PLANT MACROFOSSILS in PALAEOECOLOGY

Lecture 3

Macrofossils and Pollen

Macrofossils and Pollen

1. Comparison between plant macrofossils and pollen in sediments

2. How do plant macrofossils enhance interpretations made from pollen alone?

   Macrofossils and pollen from same core: Abernethy Forest

Tree migrations:	Eastern USA; Minnesota
Altitudinal tree-limits:	Eastern USA
	European Alps
	Swedish Lapland
	Southern Norway
Latitudinal tree-limits:	Siberia
Local forest dynamics:	Denmark

3. Value of macrofossils when pollen is unreliable

   Arctic: Holocene in Spitsbergen

   Late-glacial: Scotland; western Norway

Why, if we have done a detailed pollen analysis, do we need to study macrofossils? What more will they tell us?

General features of macrofossils and pollen from lake sediments

Macrofossils	**Pollen**
Can often be identified to low taxonomic level	Can rarely be identified to low taxonomic level
Some taxa only recorded as macrofossils	Some taxa only recorded as pollen
No evenly mixed 'macrofossil rain'	Homogenous 'pollen rain'
Derived from small area, mainly wetland habitats	Derived from large area, including dry upland habitats
Can reconstruct local vegetation in floristic and even phytosociological detail	Can reconstruct general character of vegetation in the catchment and some local detail

Macrofossils	Pollen
Local vegetation reconstruction	Regional vegetation reconstruction
Relatively low annual flux	Relatively high annual flux
Need large samples, wide cores/monoliths	Small samples, narrow cores
Numbers between samples may differ greatly	Numbers between samples within same order of magnitude
Concentration (influx)	Percentages (concentration, influx)

Principal of macrofossil analysis is same as pollen analysis, but method has to be adapted for the special features of macrofossils.

How do Plant Macrofossils Enhance Interpretation Made from Pollen Alone?

Macrofossils and pollen from the same core

Abernethy Forest, Scotland

Tree migrations - Appalachia, USA

Minnesota, USA

Altitudinal tree limits - Adirondack Mountains, USA

European Alps

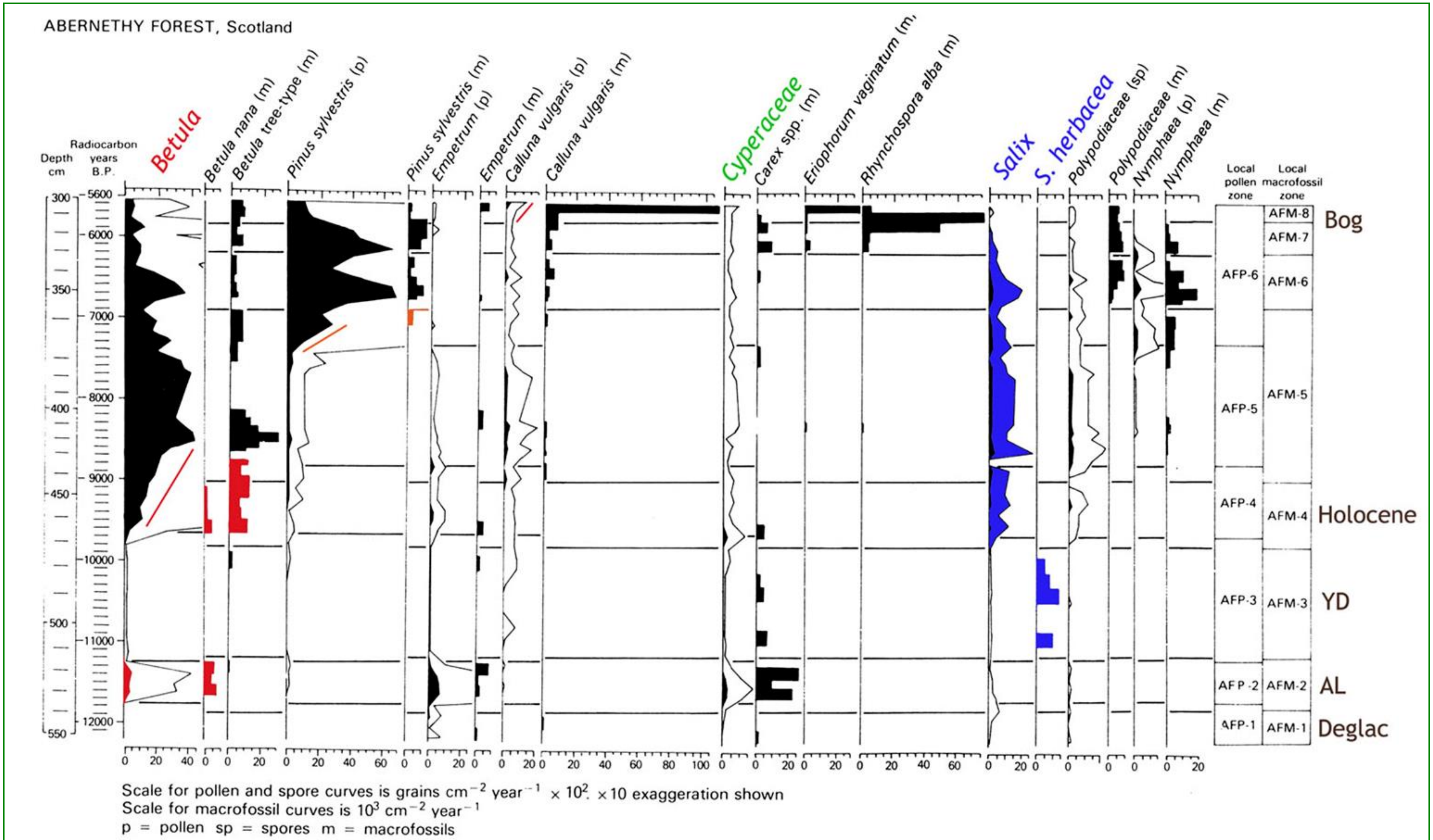
Swedish Lapland

Southern Norway

Latitudinal tree limits - Siberia

Local forest dynamics - Denmark

Macrofossils and Pollen from the same Core



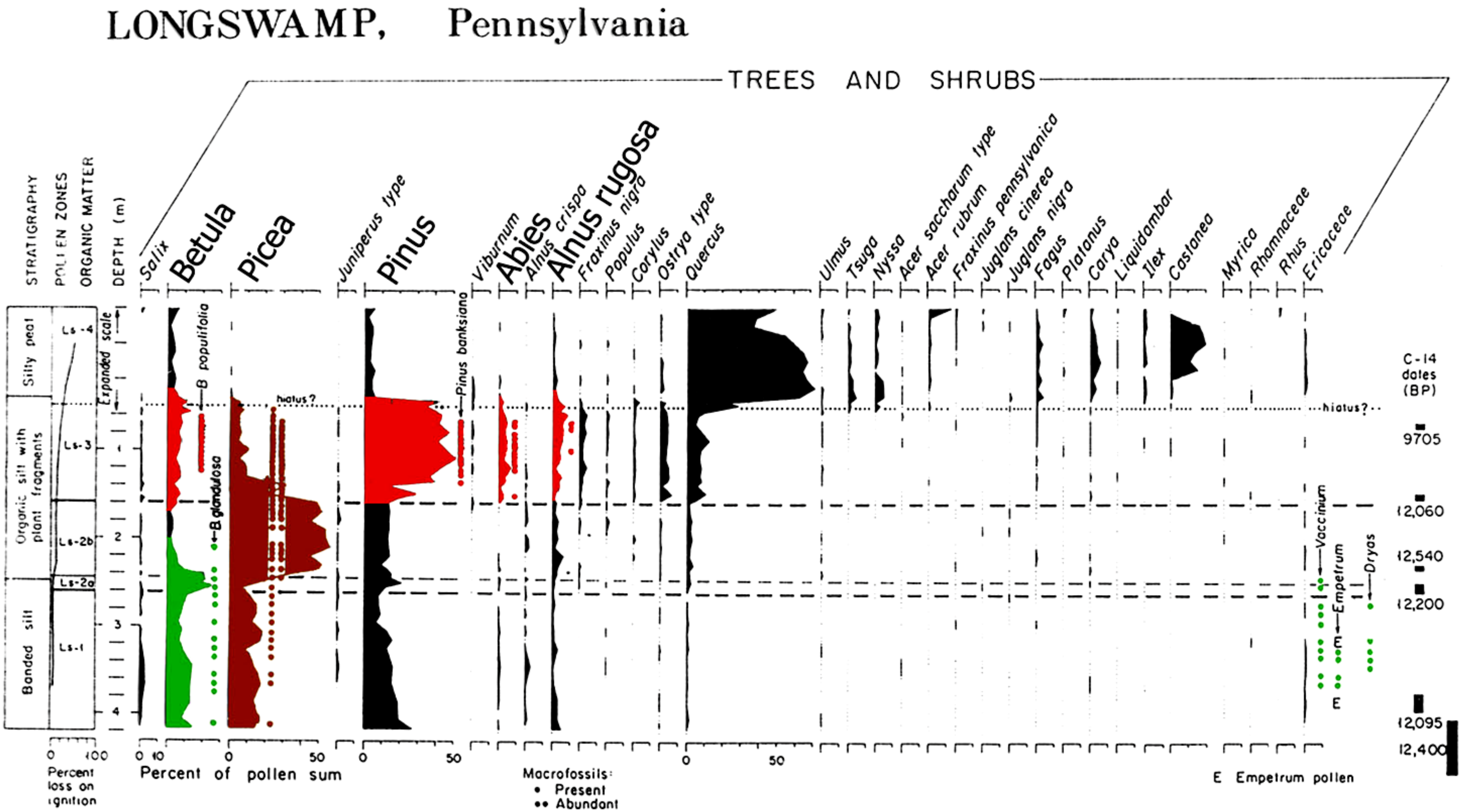
Comparison of pollen or spore and macrofossil influx values at Abernethy Forest, Scotland. The pollen or spore taxon (taxa) are presented followed by the equivalent macrofossil taxon (taxa). The values are plotted against radiocarbon age of the sediment. (After Birks & Mathewes, 1978).

Tree-line studies - Combination of Pollen and Macrofossils

1. Tree migration in early Holocene
   - Longswamp, Pennsylvania (USA),
   - Spider Creek (Minnesota, USA),

2. Altitudinal tree-line changes in the Holocene
   - Adirondack Mountains (USA),
   - European Alps,
   - Northern Sweden,
   - Southern Norway

Late-Glacial/Holocene Tree Immigration, Eastern USA



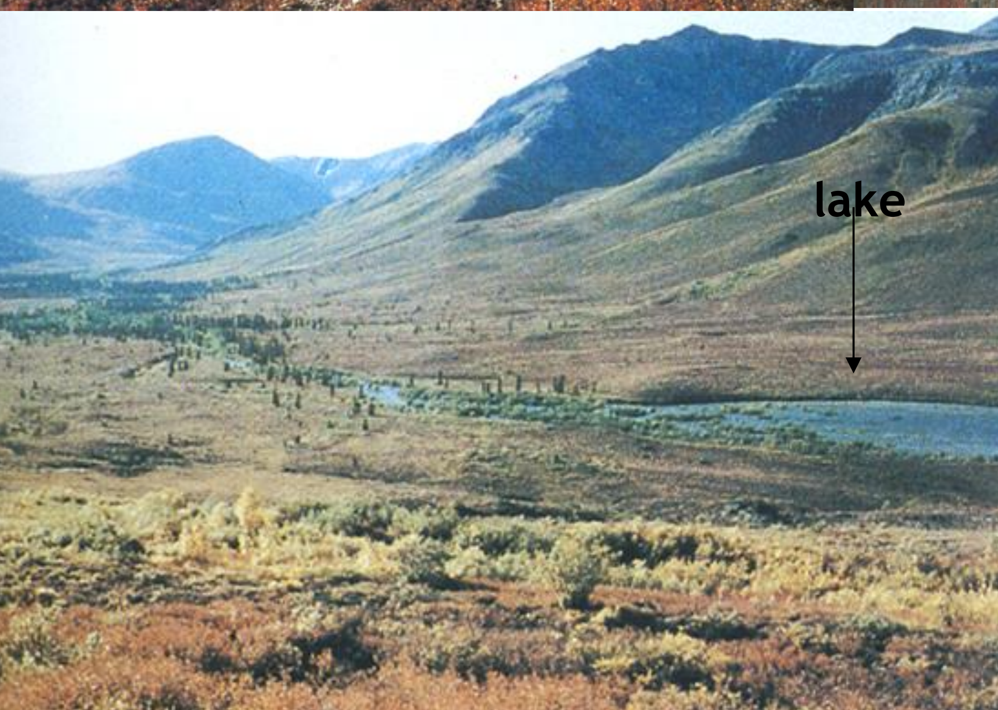
Watts (1979)

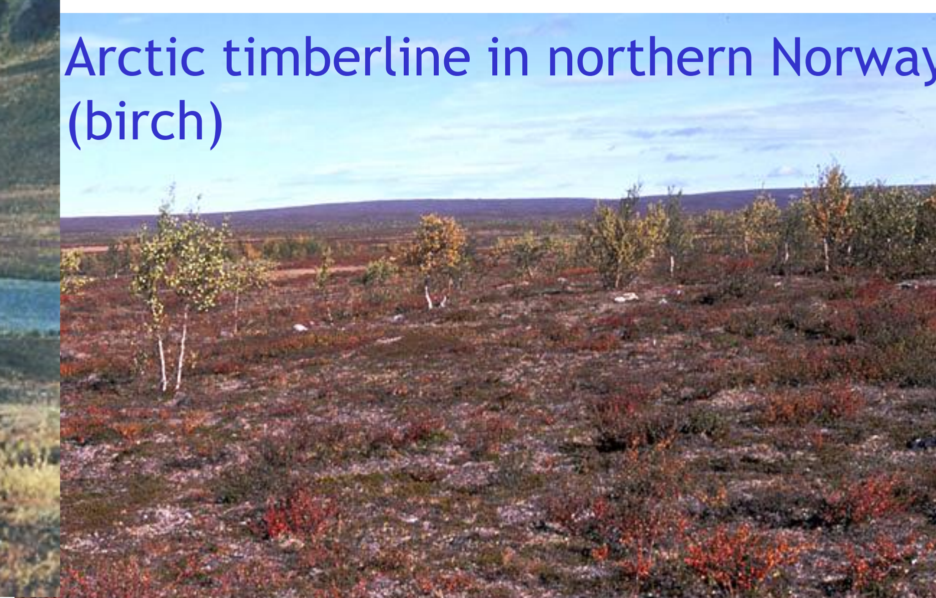
A modern analogue; spruce copse at 59ºN 94ºW at Churchill, Manitoba

Petit et al. *Science* 320:1450 (2008)

Could produce needles but not much pollen – as in zone LS-1 at Longswamp

Arctic timberlines (spruce) in Alaska and Yukon; modern analogues

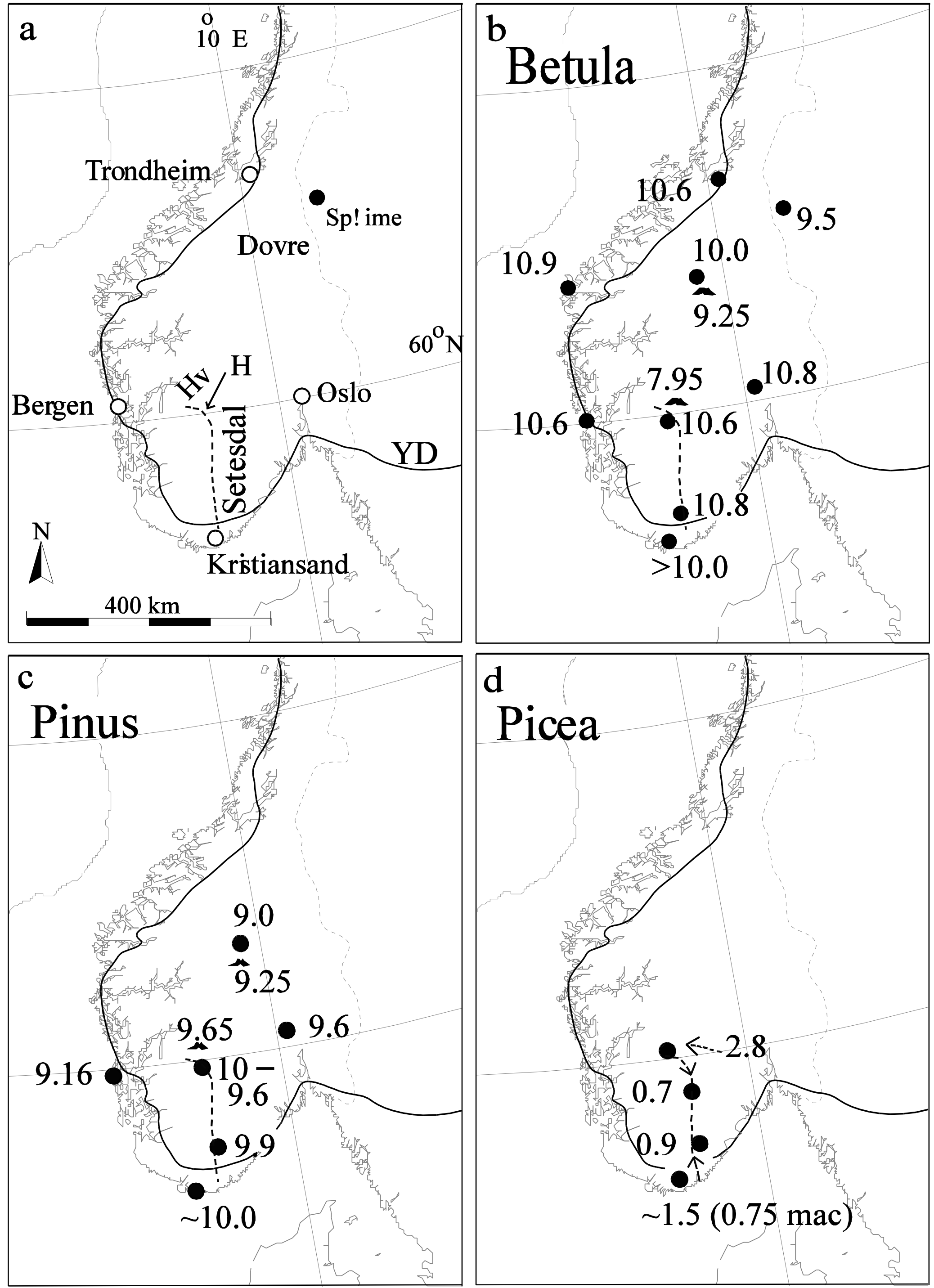




Arctic timberline in northern Norway (birch)

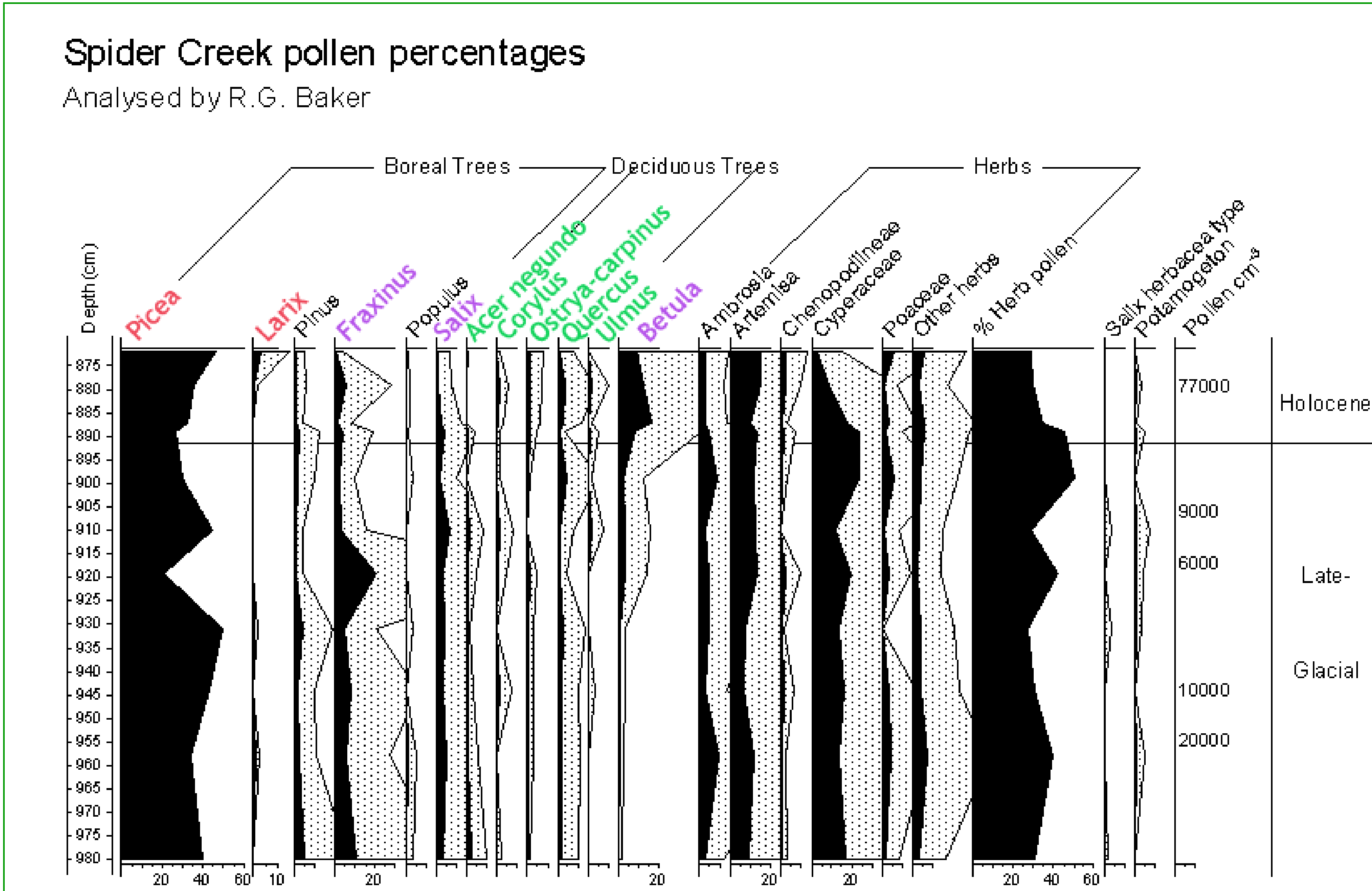
Migration patterns

of Betula, Pinus, and Picea in southern Norway shown by macrofossil and megafossil evidence



Birks et al. 2005

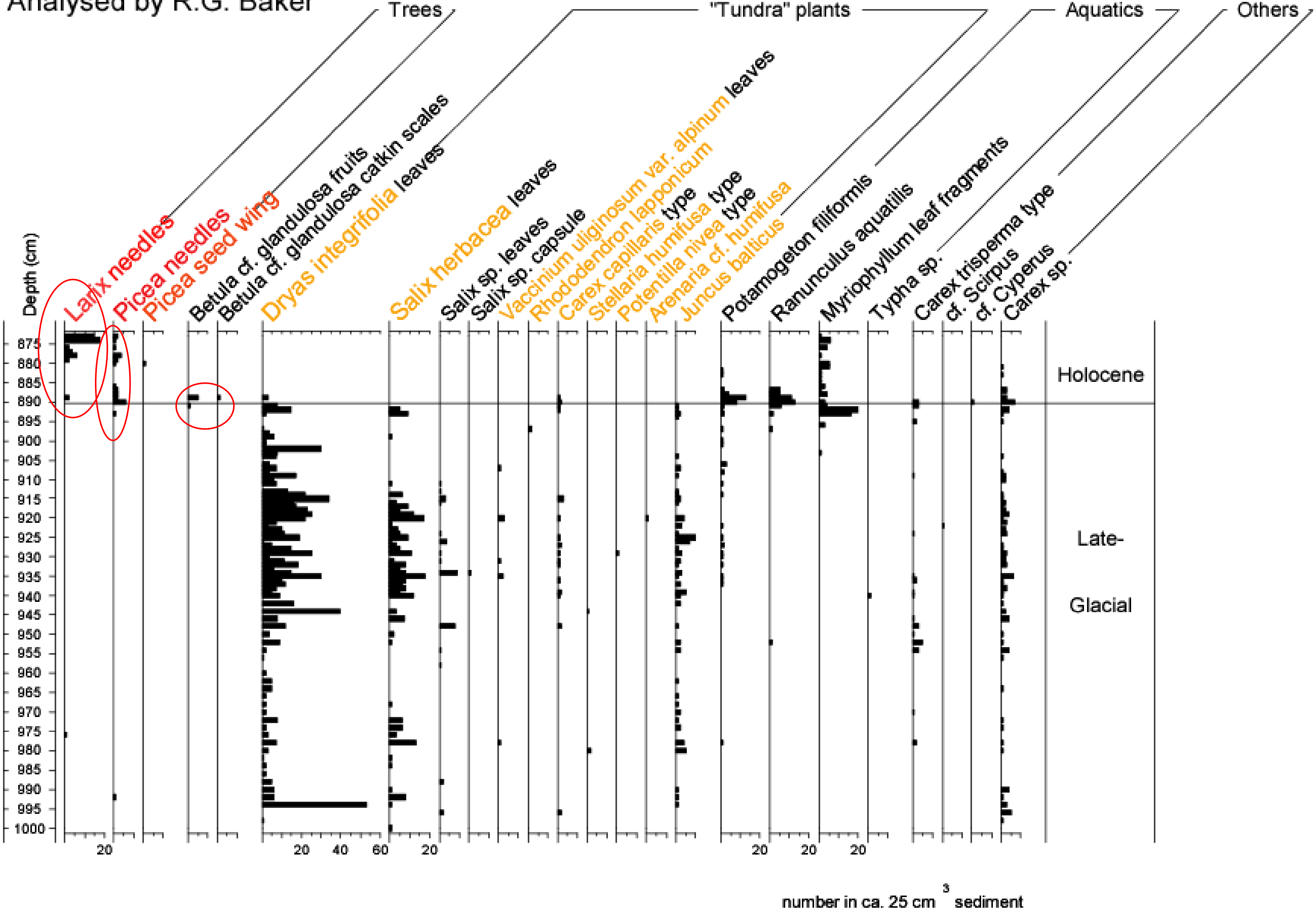
1. Late-glacial/Holocene tree immigration, (Minnesota, USA)



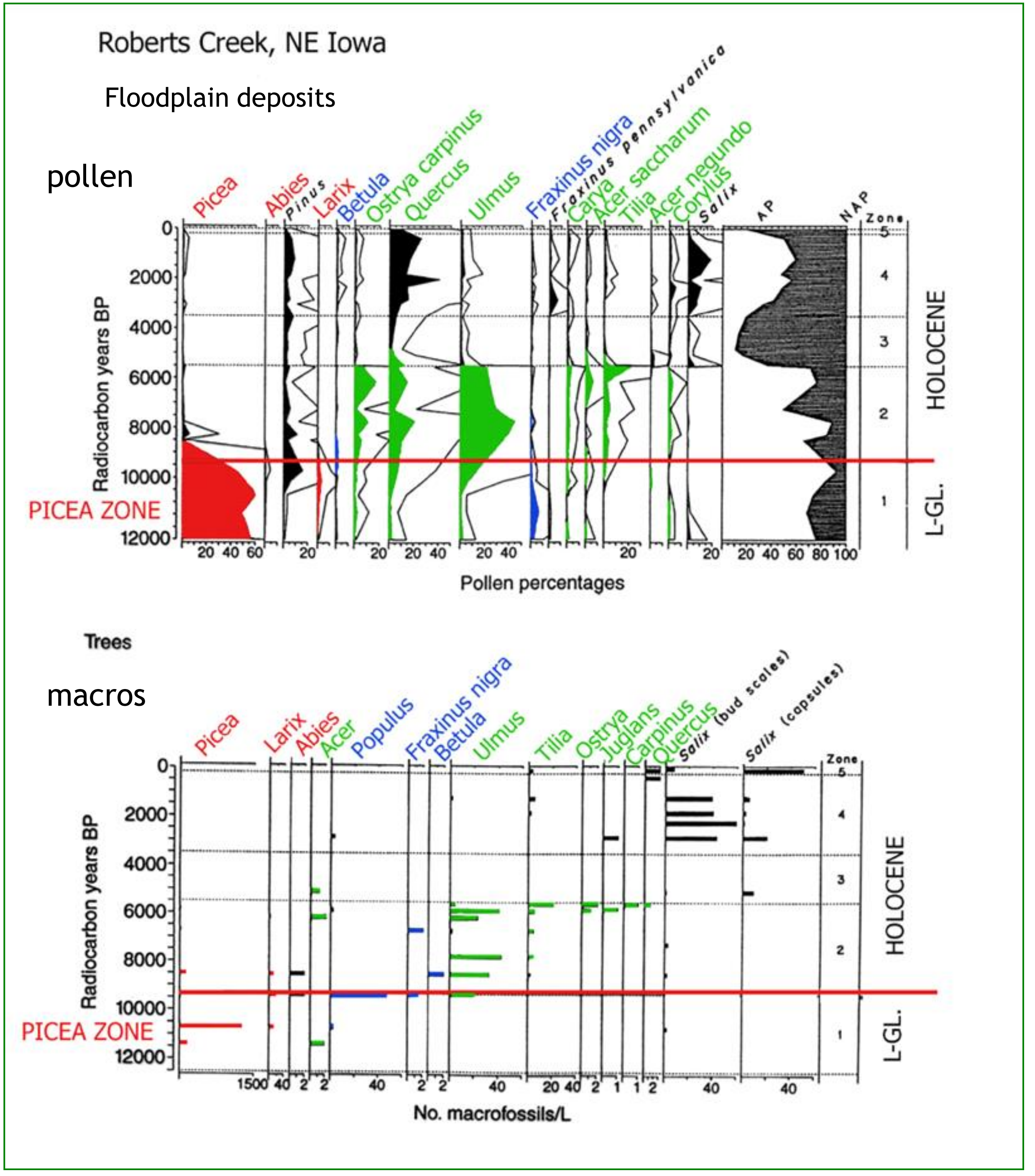
When did the trees arrive?

Spider Creek macrofossil concentrations

Analysed by R.G. Baker



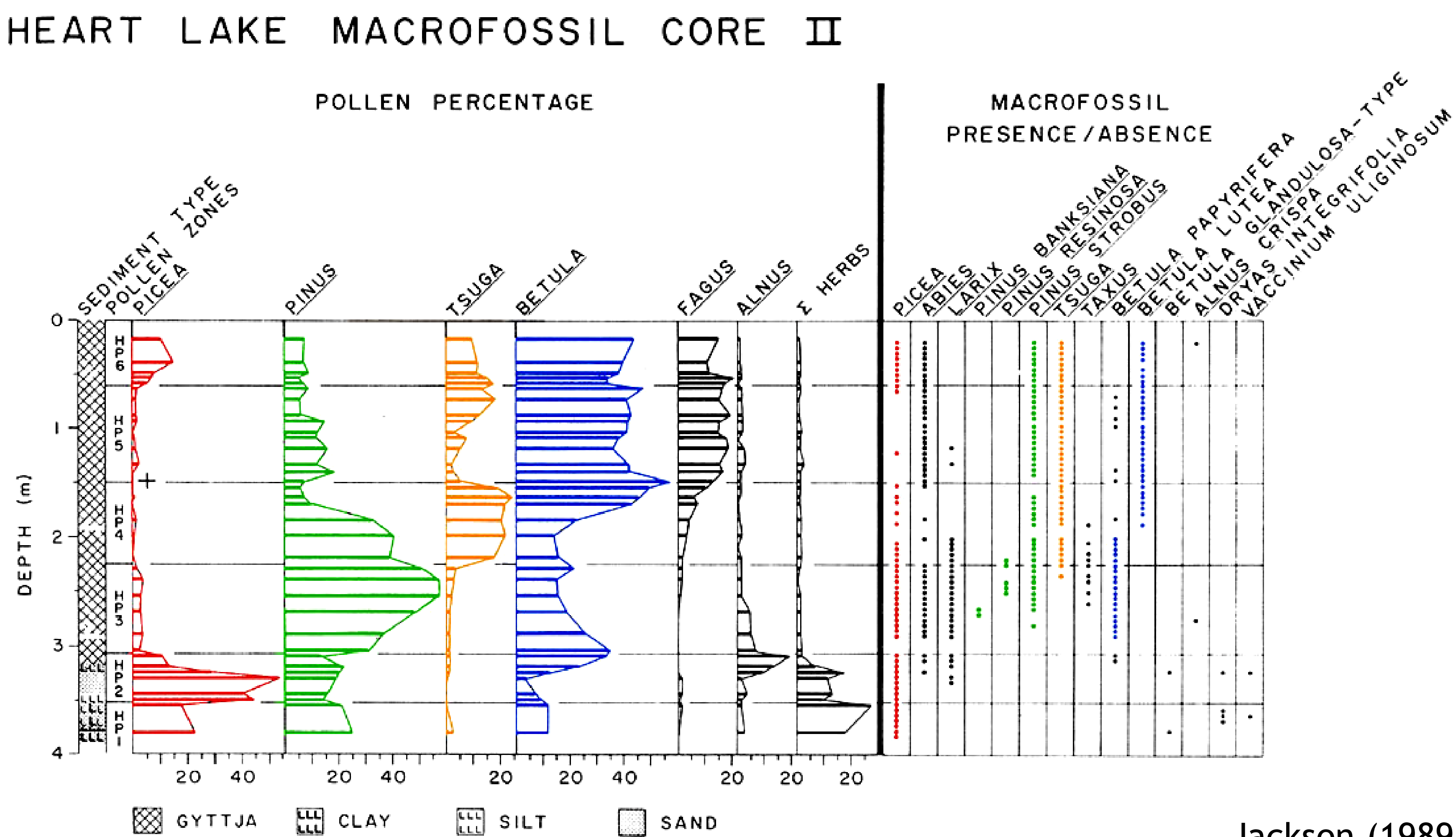
Where were the thermophilous deciduous trees?



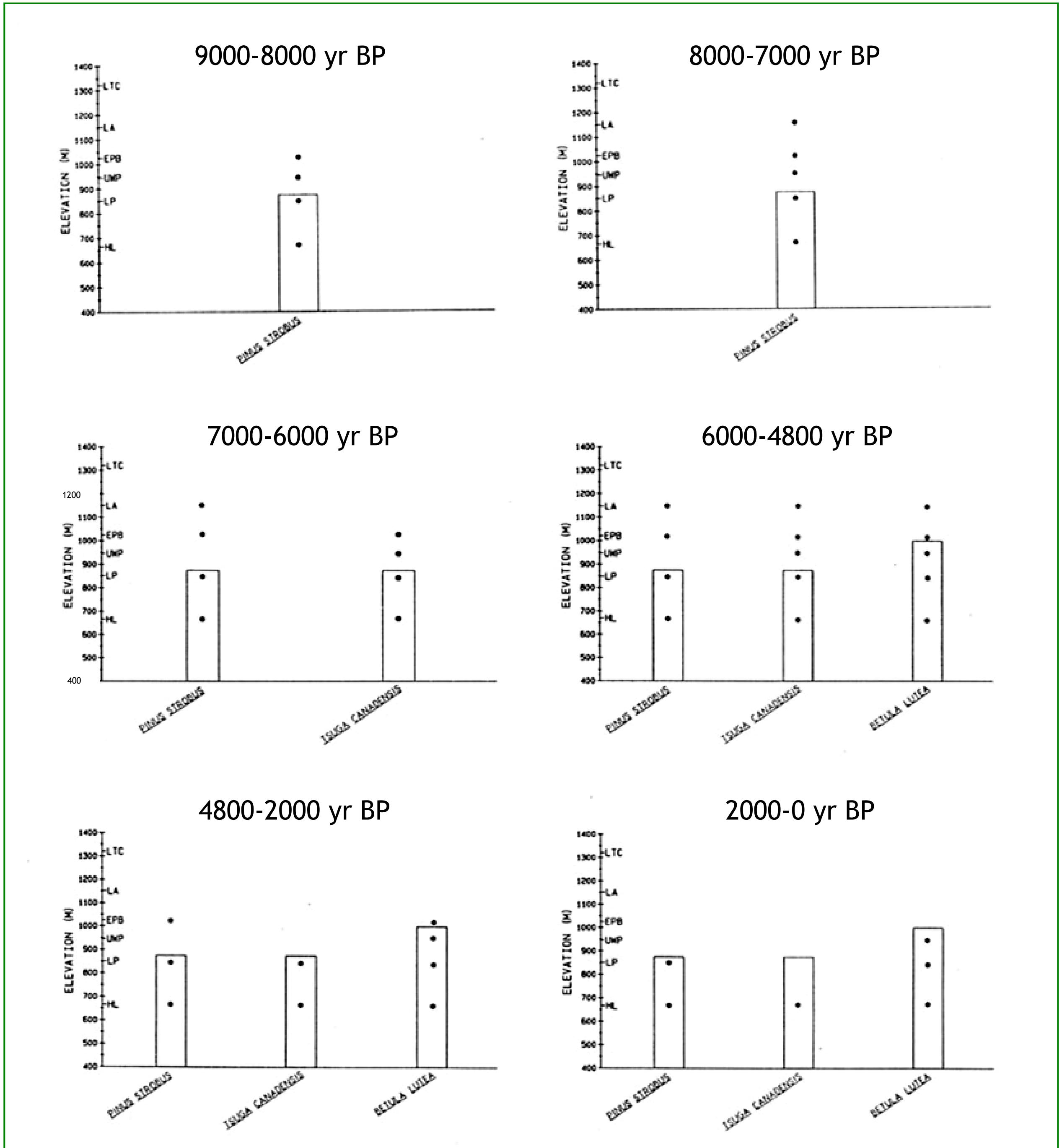
R.G. Baker *et al.* (1996), Baker (2007)

Holocene Tree-Line Reconstructions in the Mountains

Altitudinal tree-limits in the Adirondack Mountains, Eastern USA



Jackson (1989)

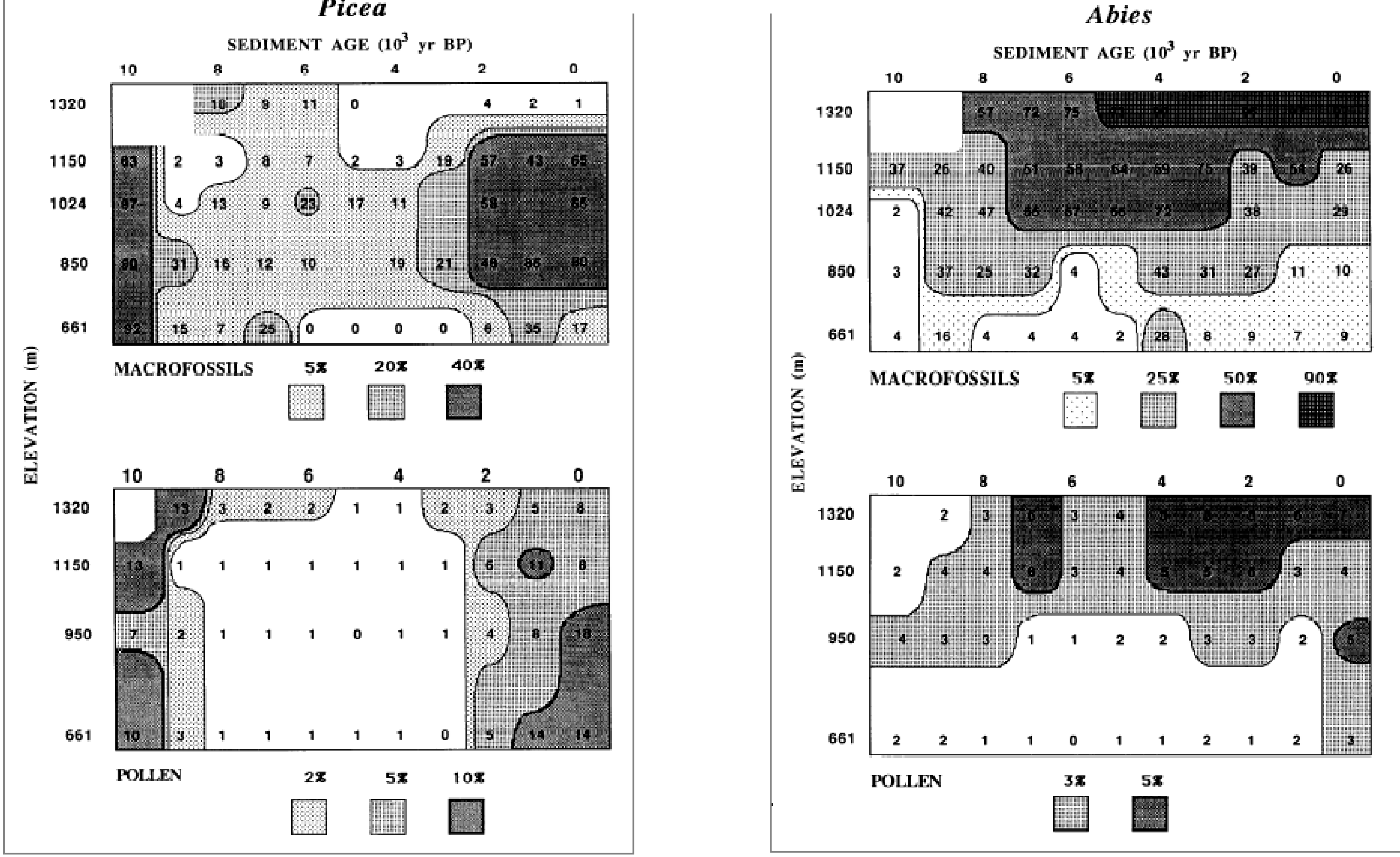


Adirondack Mountains – Holocene tree-limit changes

Dots refer to consistent occurrence of a taxon during the indicated time interval. Silhouettes represent modern absolute ranges of the respective taxa in the High Peaks.

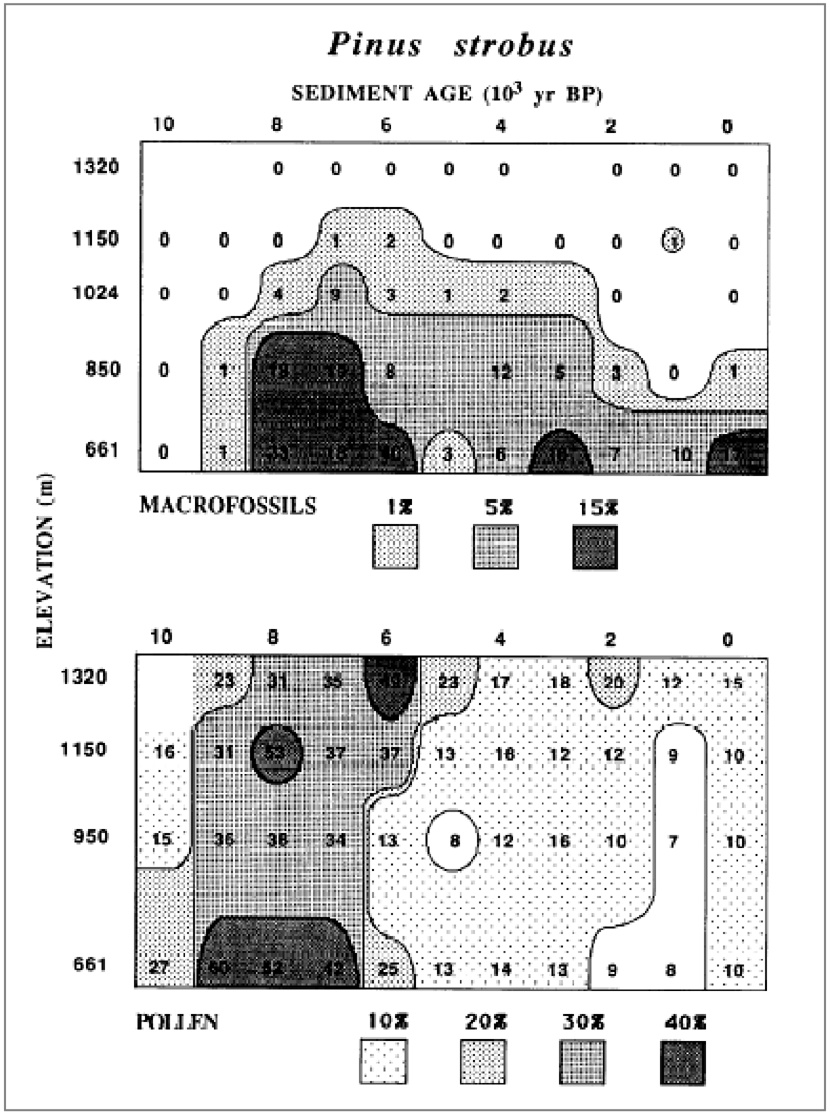
Jackson (1989)

Adirondack Mountains

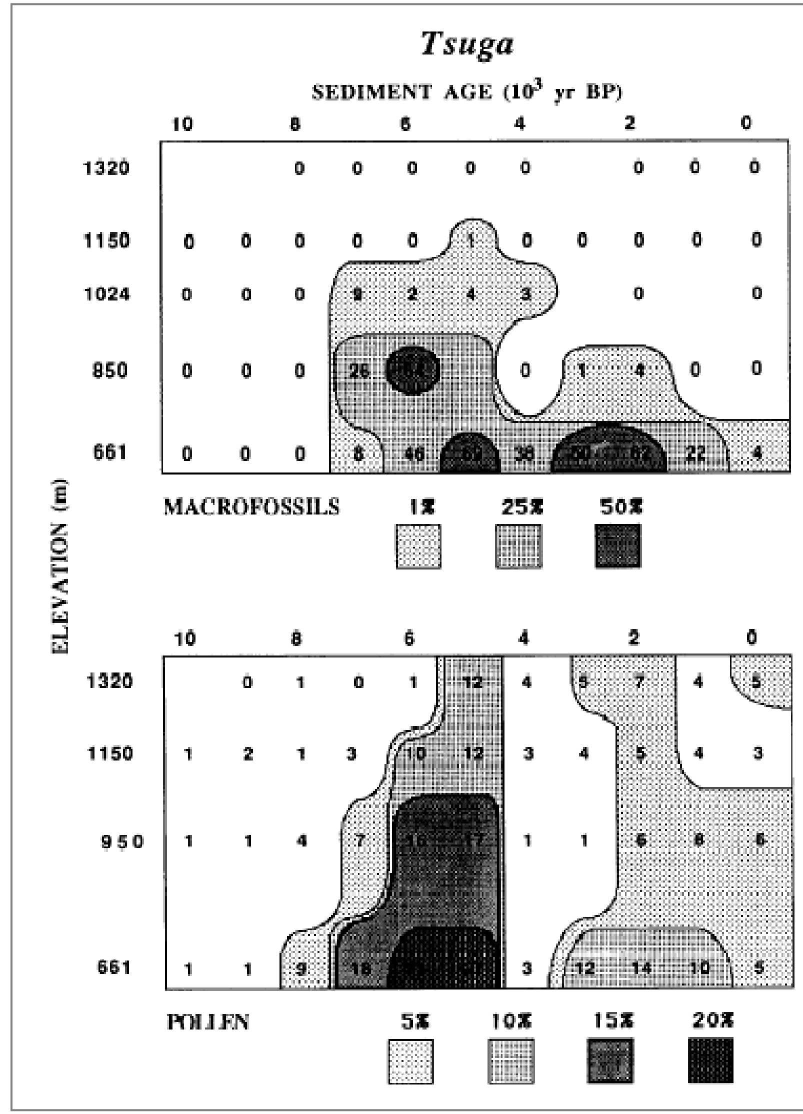


Space-time diagrams for *Picea* and *Abies* macrofossil and pollen percentage data. Numbers in diagrams represent macrofossil or pollen percentages from a specific site at a particular time interval.

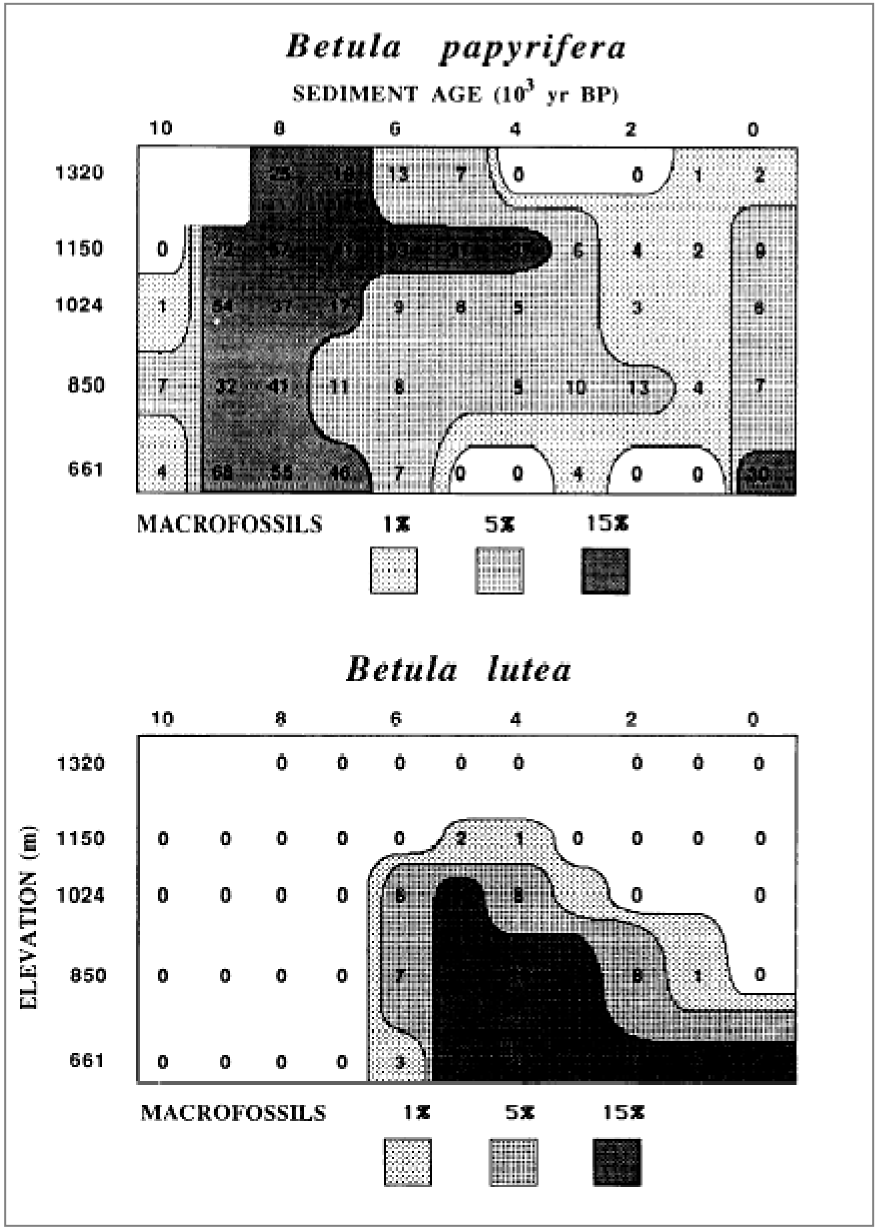
Jackson & Whitehead (1991)

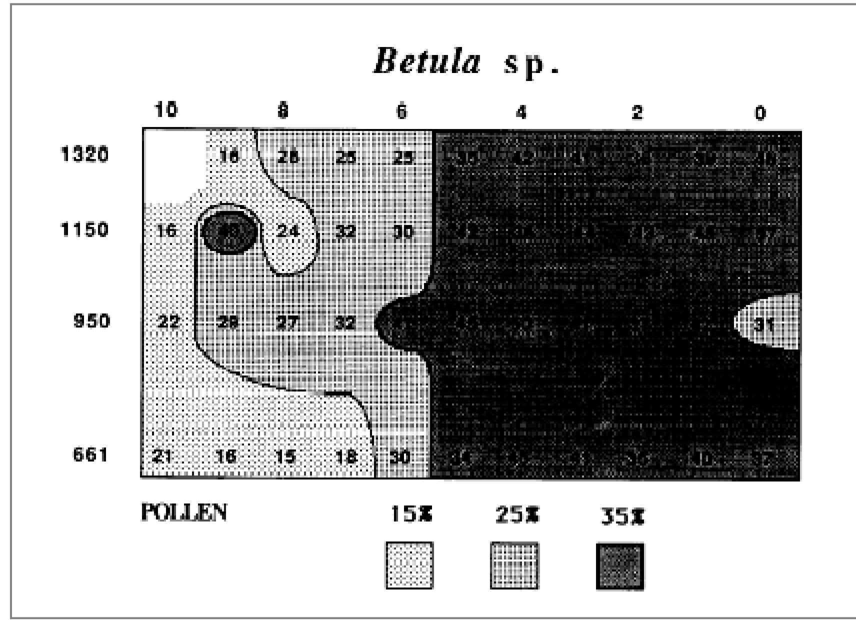


Pinus strobus
SEDIMENT AGE (10^3 yr BP)
ELEVATION (m)
MACROFOSSILS
1%
5%
15%
POLLEN
10%
20%
30%
40%



Tsuga
SEDIMENT AGE (10^3 yr BP)
ELEVATION (m)
MACROFOSSILS
1%
25%
50%
POLLEN
5%
10%
15%
20%





Space-time diagrams for *Betula papyrifera* and *B. lutea* macrofossil and pollen percentage data. Numbers in diagrams represent macrofossil or pollen percentages from a specific site at a particular time interval.

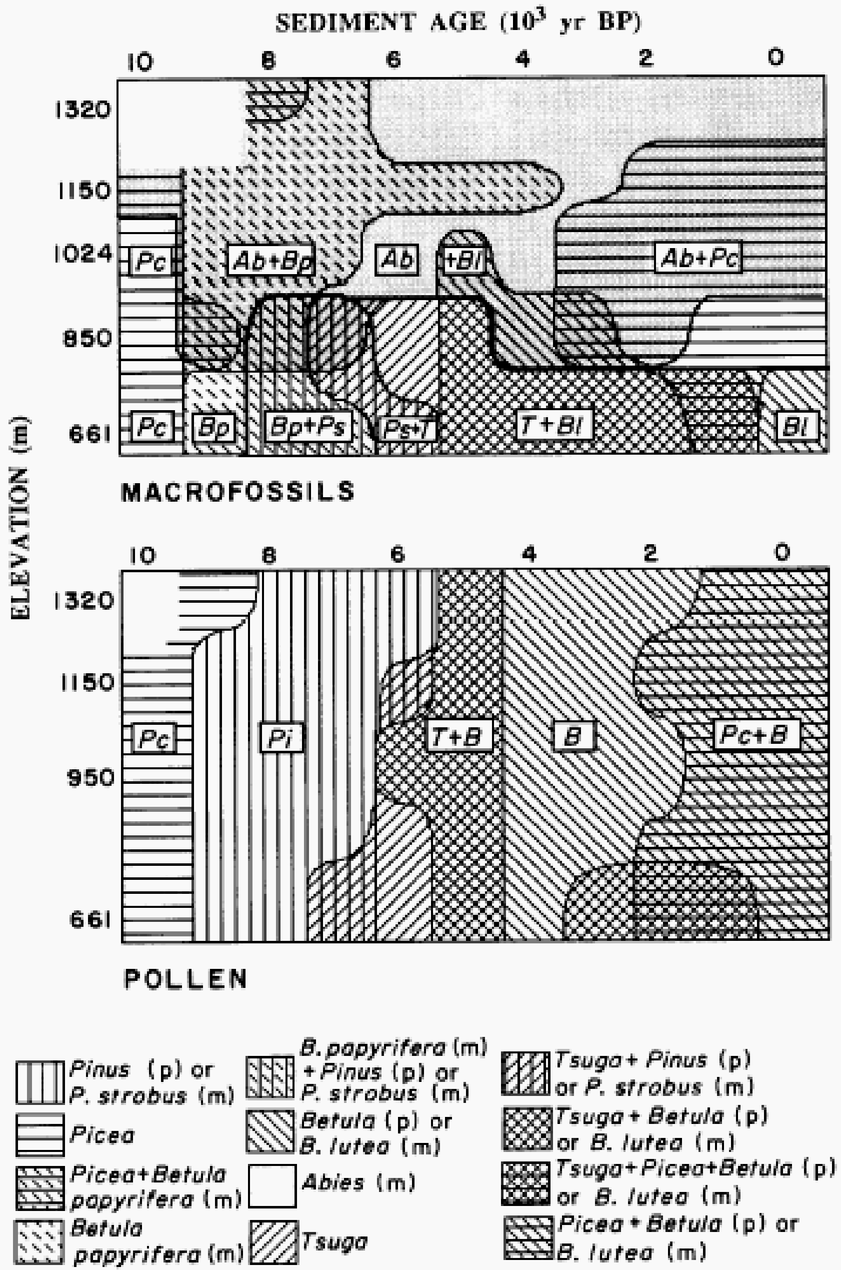
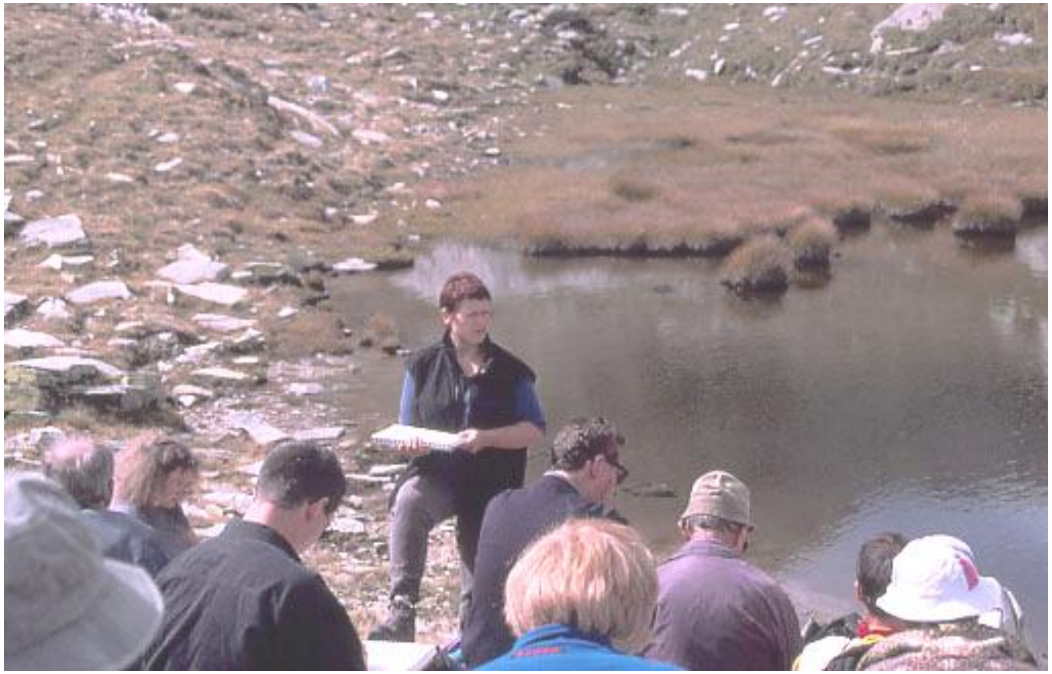


FIG. 7. Summary space–time diagrams for pollen and macrofossil data, in which the abundance maxima for the various taxa are superimposed. Data presentation as in Fig. 2. Macrofossil contours and symbols are as follows: 20% *Picea* (*Pc*); 20% *Abies* (*Ab*); 15% *Pinus strobus* (*Ps*); 20% *Tsuga* (*T*); 15% *Betula papyrifera* (*Bp*); 15% *Betula lutea* (*Bl*). Pollen contours and symbols are: 10% *Picea* (*Pc*); 30% *Pinus* (*Pi*); 10% *Tsuga* (*T*); 35% *Betula* (*B*). *Abies* pollen is not shown. In the shading key, "m" refers to macrofossils; "p" refers to pollen.

Lago Basso,

North Italian Alps



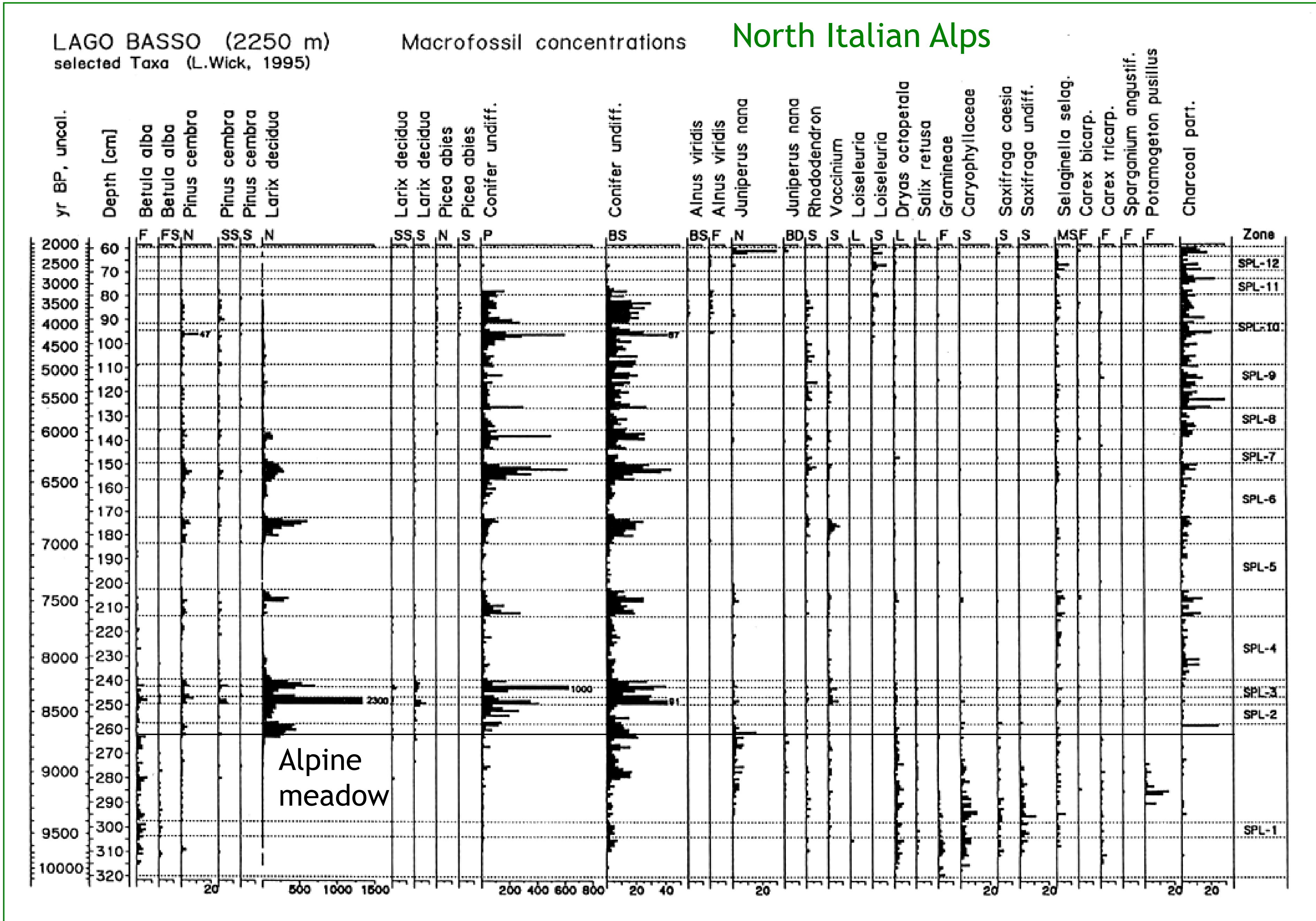
Above tree-line today

(Lucia Wick)

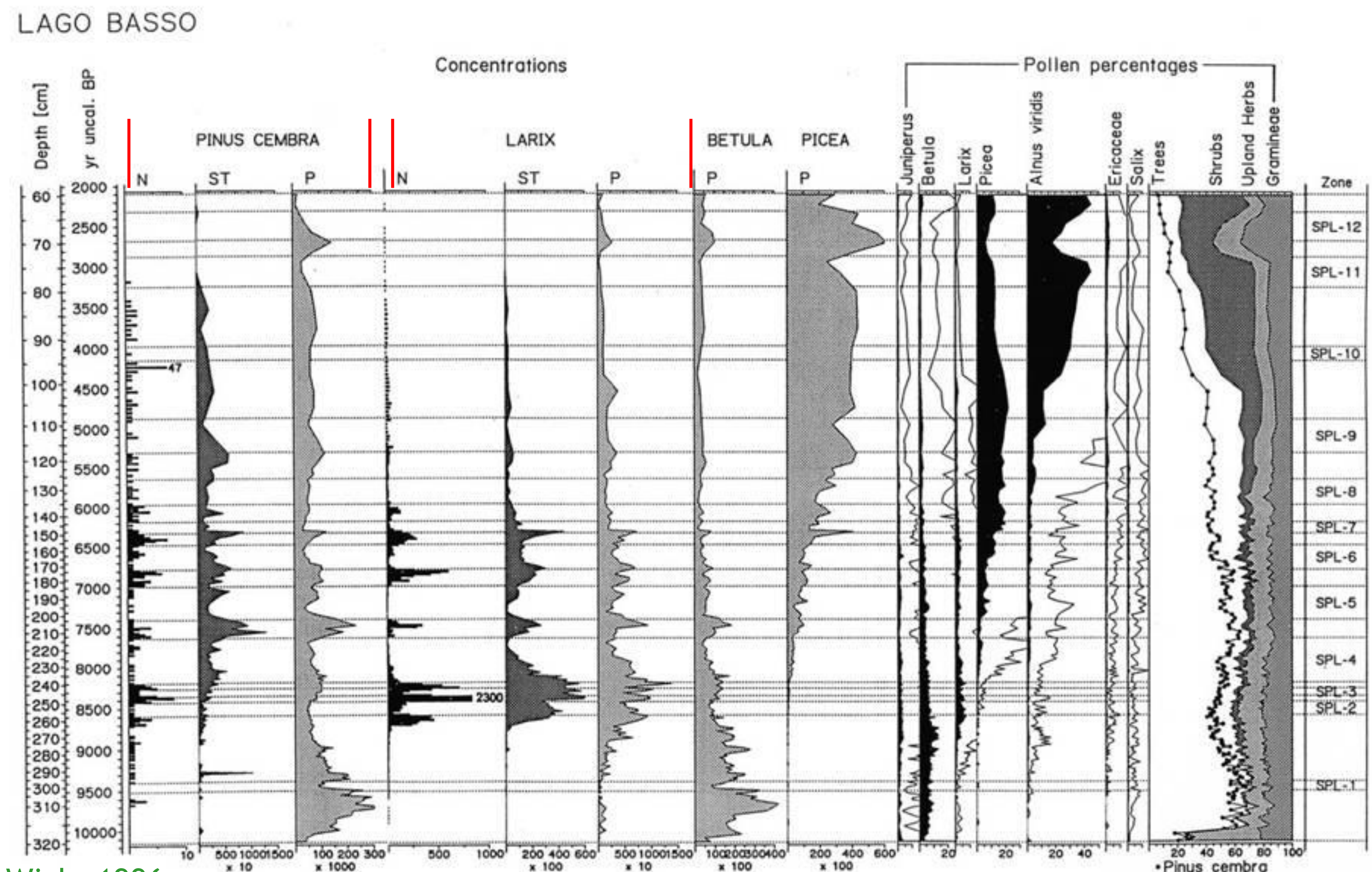
Tree-line in N. Italy / S. Austria

Vent Village, Austria

Pinus cembra, near tree-line, Vent



Wick & Tinner (1997)

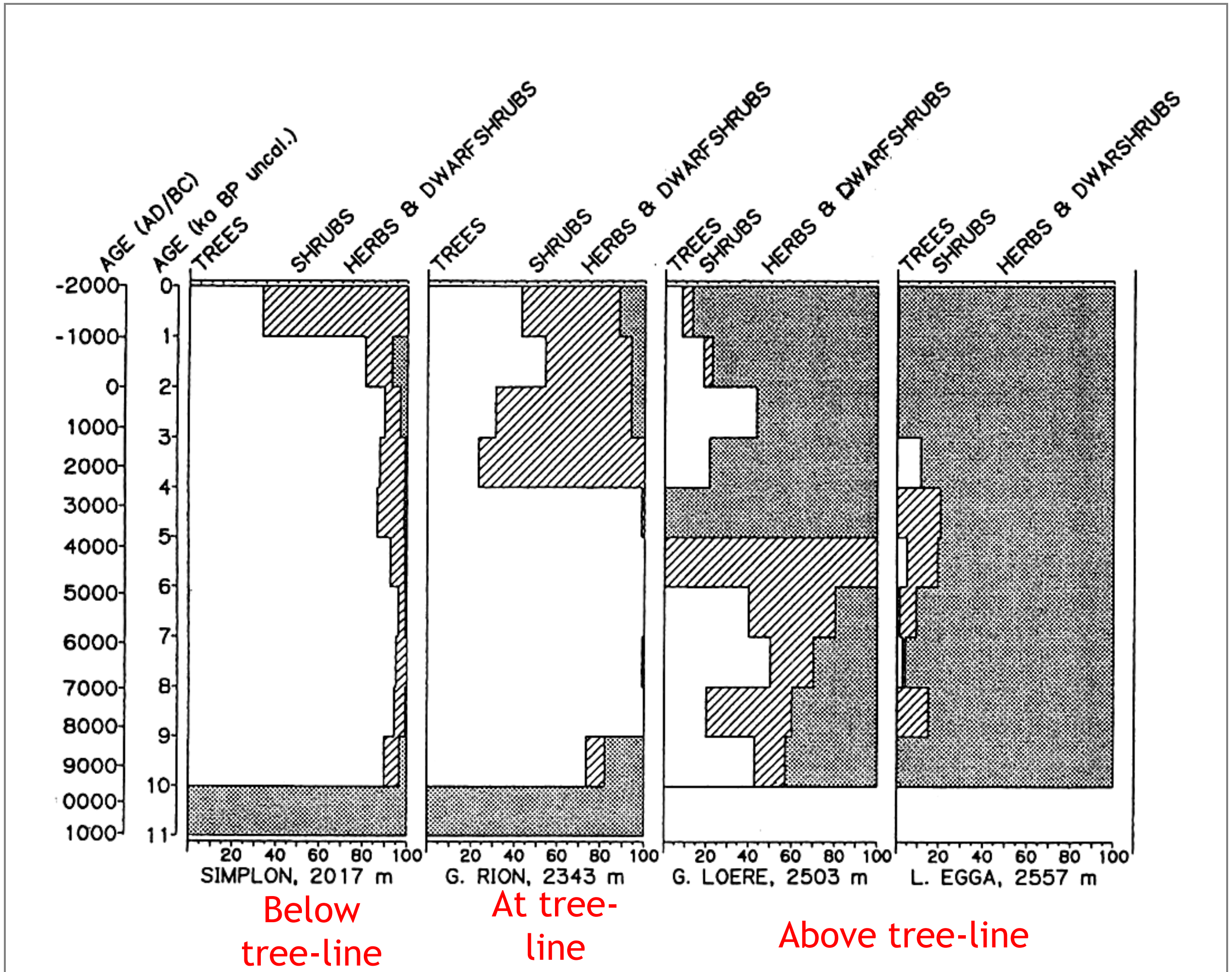


Wick, 1996

Lago Basso: Comparison of concentration of needles, stomata, and pollen influx and with pollen % for other major taxa. N = needles, ST = stomata, P = pollen. The zones labelled SPL-1 to SPL-12 are interpreted as timberline depressions.

Central Swiss Alps altitudinal transect

Macrofossils, % of habitat types



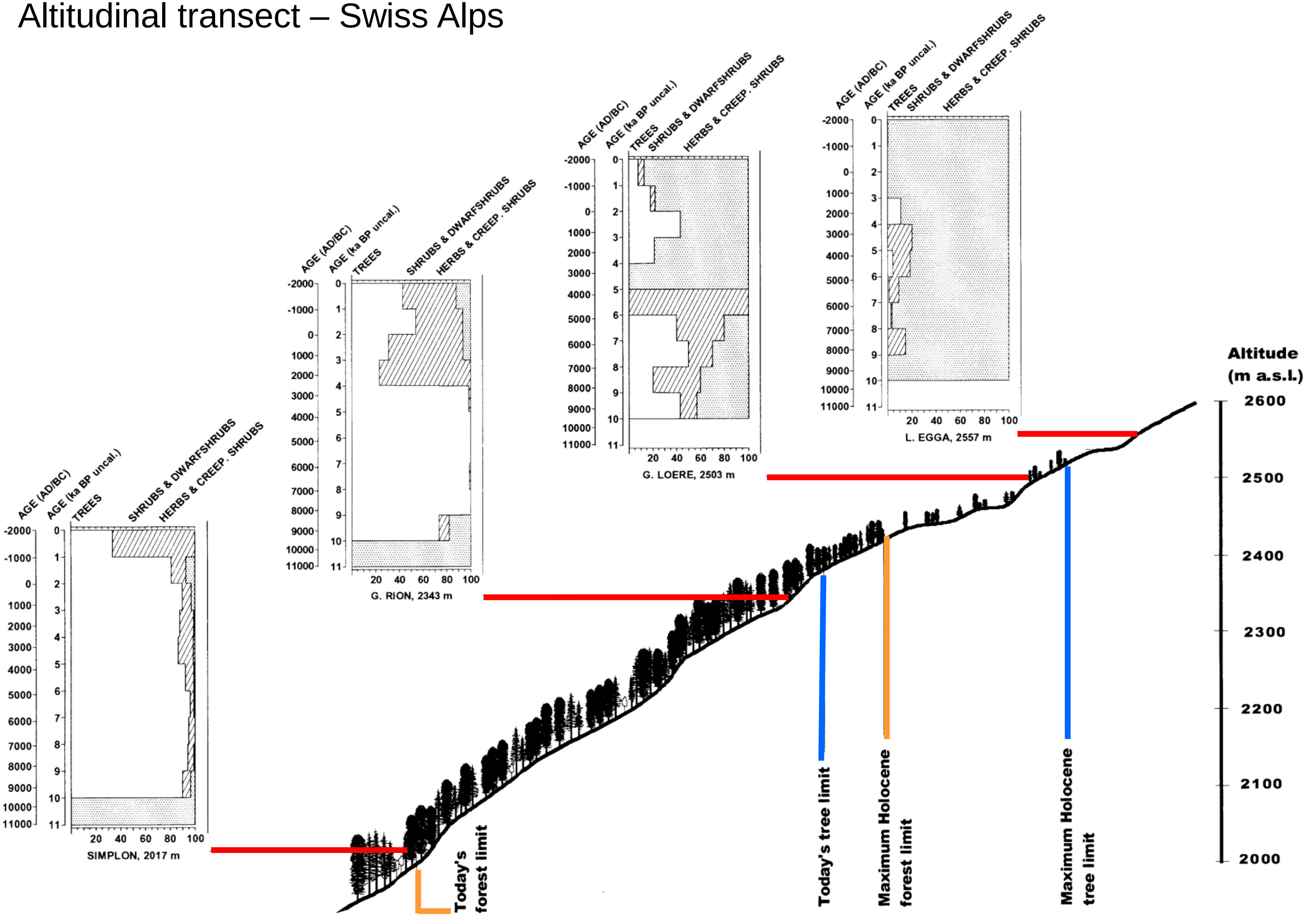
Macrofossil-percentage diagrams of four sites in the central Swiss Alps. Today's tree-line is at about 2350 m a.s.l. Only taxa that could be attributed unambiguously to trees (indicating forests), shrubs (shrub-lands), and dwarf shrubs and upland herbs (alpine meadows) were considered for percentage calculation. The diagrams were subdivided into eleven 1000 radiocarbon-year steps.

Tinner & Theurillat (2003), Tinner (2007)

Gouillé Rion 2343 m

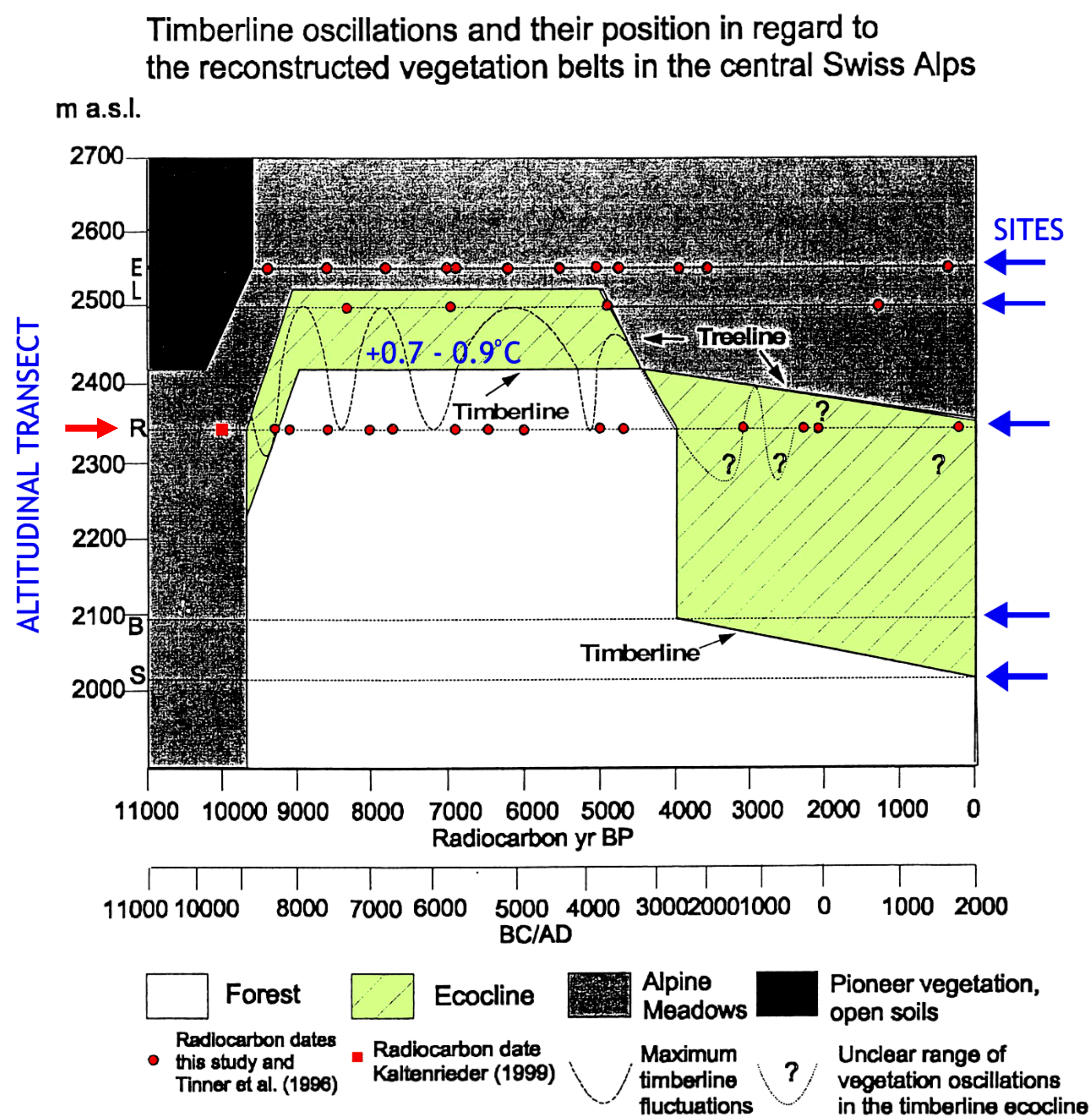
just above tree-line today

Altitudinal transect – Swiss Alps



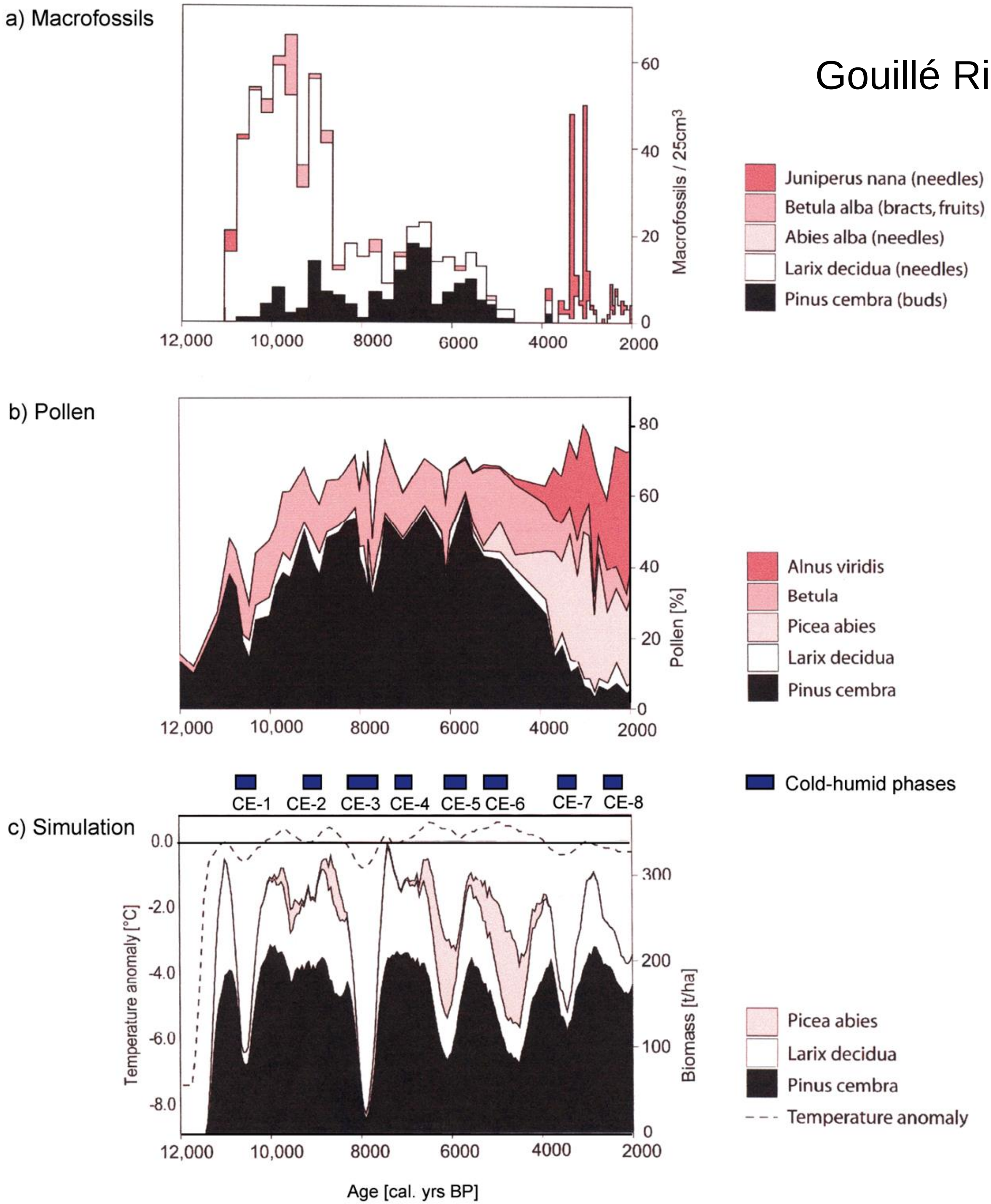
Tinner & Theurillat 2003; Tinner 2007

Changes in the altitudinal ranges of the main vegetational belts in the central Swiss Alps during the past 13,000 cal yr. The limits of the vegetational belts are placed between the sites recording the presence of the respective vegetation type as inferred by macrofossil analysis. The chronology relies on AMS-dating of terrestrial macrofossils and is supported by radiocarbon dating of gyttja samples.



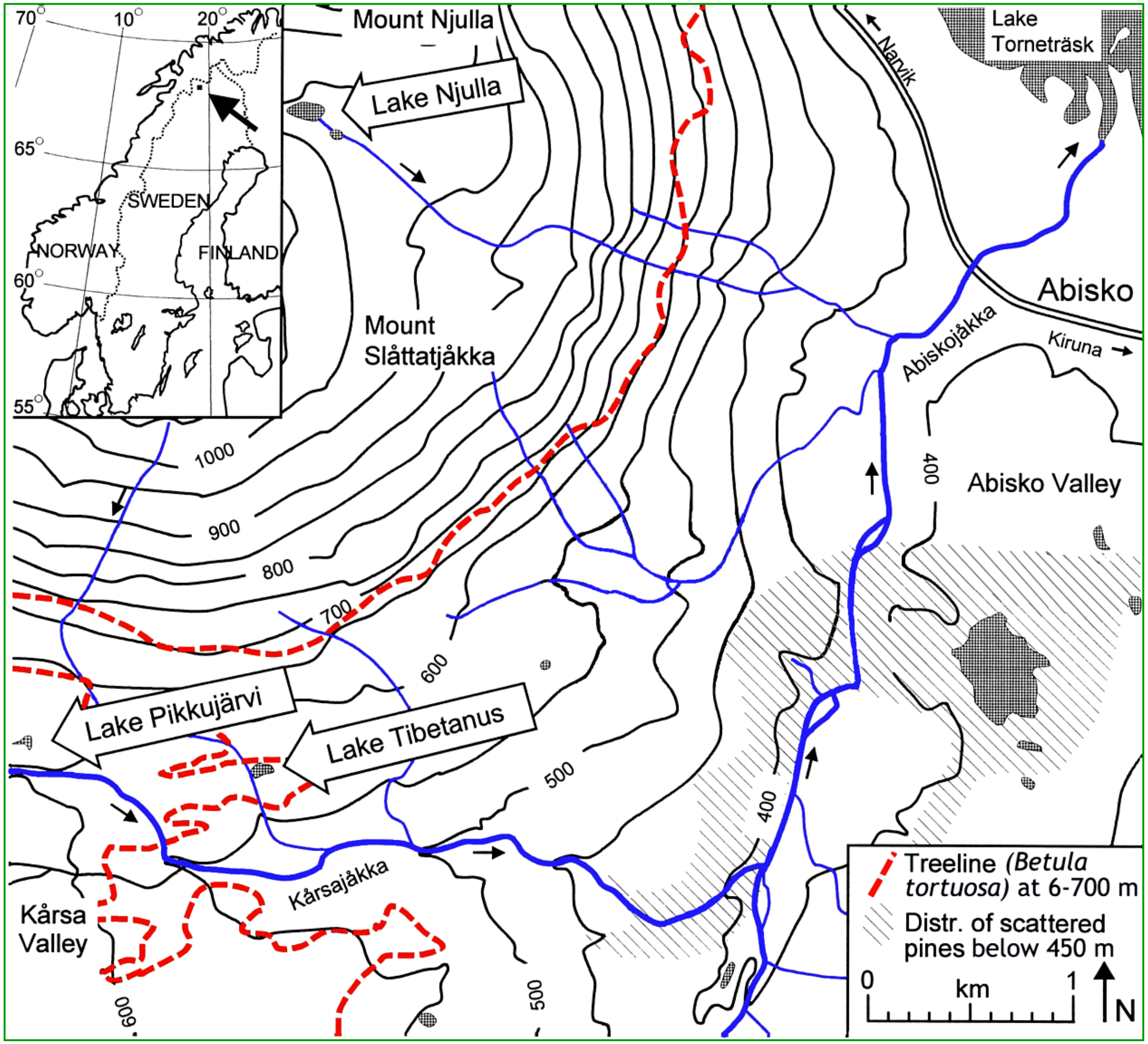
? Why did the ecocline expand after 4000 BP: Climate or Man?

Gouillé Rion (2343 m – at tree-line)



Heiri et al. 2006; Tinner 2007

Holocene tree-limit changes in north Sweden



Barnekow (1999)

Lake Tibetanus, 560 m, at tree-line; Lake Pikkujärvi, 625 m, just above tree-line; Lake Njulla, 999 m, alpine zone tundra.

Abisko Valley

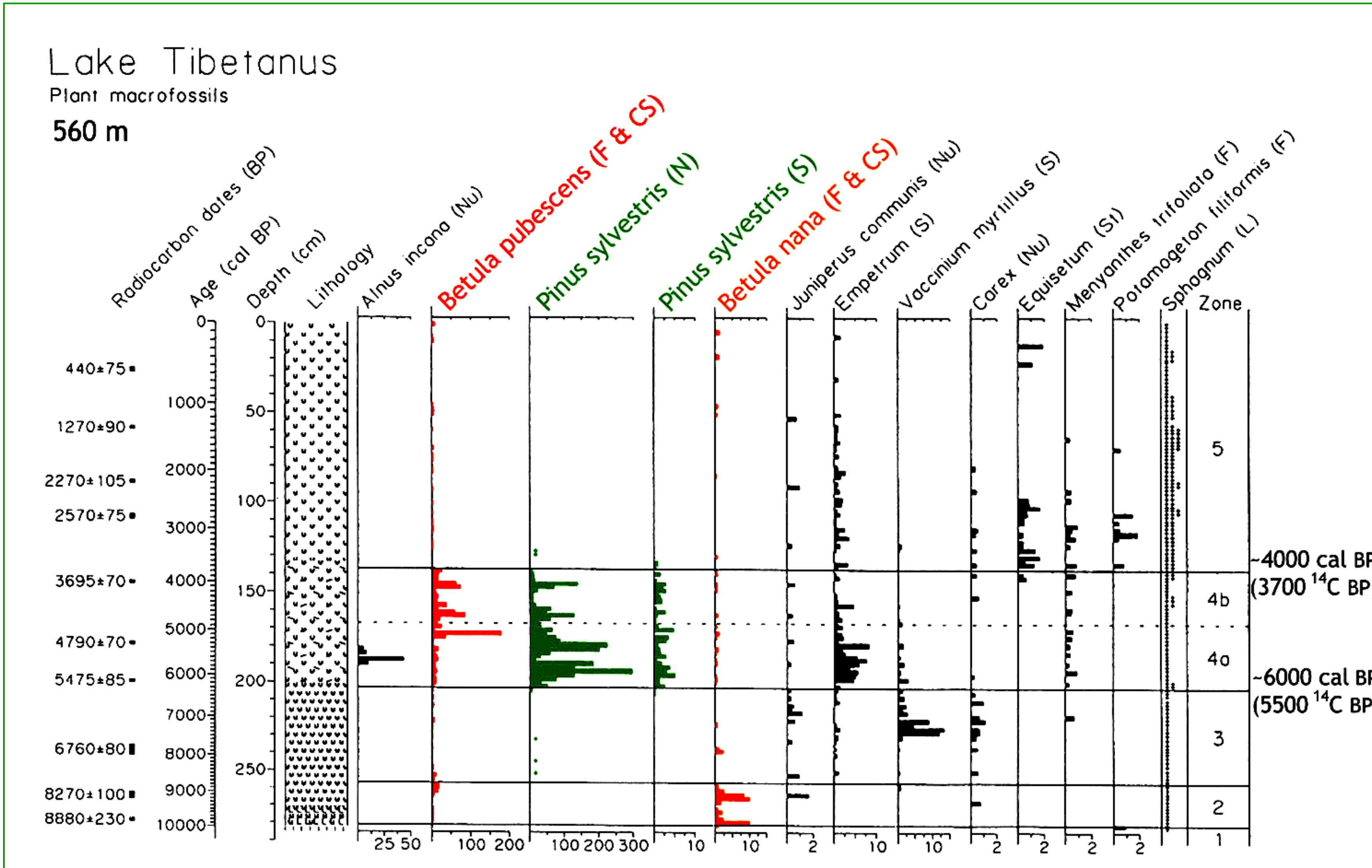
Abisko pines

Birch forest belt

Birch tree-line

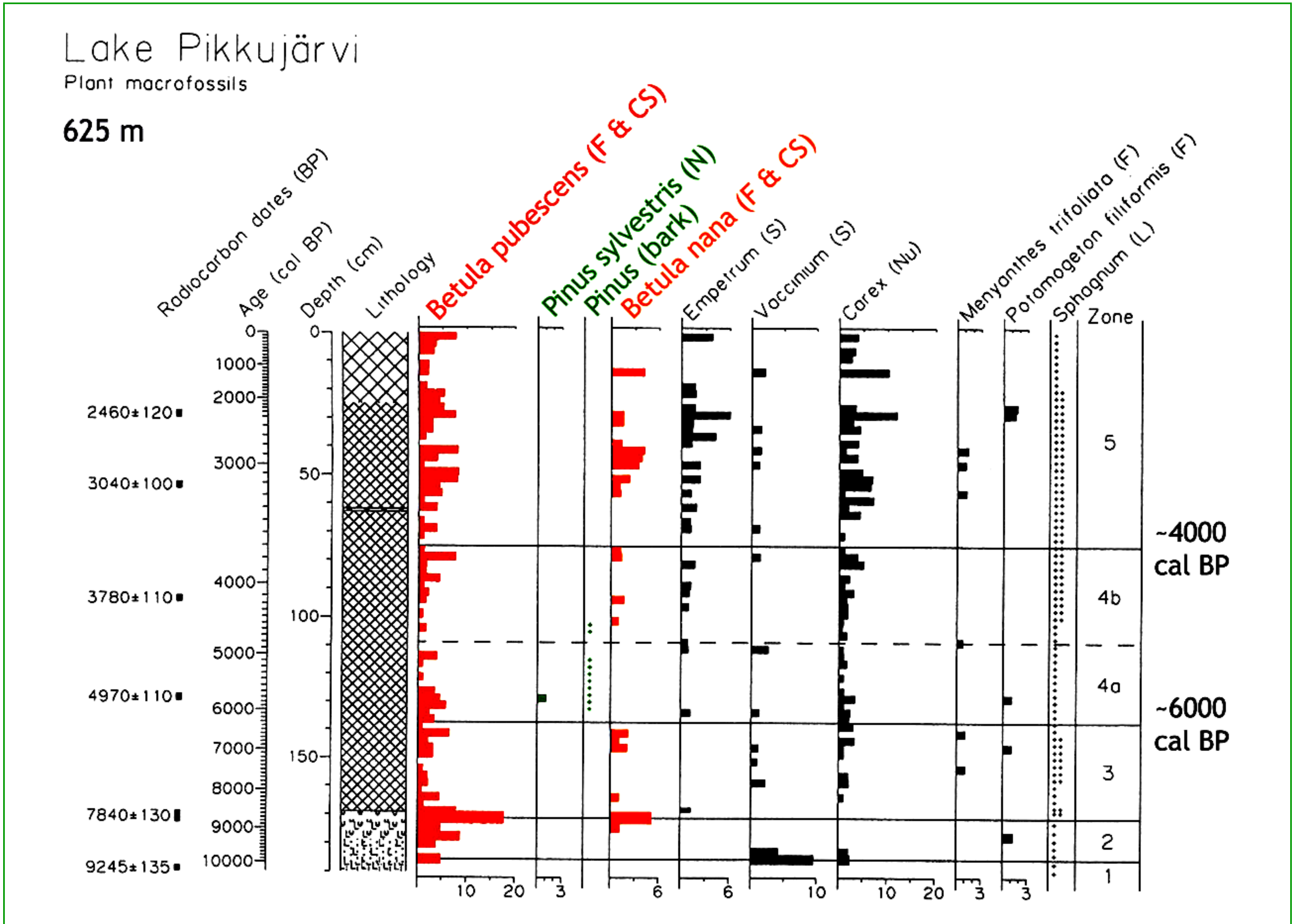
Low alpine zone, Abisko

High alpine zone

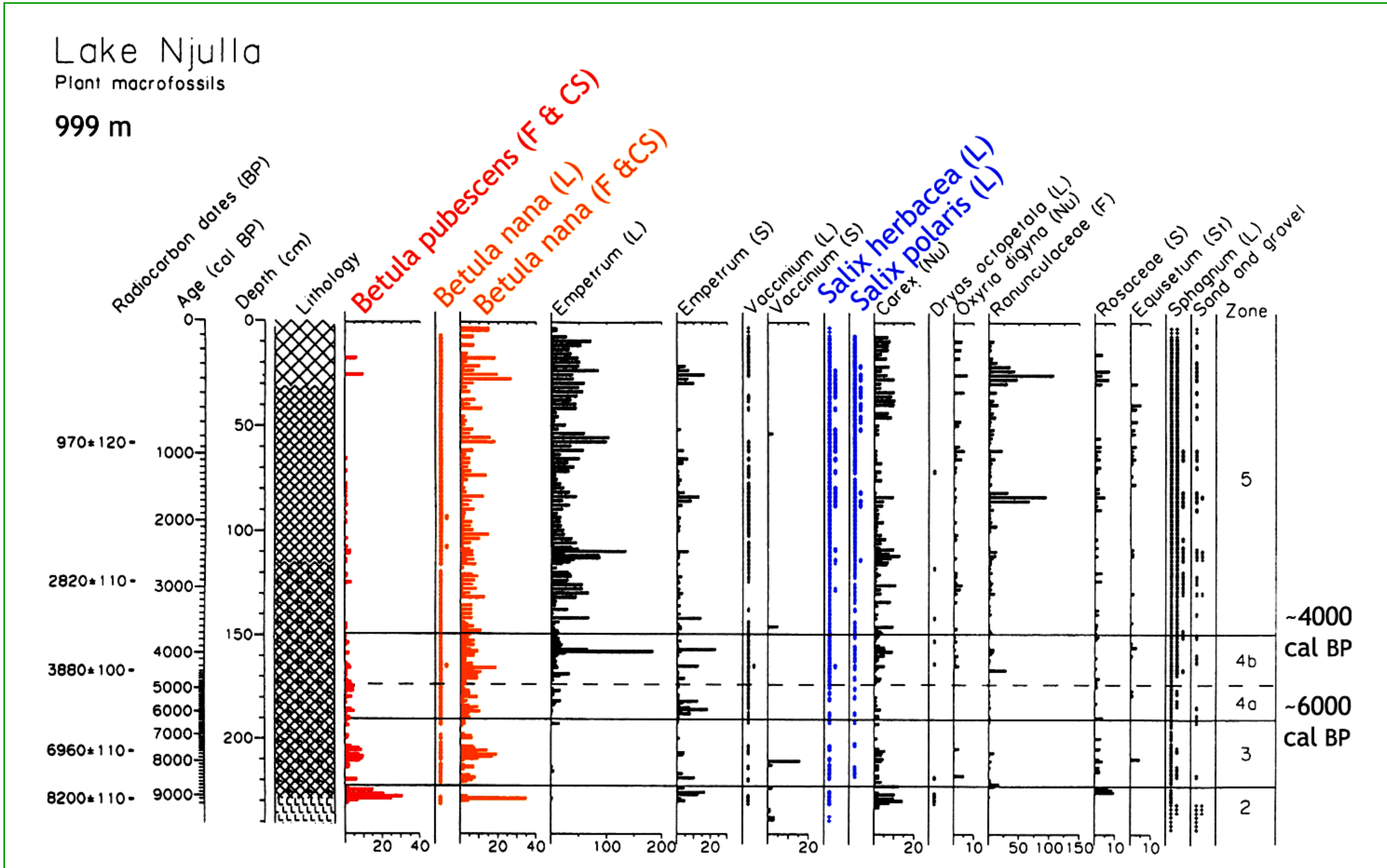


F=Fruit, S= seed, CS=Catkin scale, N=Needle, Nu=Nut, St=stem,L=Leaf

Barnekow (1999)



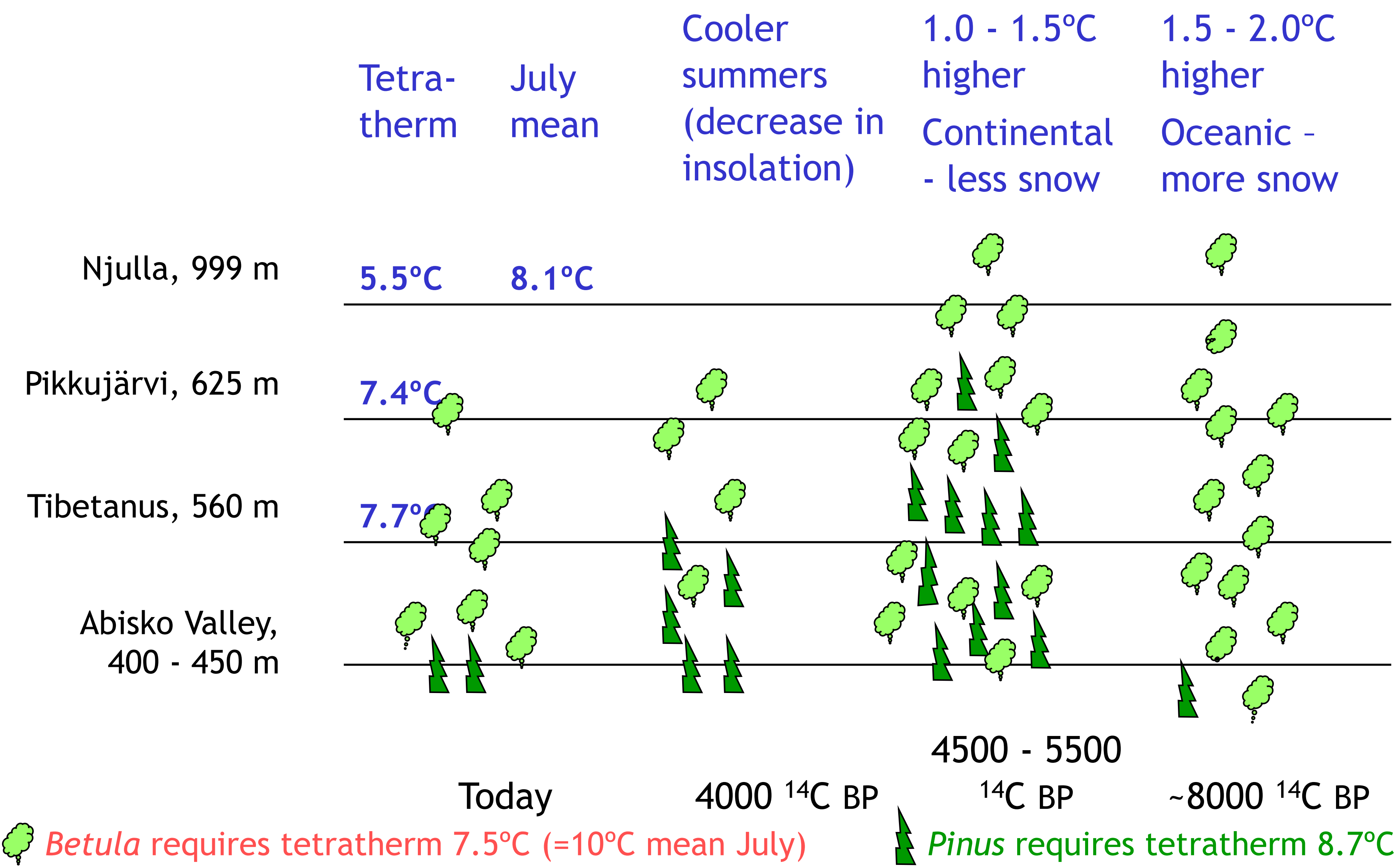
Barnekow (1999)



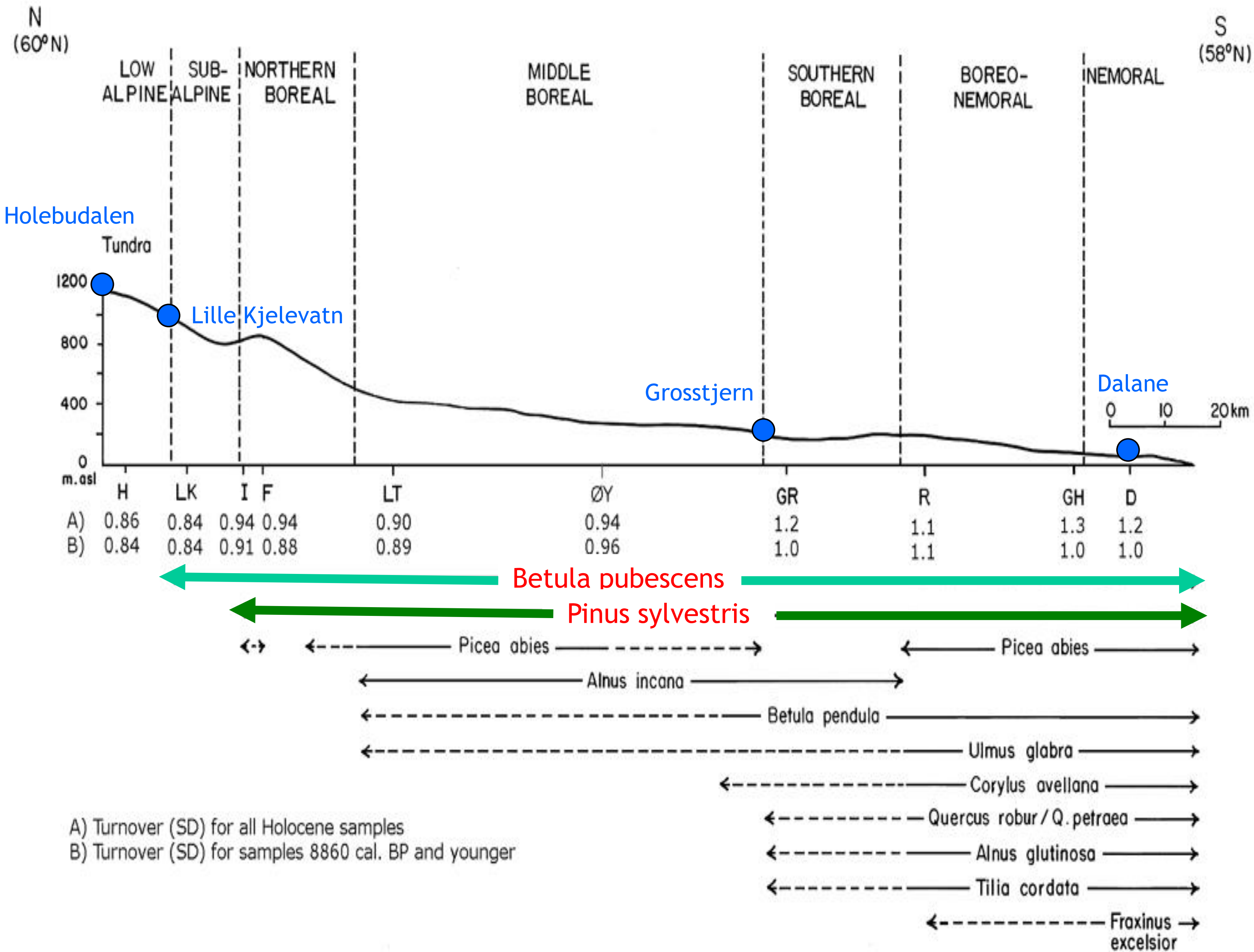
Barnekow (1999)

Abisko, N Sweden

Holocene tree-lines



Transect along Setesdal, S. Norway



Lille Kjelevatn (1000 m asl)

Betula tree limit

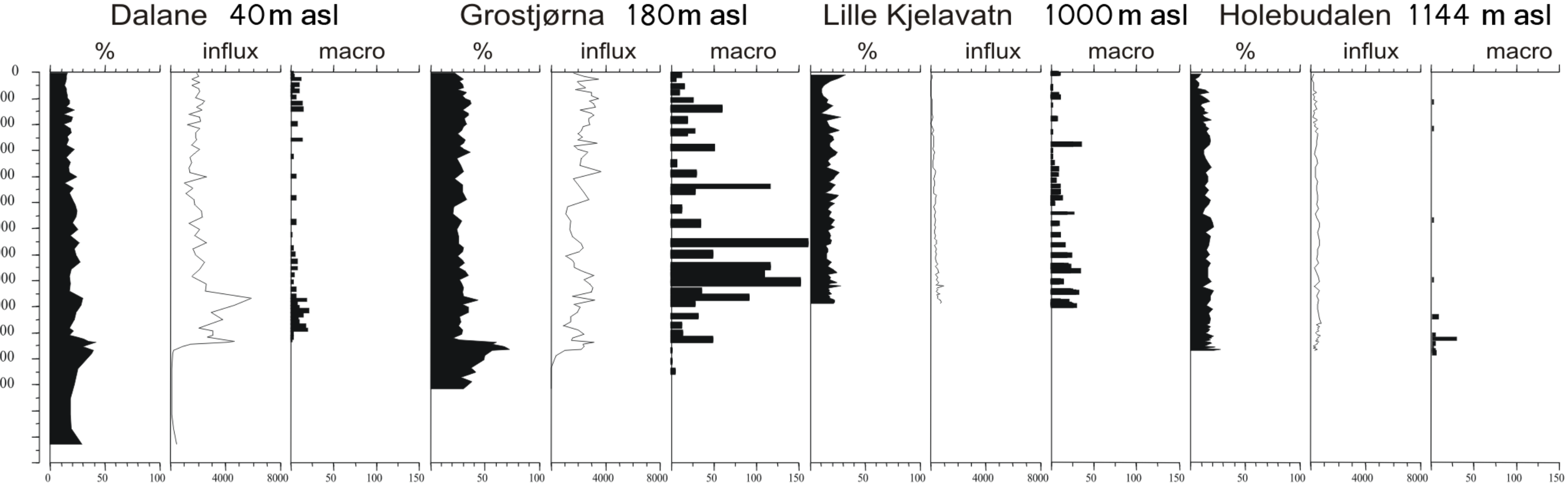
Grosstjørna 180 m asl

Mixed conifer/deciduous
(northern boreal)

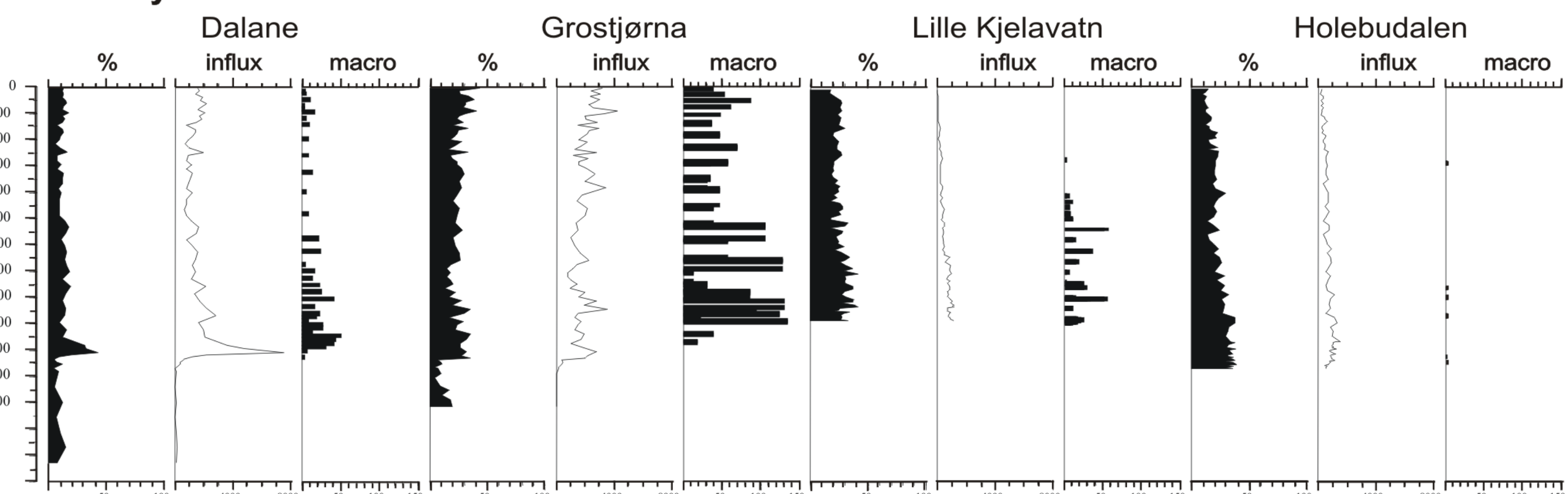
Setesdal, Norway

Altitudinal transect comparing pollen percentages and influx and macrofossil concentrations

Betula

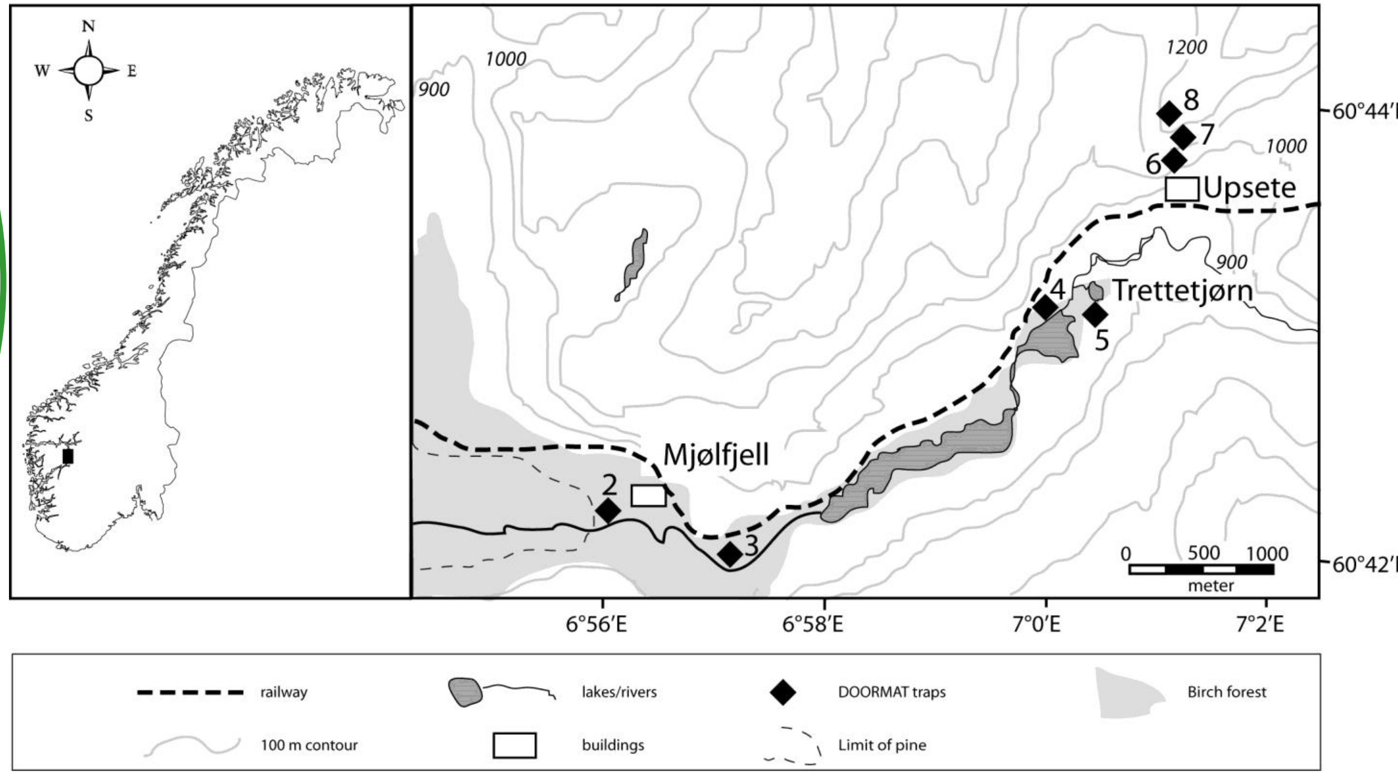


Pinus sylvestris



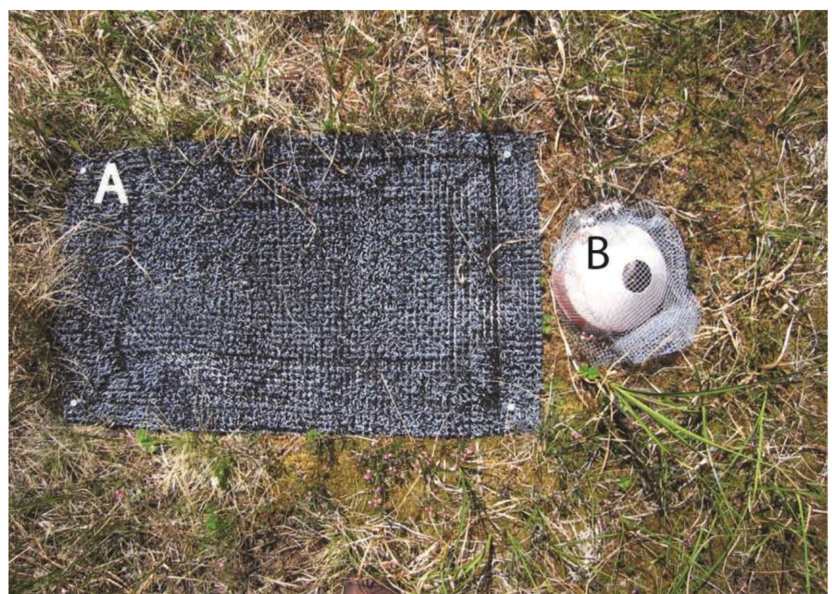
Eide & Birks (2006) Birks (2007)

What do isolated birch fruits and Pinus remains mean in terms of local growth?



DOORMAT

Direct
Observation
Of **R**ecent
Macrofossils
Across
Treeline

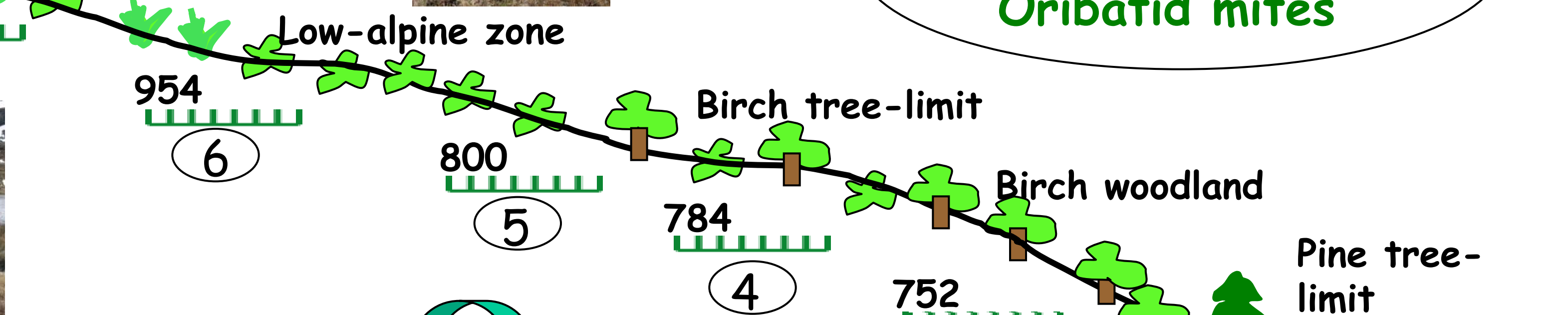


DOORMAT

Direct Observation Of Recent Macrofossils Across Treeline

Plant remains, Pollen

Oribatid mites



Results

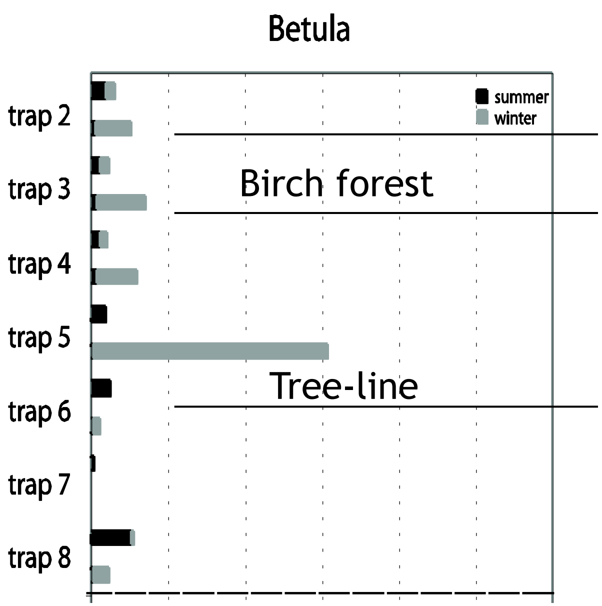
Tree pollen percentages are insensitive across treeline

Tree plant remains reflect the surrounding vegetation

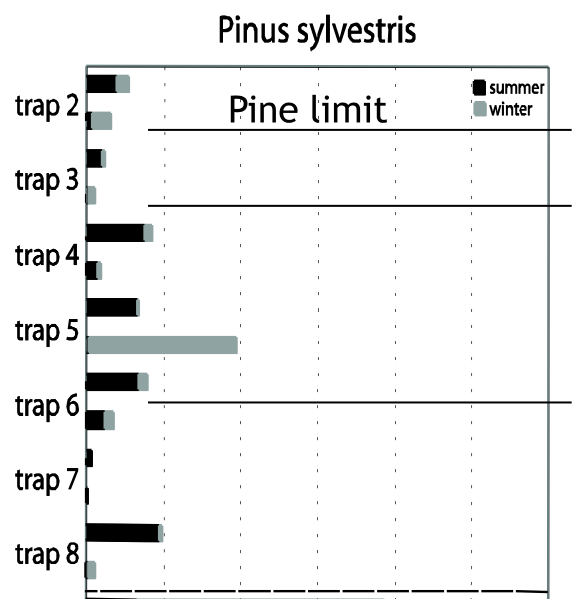
The lake is an efficient pollen trap. It also collects a few birch macrofossils.

Hilary Birks, Anne Bjune, Arguitxu de la Riva Caballero,   Birks and Bjune 2010, VHA

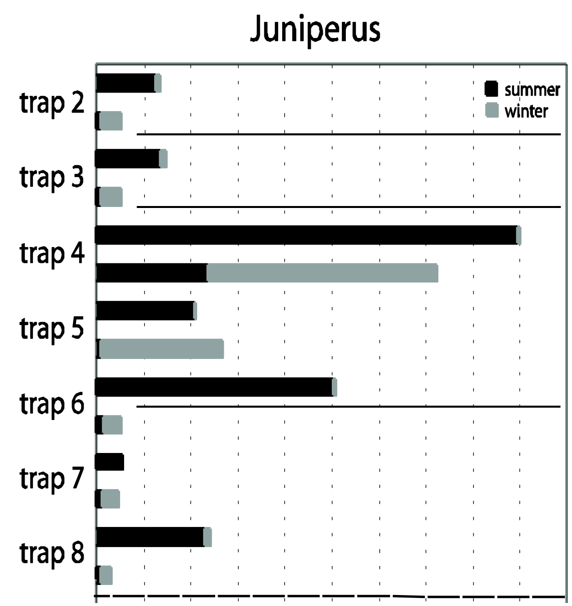
DOORMAT pollen influx



Birch pollen decreases at treeline. Values above treeline can be as great as in birch forest



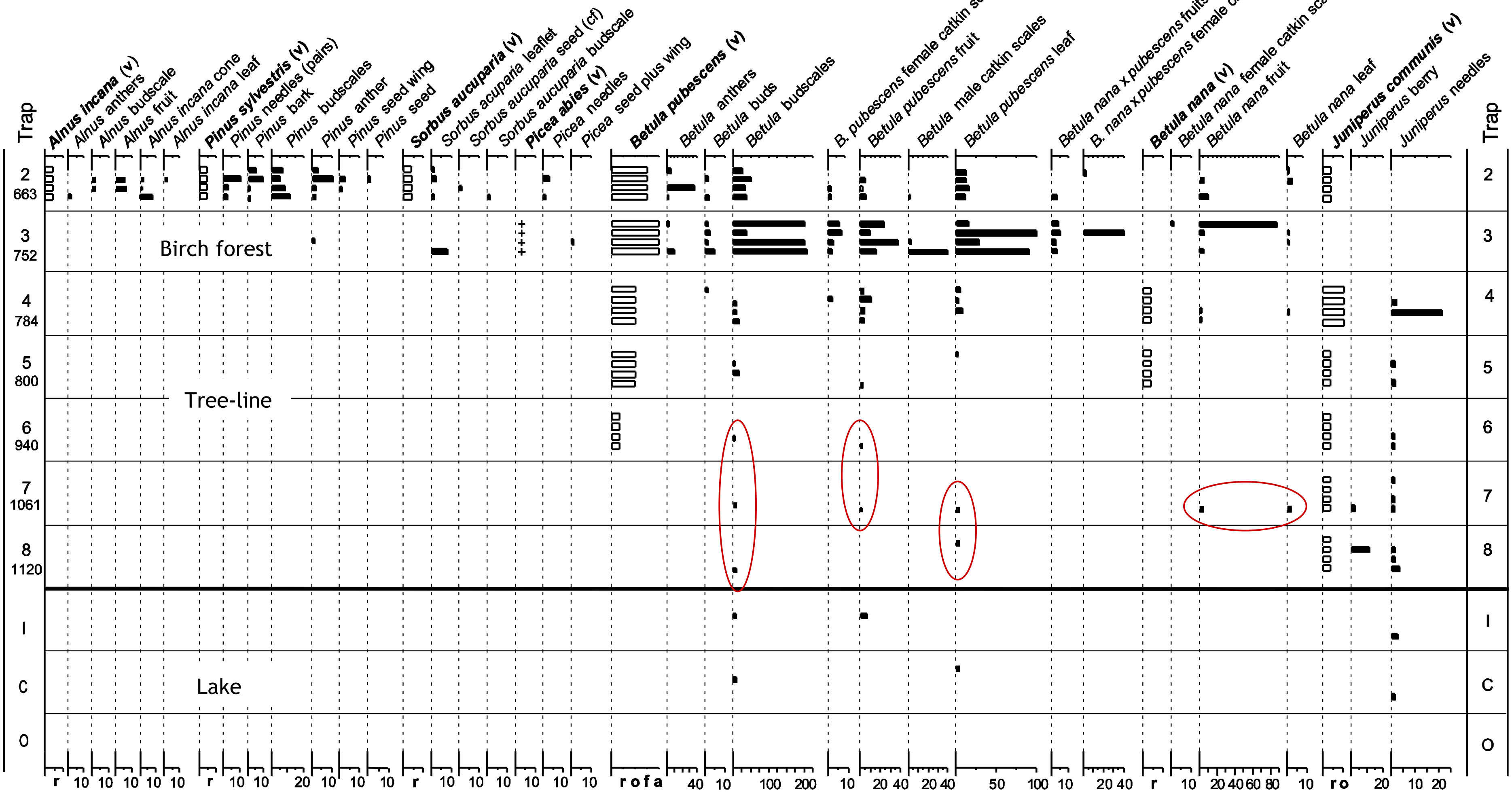
Pine pollen decreases in closed birch forest but increases in open birch forest near treeline. Its values above treeline are similar to those at the pine limit



Juniperus pollen is low in closed woodland. It increases in open woodland and is present in low amounts above treeline where it grows locally

DOORMAT Macroremains

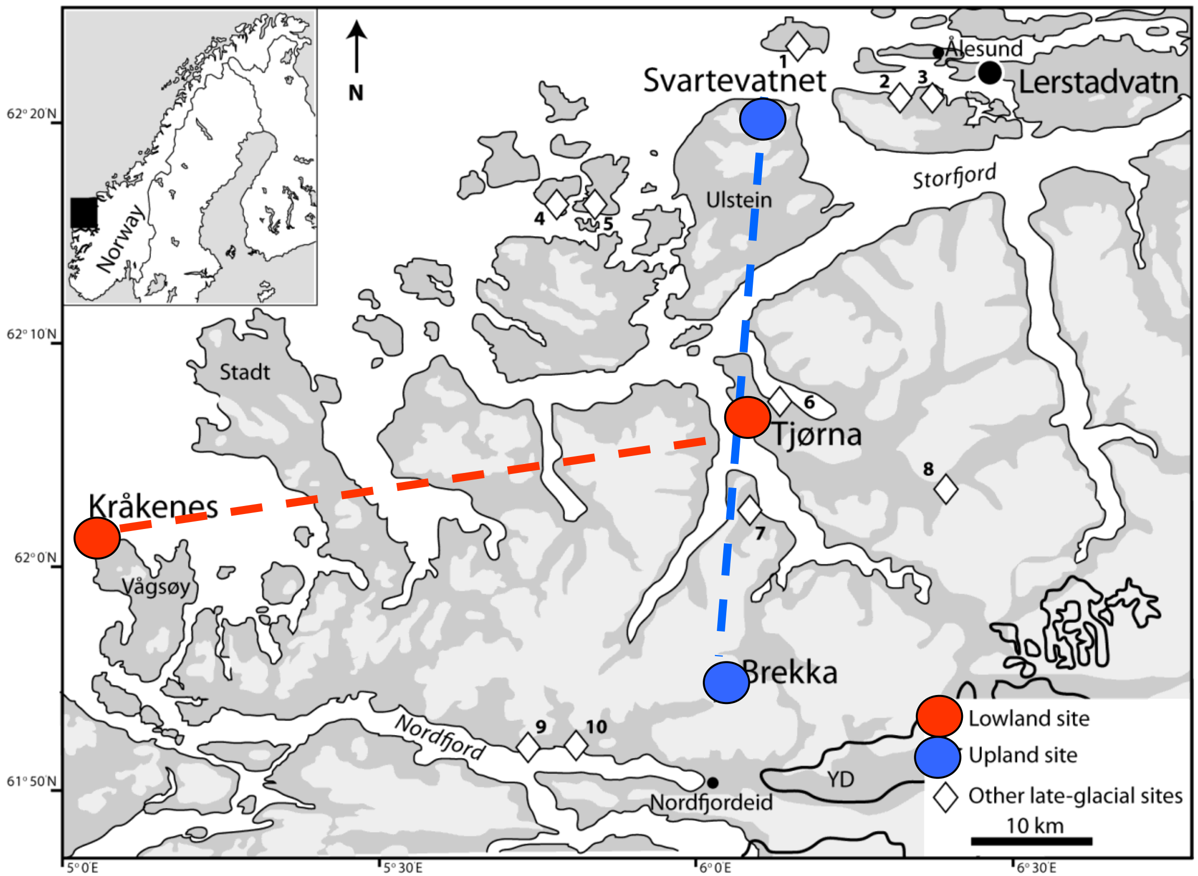
Trees and shrubs

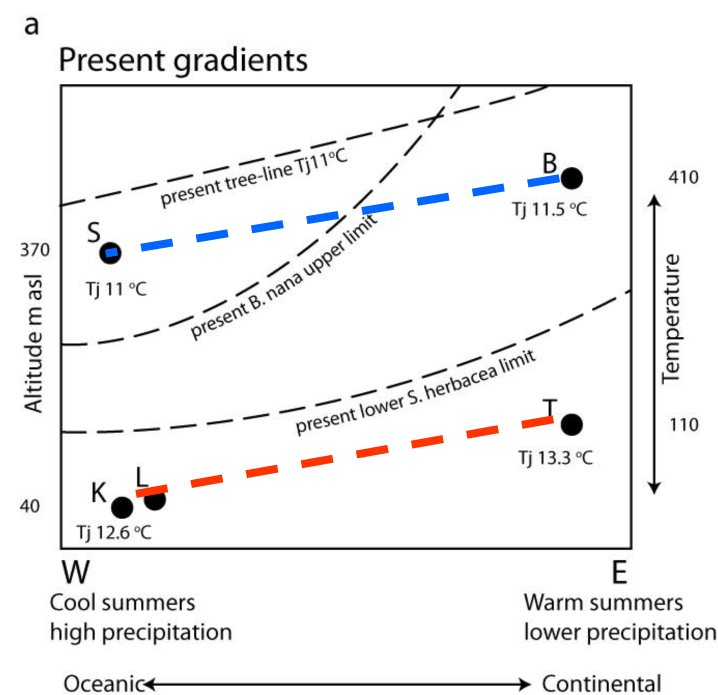


Birch fruits and other remains can be found at least 300 m above the birch treeline

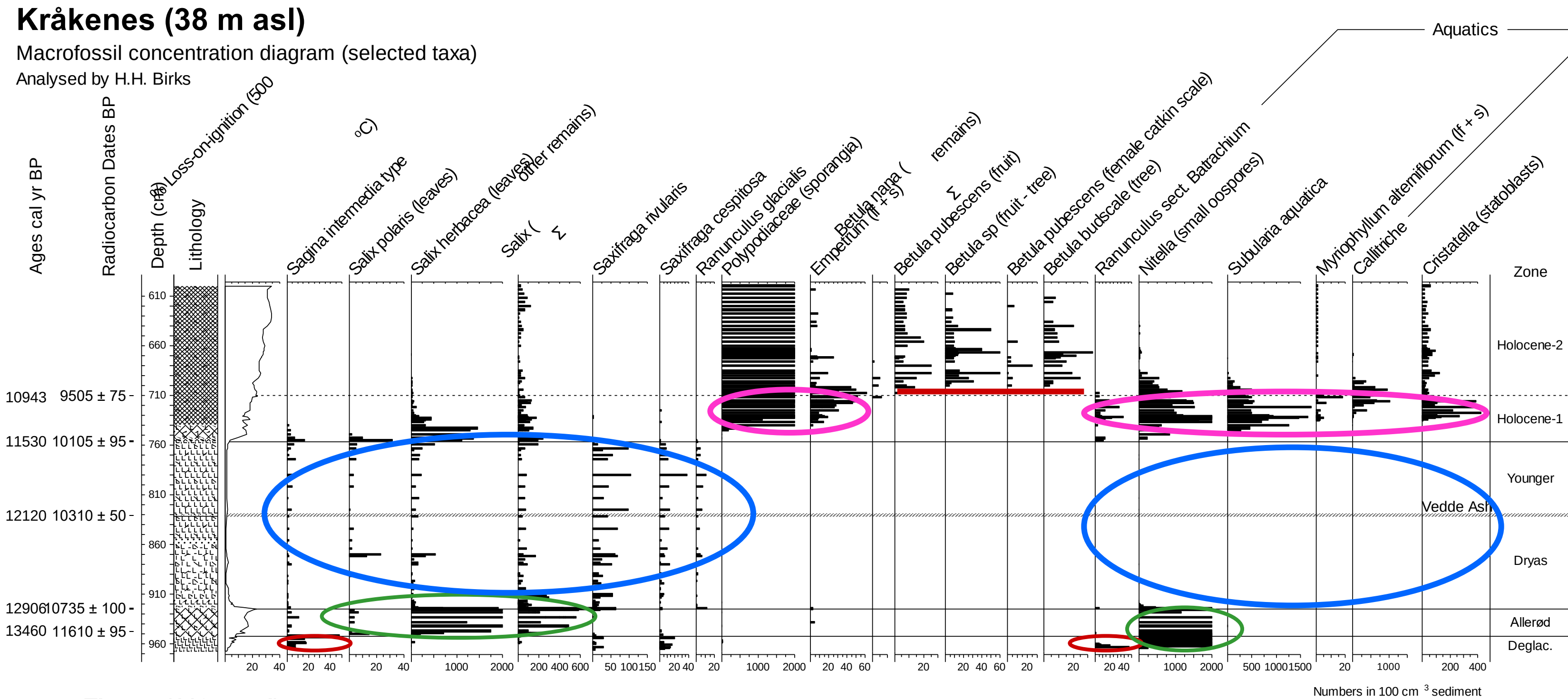
Lateglacial and early Holocene vegetation and climate gradients in the Nordfjord-Ålesund area, western Norway

Sites selected to sample vegetation and climate gradients in time and space; western Norway

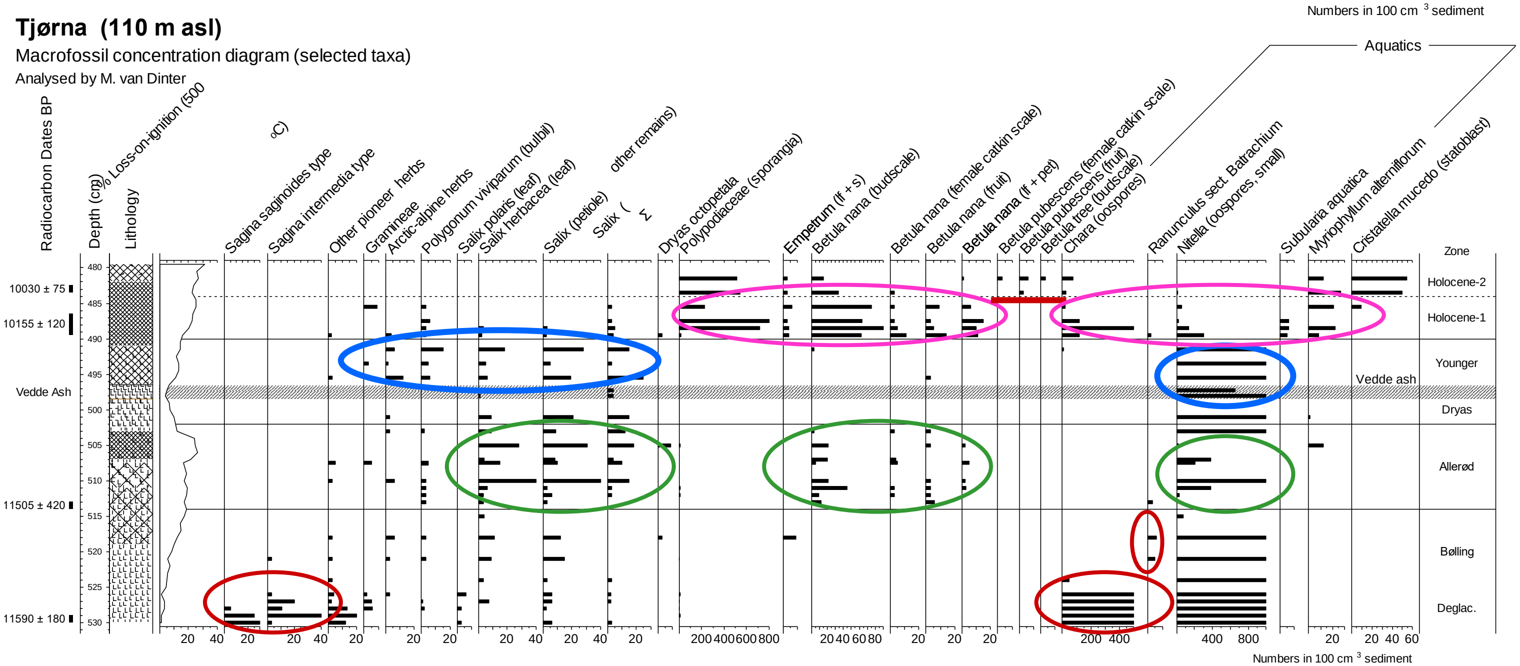




Hilary H Birks and Marieke van Dinter (2010) Lateglacial and early Holocene vegetation and climate gradients in the Nordfjord-Ålesund area, western Norway. *Boreas* 39,783-798.



Kråkenes (38 m asl)
Macrofossil concentration diagram (selected taxa)
Analysed by H.H. Birks
Aquatics
Ages cal yr BP
Radiocarbon Dates BP
Depth (cm)
Lithology
% Loss-on-ignition (500 °C)
Sagina intermedia type
Salix polaris (leaves)
Salix herbacea (leaves)
Salix (Σ other remains)
Saxifraga rivularis
Saxifraga cespitosa
Ranunculus glacialis
Polypodiaceae (sporangia)
Empetrum (f + s)
Betula nana (Σ remains)
Betula pubescens (fruit)
Betula sp (fruit - tree)
Betula pubescens (female catkin scale)
Betula budscale (tree)
Ranunculus sect. Batrachium
Nitella (small oospores)
Subularia aquatica
Myriophyllum alterniflorum (f + s)
Callitriche
Cristatella (statoblasts)
Zone
Holocene-2
Holocene-1
Younger
Vedde Ash
Dryas
Allerød
Deglac.
10943 9505 ± 75
11530 10105 ± 95
12120 10310 ± 50
12906 10735 ± 100
13460 11610 ± 95
610
660
710
760
810
860
910
960
Numbers in 100 cm ³ sediment

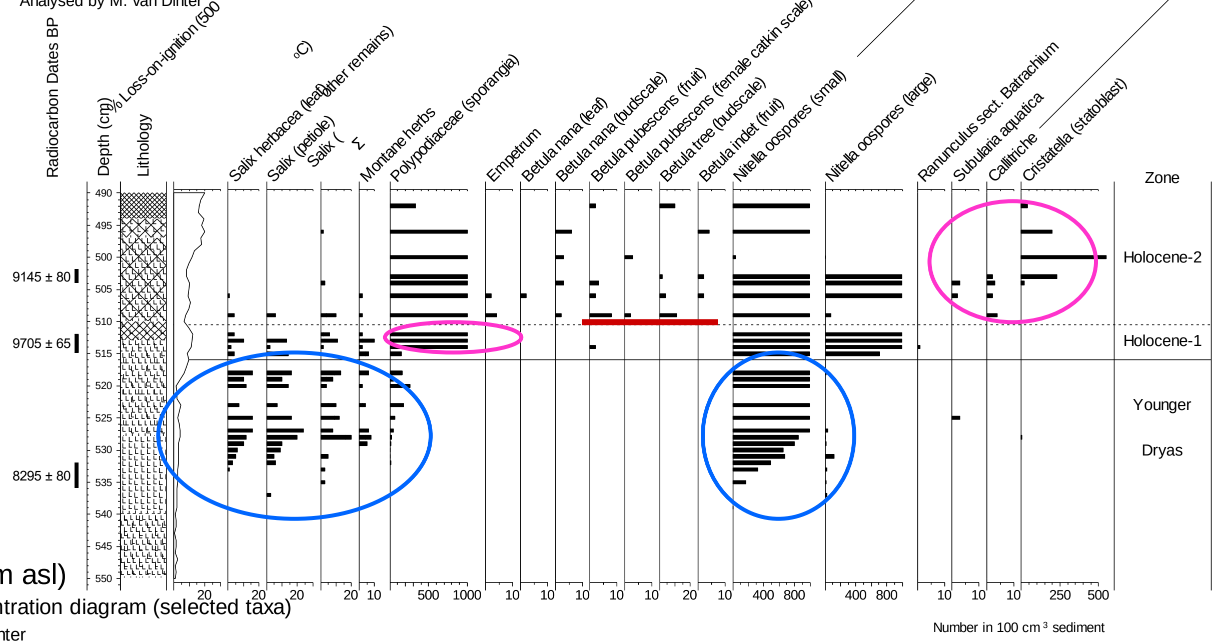


Tjørna (110 m asl)
Macrofossil concentration diagram (selected taxa)
Analysed by M. van Dinter
Aquatics
Radiocarbon Dates BP
Depth (cm)
Lithology
% Loss-on-ignition (500 °C)
Sagina saginoides type
Sagina intermedia type
Other pioneer herbs
Gramineae
Arctic-alpine herbs
Polygonum viviparum (bulbil)
Salix polaris (leaf)
Salix herbacea (leaf)
Salix (petiole)
Salix (Σ other remains)
Dryas octopetala
Polypodiaceae (sporangia)
Empetrum (f + s)
Betula nana (budscale)
Betula nana (female catkin scale)
Betula nana (fruit)
Betula nana (f + pet)
Betula pubescens (female catkin scale)
Betula pubescens (fruit)
Betula tree (budscale)
Chara (oospores)
Ranunculus sect. Batrachium
Nitella (oospores, small)
Subularia aquatica
Myriophyllum alterniflorum
Cristatella mucedo (statoblast)
Zone
Holocene-2
Holocene-1
Younger
Vedde ash
Dryas
Allerød
Bølling
Deglac.
10030 ± 75
10155 ± 120
Vedde Ash
11505 ± 420
11590 ± 180
Numbers in 100 cm ³ sediment

Svartevatnet (370 m asl)

Macrofossil concentration diagram (selected taxa)

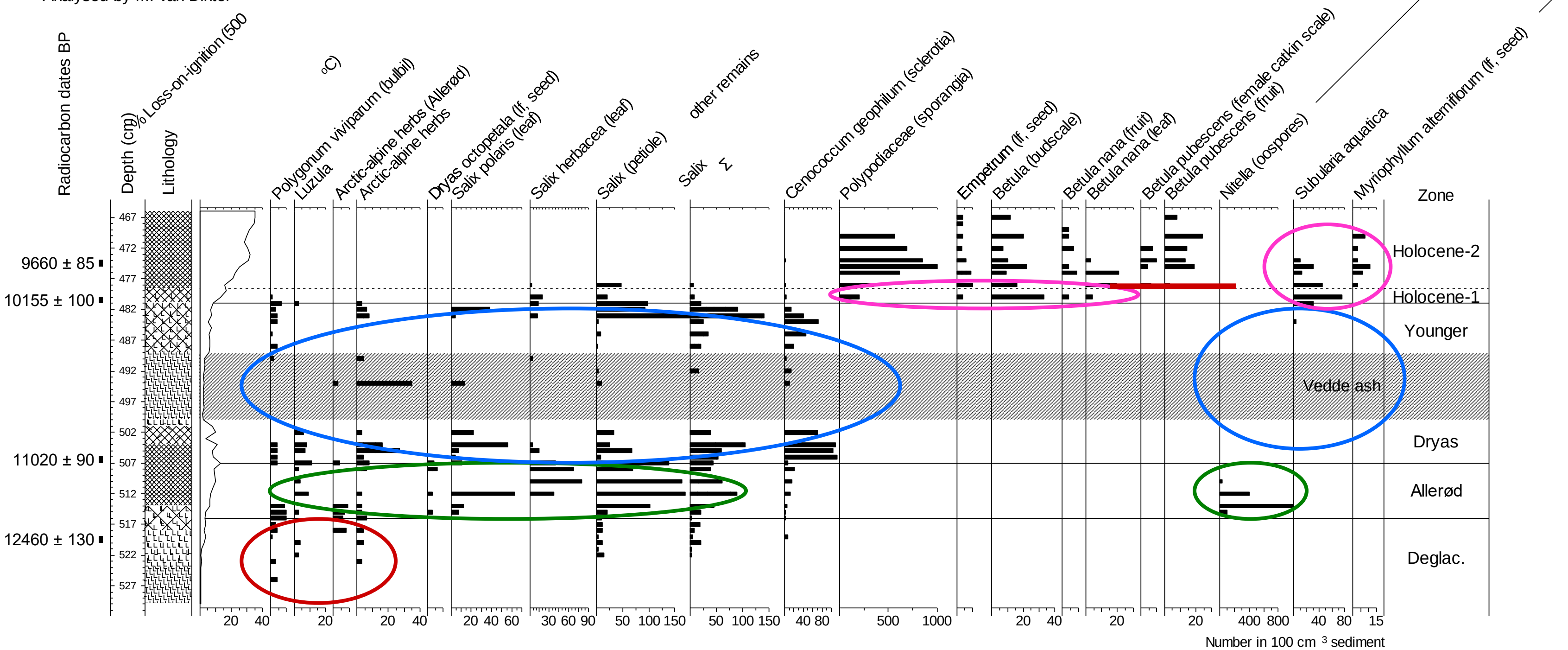
Analysed by M. van Dinter



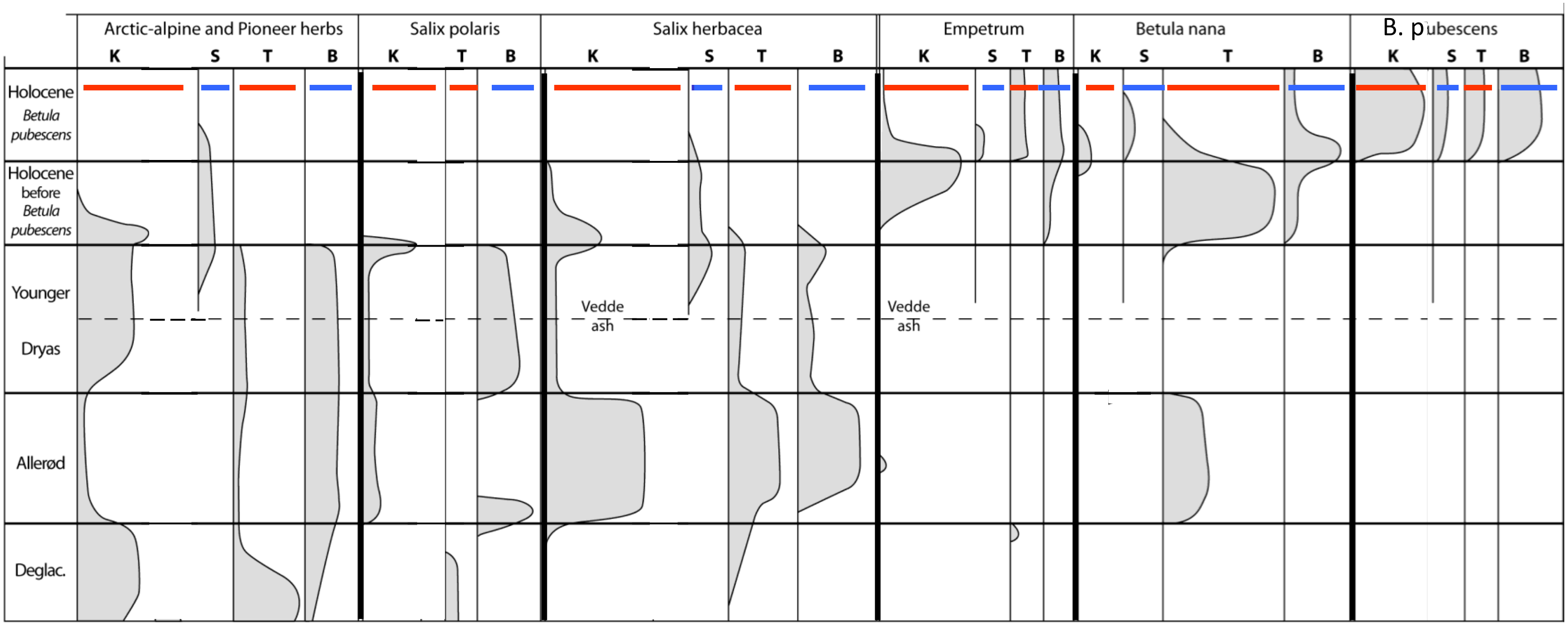
Brekka (410 m asl)

Macrofossil concentration diagram (selected taxa)

Analysed by M. van Dinter

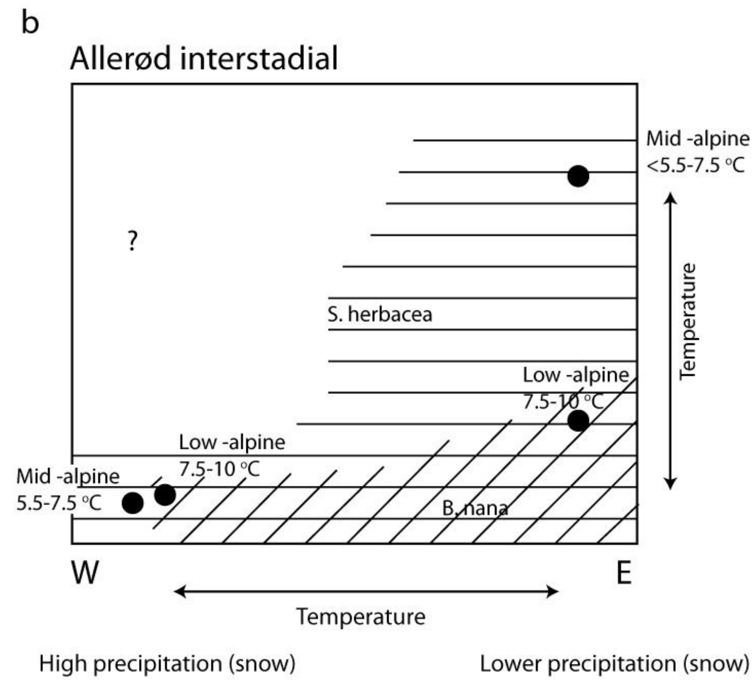


Comparison of late-glacial lowland and upland vegetation along Nordfjord



K = Kråkenes Lowland 38 m asl (coast)
S = Svartevatnet Upland 370 m asl (coast)
T = Tjørna Lowland 110 m asl (inland)
B = Brekka Upland 410 m asl (inland)

Gradients existed throughout the late-glacial and the early Holocene



Allerød interstadial

Lowland: S. herbacea in west, Betula nana in inland. Warmer and drier inland than at the coast

Upland:

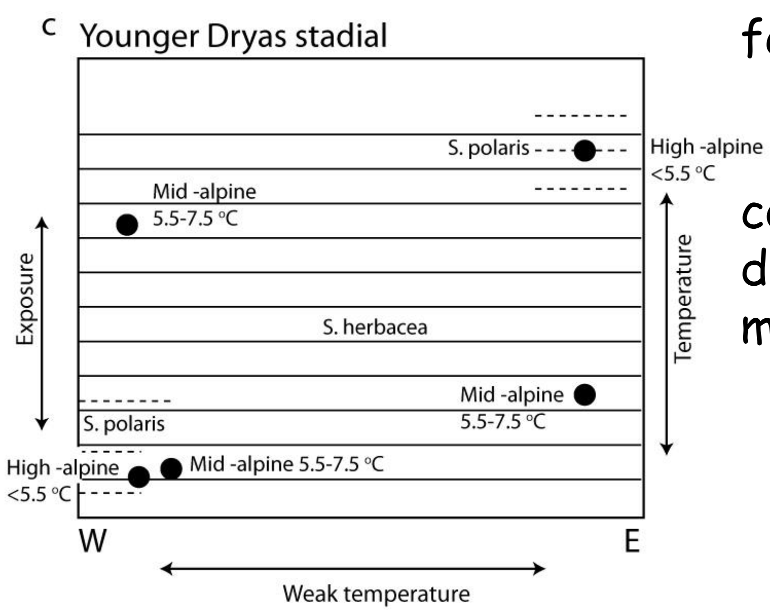
Altitudinal gradient inland; low-alpine to mid-alpine

Younger Dryas

Lowland: S. herbacea common at both. Severe at coast – S. polaris and other high-alpine herbs. Mid-alpine inland. Weak temperature gradient.

Upland: Mid-high alpine at coast with much S. herbacea. High alpine inland with S. polaris and fellfield. Drier and colder inland.

Altitudinal: little gradient at coast; more severe climate at Kråkenes due to glacier. Gradient inland from mid- to high-alpine.

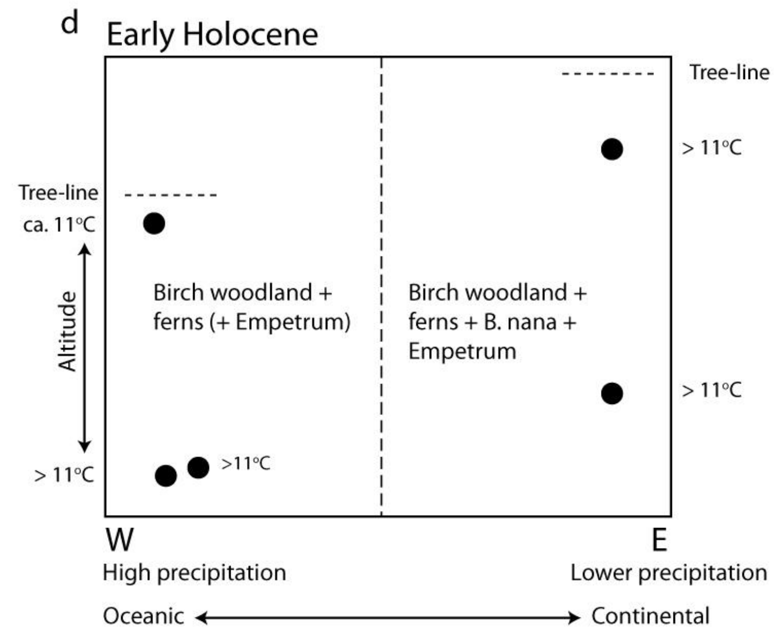


Holocene

Lowland: Birch woodland with ferns and Salix at coast, but with ferns and dwarf shrubs inland. Oceanicity gradient.
Tree-birch probably arrived earlier at the inland sites.

Upland: Open birch woodland near tree-line at coast (370 m). Dense heathy birch woodland inland (410 m). Tree-line rising inland with increased continentality – temperature gradient

Altitude: gradient to tree-line at coast. No detectable gradient inland.



Conclusions

Pollen percentages are not good at detecting tree-lines and tree-line changes
1. The low pollen productivity of vegetation above tree-line is masked by the abundantly produced tree-pollen derived from the forests below
2. The pollen productivity of trees such as Betula and Pinus may decrease in unfavourable conditions, such as near tree-line

Pollen influx is better at delimiting tree-lines.
1. However, it is affected by reduced productivity near tree-line
2. Influx may vary among lakes depending on bathymetry, inflowing streams, etc.

Macrofossils
1. are produced locally
2. can be vegetative as well as reproductive parts
3. can be influenced by lake bathymetry, inflowing streams etc
4. can show some long-distance transport e.g. Betula fruits
5. can be used alone to infer vegetation and tree-line changes

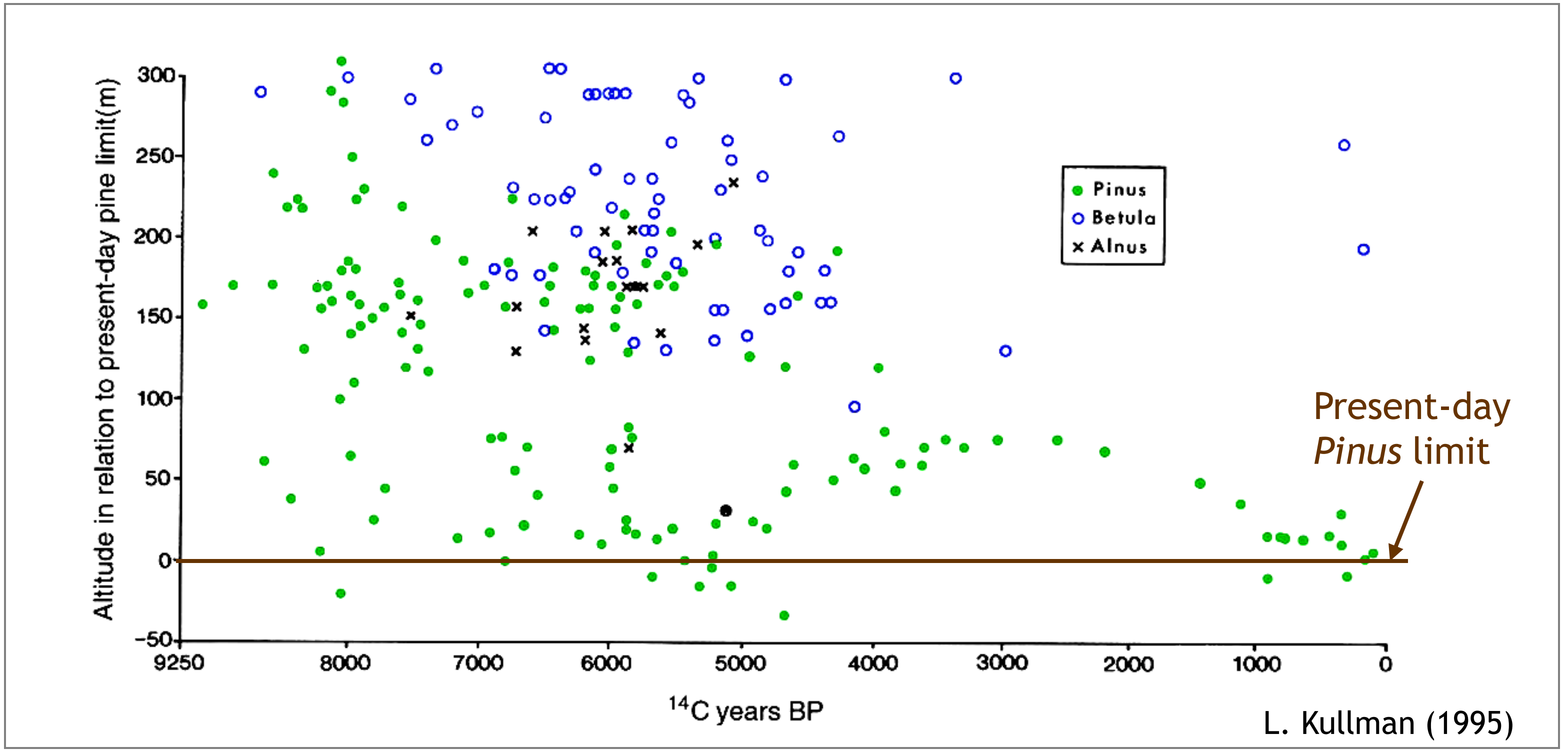
Megafossils (see MacDonald 2007)

Spot samples; each has to be radiocarbon dated

Direct evidence of tree growth

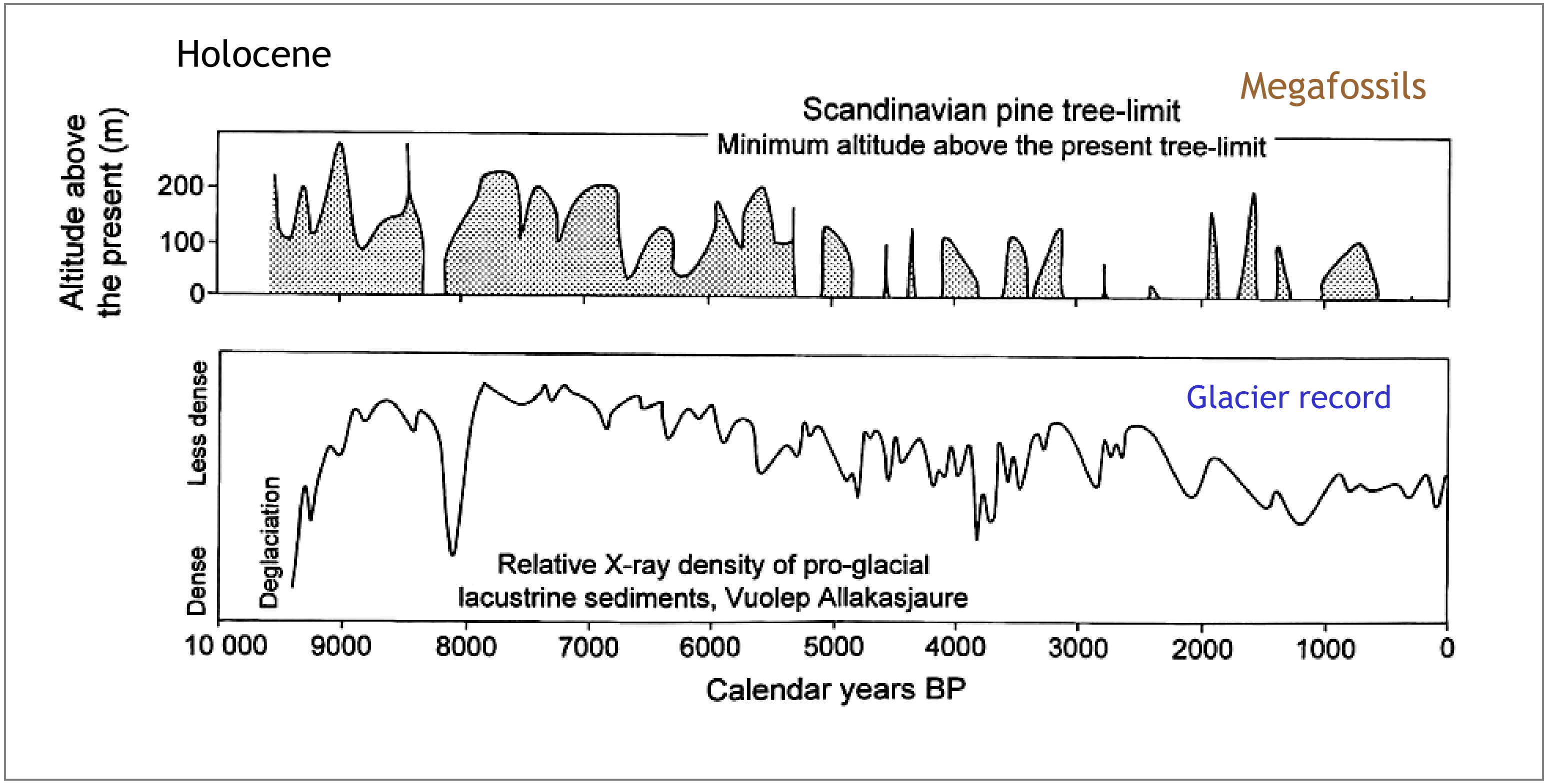
Not necessarily growing at the tree-line. Need a large data-set

Absence proves nothing - need to have right conditions for preservation



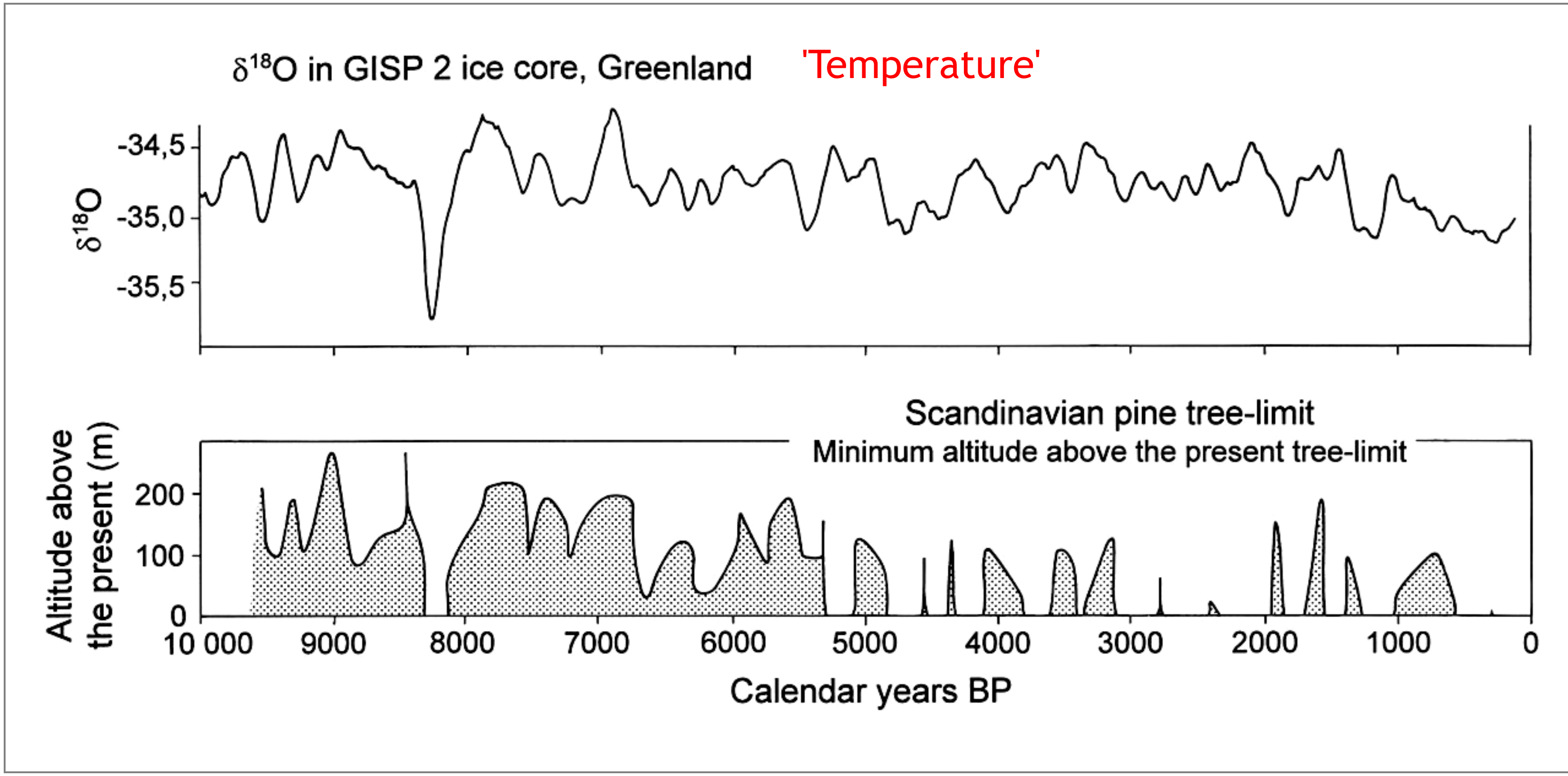
Central Swedish Mountains

Northern Swedish mountains: megafossil altitudes above present pine limit



Variations in a pro-glacial lacustrine sediment record show that glacier expansions have occurred during periods for which there are no indications of high tree-limit. The pro-glacial lacustrine sediment diagram is based on digitised X-radiographs of a sediment core from Vuolep Allakasjaure, a lake below a small glacier on the border between Sweden and Norway. Major events are recognised in both types of record, but they differ in detail.

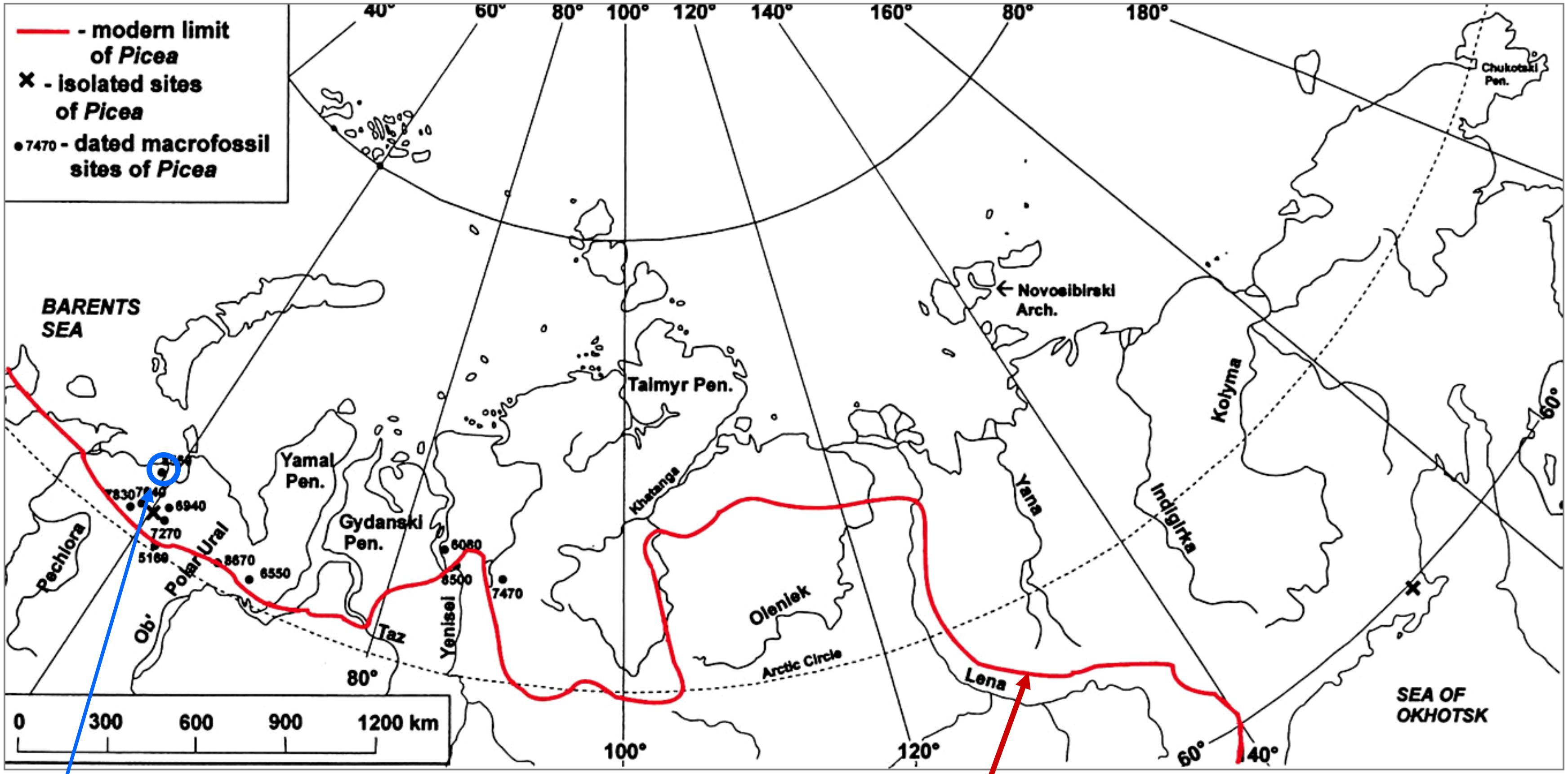
Karlén (1998)



The Greenland data expressed here as $\delta^{18}O$ in the GISP-2 ice core indicates changes in climate similar to those suggested by the pine tree-limit data from Scandinavia. The similarity between these records shows that climatic changes may affect large areas simultaneously.

Latitudinal Tree-Lines, Siberia

Picea obovata



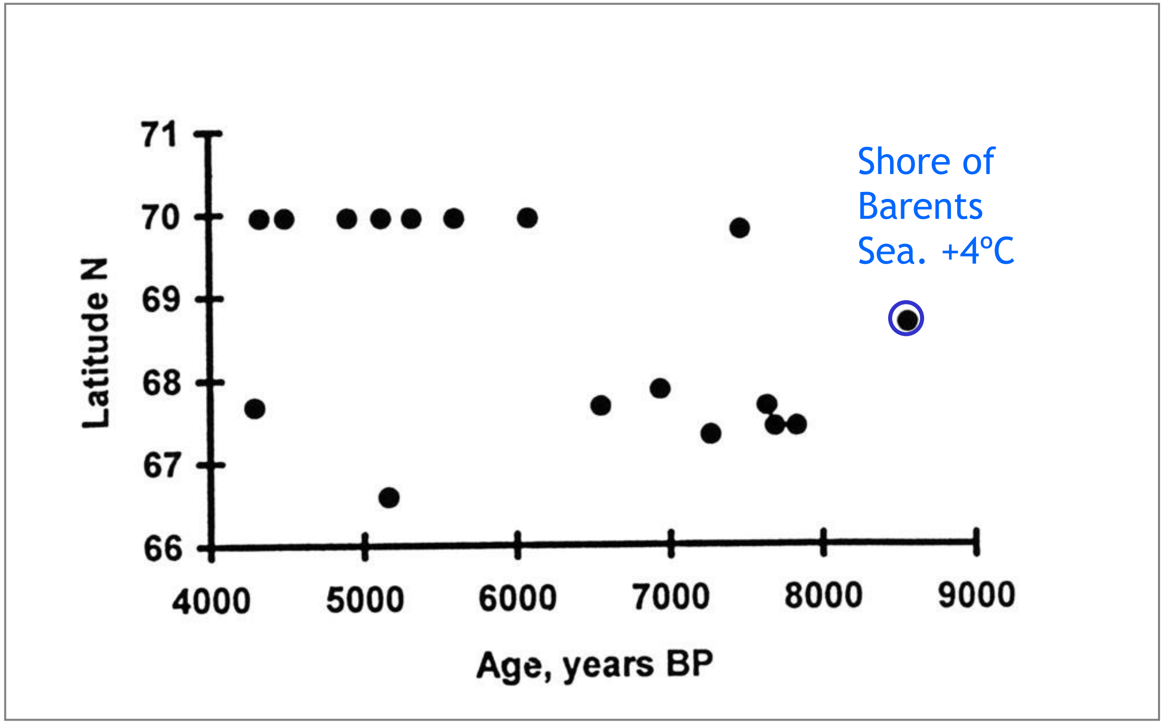
Shore of Barents Sea. +4°C

Present northern limit of *Picea obovata*

- Megafossil records (^{14}C dated)

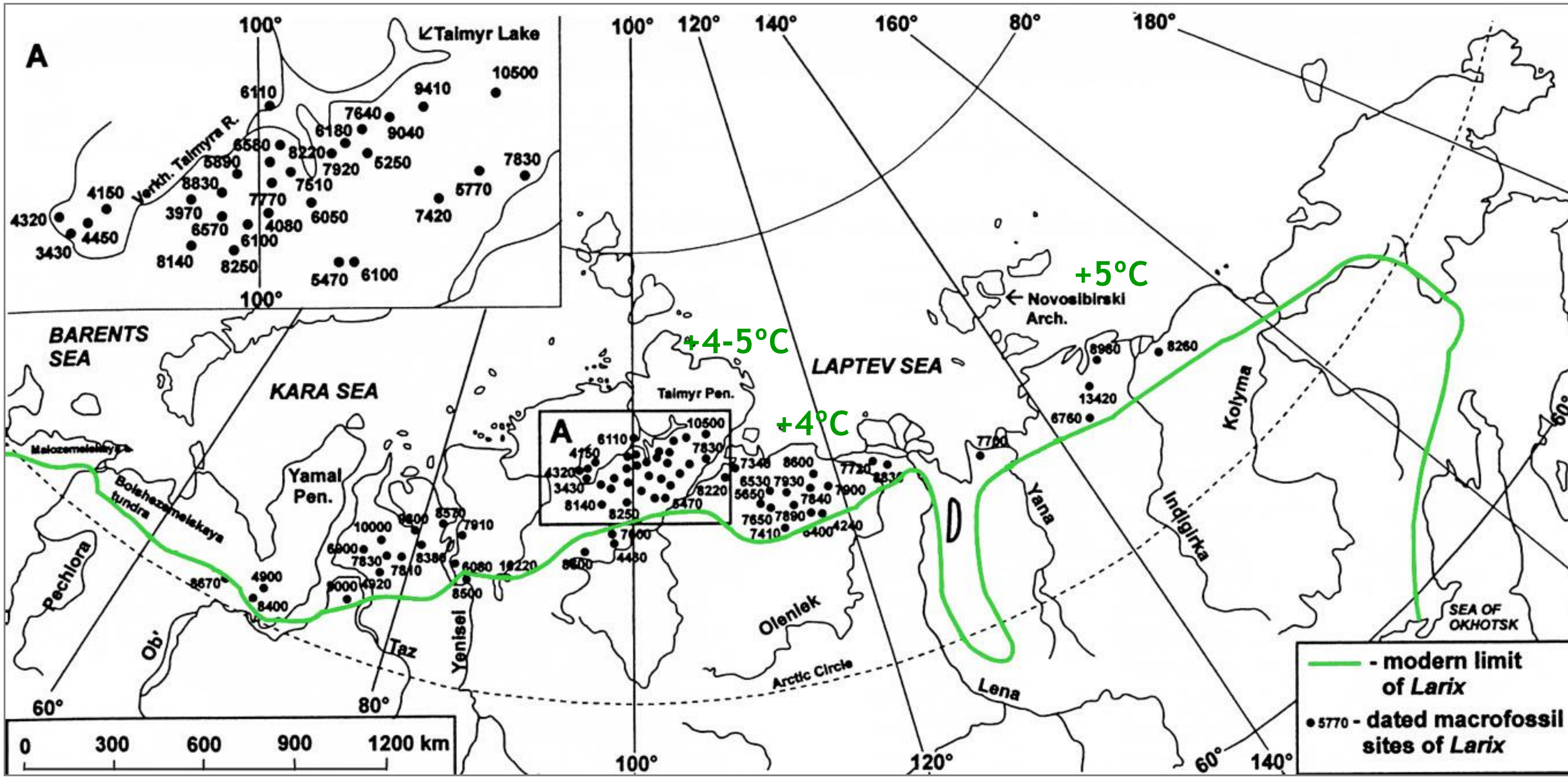
Kremenetski *et al.* (1998)

Retreated to present limit by ca. 4500 BP

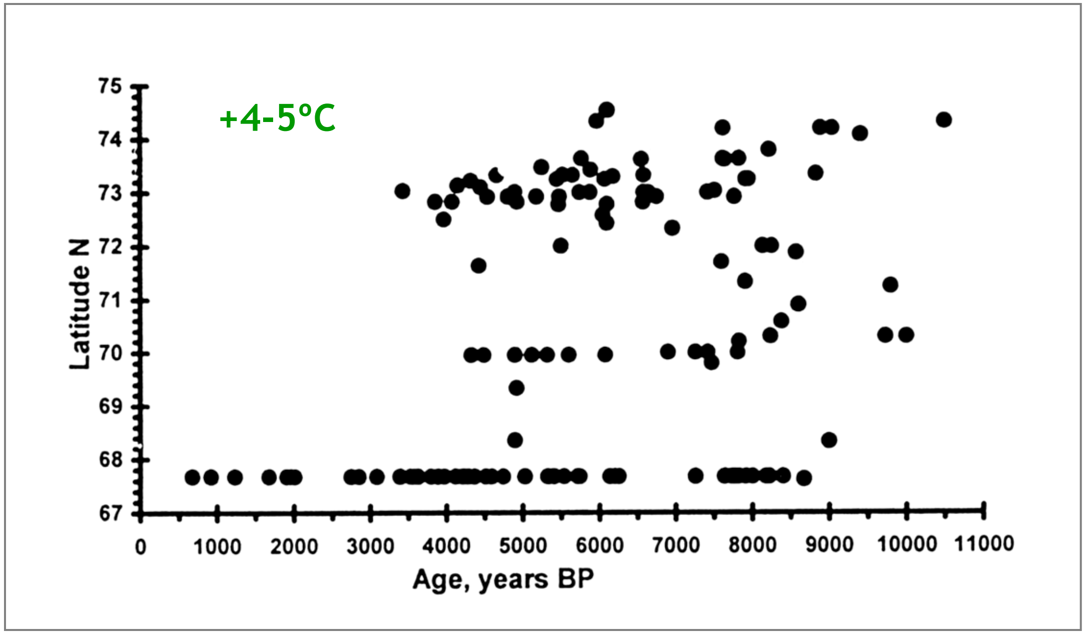


Latitudinal distribution of dated *Picea* macrofossils beyond the present range of *Picea obovata*.

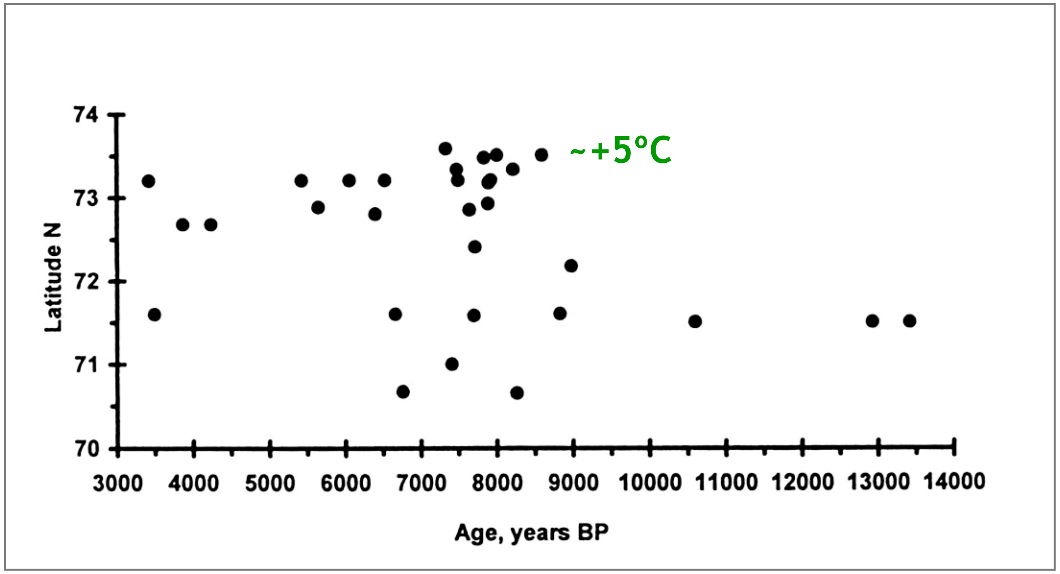
Larix



A
Taimyr Lake
Verkh. Taimyra R.
BARENTS SEA
KARA SEA
LAPTEV SEA
Taimyr Pen.
Novosibirski Arch.
Yamal Pen.
Pechlora
Ob'
Taz
Yenisei
Olenlek
Lena
Yana
Indigirka
Kolyma
SEA OF OKHOTSK
Arctic Circle
Bolshezemelskaya tundra
+5°C
+4-5°C
+4°C
0 300 600 900 1200 km
- modern limit of *Larix*
5770 - dated macrofossil sites of *Larix*

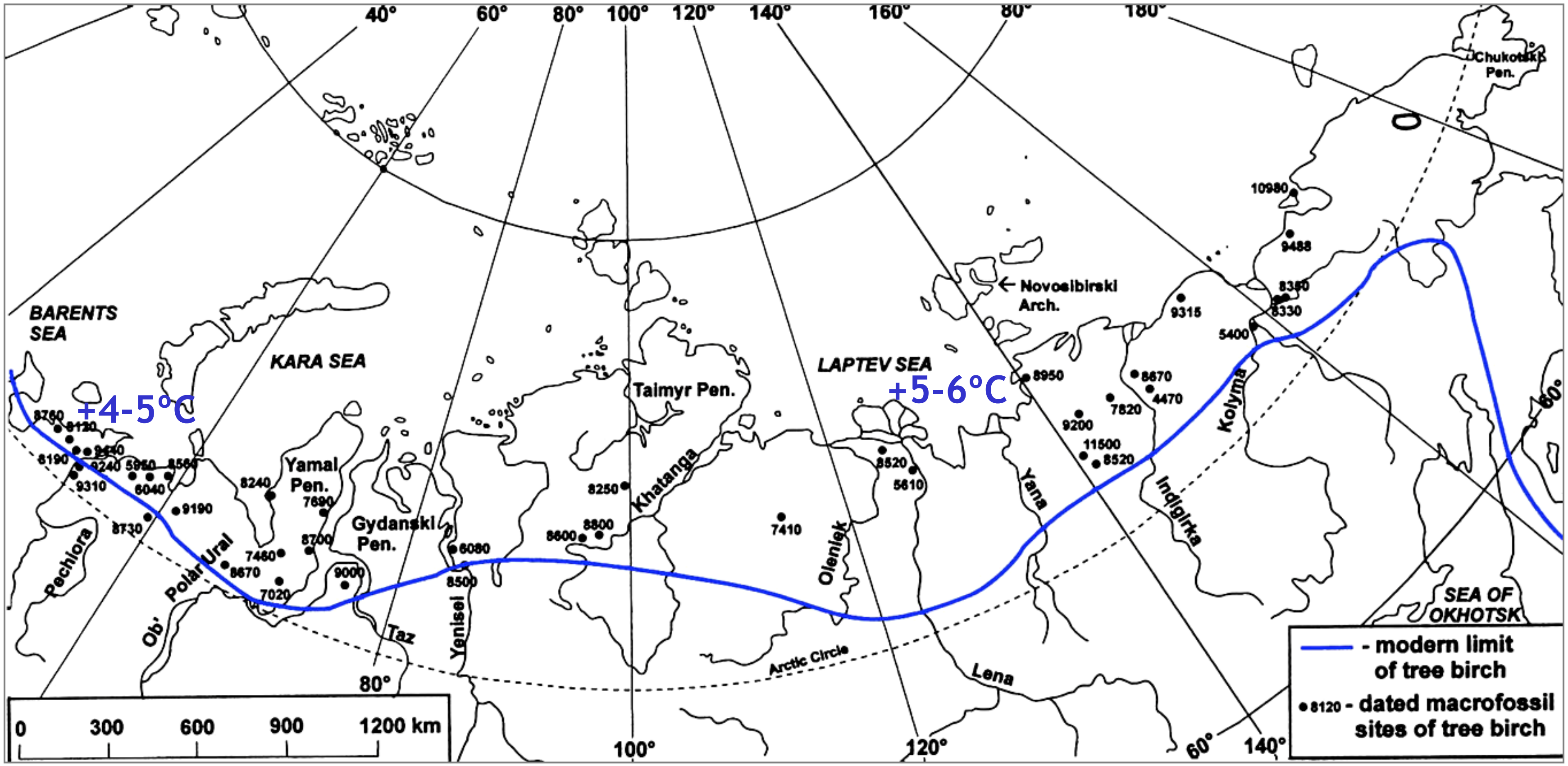


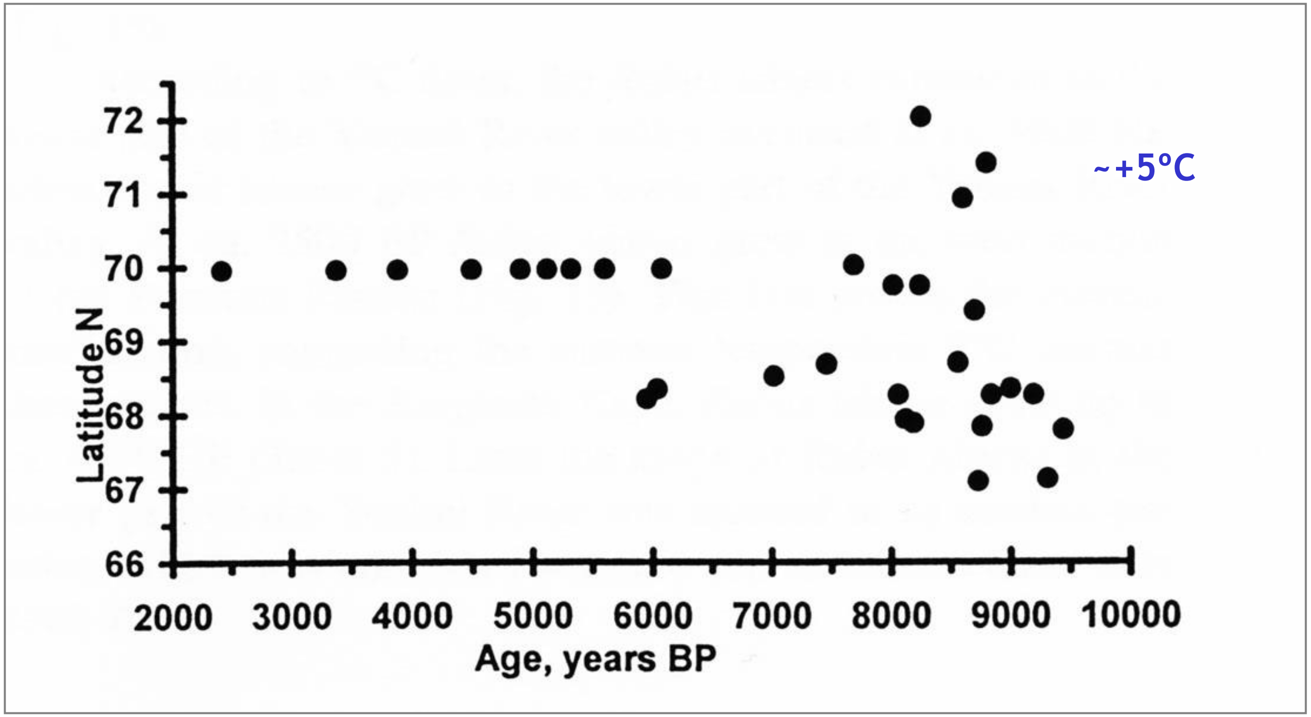
Latitudinal distribution of dated *Larix* macrofossils beyond the present range of *Larix* spp., west Siberia and Taimyr peninsula



Latitudinal distribution of dated *Larix* macrofossils beyond the present range of *Larix* spp., northeast Siberia

Betula pubescens and *B. pendula*





Latitudinal distribution of dated tree birch macrofossils beyond the present range of tree birch, European Russia, west Siberia, and Taimyr peninsula.

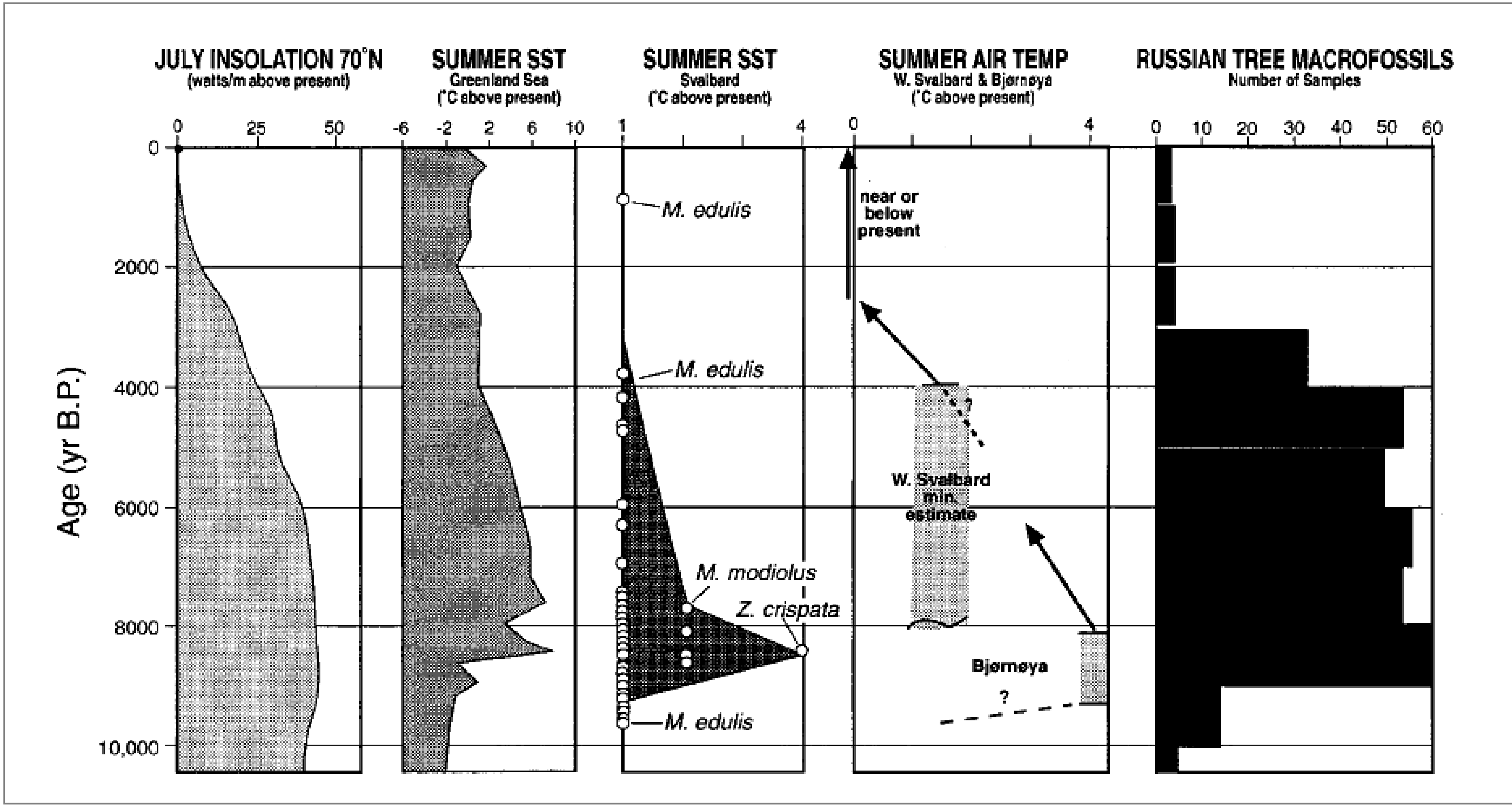


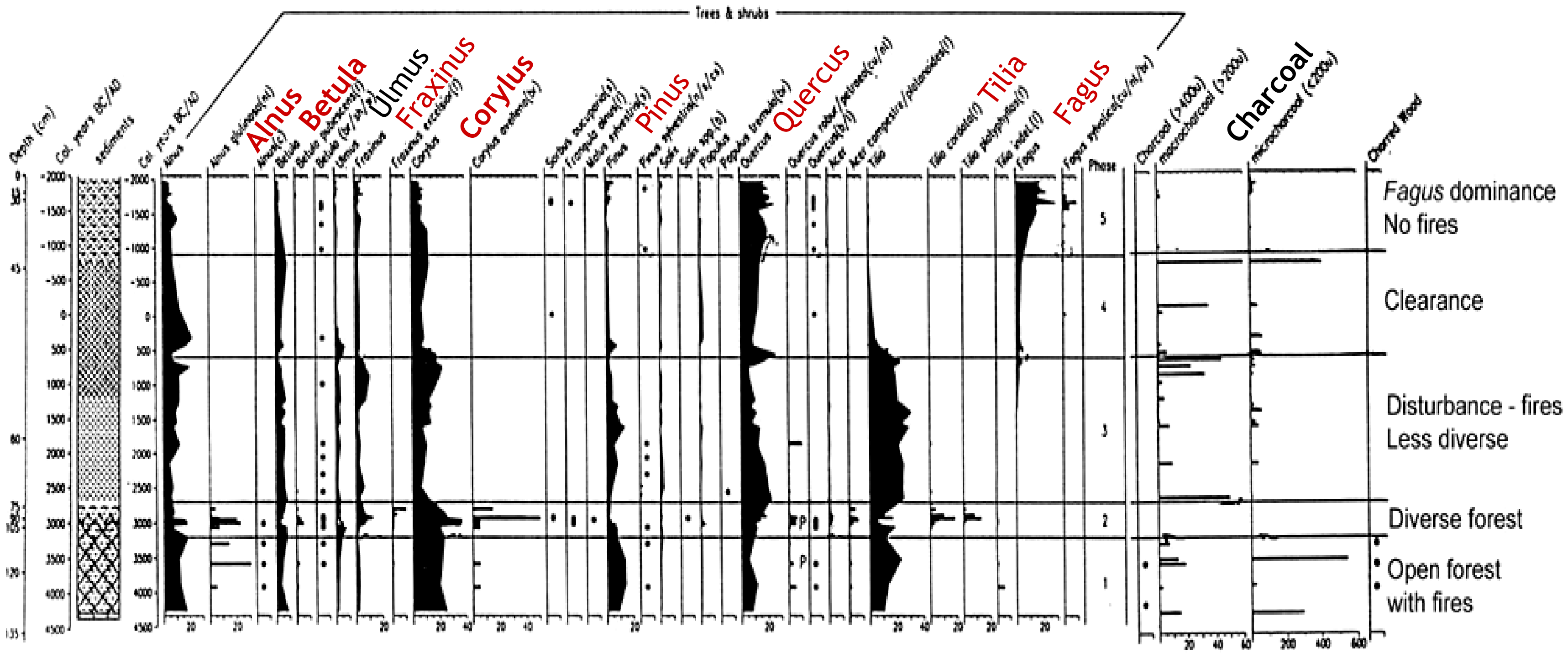
FIG. 4. July insolation at 70° N (Berger, 1978). Summer sea surface temperatures (SSTs) in the Greenland Sea reconstructed on the basis of diatoms (Koç *et al.*, 1993). SSTs near Svalbard inferred from the occurrence of *Mytilus edulis, M. modiolus,* and *Zirphaea* shells (Salvigsen *et al.*, 1992). Summer air temperatures for Svalbard and Bjørnøya reconstructed from plant macrofossil and paleolimnological records (Birks, 1991; Wolfarth *et al.*, 1995). The chronological distribution of all tree macrofossils from the Russian treeline. All records are presented in uncalibrated radiocarbon years before present, and this imparts an uneven profile to the insolation curve due to variations in the relationship between radiocarbon years and calendar years (Stuiver and Riemer, 1993).

MacDonald *et al.* (2000)

Holocene forest dynamics

Small wet hollow in Suserup Skov, Denmark

Suserup Skov, Denmark



Questions.

Today's semi-natural Fagus-dominated forest replaced Tilia-Quercus-Alnus forest ca. 3000 years ago. Was this natural or due to human influence?

What was the role of Pinus in the forest? Was it related to fire disturbance?

Were the stands mixed or were the species spatially separated?

Hannon *et al.*, (2000)

Value of Macrofossils where Pollen is Unreliable

(Already discussed the tree-line situation)

- Full-glacial vegetation buried by tephra
- Holocene macrofossils from the American prairie
- Holocene in Spitsbergen
- Late-glacial in Scotland and western Norway

Vegetated surface buried by tephra ca. 18,000 BP on Seward Peninsula, Alaska (Beringia)

V.G. Goetcheus & H.H. Birks (2001)

Vascular plant taxa identified from the buried surface and their habitats. The hatbitat information is from Hultén (1968) and other references in this paper, supplemented by personal observations

Plant taxa	Modern habitat
Bupleurum triradiatum	Dry grassy and open tundra, fell–field
Carex nardina type	Wind–exposed open grassy tundra on calcareous soils
Cerastium beeringianum	Gravel and cliffs, soil disturbed by animals
Draba spp.	Open, often calcareous, soil
Eutrema edwardsii	Open damp soil on tundra, solifluction areas
Kobresia myosuroides	Dry, calcareous tundra with stable soils and little snow–cover in winter
Luzula spp.	Open soils, fell–field, screes and gravel
Melandrium affine	Dry places, open rocks and disturbed soil
Melandrium apetalum	Dry grassy slopes, open gravel and screes
Minuartia arctica	Dry ridges and rocky slopes, on open soils in grassy tundra
Minuartia obtusiloba	Dry slopes and snow beds
Oxyria digyna	Snow beds on tundra, open gravel, screes
Papaver walpolei	Dry calcareous soil
Polygonum viviparum	Dry and damp meadows and open grassland
Potentilla hookeriana	Dry calcareous open grassland
Salix arctica	Dry tundra with winter snow protection
Saxifraga oppositifolia	Dry to moist exposed calcareous soils
Valeriana (capitata)	Mesic grassland

Pollen and plant macrofossils in USA prairie stream-bank sediments

Conclusions

1. The lack of abundant pollen from indicator species can make it difficult to recognize past prairies along the prairie-forest border.

Consistent Artemisia, Poaceae, Chenopodiaceae pollen assemblage

2. Plant macrofossils from stream cutbanks hold great promise for detailed prairie reconstructions. These deposits are widespread in the midwestern U.S.A. wherever the water table on floodplains has remained high throughout the Holocene. Many prairie-indicator species are present in such deposits.

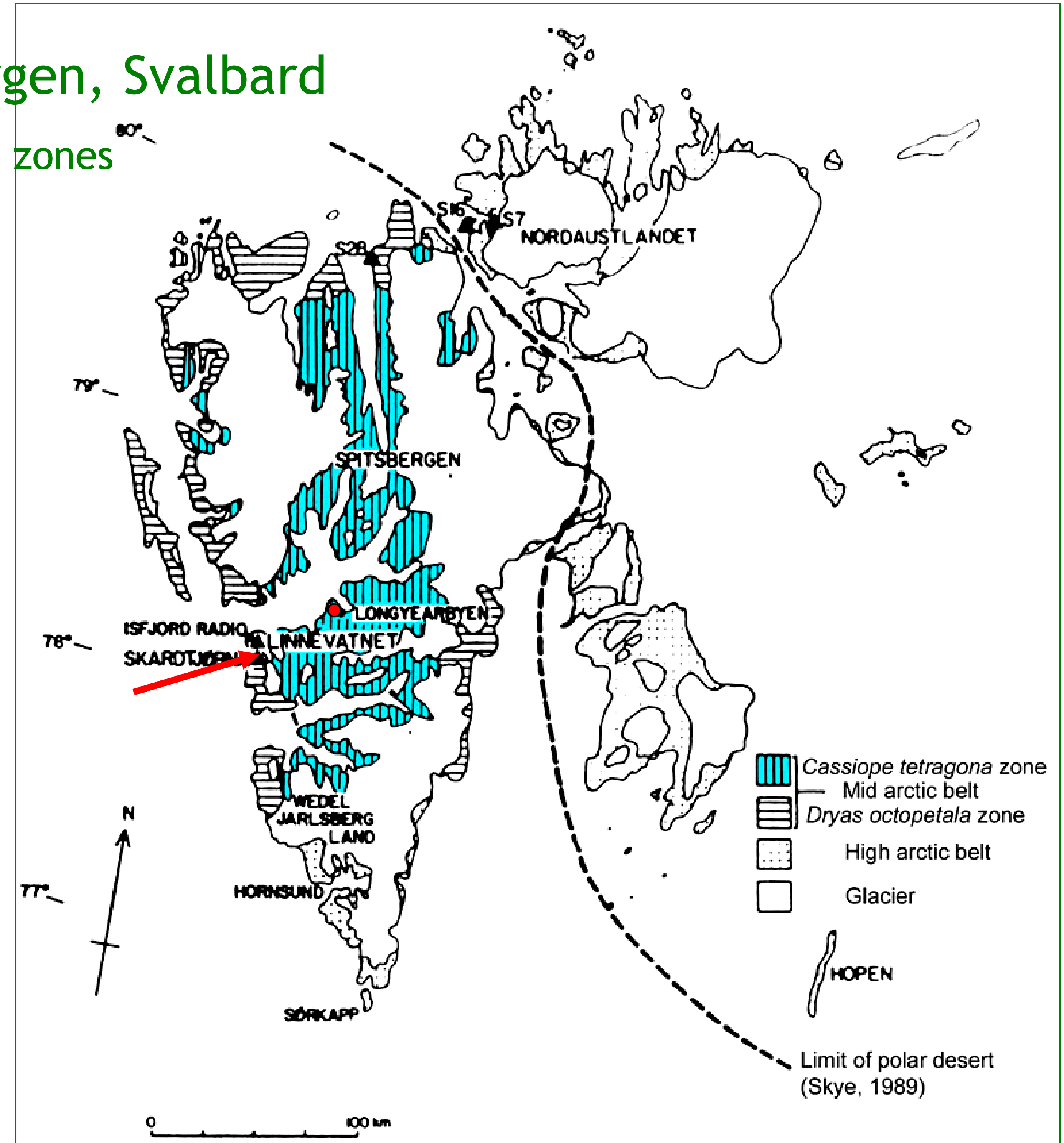
3. Taphonomy of a modern prairie stream indicates that a diverse and abundant assemblage of macrofossils is present, especially following prairie fires. It may be possible to recognize intra-prairie communities in the fossil record.

4. The Holocene biogeographic history of prairie species may be traceable by the use of plant macrofossils.

Baker & Drake (1994),
Baker (2007)

Spitsbergen, Svalbard

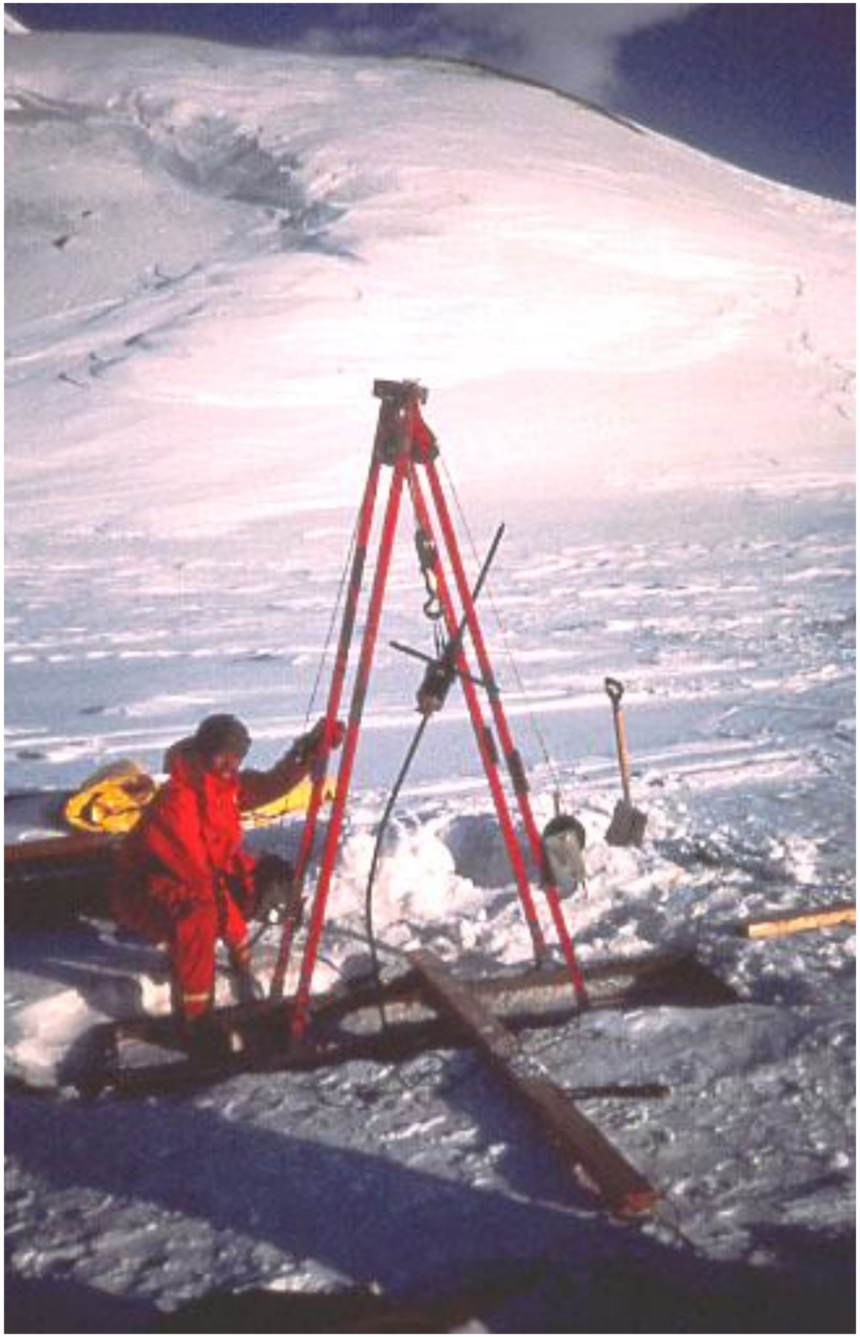
Vegetation zones

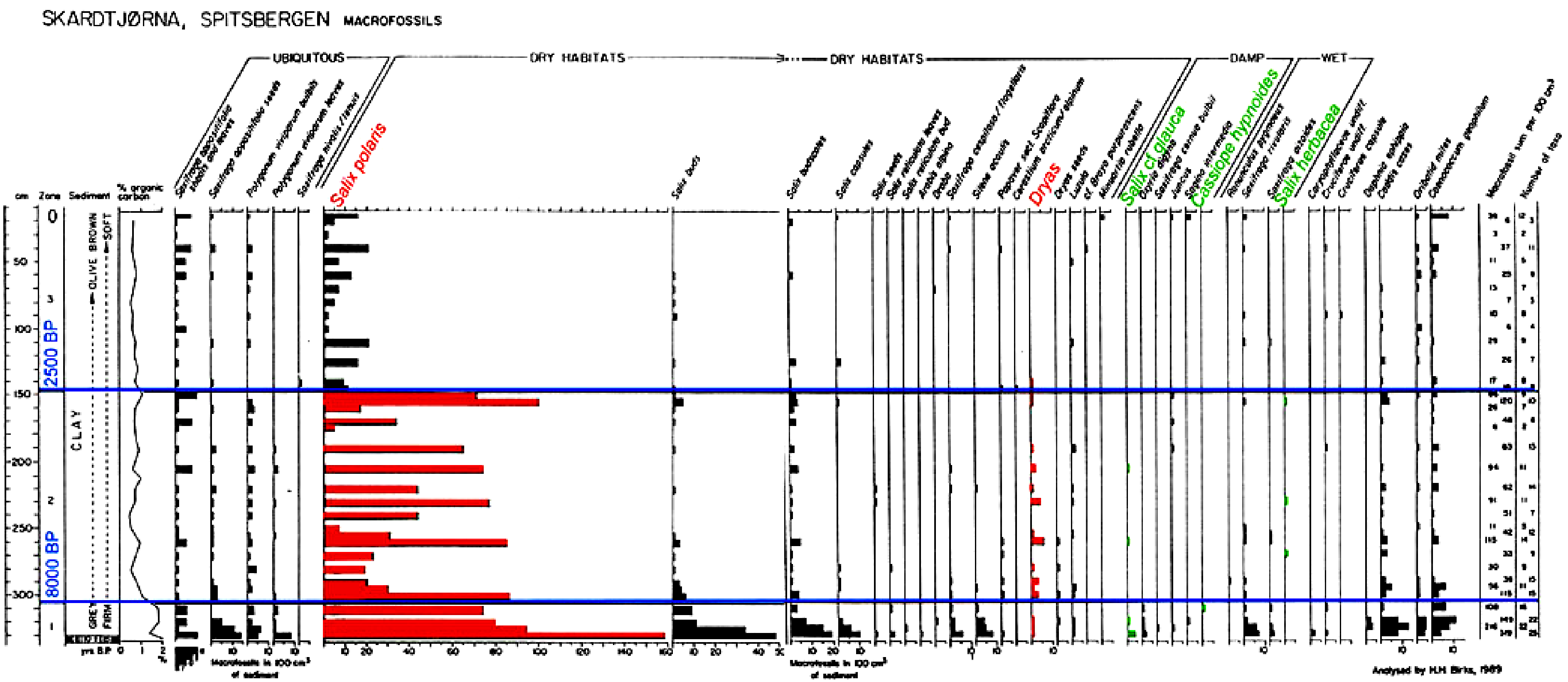


Birks (1991)

Coring Skardtjørna

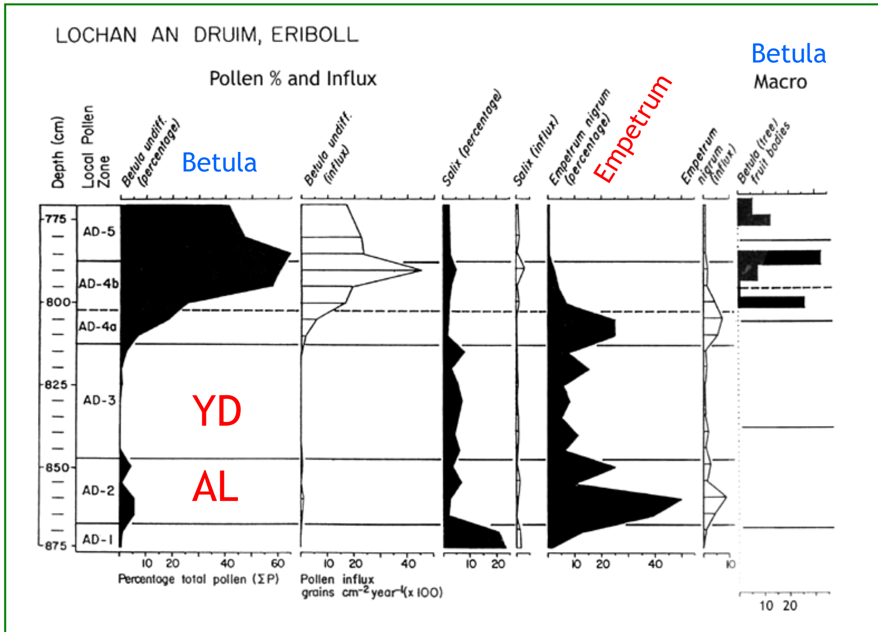
(April)

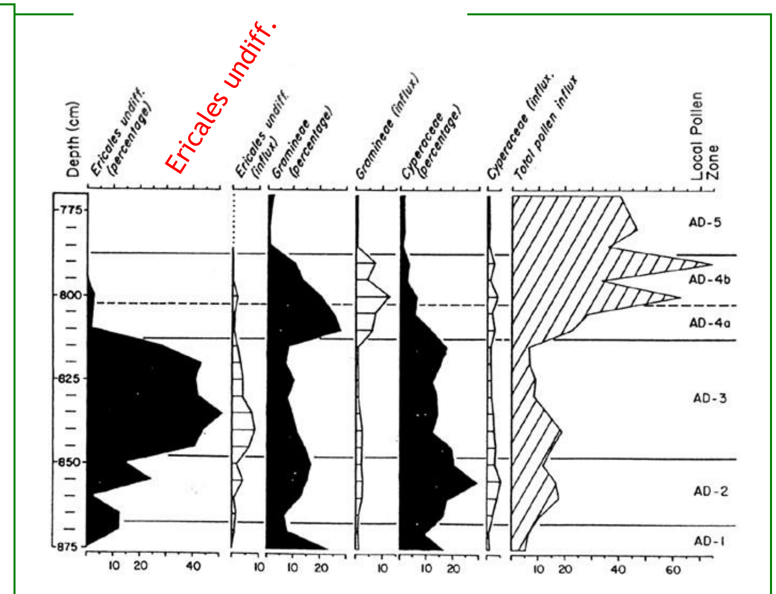


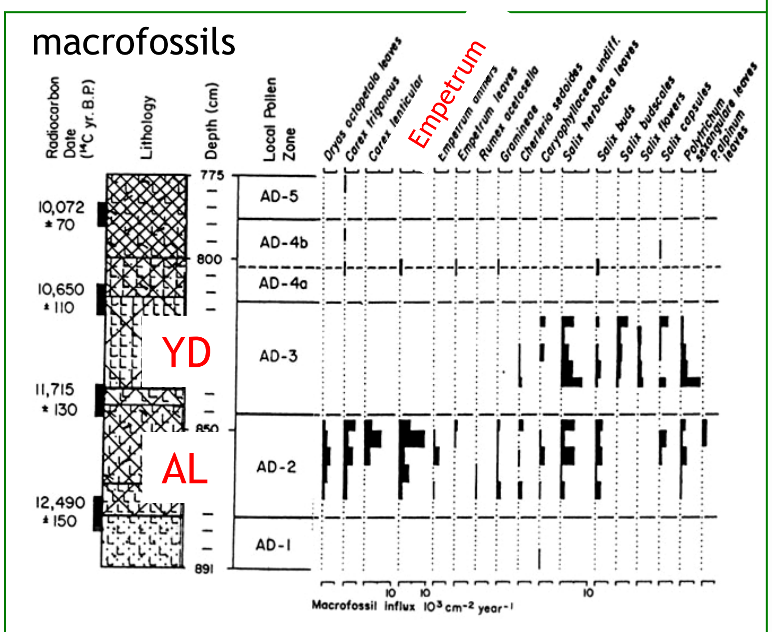

SKARDTJØRNA, SPITSBERGEN MACROFOSSILS
UBIQUITOUS
DRY HABITATS
DRY HABITATS
DAMP
WET
Salix polaris
Dryas
Salix cf glauca
Cassiope hypnoides
Salix herbacea
2500 BP
8000 BP
cm
Zone
Sediment
% organic carbon
OLIVE BROWN
SOFT
CLAY
GREY
FIRM
Salix buds
Macrofossils in 100 cm³ of sediment
Analysed by H.H Birks, 1989

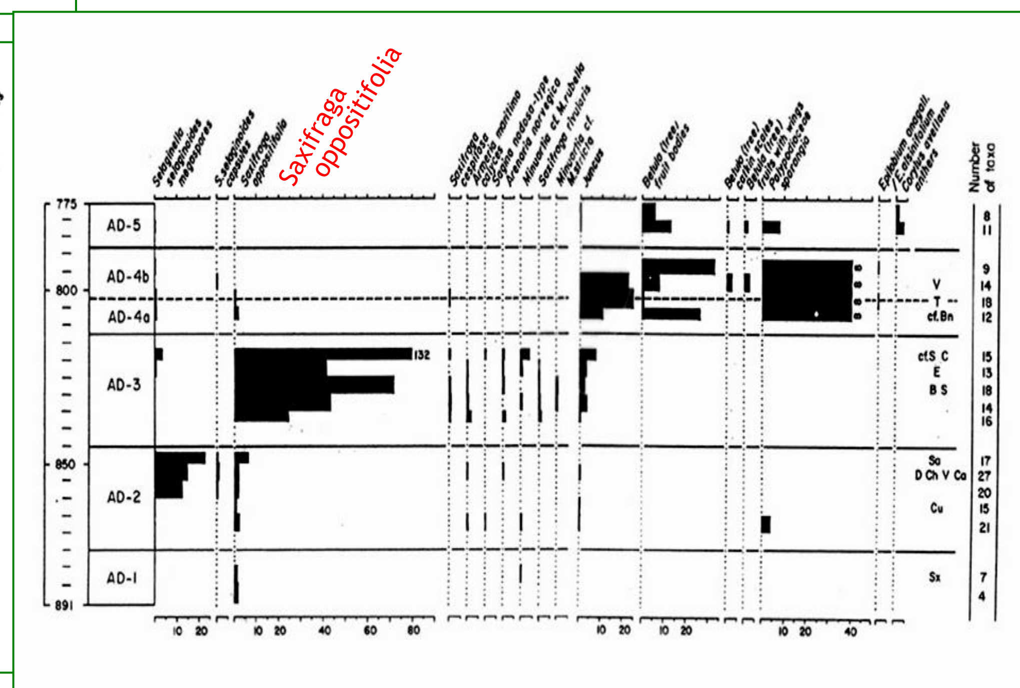
Birks (1991)

Macrofossils and pollen from Lochan an Druim, N.W. Scotland
(Birks 1984)

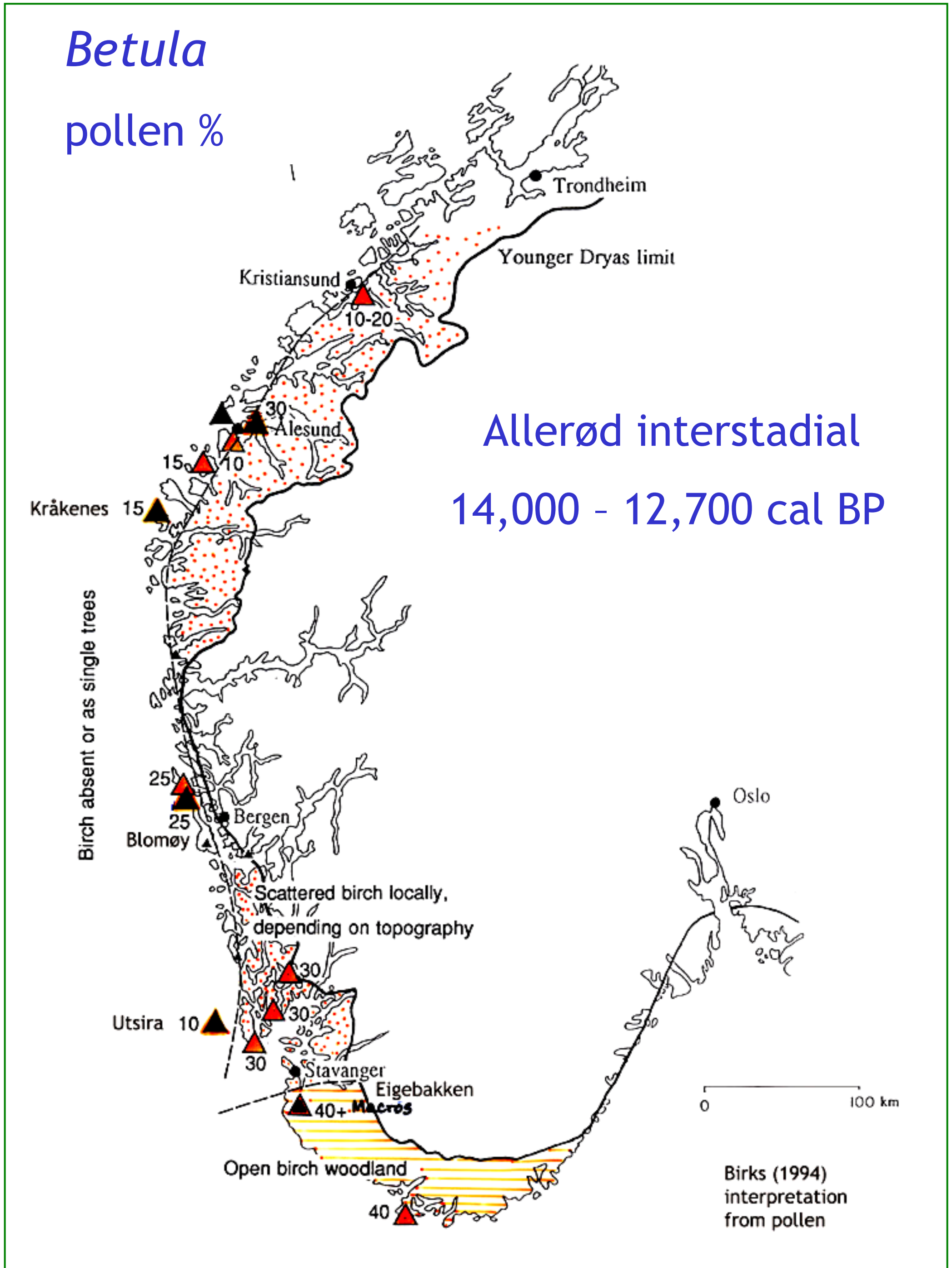

LOCHAN AN DRUIM, ERIBOLL
Pollen % and Influx
Betula
Macro
Depth (cm)
Local Pollen Zone
Betula undiff. (percentage)
Betula
Betula undiff. (influx)
Salix (percentage)
Salix (influx)
Empetrum nigrum (percentage)
Empetrum
Empetrum nigrum (influx)
Betula (tree) fruit bodies
775
800
825
850
875
AD-5
AD-4b
AD-4a
AD-3
AD-2
AD-1
YD
AL
Percentage total pollen (ΣP)
Pollen influx grains cm-2 year-1 (x 100)


Depth (cm)
Ericales undiff. (percentage)
Ericales undiff.
Ericales undiff. (influx)
Gramineae (percentage)
Gramineae (influx)
Cyperaceae (percentage)
Cyperaceae (influx)
Total pollen influx
Local Pollen Zone
AD-5
AD-4b
AD-4a
AD-3
AD-2
AD-1


macrofossils
Radiocarbon Date (14C yr. B.P.)
Lithology
Depth (cm)
Local Pollen Zone
Dryas octopetala leaves
Carex trigonous
Carex lenticular
Empetrum
Empetrum anthers
Empetrum leaves
Rumex acetosella
Gramineae
Cherleria sedoides
Caryophyllaceae undiff.
Salix herbacea leaves
Salix buds
Salix budscales
Salix flowers
Salix capsules
Polytrichum sexangulare leaves
10,072 ± 70
10,650 ± 110
11,715 ± 130
12,490 ± 150
775
800
850
891
AD-5
AD-4b
AD-4a
AD-3
AD-2
AD-1
YD
AL
Macrofossil influx 10³ cm-2 year-1


Saxifraga oppositifolia
Betula (tree) fruit bodies
Number of taxa
775
800
850
891
AD-5
AD-4b
AD-4a
AD-3
AD-2
AD-1
132

poem

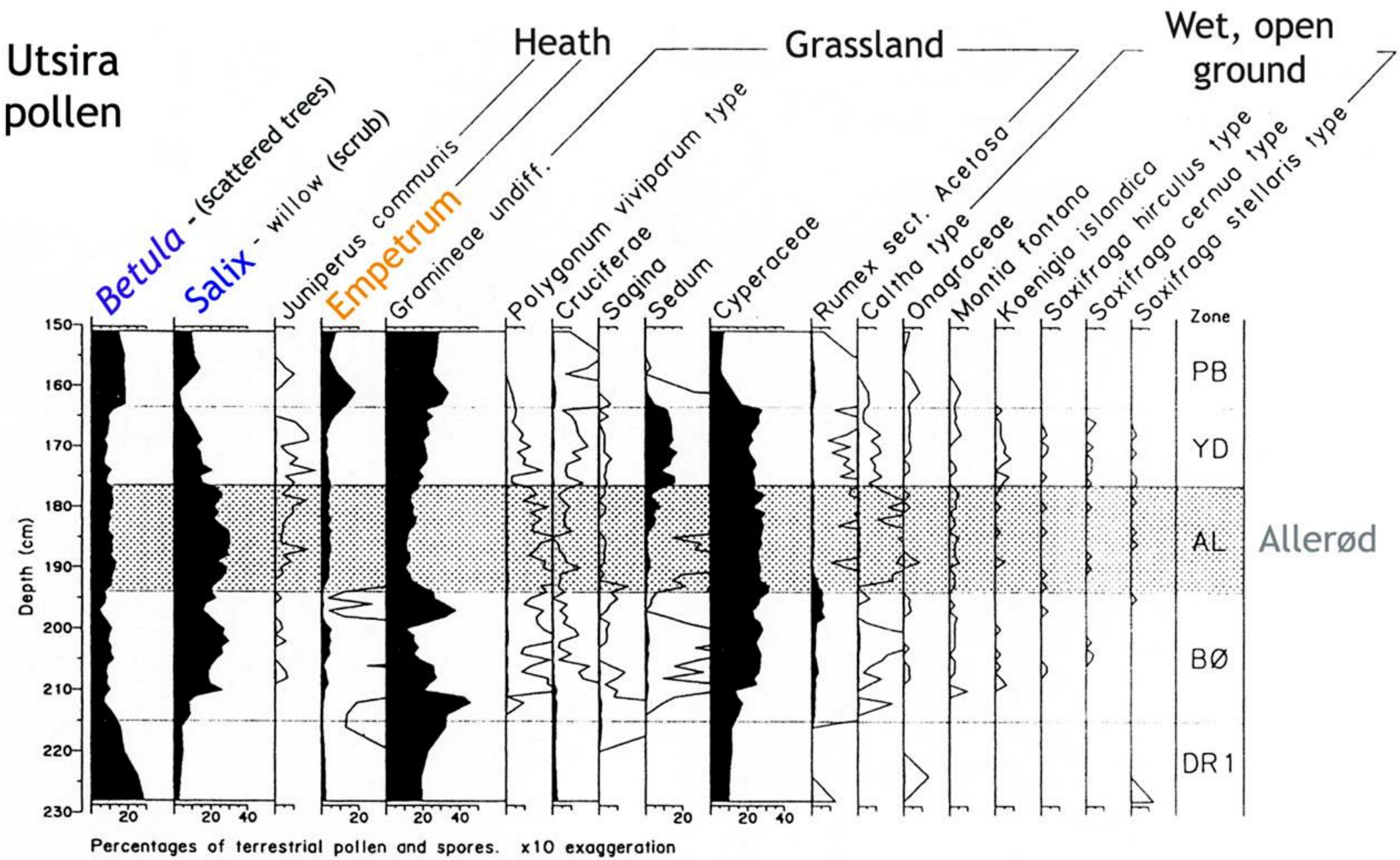


Macrofossils and pollen from the Norwegian late-glacial

Late-glacial *Betula* (birch) pollen in western Norway

Question: was tree-birch present in Norway during the Allerød interstadial?

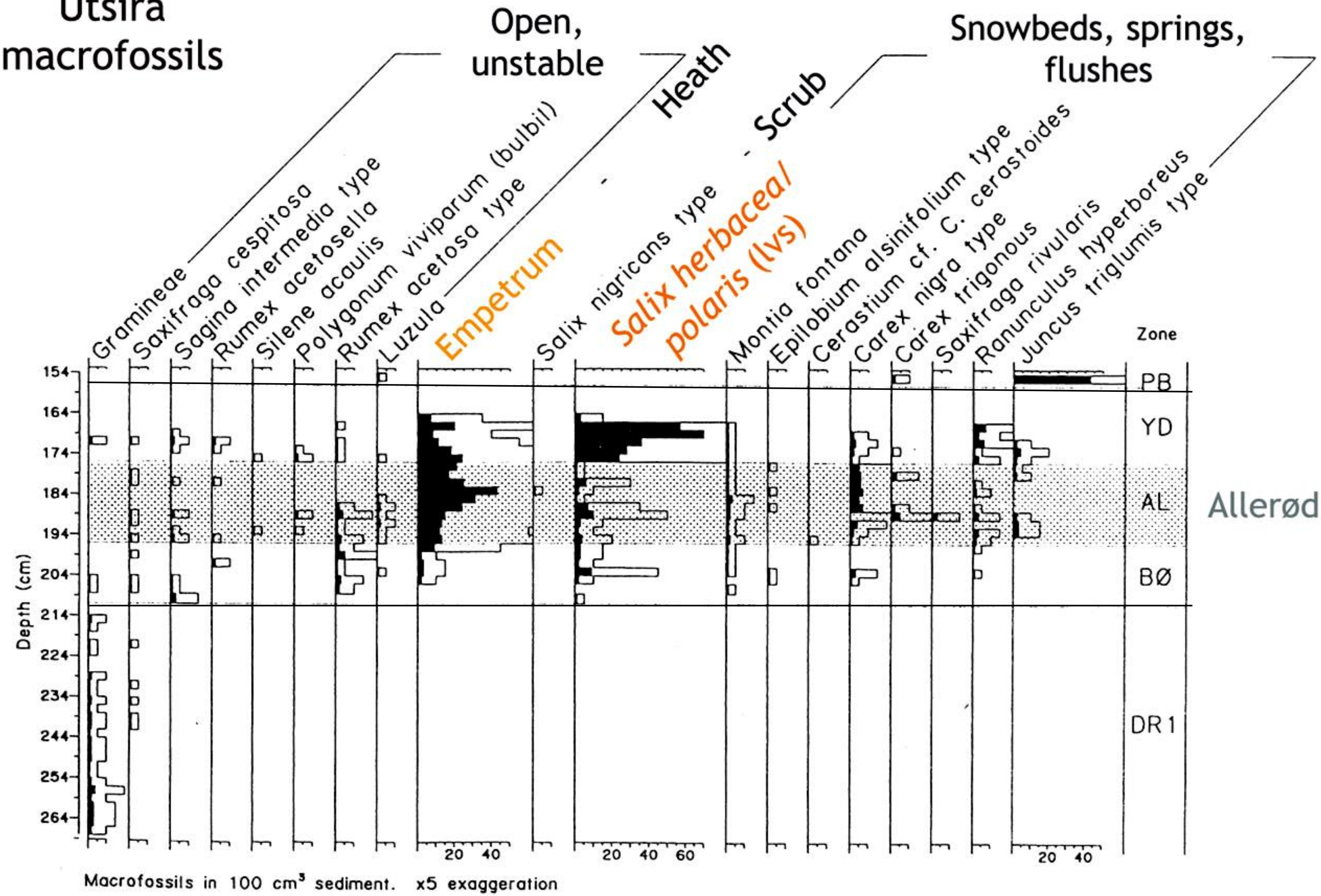
Birks (1993, 2003)

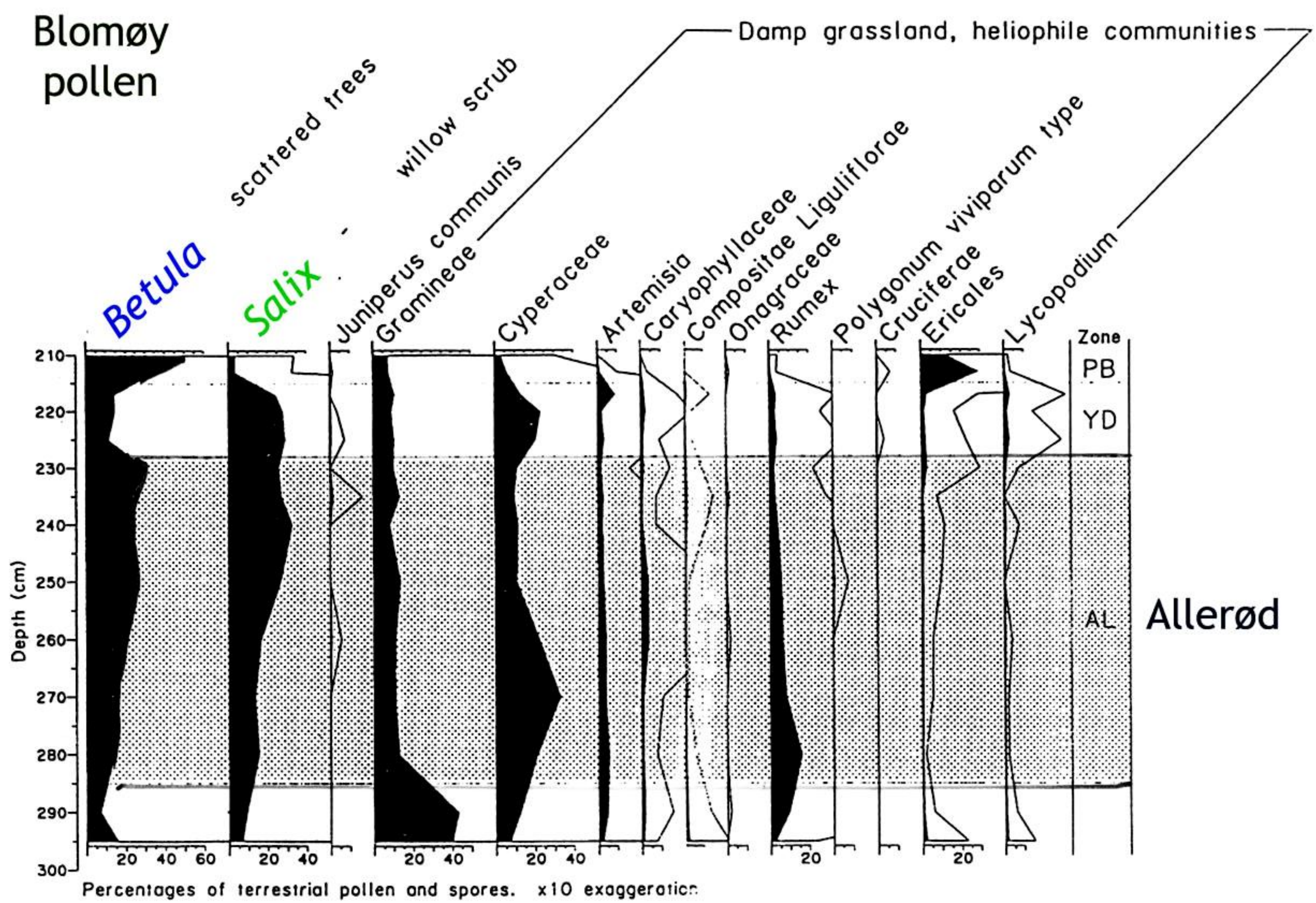


Utsira pollen
Heath
Grassland
Wet, open ground
Betula - (scattered trees)
Salix - willow (scrub)
Juniperus communis
Empetrum
Gramineae undiff.
Polygonum viviparum type
Cruciferae
Sagina
Sedum
Cyperaceae
Rumex sect. Acetosa
Caltha type
Onagraceae
Montia fontana
Koenigia islandica
Saxifraga hirculus type
Saxifraga cernua type
Saxifraga stellaris type
Zone
PB
YD
AL
BØ
DR 1
Allerød
Depth (cm)
150
160
170
180
190
200
210
220
230
20
40
Percentages of terrestrial pollen and spores. x10 exaggeration

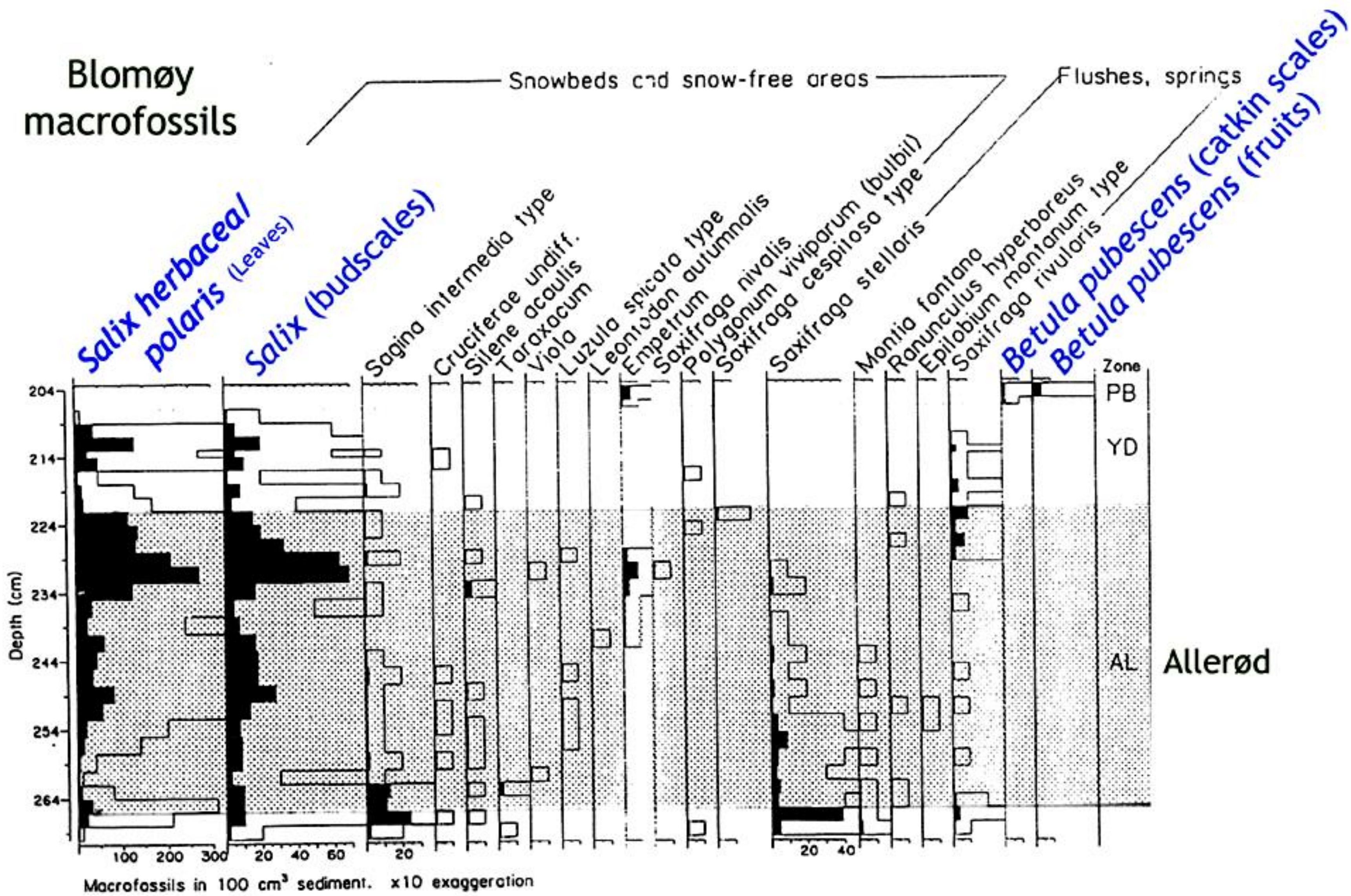
Birks (1993)

Utsira macrofossils

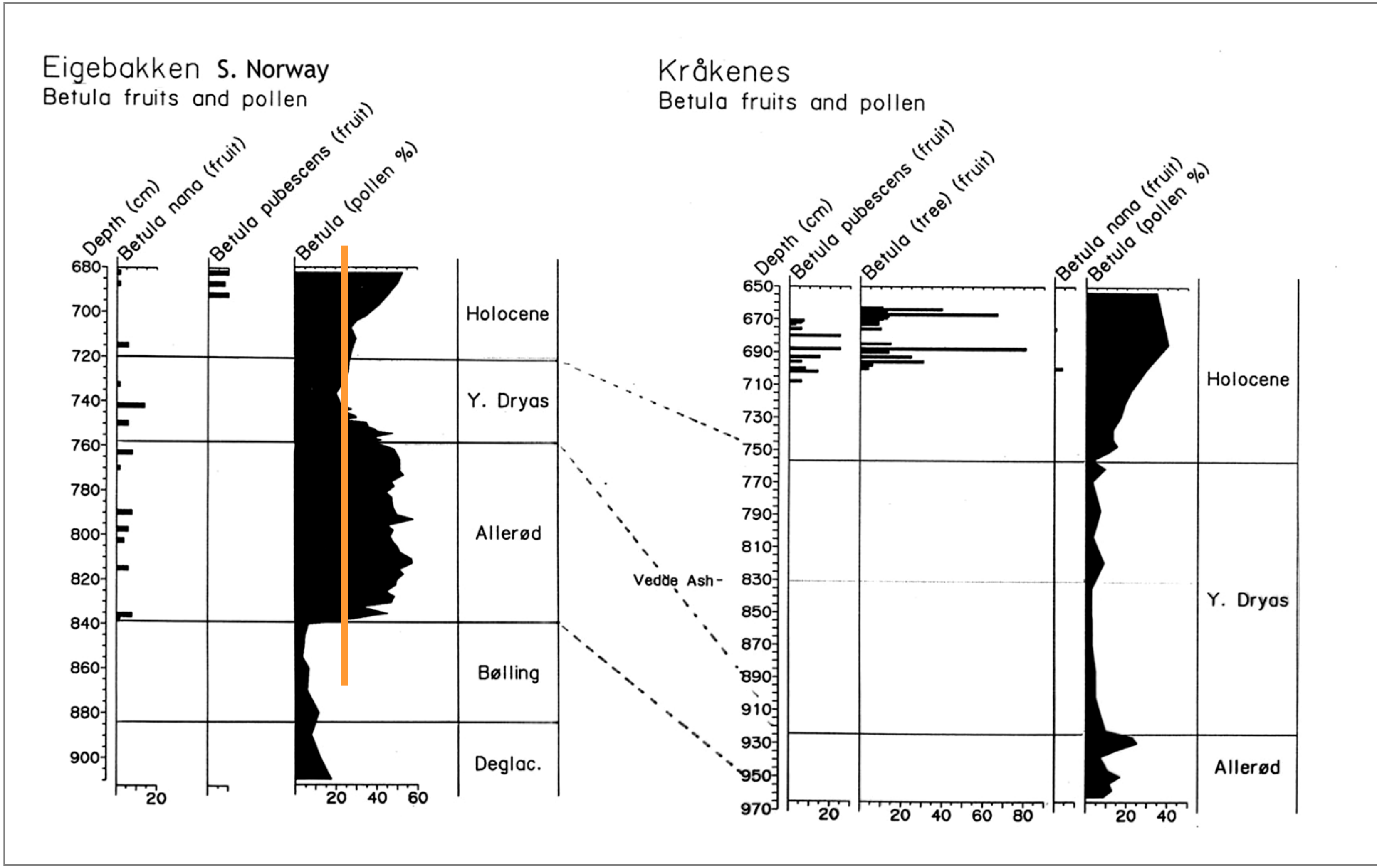




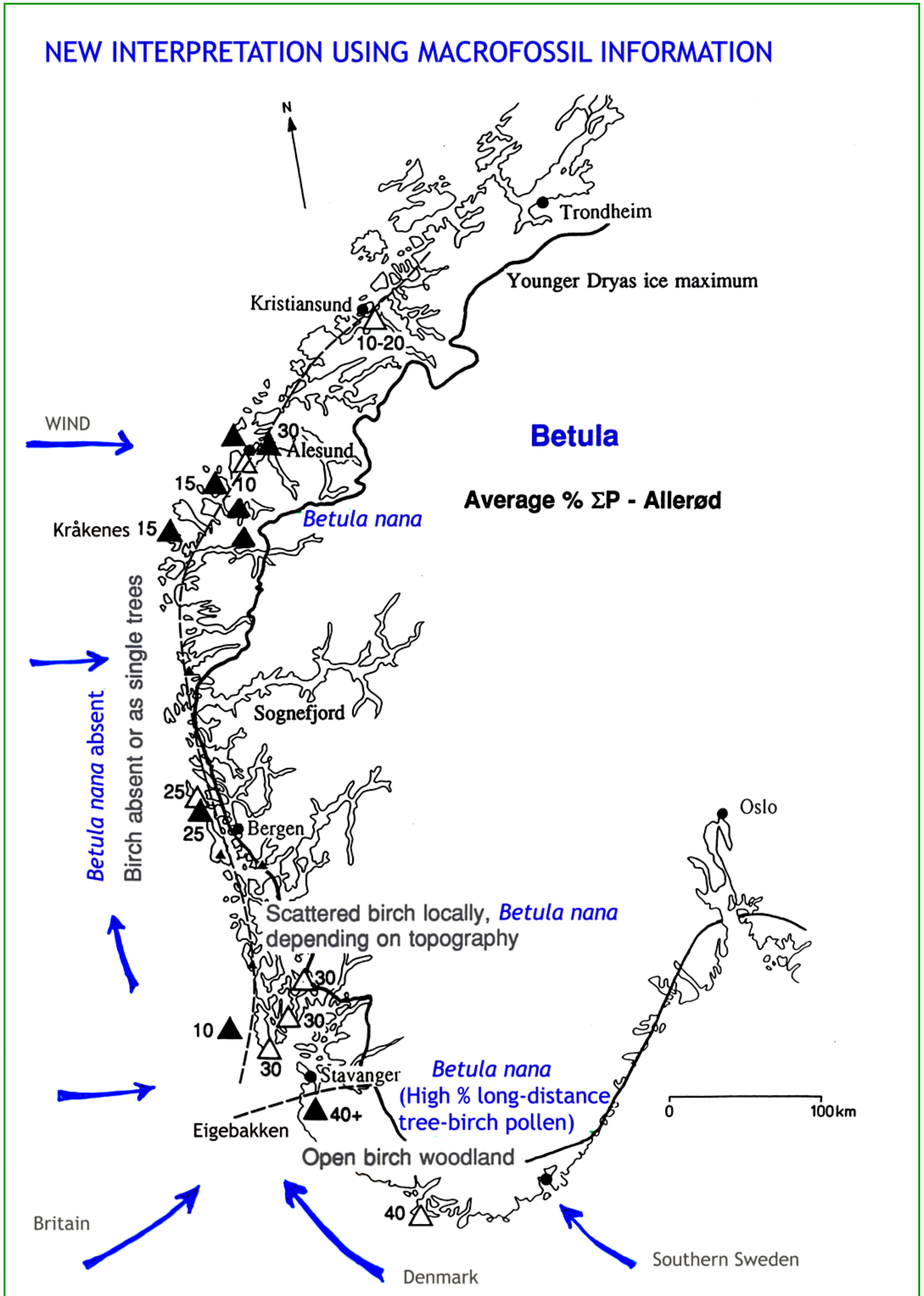
Blomøy pollen
Damp grassland, heliophile communities
Betula
scattered trees
Salix
willow scrub
Juniperus communis
Gramineae
Cyperaceae
Artemisia
Caryophyllaceae
Compositae Liguliflorae
Onagraceae
Rumex
Polygonum viviparum type
Cruciferae
Ericales
Lycopodium
Zone
PB
YD
AL
Allerød
Depth (cm)
210
220
230
240
250
260
270
280
290
300
20 40 60
20 40
20 40
20 40
20
20
Percentages of terrestrial pollen and spores. x10 exaggeration



Blomøy
macrofossils
Snowbeds and snow-free areas
Flushes, springs
Salix herbaceal polaris (Leaves)
Salix (budscales)
Sagina intermedia type
Cruciferae undiff.
Silene acaulis
Taraxacum
Viola
Luzula spicata type
Leontodon autumnalis
Empetrum
Saxifraga nivalis
Polygonum viviparum (bulbil)
Saxifraga cespitosa type
Saxifraga stellaris
Montia fontana
Ranunculus hyperboreus
Epilobium montanum type
Saxifraga rivularis
Betula pubescens (catkin scales)
Betula pubescens (fruits)
Zone
PB
YD
AL
Allerød
Depth (cm)
204
214
224
234
244
254
264
100 200 300
20 40 60
20
20 40
Macrofossils in 100 cm³ sediment. x10 exaggeration



van Dinter & Birks (1996)



Birks (2003)

See also Kullman (2002) and Birks et al. (2005)