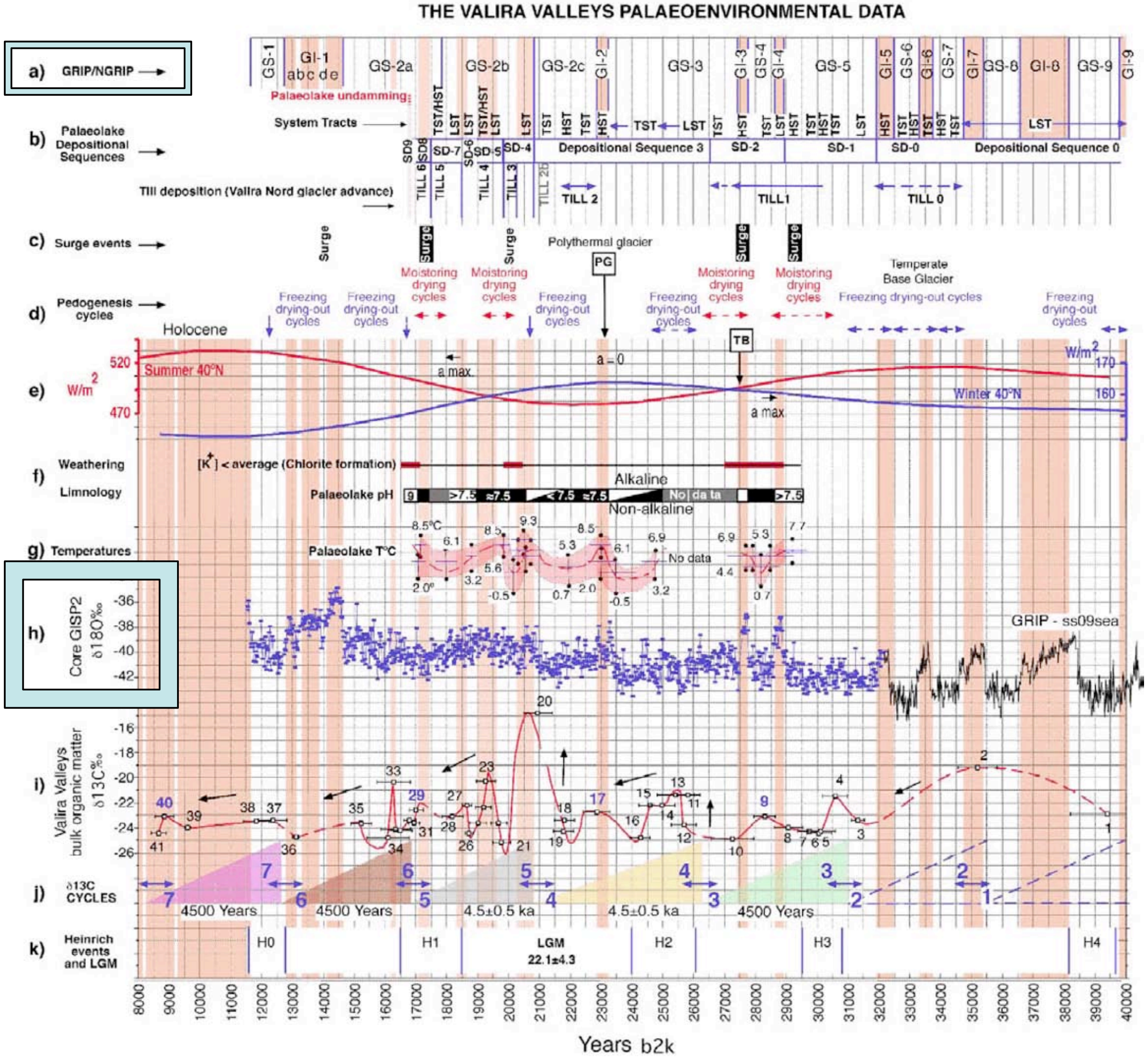
Palaeotemperatures at La Massana

GISP 2 (global reference)

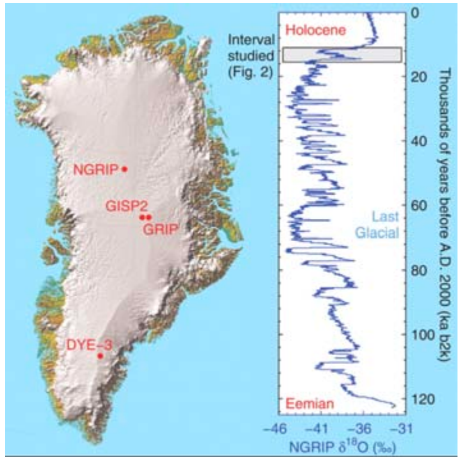
P Cycles

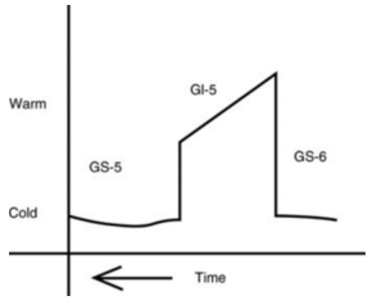
Heinrich events

…… 40.000 to 8.000 yrs ago

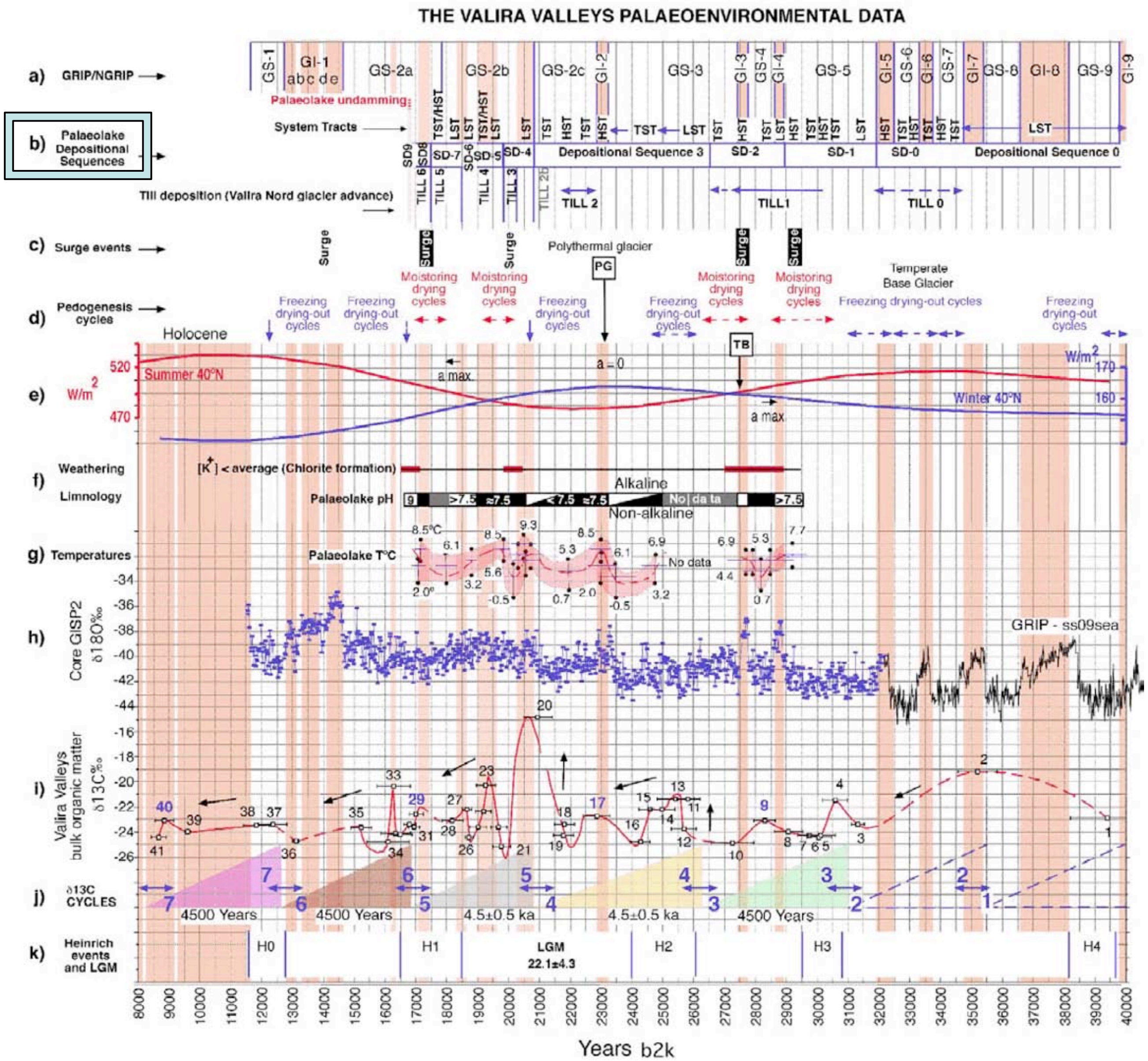


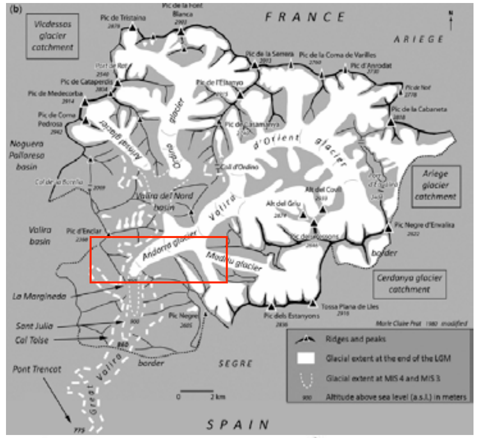
Greenland stadials

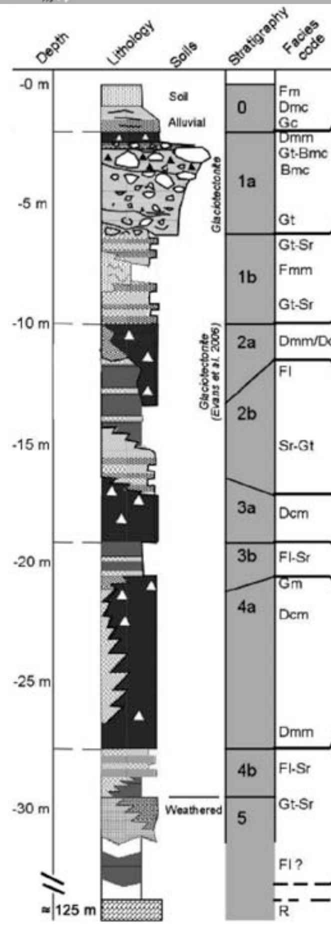




…… 40.000 to 8.000 yrs ago

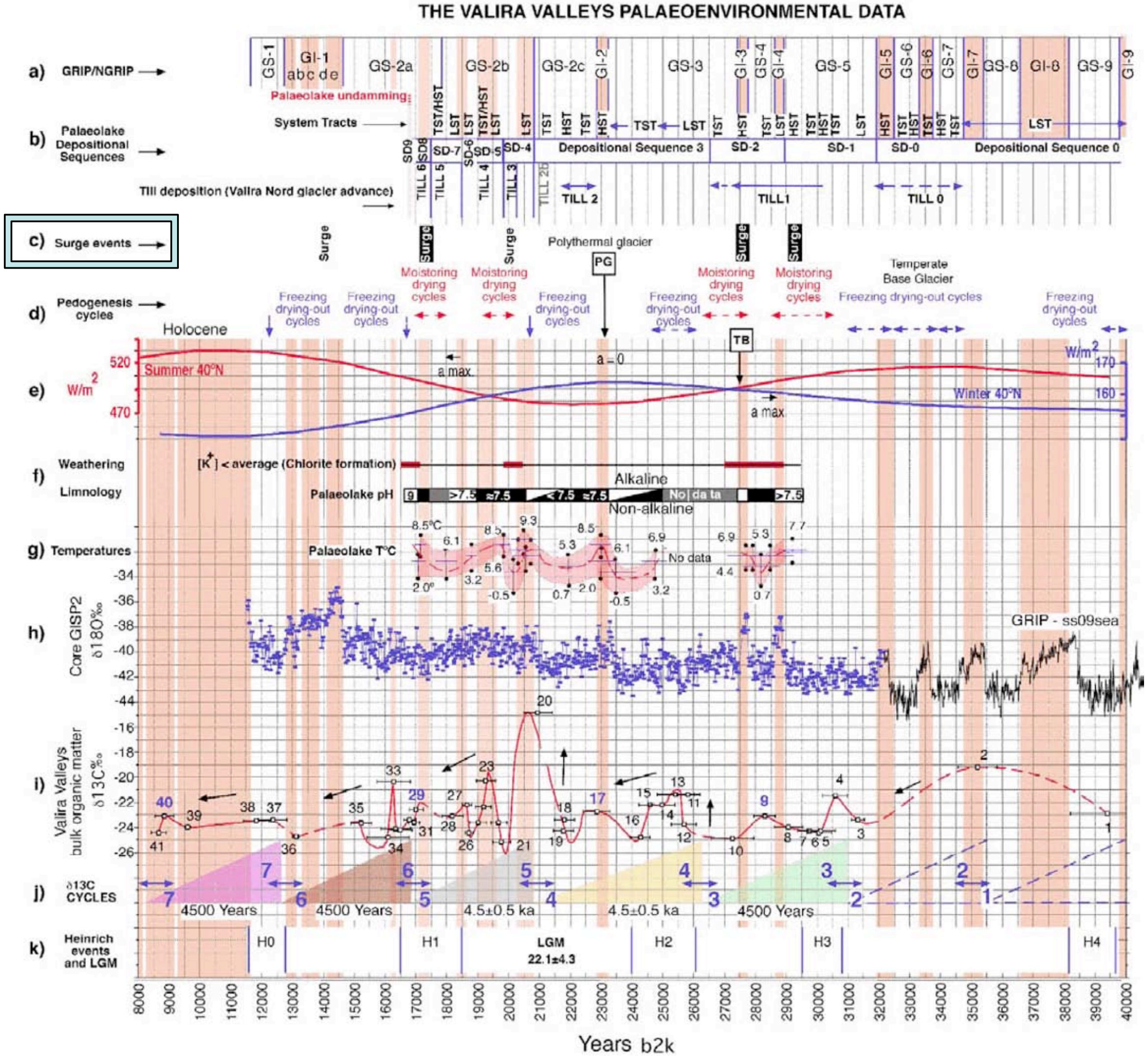


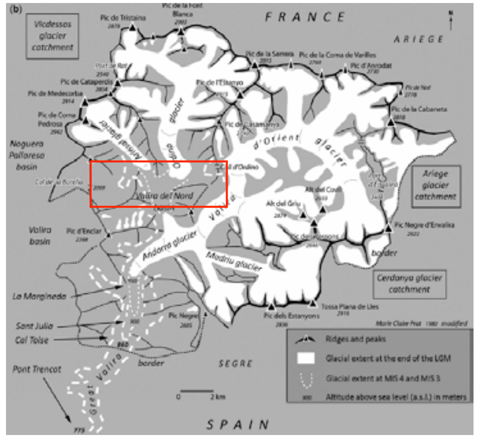




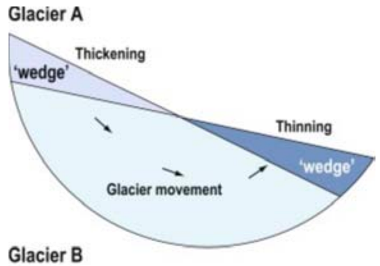
Stratigraphy

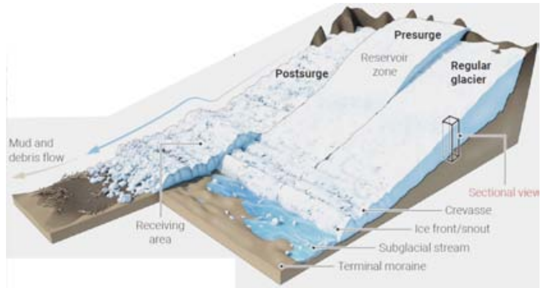
…… 40.000 to 8.000 yrs ago



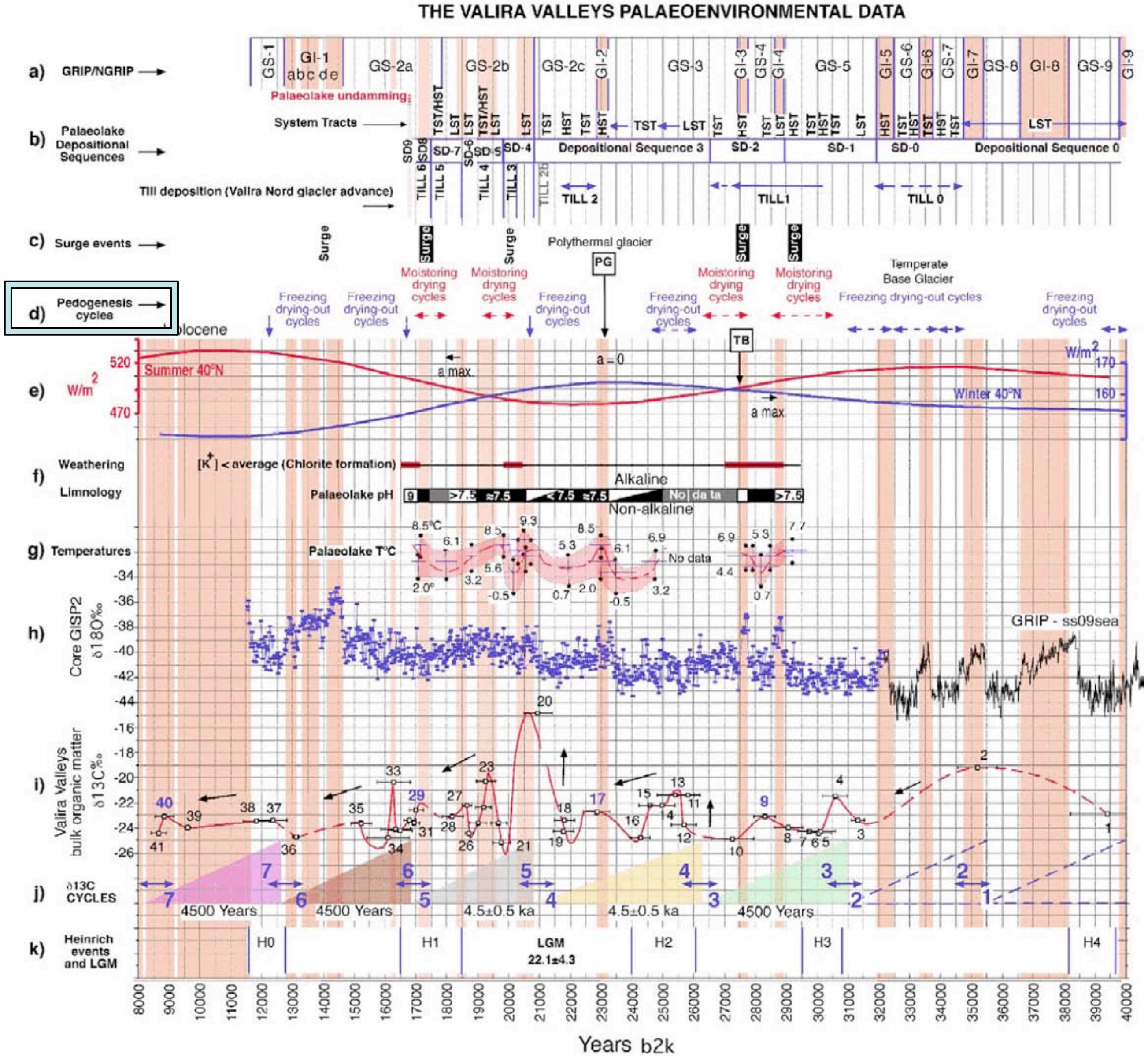


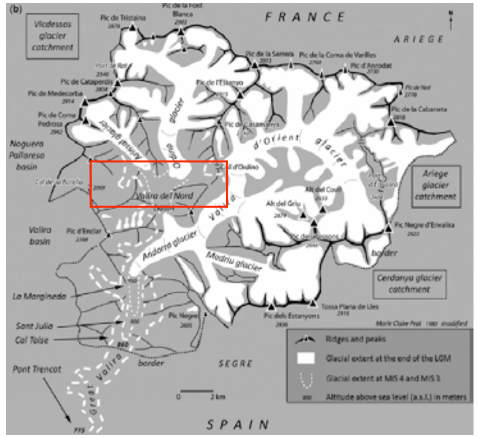
Surges events





…… 40.000 to 8.000 yrs ago





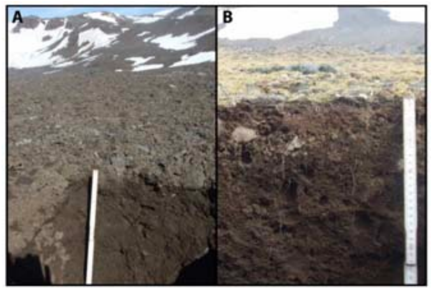
Soil weathering

Example from Antartica
Krauze, P. et al. (2021)

Photographs of the investigated Cryosols on King George Island, South Shetland Islands.

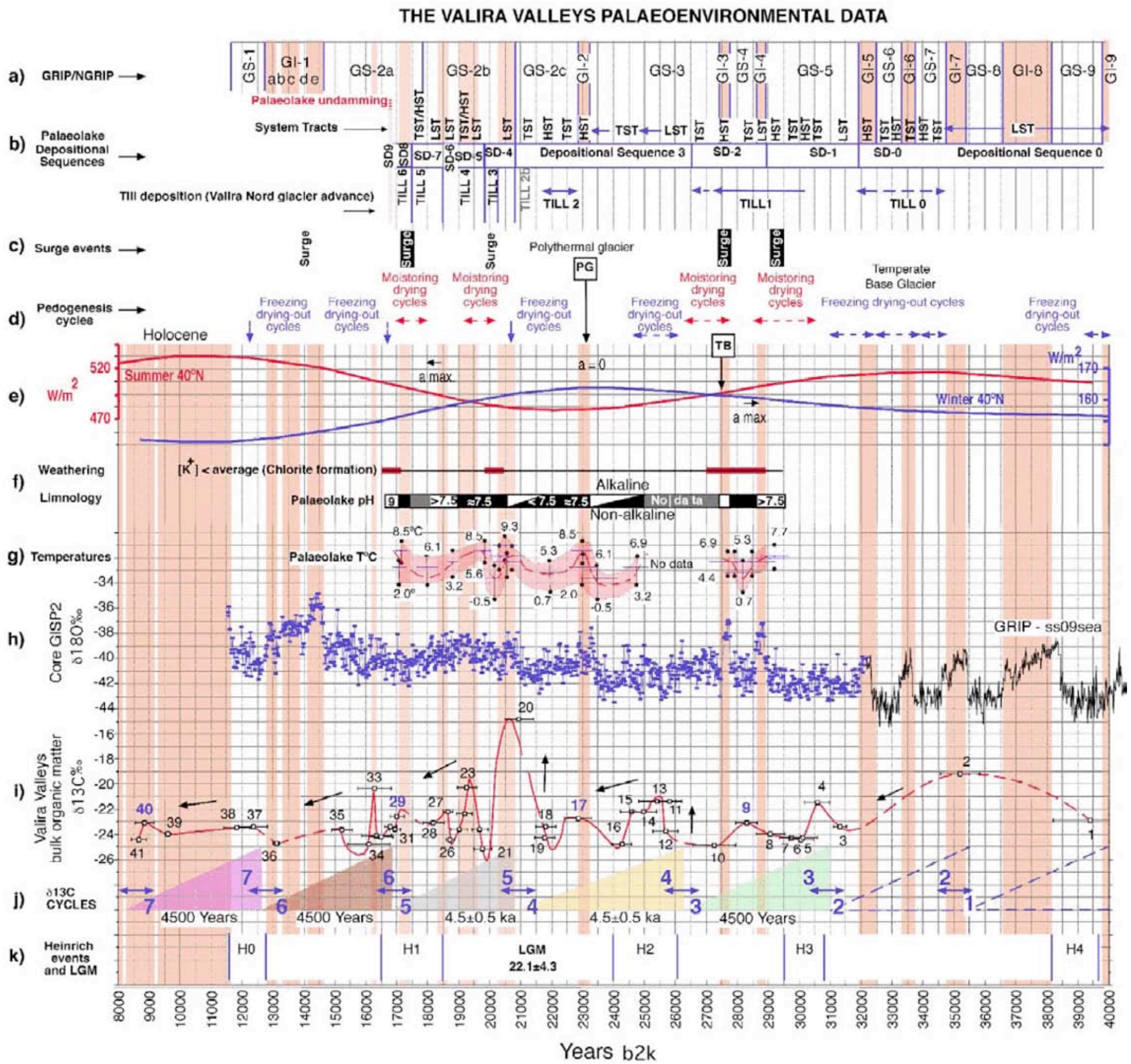
(A) KGI A, a hyperskeletic Cryosol, was located in the foreland of the Ecology Glacier, which was deglaciated after 1979

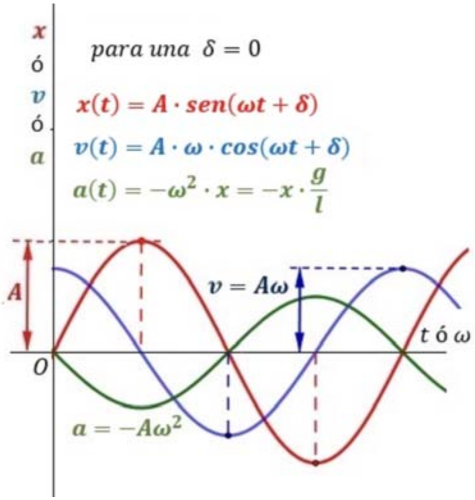
(B) Soil profile KGI D, a Cambic Cryosol, was located distal to the lateral moraine of the Ecology Glacier and was deglaciated before 1956



https://doi.org/10.1038/s41598-021-92205-z

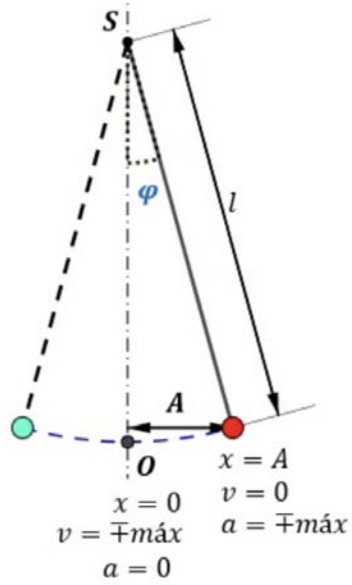
…… 40.000 to 8.000 yrs ago



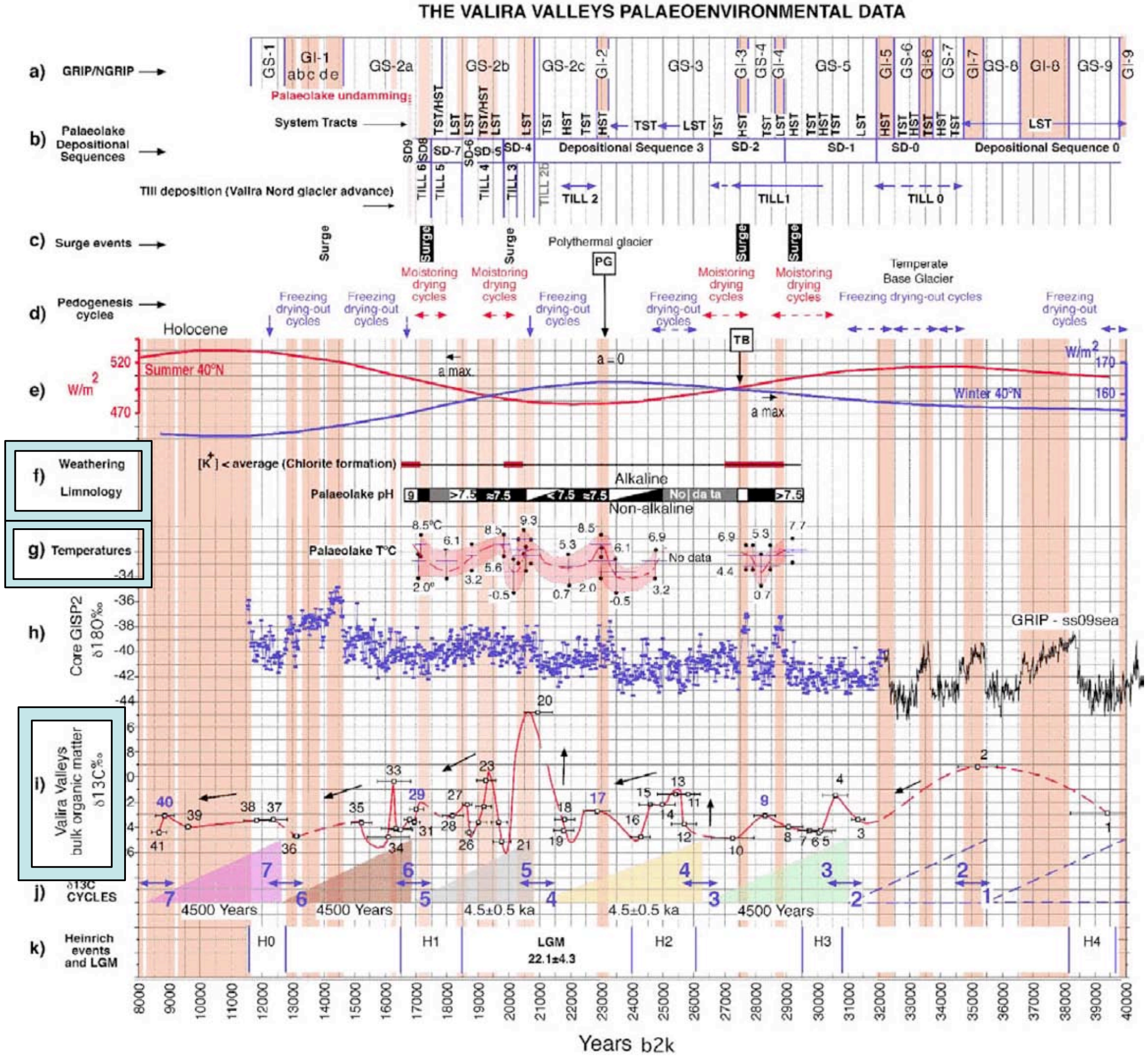


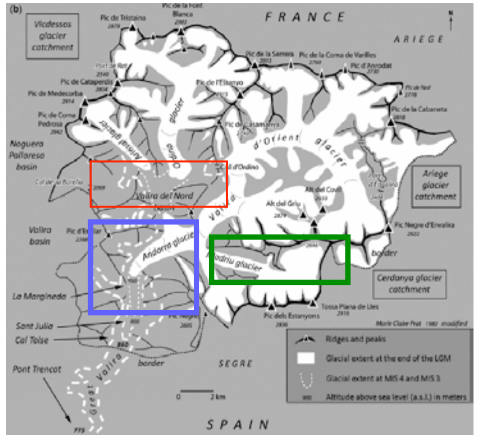
Solar irradiation

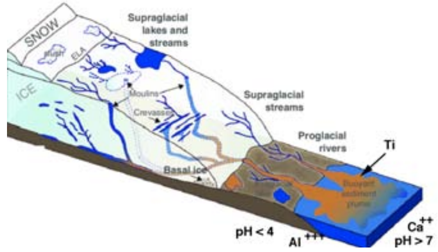
and the role of “a”



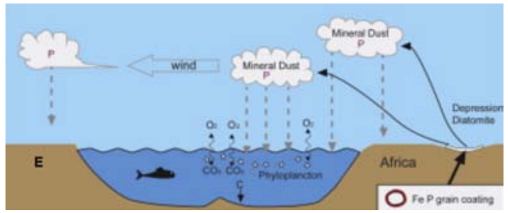
…… 40.000 to 8.000 yrs ago



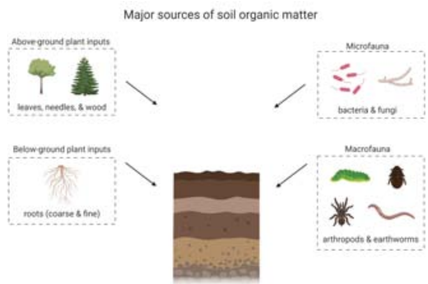




Palaeolimnology

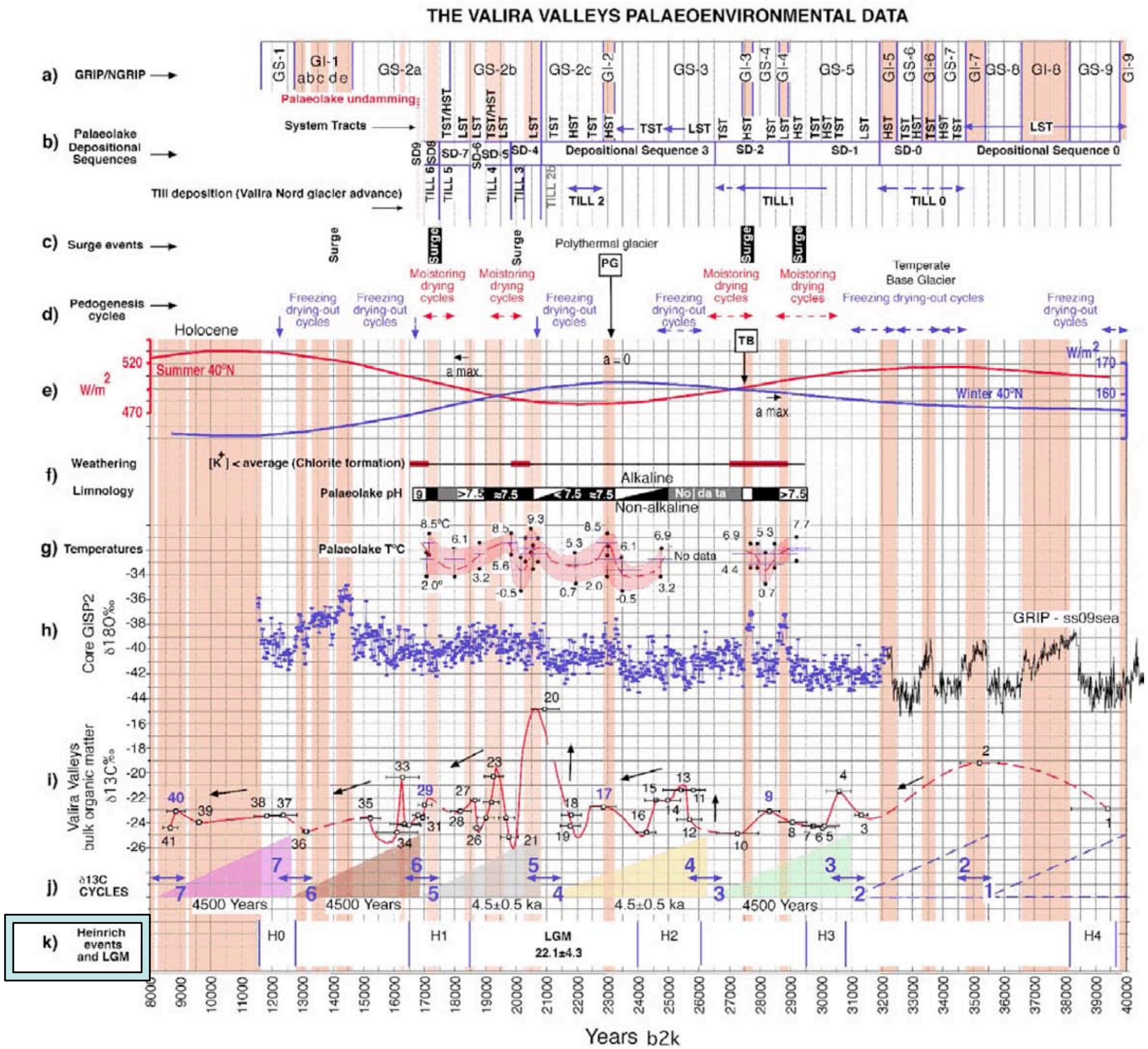


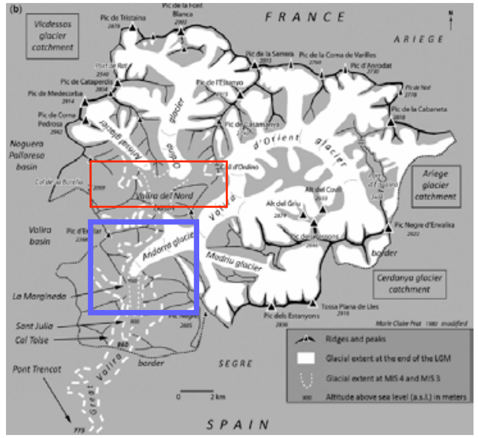
P content as a proxy



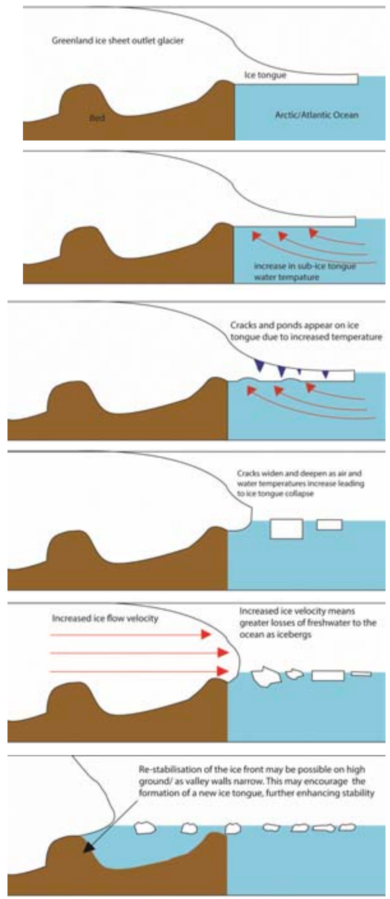
Carbon isotopes data

…… 40.000 to 8.000 yrs ago





Heinrich events



Motion by Neil McDonald, Stirling University

…depicting the contribution of the P-cycles, LGM and Heinrich events together

Hiatus > 40 ka

P Cycles swich at

32-31.5 ka

Gravettien

26.5-26 ka

Solutrean

21.5-21 ka

Badegoulien

The LGM peak two times twice. First within a P-cycle and the last at

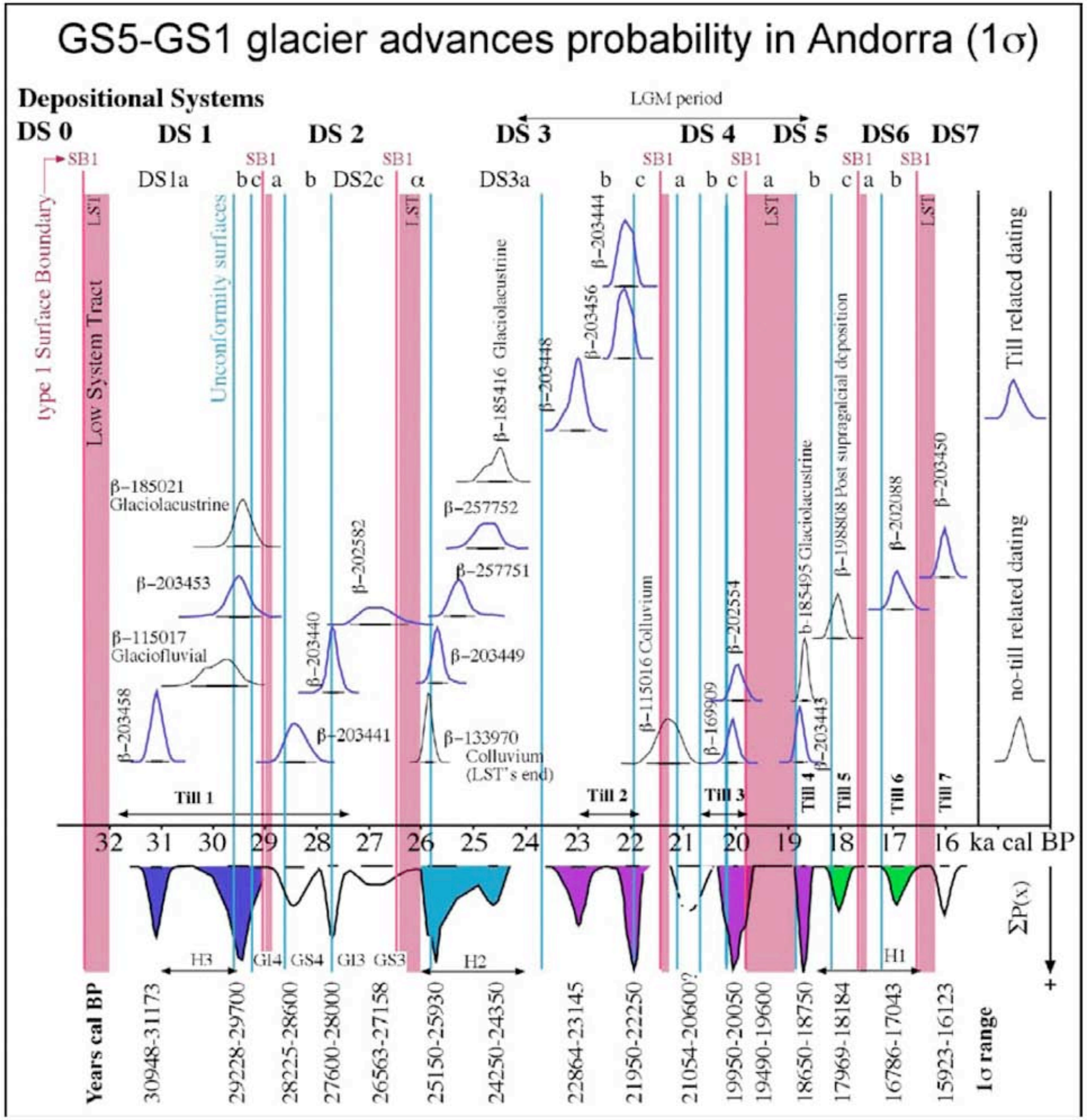
20 and 18.75 ka,

the changeover to

Magdalenian

Glaciers peaked twice at each Henrich event

…adding subfacies to the Gravettian, the Solutrean, the Badegoulien and the Magalenian



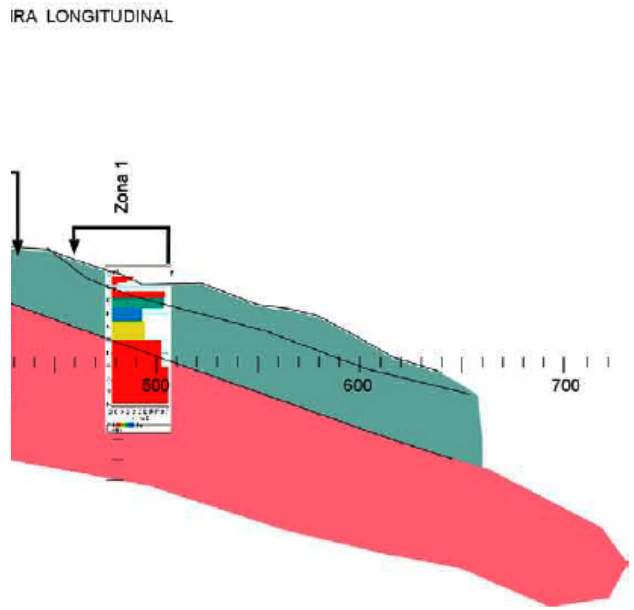
DS = Depositional sequences

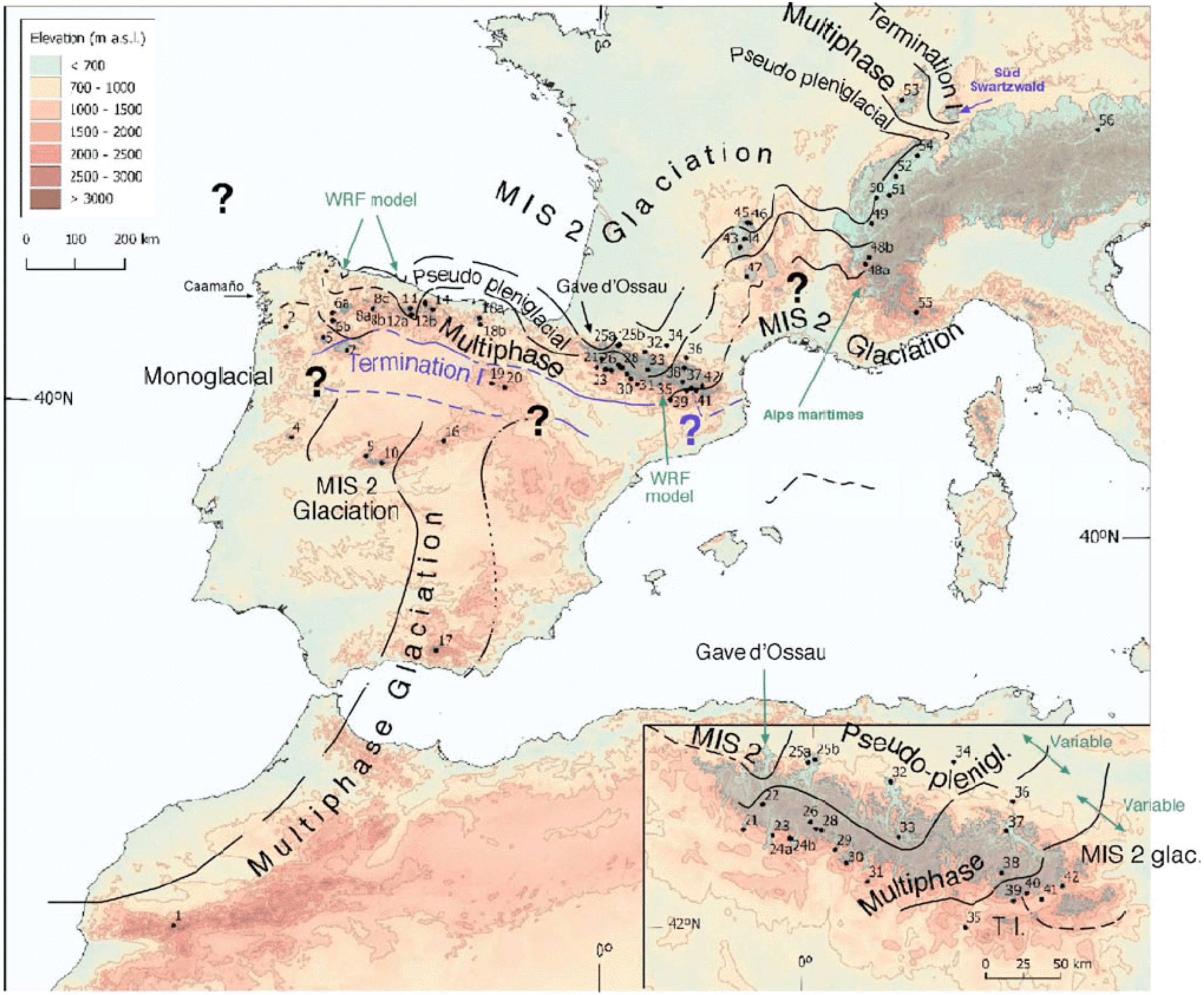
Pleistocene geomorphological transformations in the Valira valleys (SE Pyrenees)

Correlation

The Last Glacial Cycle

Valentí Turu Michels



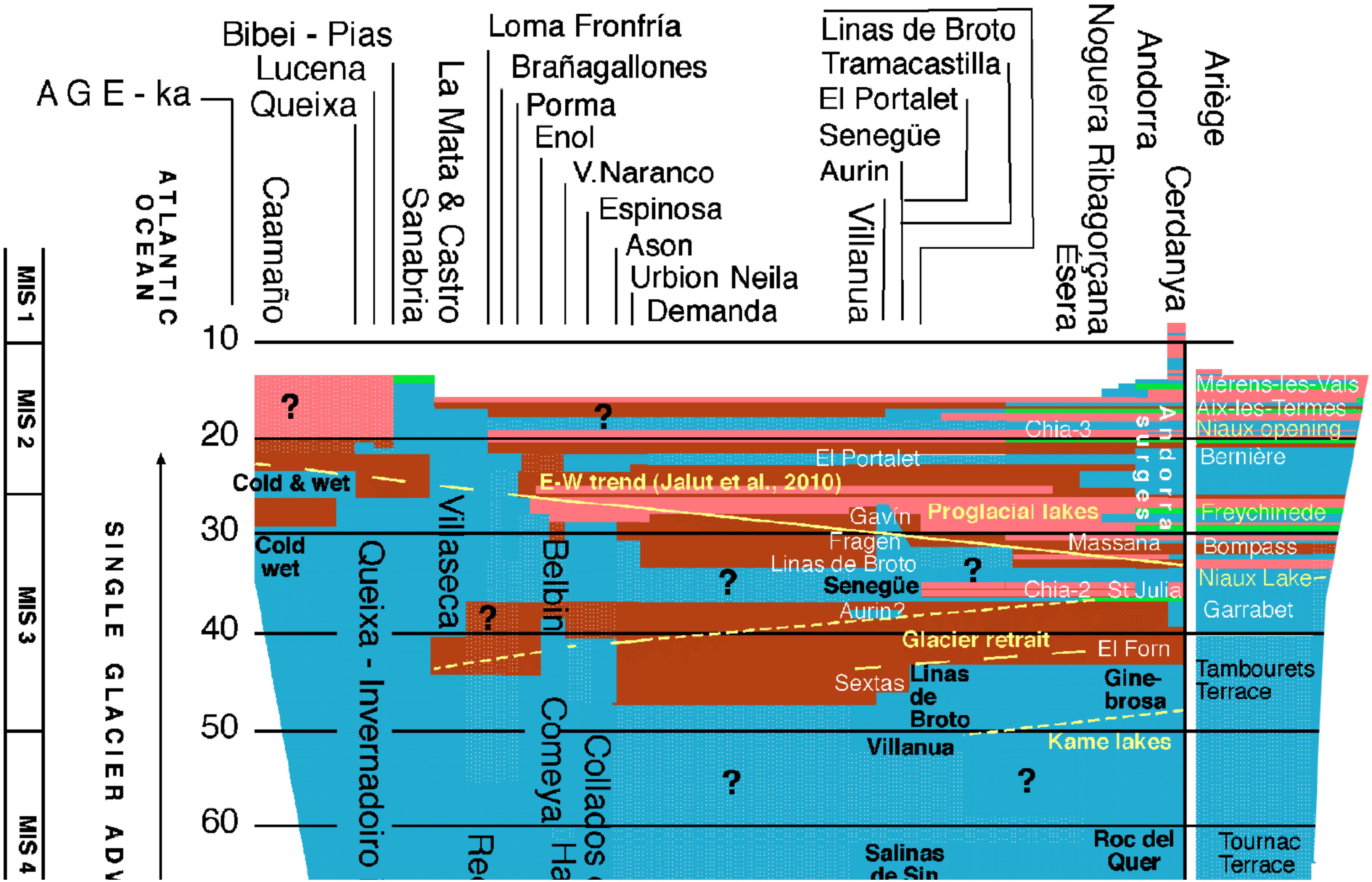

Elevation (m a.s.l.)
< 700
700 - 1000
1000 - 1500
1500 - 2000
2000 - 2500
2500 - 3000
> 3000
0 100 200 km
WRF model
Caamaño
Monoglacial
Pseudo pleniglacial
Multiphase
Termination I
MIS 2 Glaciation
Gave d'Ossau
Multiphase
Termination I
Pseudo pleniglacial
Süd Swartzwald
MIS 2 Glaciation
Alps maritimes
WRF model
MIS 2 Glaciation
Multiphase Glaciation
40ºN
0º
Gave d'Ossau
MIS 2
Pseudo-pleniglacial.
Variable
Variable
MIS 2 glac.
Multiphase
T.I.
42ºN
0 25 50 km

Turu (2023)

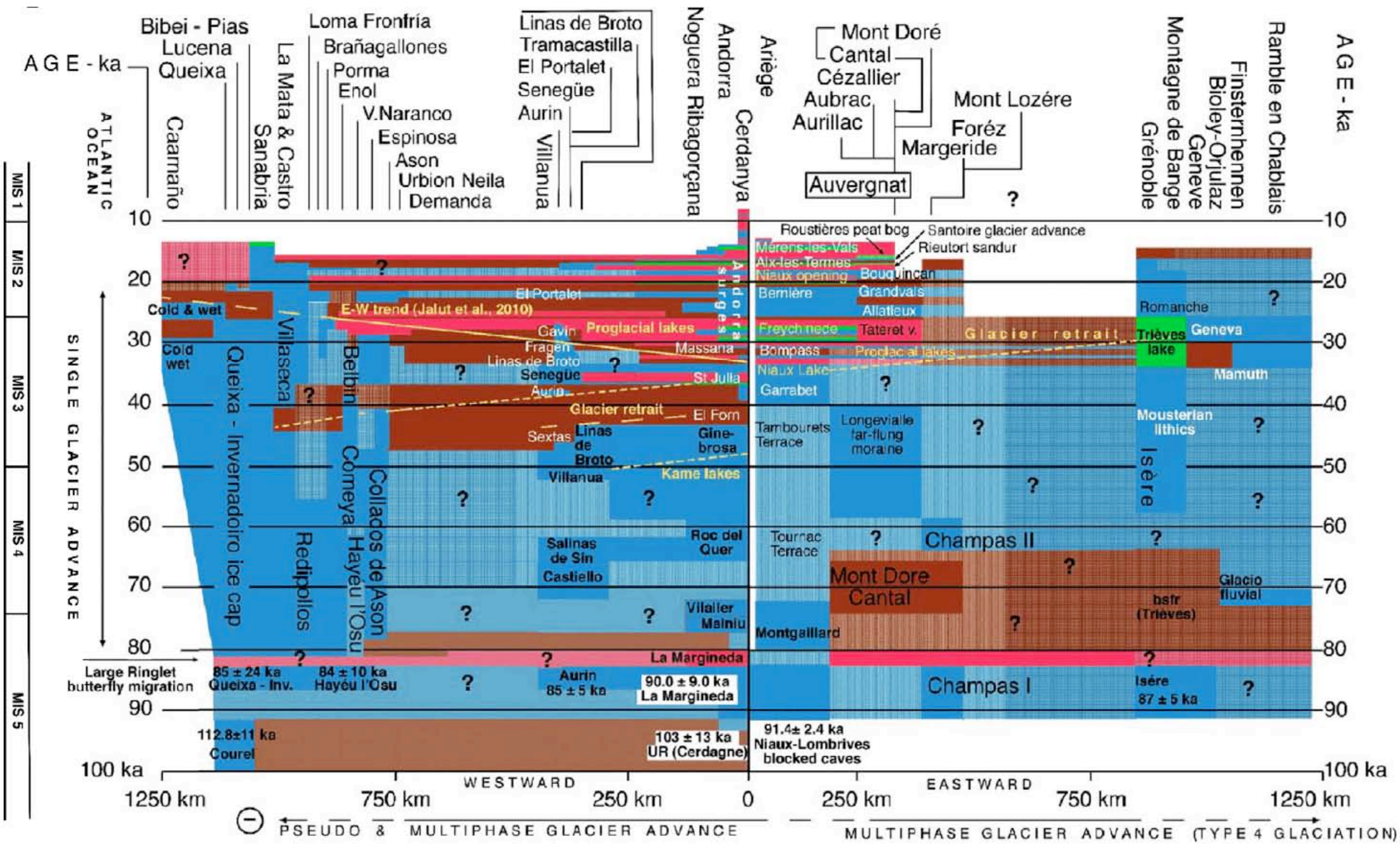
Legend

Glaciation types boundaries and sites: 1-Toubkal-4, 2-Serra do Xistral, 3-Sextas, 4-Serra da Estrela, 5-Queixa-Invernadoiro, 6a-Oribio Mounts, 6b-O Courel, 7-Sanabria, 8a-Castro Lake (Villaseca de Laciana), 8b-Laguna-A-Lucenza, 8c-Laguna Grande de Neila, 9-Bejar massif, 10-Gredos massif, 11-Brañagallones, 12a-, Porma/Lillo, 12b-Redipollos, 13a-Comeyas' polje, 13b-Hayéu l'Osu cave, 14-Campo Mayor, 15-Bibei, 16-Guadarrama, 17-Hoya Pelada, 18a-Ansón, 18b-Trueba, 19-Laguna de Miro (Villaseca Laciana), 20-Sierra Cebollera, 21-Villanúa(Castiello de Jaca, 22-Serra Faro de Avión, 23-Gavin, 24a-Llinàs de Broto, 24b-Viu, 25a-Soum d'Ech, 25b-Lourdes and Monge, 26-Garbarnie, 27-Pineta (Lago), 28-Larri hanged valley, 29-Salinas de Sin, 30-Cotiella, 31-Turbon, 32-Barbazán, Garonne paleolake, 33-Joèu, 34-Têt – La Borde, 35-Segre- TQ4 (Organyà), 36-Tournac, 37-Niaux cave, 38-Roc del Quer, 39-La Llosa/Duran, 40-Malniu, 41-Querol/Puigcerda, 42-Tamboreurets, 43-Cantal, 44-Lugarde (Cantal), 45-Mont Dore, 46-Couze Chambon (Auvernat), 47-Aubrac, 48a-Isère-Grenoble, 48b-Trieves/Avignonet, 49-Montagne de Bange, 50-Genève, 51-Ramble de Chablais, 52-Biolet-Orjulaz, 53-Vosges massif, 54-Finsterhennen, 55-Maritime Alps, 56-Unterangerberg. Arrows, influence from the Mediterranean over the SE of France and the NE of Spain.

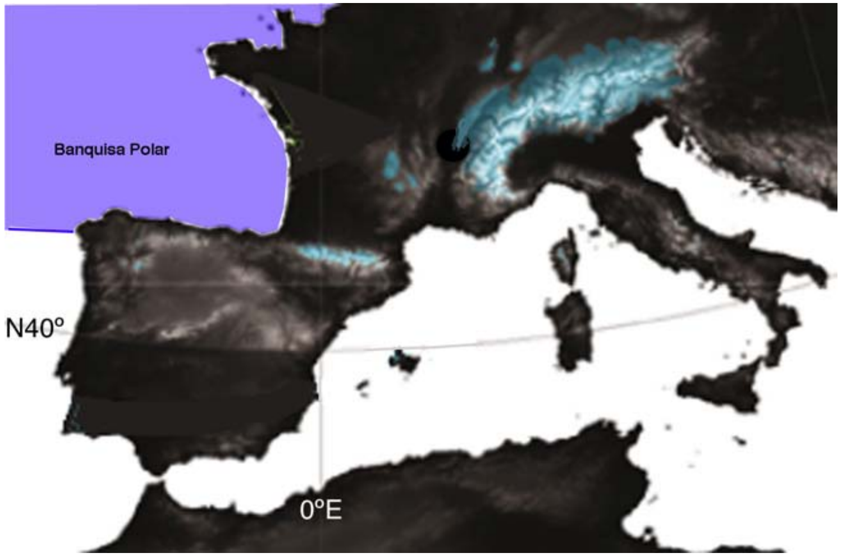
Iberia northern fringe palaeoenvironmental correlation

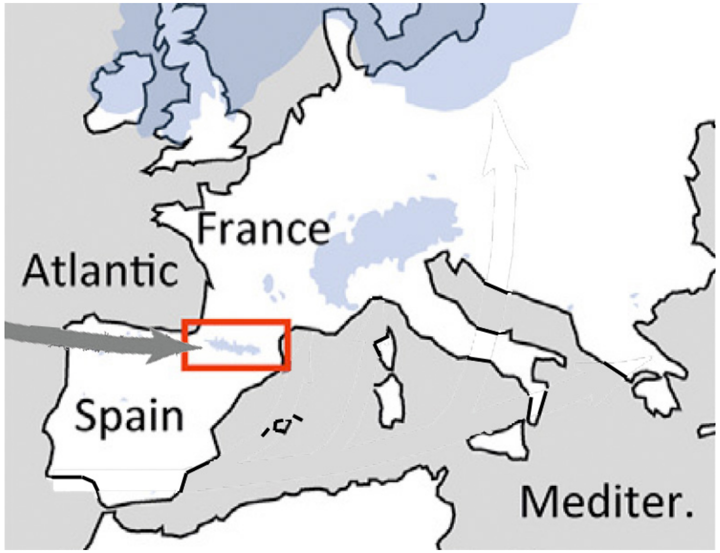


…and palaeoenvironmental correlation to the Alps

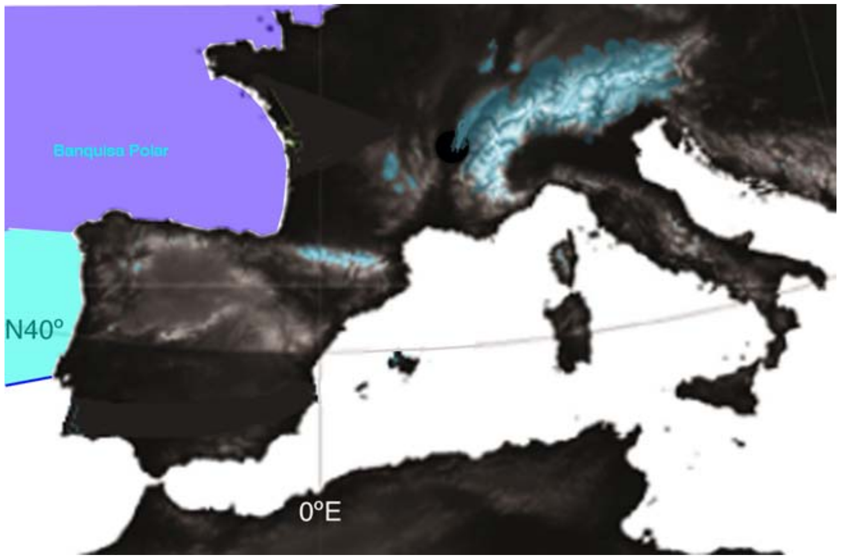


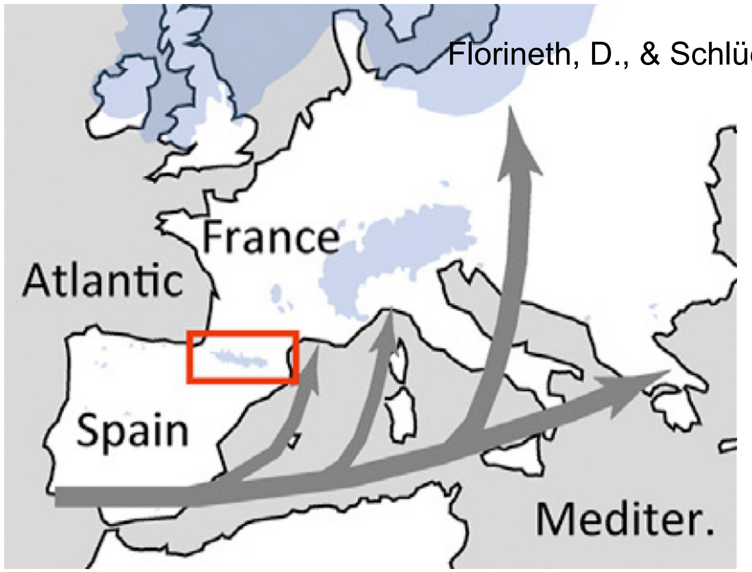
Two situations for storm tracks affecting the Pyrenees





LMIE
70-46 ka
36-32 ka



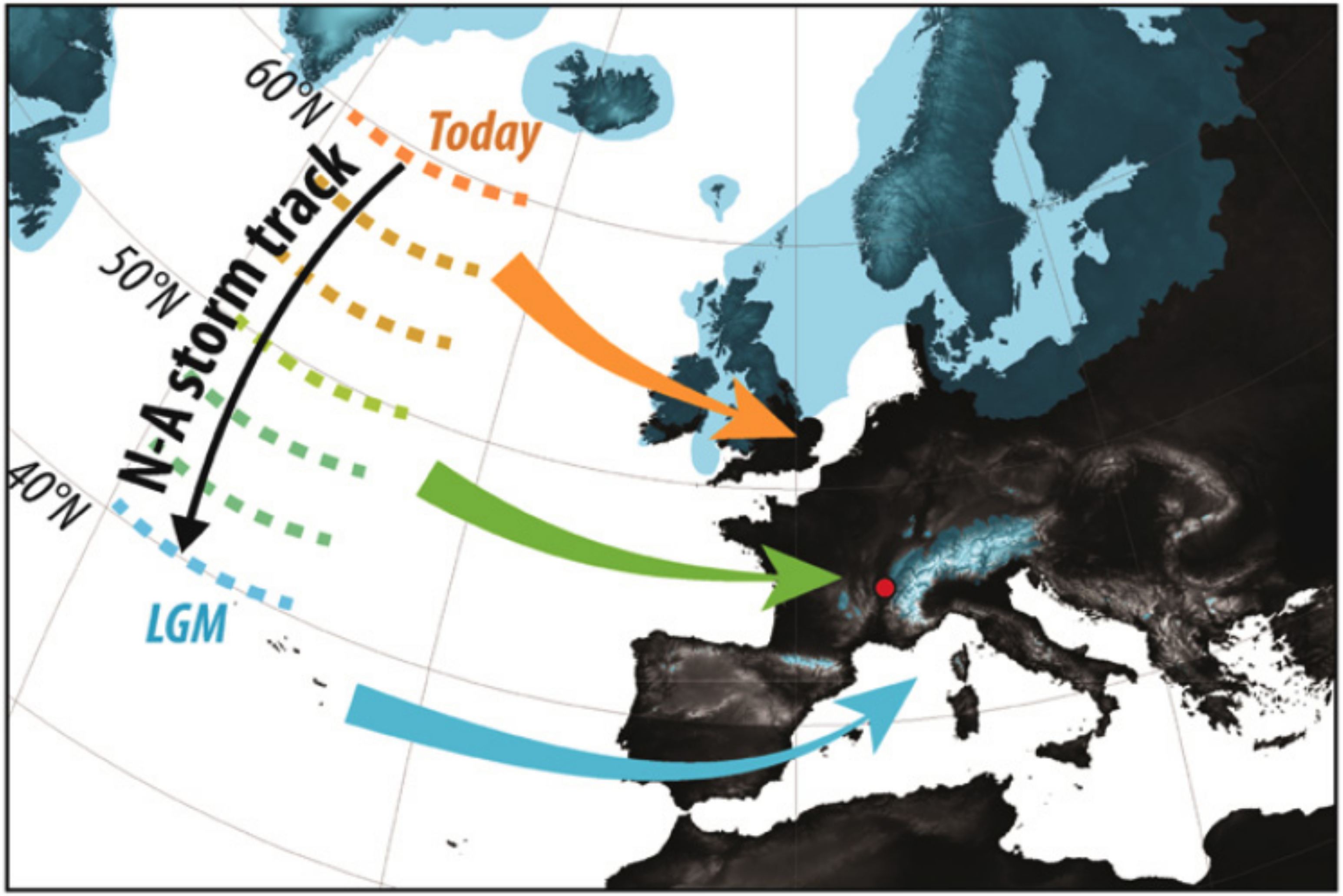


Florineth, D., & Schlüchter, C. (2000)

46−36 ka

LGM
25-19 ka

Storm tracks affecting the Pyrenees during the final deglaciation



< 21 ka

Gribenski et al. (2021)

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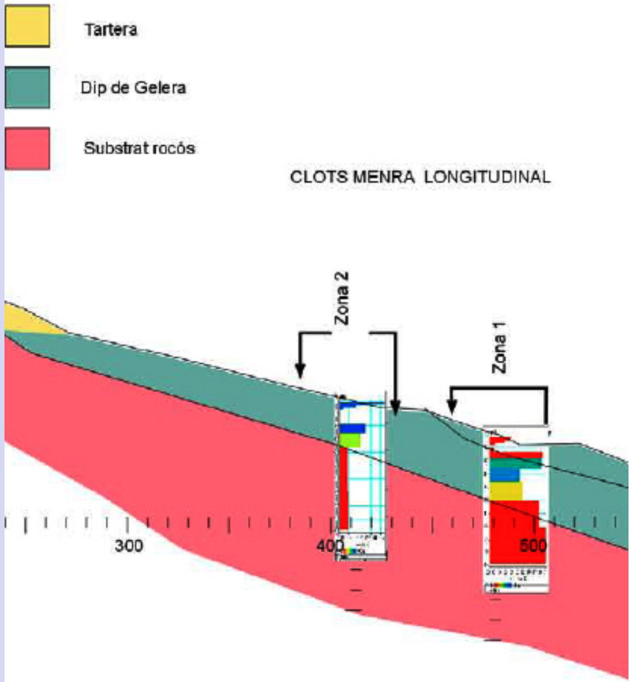
Holocene geomorphological transformations in the Valira valleys (SE Pyrenees)

Paraglacial dynamics
after
the Last Glacial Cycle

Valentí Turu Michels



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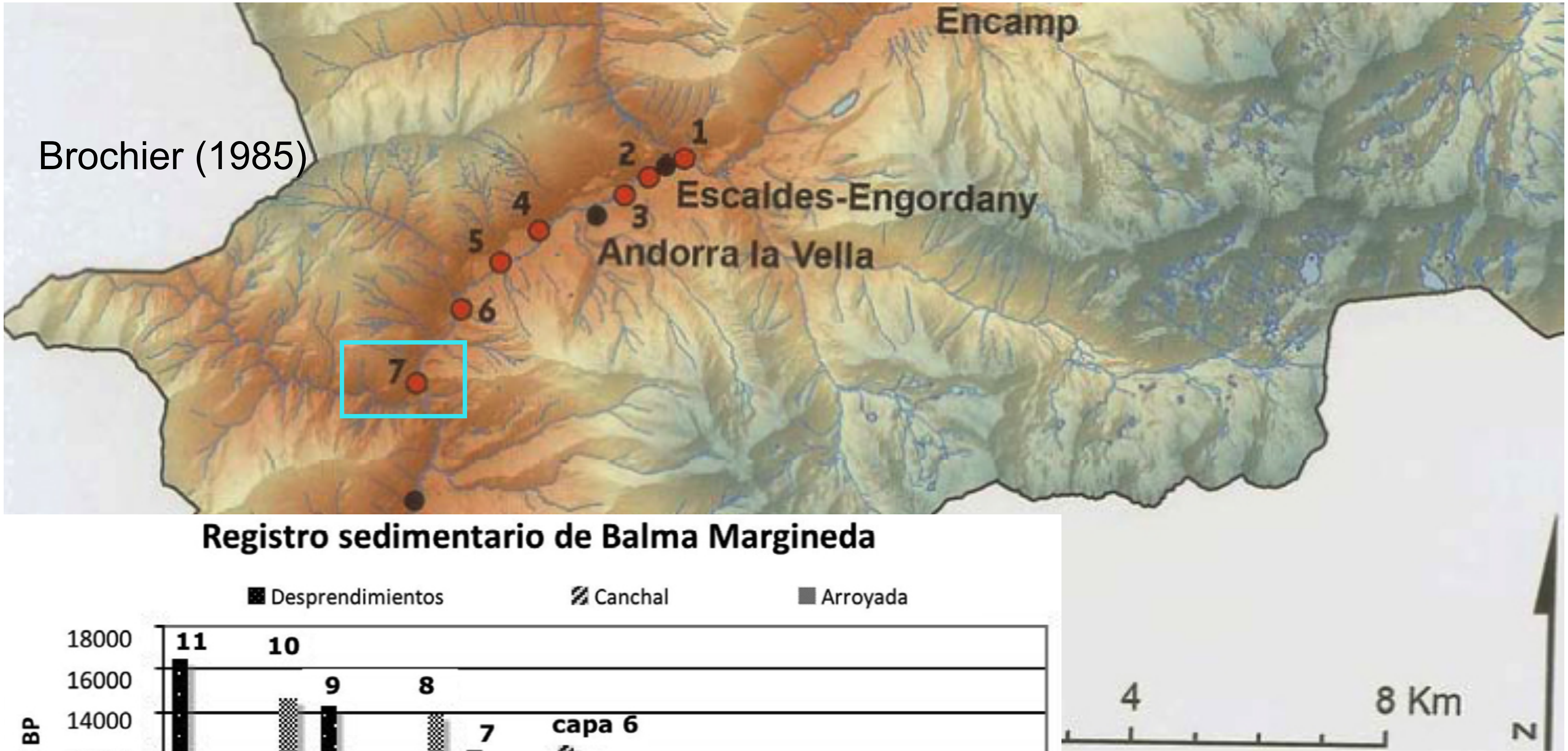
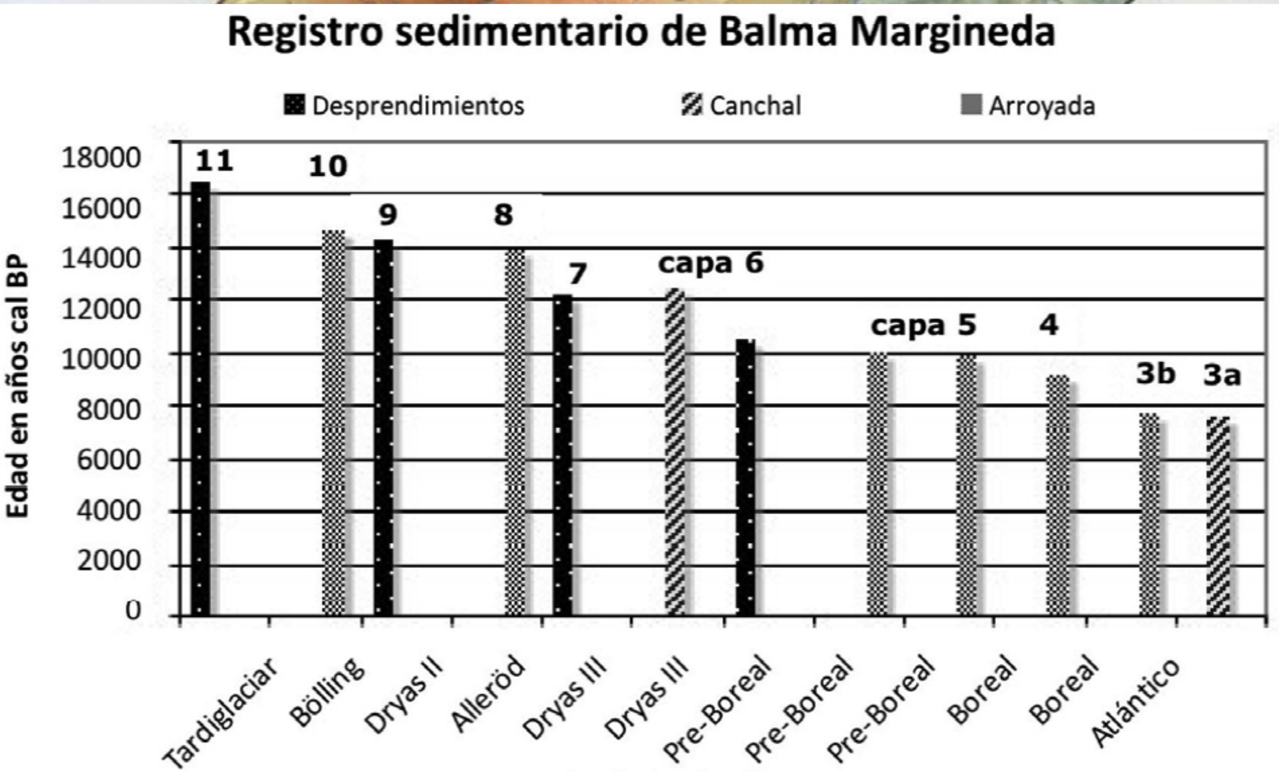
MINES DE GAVÀ





La Margineda shelter activity.
Warmer episodes entail rock fall

Bar length only means age
of the episode

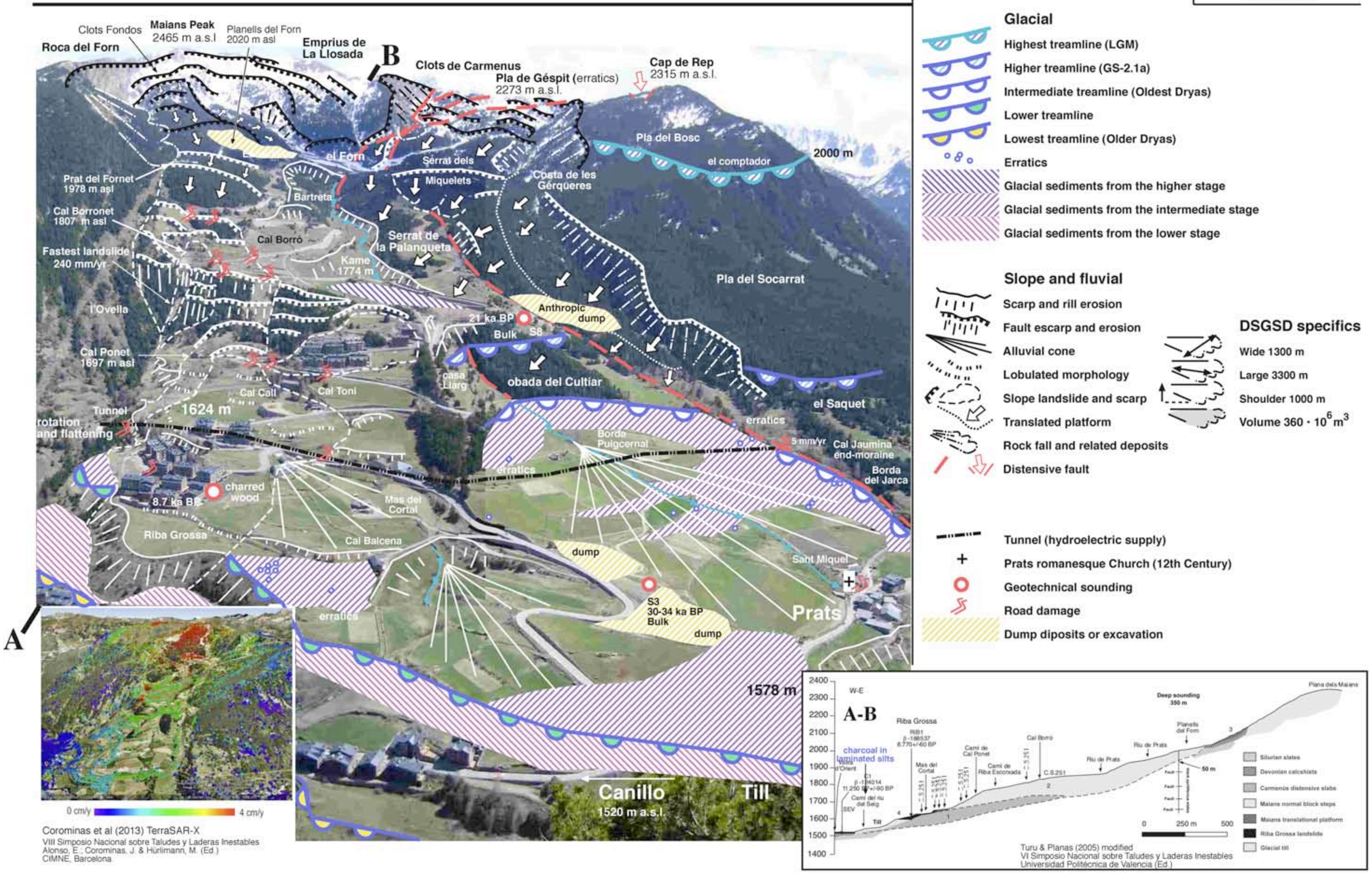
El Forn (Principality of Andorra)

A 360.000.000 m3 deep-seated gravitational slope deformation (DSGSD)

MedGU Mediterranean Geosciences Union 25-28 Nov. 2024 Barcelona, Spain

Field excursion

M. Chevalier
Valenti Turu
Marcel Chevalier Earth Science Foundation
C/Dr. Nequi 4, AD500, Andorra la Vella
vturu@andorra.ad



Slope unstability after glaciation

Turu (2024)

M. Chevalier

Holocene geomorphological transformations in the Valira valleys (SE Pyrenees)

Base level lowering
after
final deglaciation

Valentí Turu Michels

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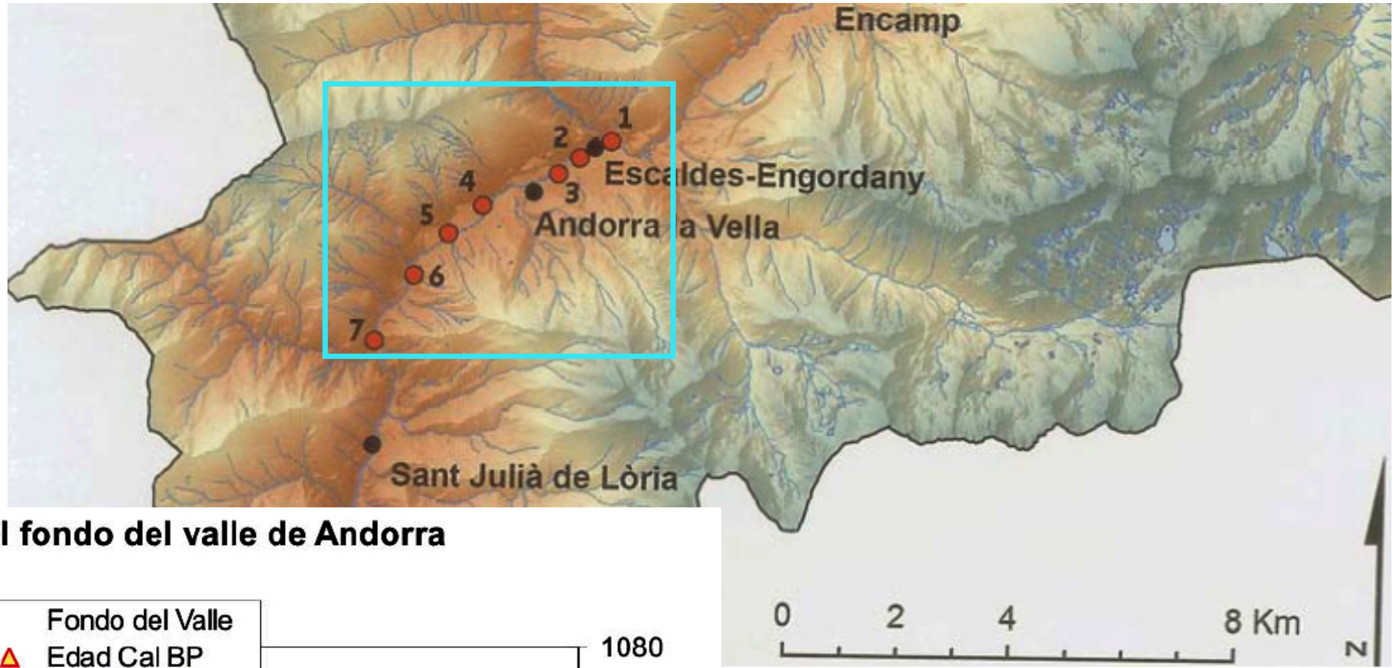
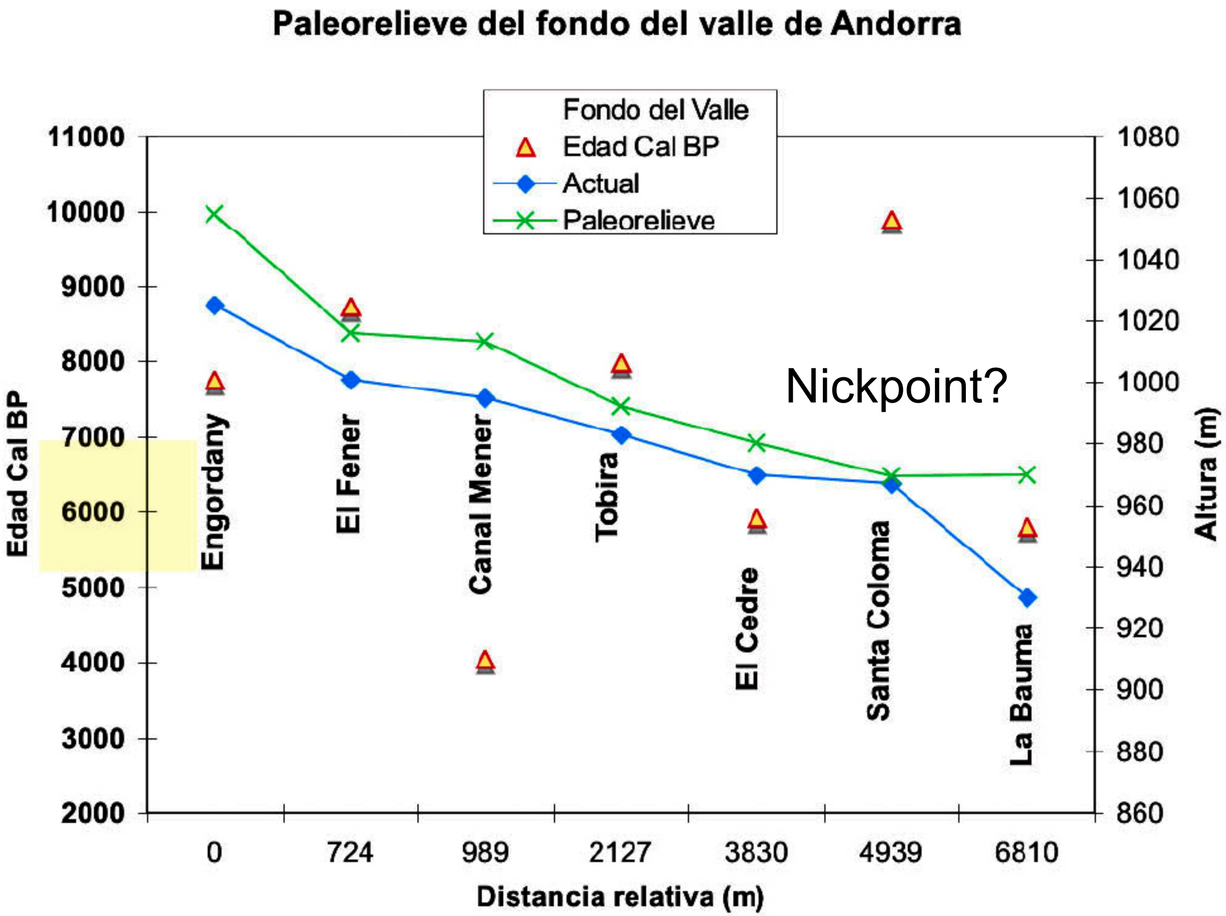
MINES DE GAVÀ

Turu (2018)

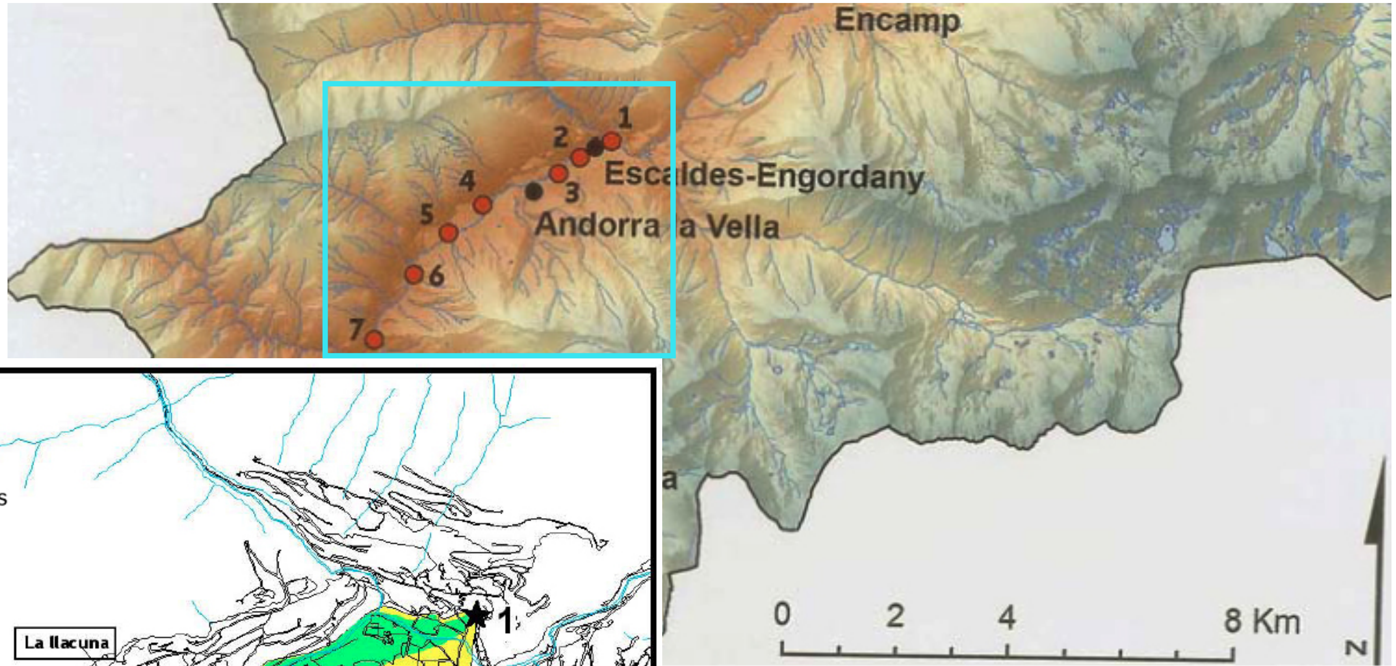


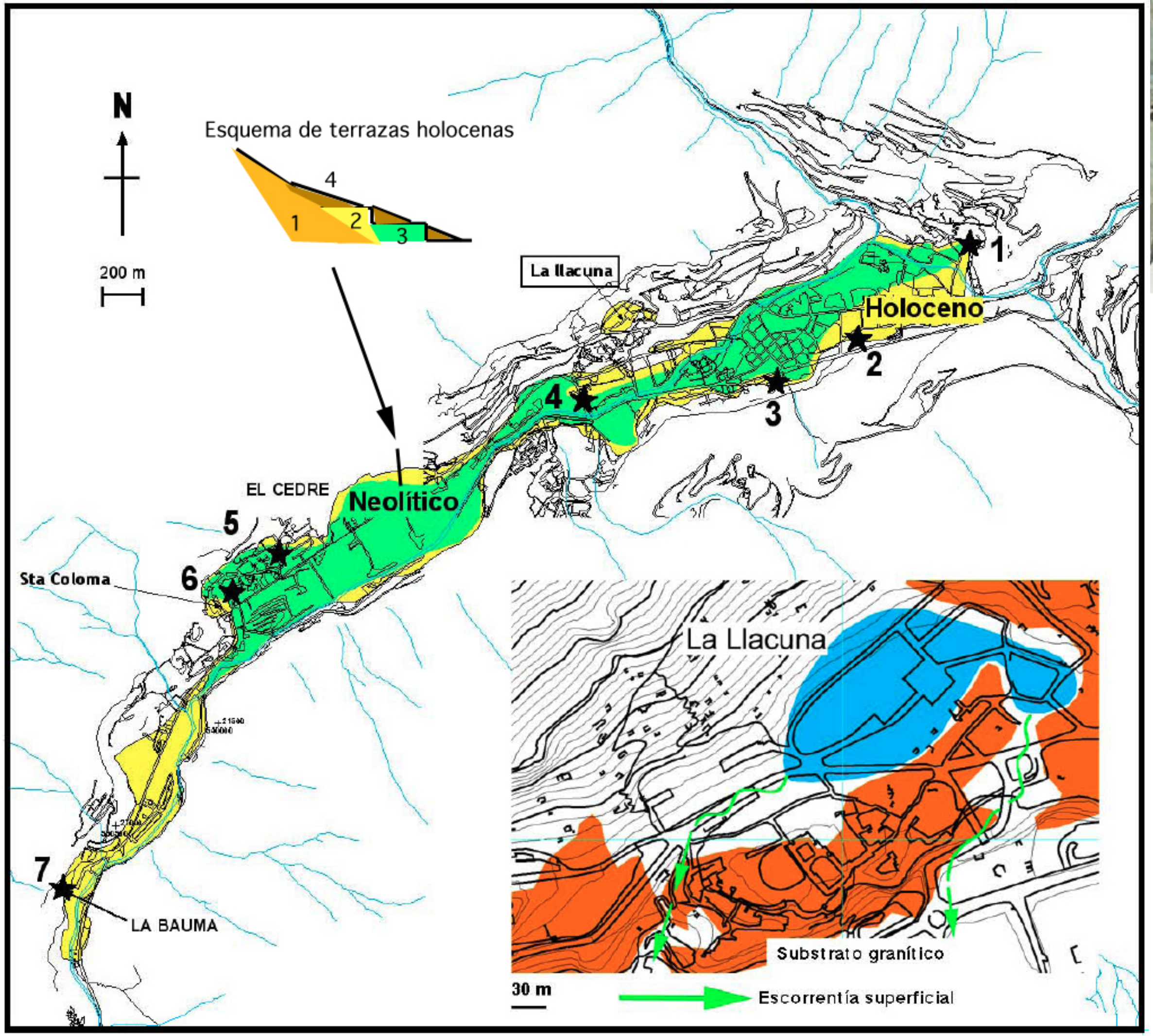


Dobble Y graph

Base level lowering by the lack
of sediments on the bottom
of the valley

Terraces





Base level lowering,recent terrace formation and filling of mires

Depression filling

Turu (2018)

M. Chevalier

Holocene geomorphological transformations in the Valira valleys (SE Pyrenees)

Charcoals in soils
after
paleofires

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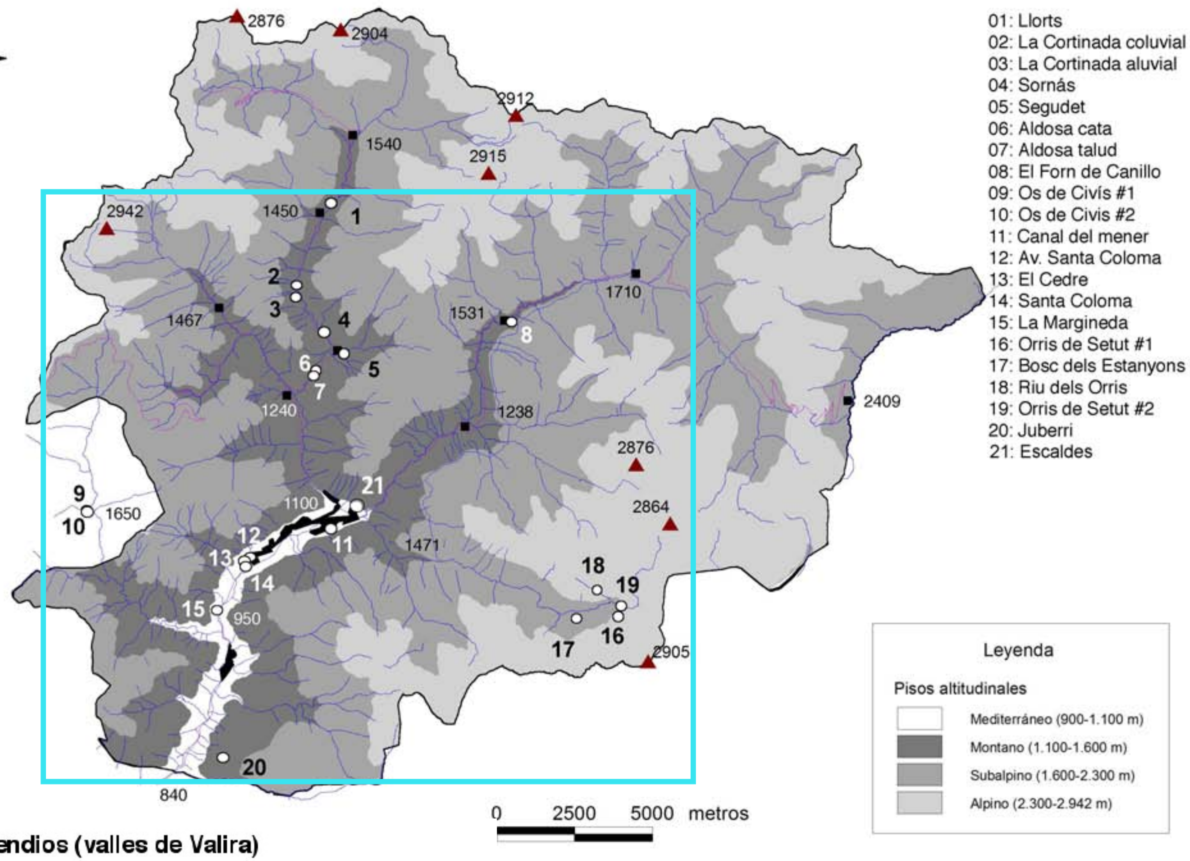
Paleofires

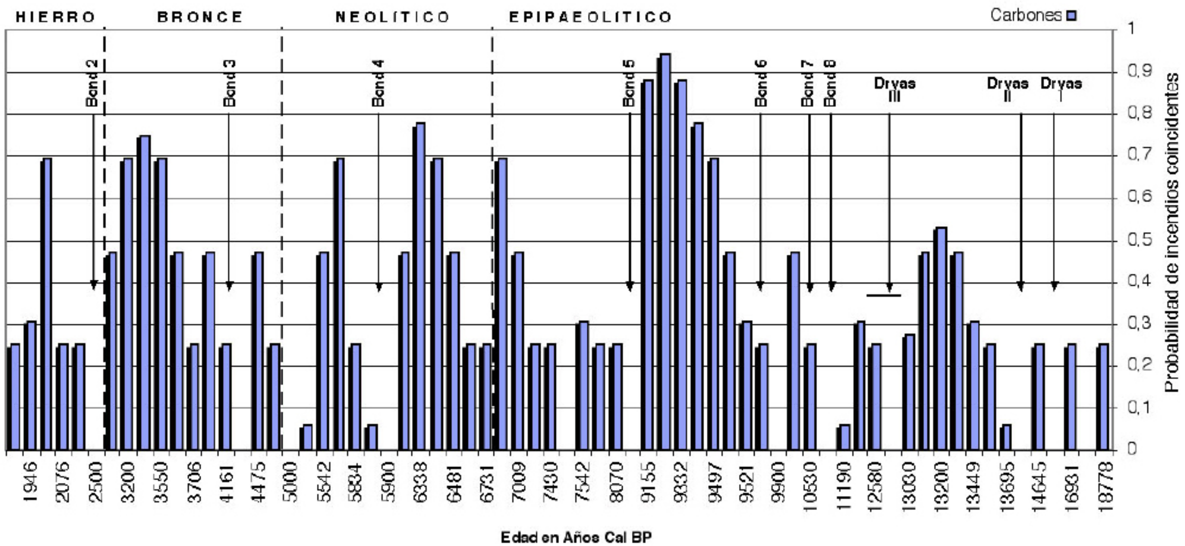
Increase of vegetation and palaeofires, both are related

Charcoals embedded in Colluvium and alluvium

Cooling and Bond events are both related, diminishing palaeofires.



Probabilidad de recurrencia de los incendios (valles de Valira)



8,2 and 4,2 ka low palaeofires

Bond events 5 & 3

Turu (2018)

Paleofires

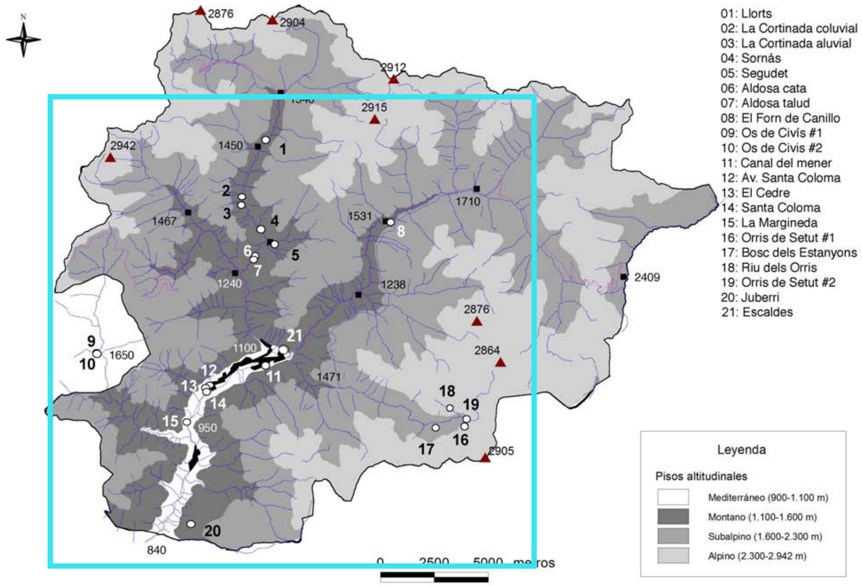
Turu (2018)

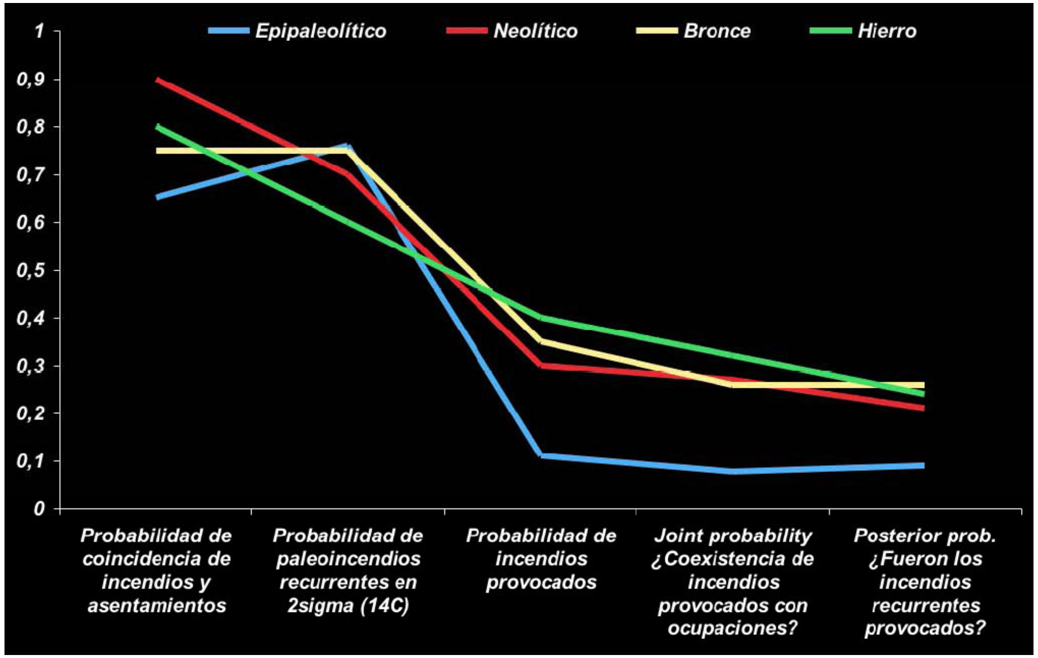
High recurrent palaeofires probability (>60 %)

JP, one of 3 palaeofires and humans coexisted

PP, one of 4 palaeofires are palaeoburnings

Low Epipaleolithic archaeological sites



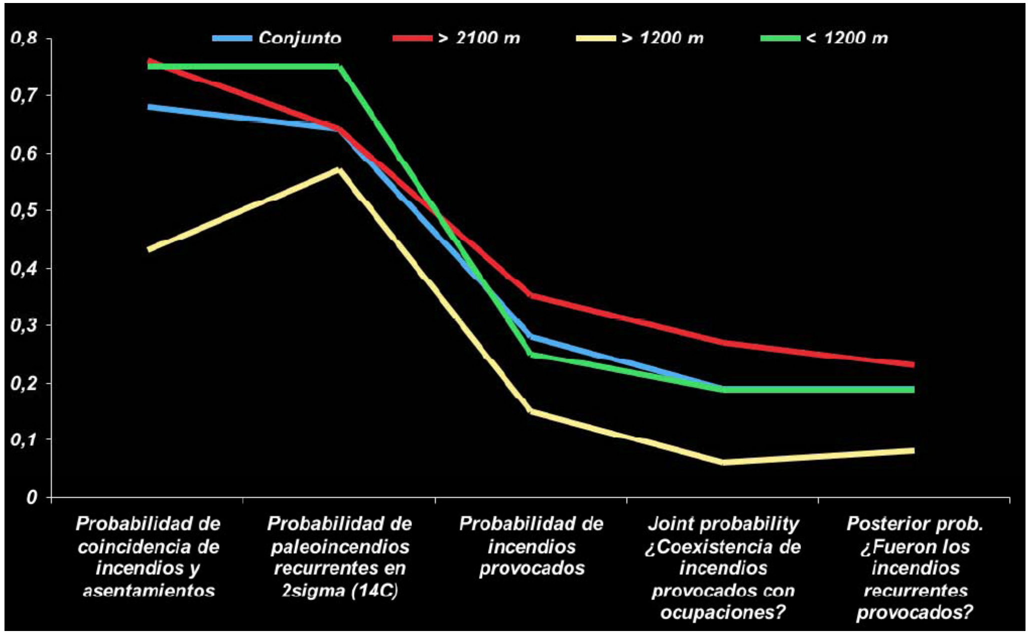


High recurrent palaeofires probability (>50 %)

Low JP, palaeofires at any height (<30%)

Low PP, only 20% palaeofires are burnings

Low archaeological sites on the tributary valleys



Thank for your time

Estany primer de Tristaina amb la vista de la capçalera del Valira del Nord i el Cassamanya al Fons (Principat d'Andorra)