PLANT MACROFOSSILS in PALAEOECOLOGY

Lecture 4

Some Applications of Plant Macrofossils (1)

Some special applications of plant macrofossils

- Historical biogeography

    Extinct species

    H. Godwin. History of the British Flora

    Papaver radicatum and the Nunatak Theory

    Osmunda regalis in western Norway

- Vegetational change: succession

    E Finland early Holocene

    Kråkenes aquatic succession

    Norfolk Broadland mires

    Lake water-level fluctuations

- Eutrophication

    Minnesota lakes

    N Africa lakes - CASSARINA

Some special applications of plant macrofossils

- Late-glacial multi-disciplinary studies using plants and animals to reconstruct late-glacial climates

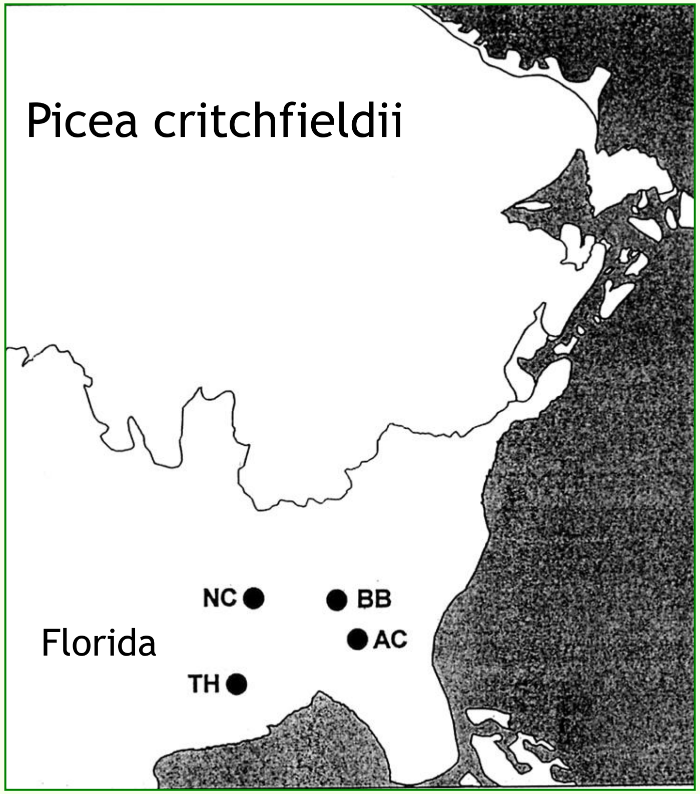
  Eastern Canada

  Kråkenes, W Norway

- Linking palaeoecology with ecology in the late glacial

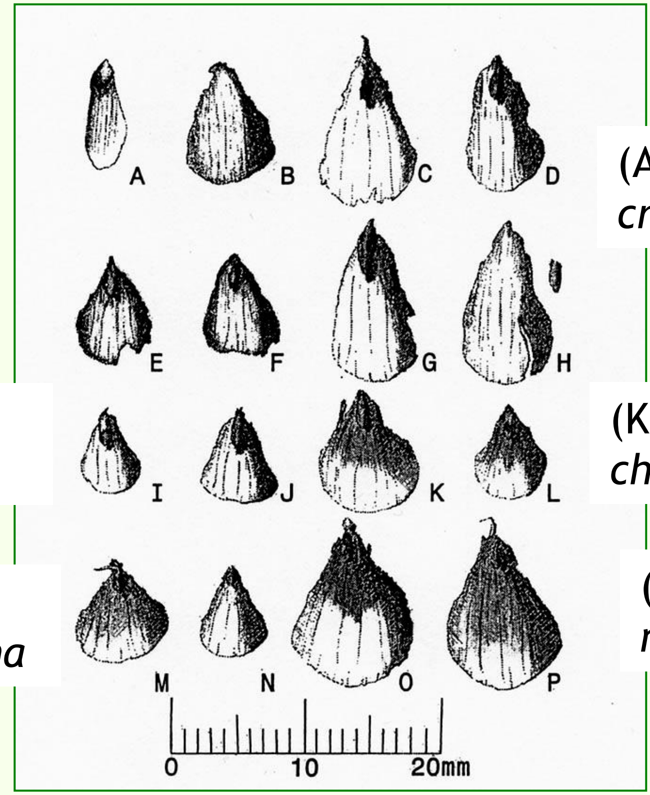
Historical Biogeography

Extinction



Palaeogeography of eastern North America at the time of the Last Glacial Maximum (18,000 yr BP). TH and BB represent Tunica Hills and Bob Black Pond, where *Picea critchfieldii* cones and/or foliage occur in sediments of the LGM and Farmdalian Interstadial. AC and NC represent the Andersonville Claypit and Nonconnah Creek sites, where cones tentatively assigned to this species occur in Late Wisconsin sediments.

(A: seed-wing, B-P: cone scales)



(A-H) *Picea critchfieldii*

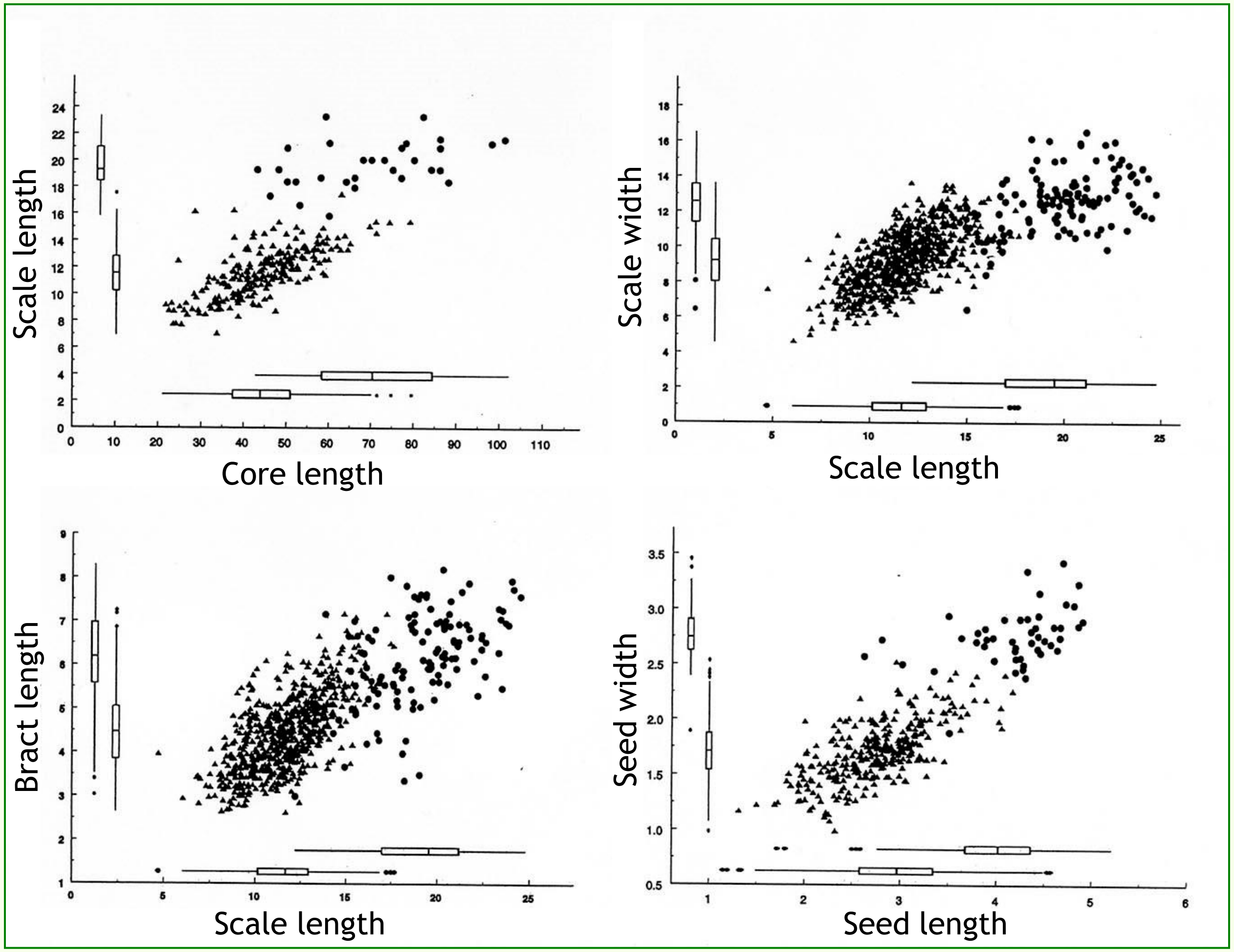
(I & J) *P. glauca*

(K & L) *P. chihuahuana*

(M & N) *P. breweriana*

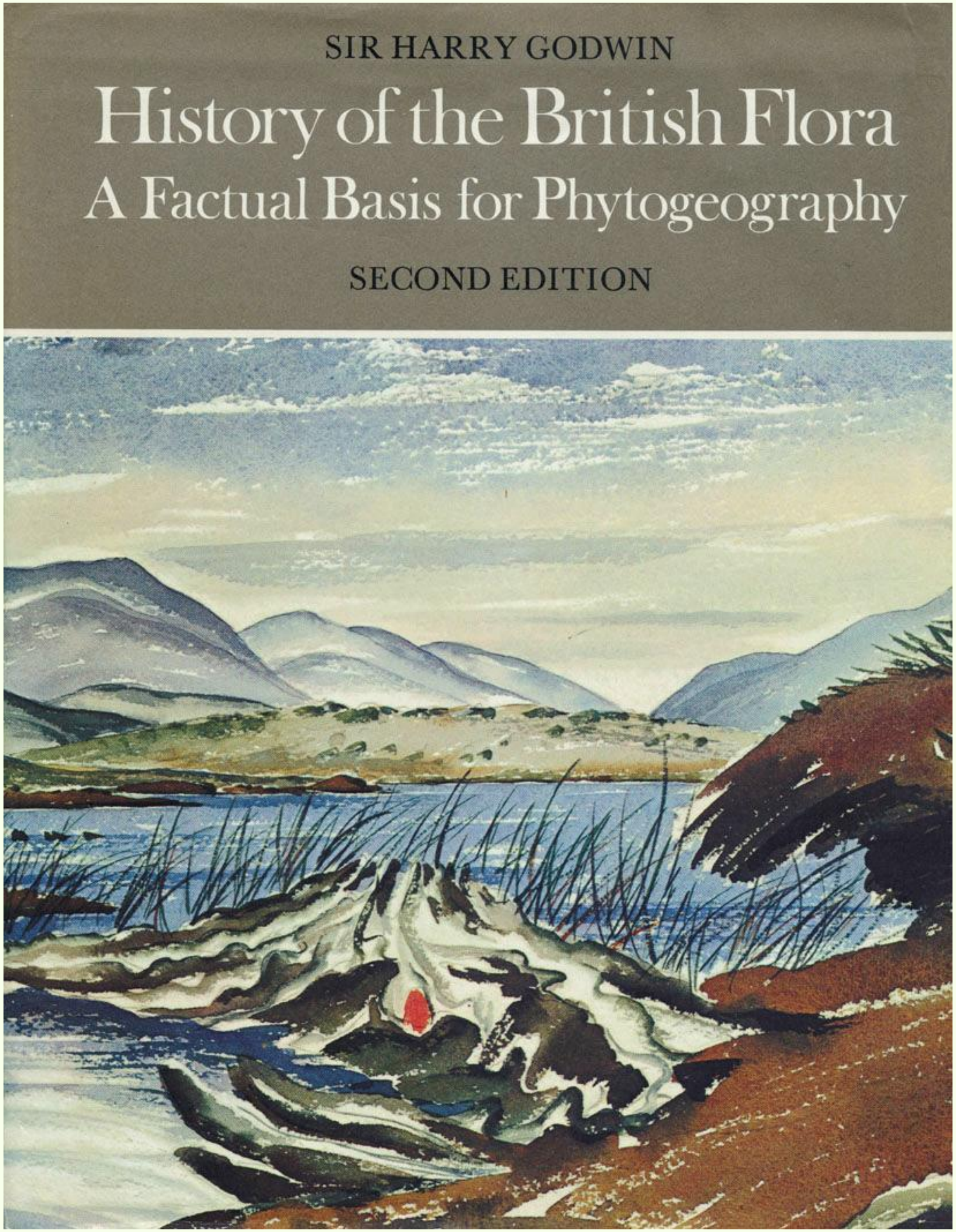
(O & P) *P. martinezii*

(**A**) Seed and seedwing of *P. critchfieldii*. (**B**-**H**) Cone scales of *P. critchfieldii* from Tunica Hills sediments. B-D, G, and H are typical of scales from middle portions of cones. Some scales are abraded or missing small portions, and bracts are missing from some specimens. (**I** and **J**) Modern *P. glauca* (**I** - Franklin Co., New York, J - Cypress Hills, Saskatschewan). (**K** and **L**) Modern *P. chihuahuana* from Mexico. (**M** and **N**) Modern *P. breweriana* from Siskiyou Co., California. (**O** and **P**) Modern *P. martinezii* from Neuvo Leon, Mexico.



S.T. Jackson & C. Weng (1999)

Cone morphology of Tunica Hills fossils (from 20 cones or fragments from 6 sites) and modern *Picea glauca* (from 240 cones from Alaska, S. Dakota, Michigan, New York, Ontario, Saskatchewan, and Alberta). Box plots along margins portray median, quartiles, adjacent values, and outside values for the entire data sets. Upper box plots along x-axis and right-hand box plots along y-axis represent fossils, and lower boxplots along x-axis and left-hand box plots along y-axis represent modern *P. glauca*. Scatter plots represent data for which paired values were available for the respective variables. <u>Black dots represent fossils, and grey triangles represent modern *P. glauca*.</u> Scales and attached bracts were obtained from the cone midpoint, 1/3 of the distance from the cone apex, and 1/3 of the distance from the cone base for each *P. glauca* cone. Number of scales and bracts measured from fossil cones varied from 3 to 25 depending on preservation. All were from the middle half of the cones. Seeds were removed from 12 fossil cones for measurement. Cone lengths for fossil specimens are minimum estimates in nearly all cases; most fossil cones were fragments lacking apical or basal portions.



This was the first data-base of Quaternary floristic records. Godwin's synthesis showed how fossil evidence provided the factual basis for phytogeography and floral history

Salix herbacea in Britain

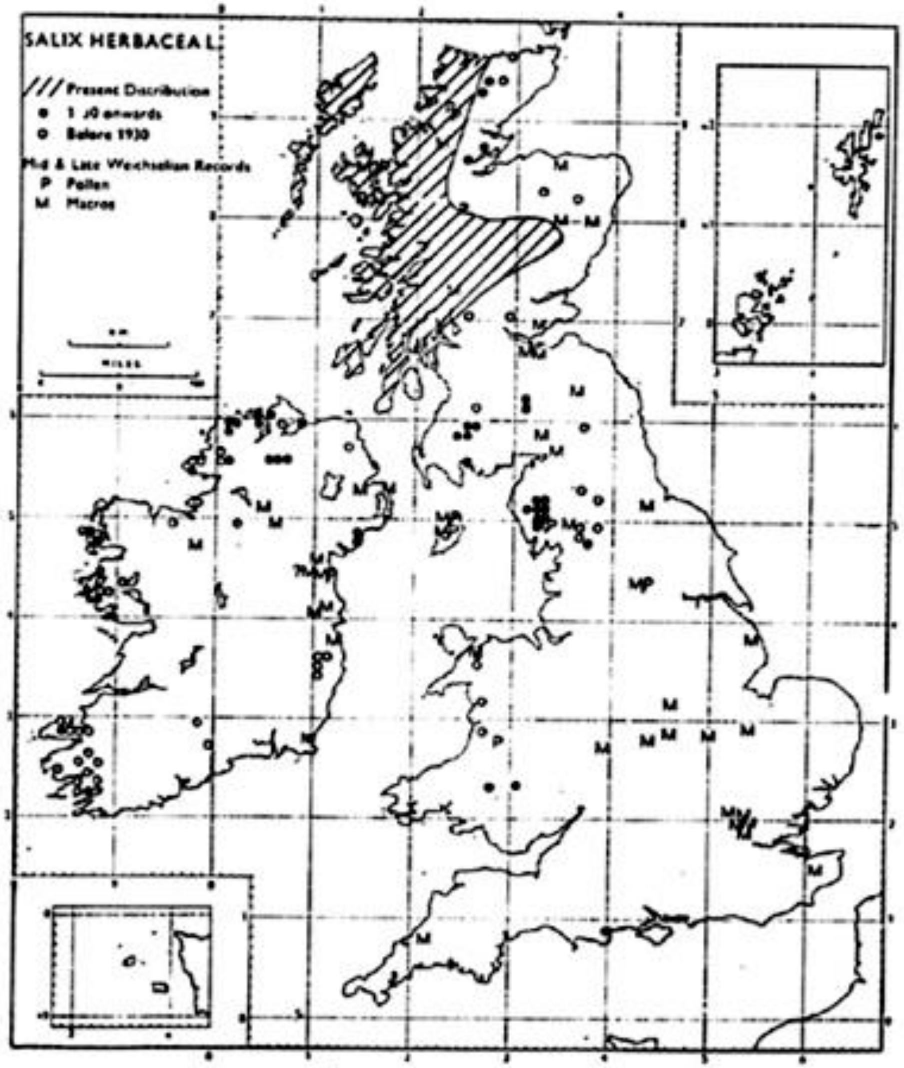
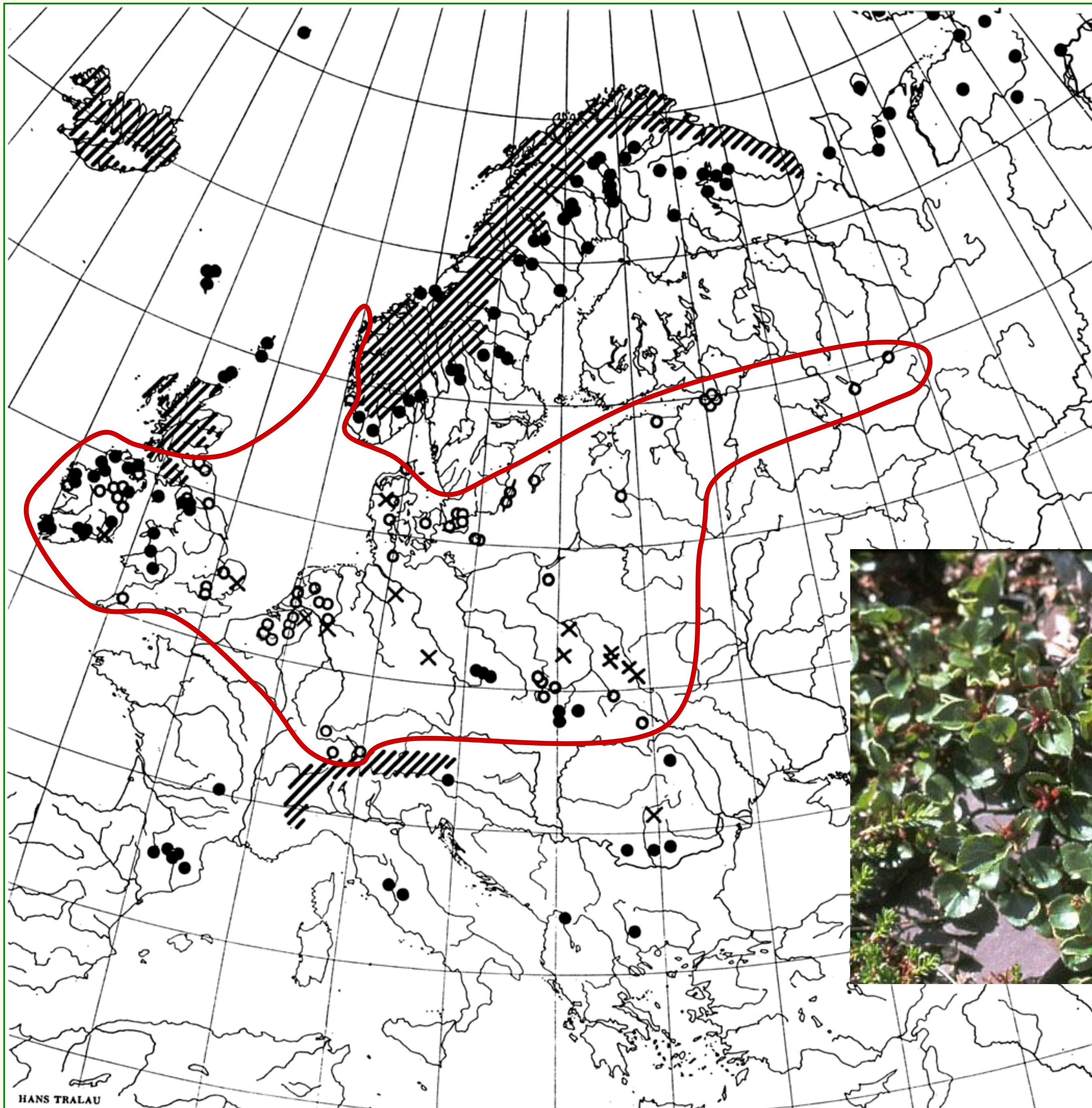


Fig. 98. Present and Weichselian distribution of *Salix herbacea* L. in the British Isles.

Salix herbacea

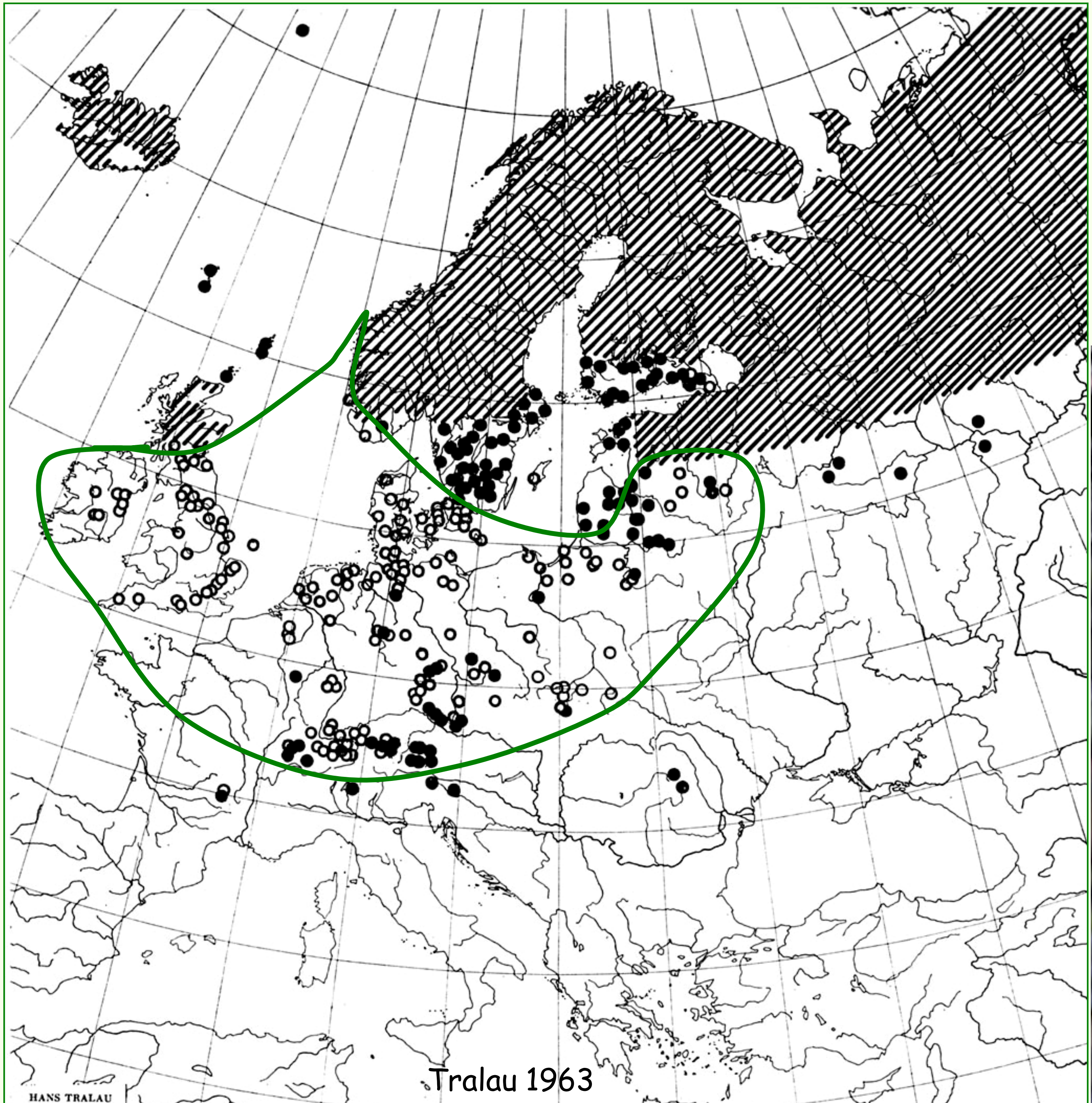
Godwin (1975) History of the British Flora



Distribution of Salix herbacea in Europe

Present (/// ●), Weichselian (O), pre-Weichselian (X)

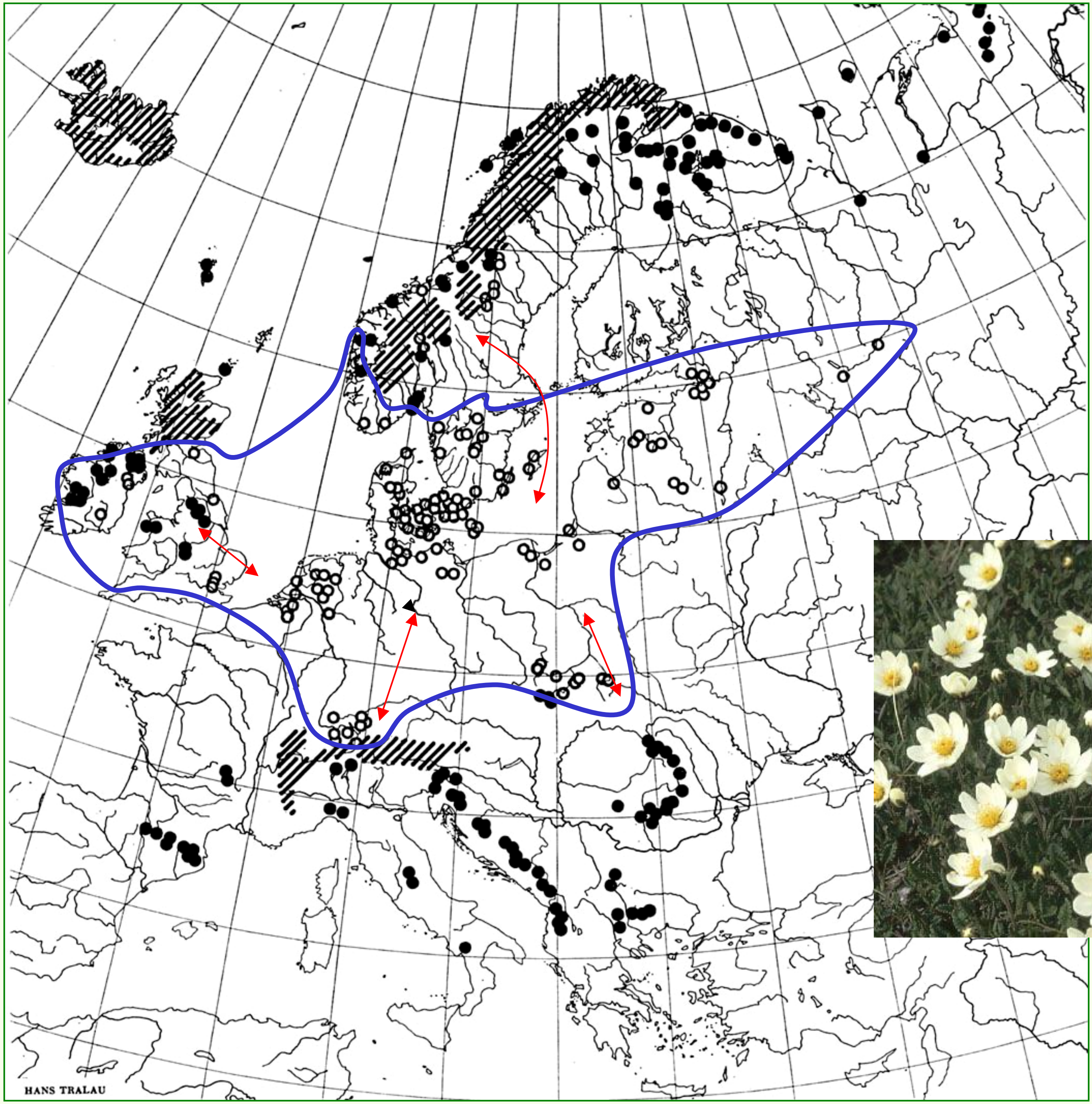
Tralau (1963) Kungl. Svenska Vetenskapsakademien



Distribution of Betula nana in Europe

Present (/// ●)
Weichselian (O)

Betula nana



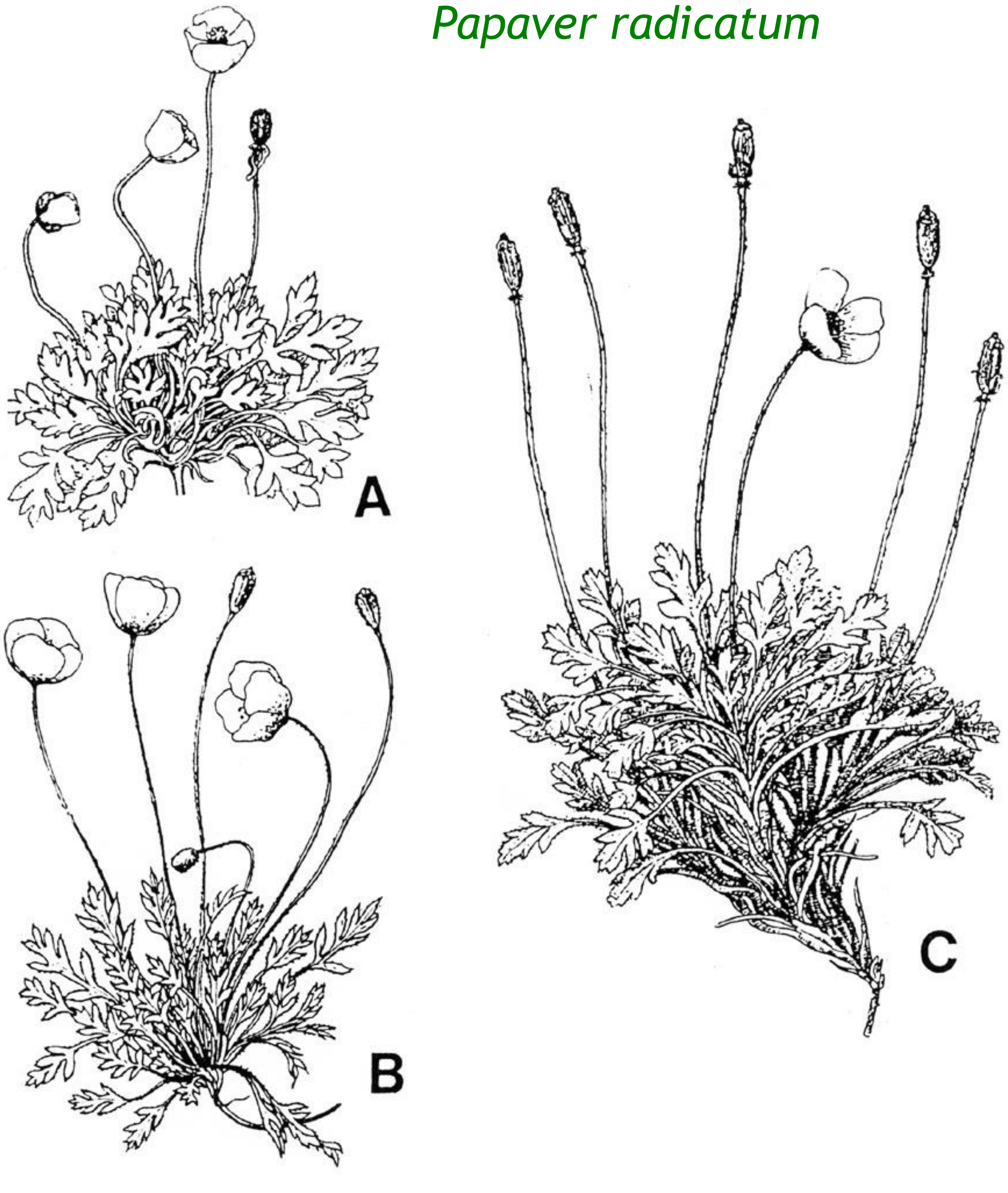
Distribution of Dryas octopetala in Europe

Present (/// ●)
Weichselian (○)

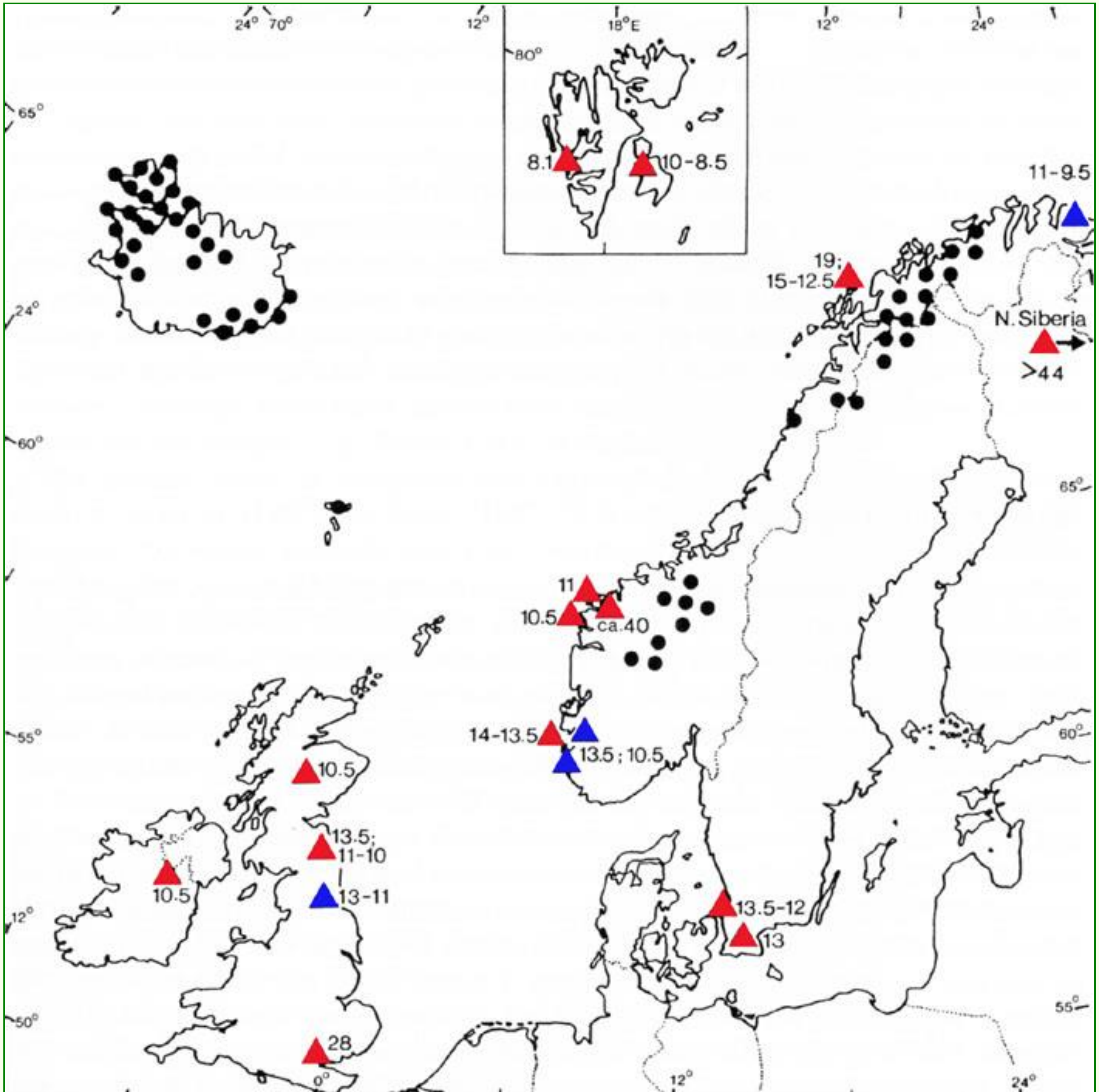
Tralau 1963

Dryas octocpetala

Papaver radicatum



Papaver radicatum
agg.



● Modern (bicentric) distribution of *Papaver radicatum agg.* (*P. dahlianum* in Svalbard)

▲ Macrofossil (seed) localities for *Papaver* sect. *Scapiflora* with approximate ages (k yr BP).

▲ Localities of *Papaver* pollen with approximate ages (k yr BP).

Birks (1994)

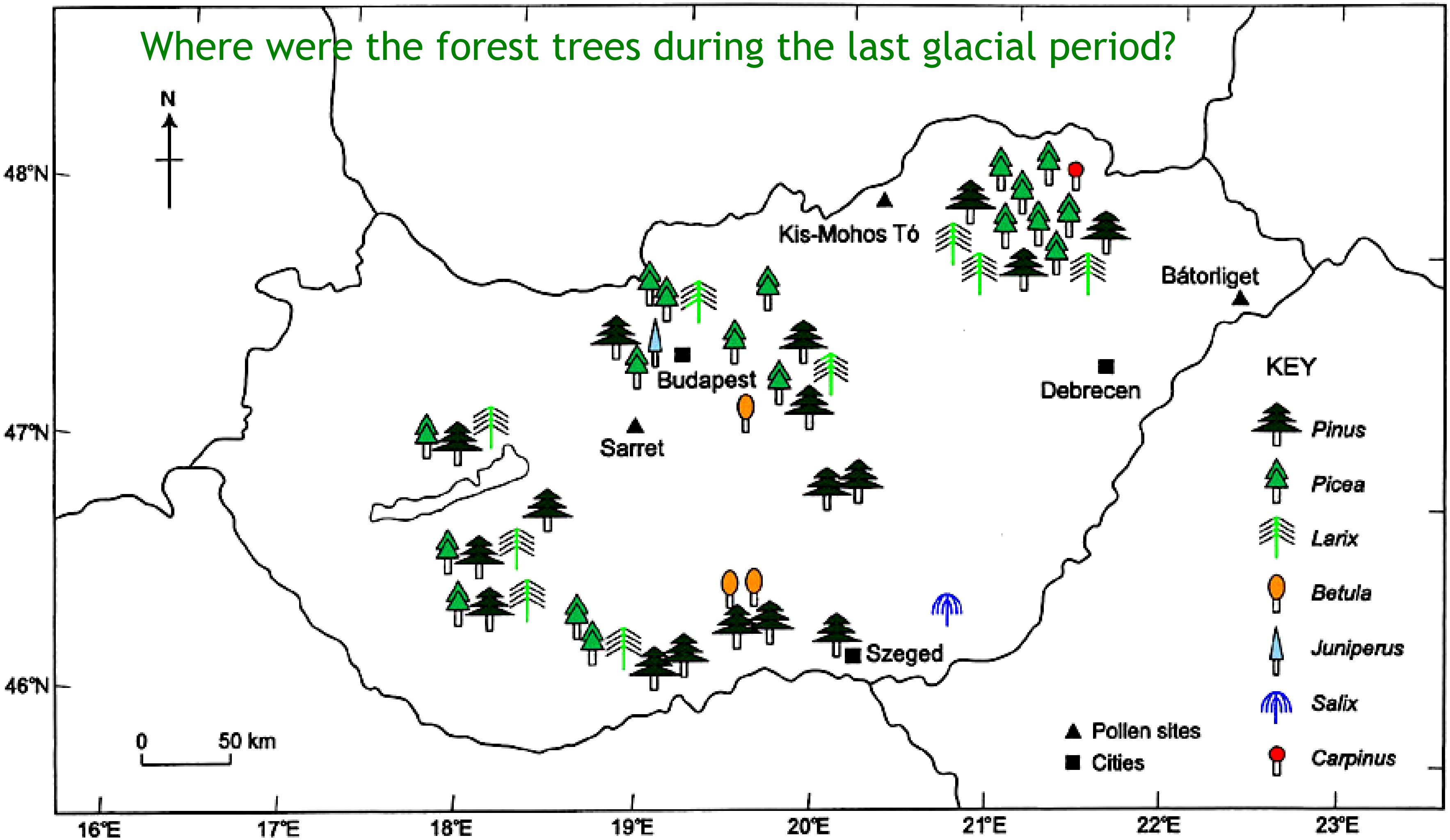
West Arctic Plants found as Fossils





Present distribution	Fossil records
Braya linearis (bicentric)	Andøya, ca. 19,000 ca. 14,000 BP
Cassiope hypnoides (wide distribution)	Massachusetts USA – late-glacial Central Scotland – late-glacial Greenland ca. 9,000 BP Spitsbergen ca. 8,000 BP
Pedicularis hirsuta (N. unicentric)	Near London 28,000 BP N of London 13,500 BP
Rhododendron lapponicum (bicentric)	Minnesota USA – late-glacial Kråkenes ca. 9,000 BP
Chrysoplenium cf *C. tetrandrum* (N. unicentric)	Andøya ca. 19,000 BP
Cassiope tetragona (N. unicentric)	Andøya ca. 12,500 BP

Where were the forest trees during the last glacial period?

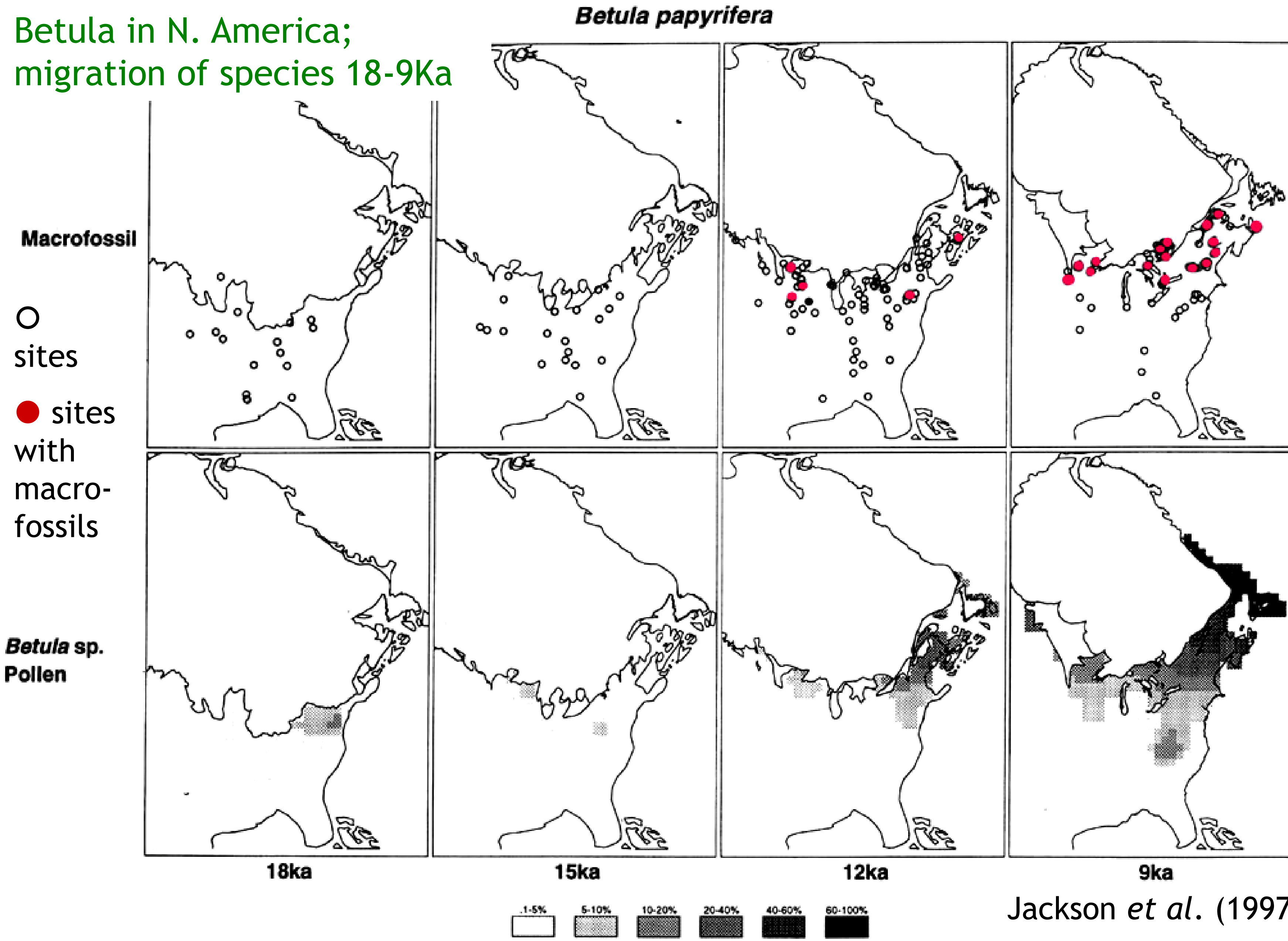


Tree types represented in the macrofossil charcoal record and their distributions within Hungary.

Full-glacial refugia in small favourable habitats

K.J. Willis *et al.* (2000)

Betula in N. America; migration of species 18-9Ka

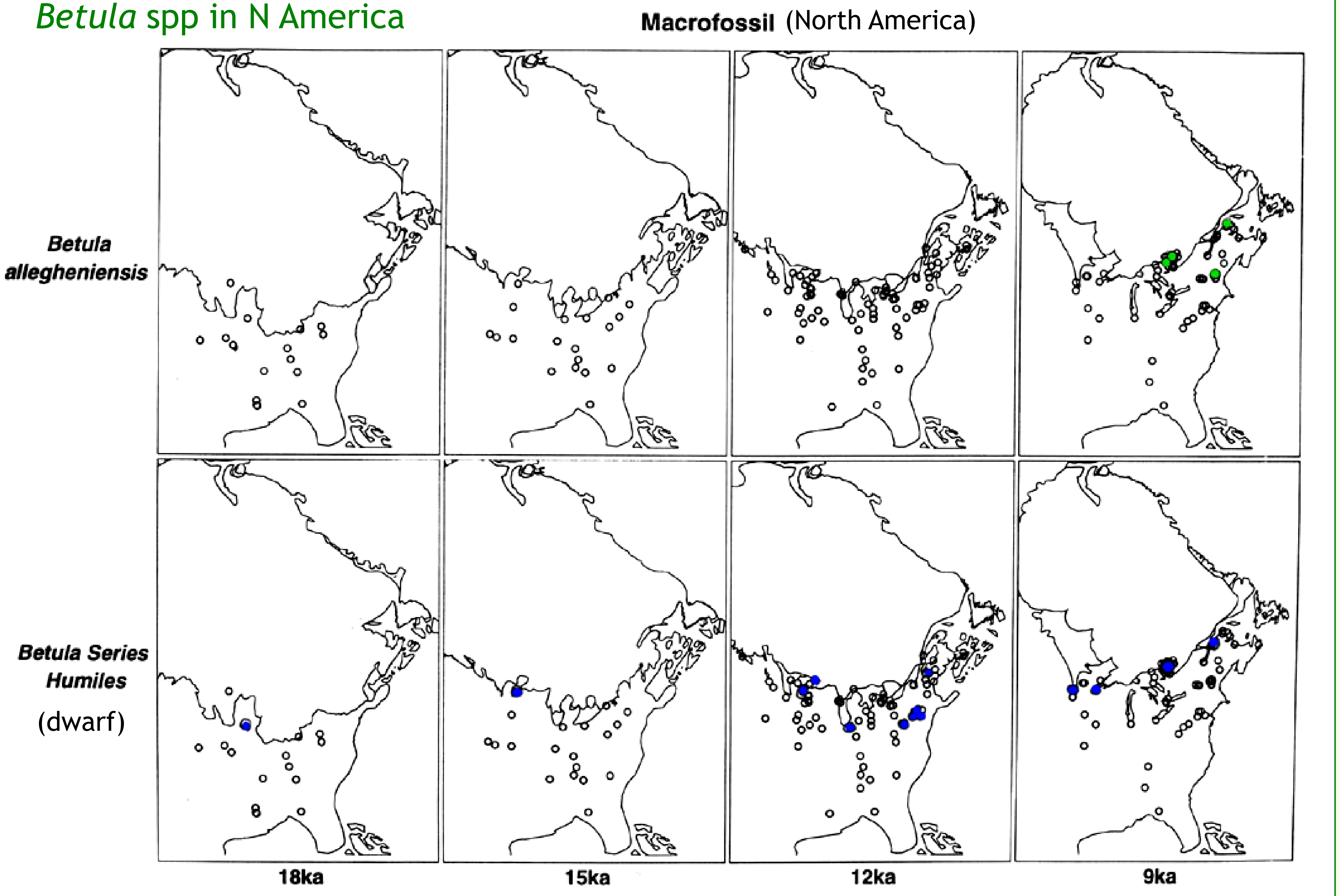


○ sites

● sites with macro-fossils

Jackson *et al*. (1997)

Betula spp in N America



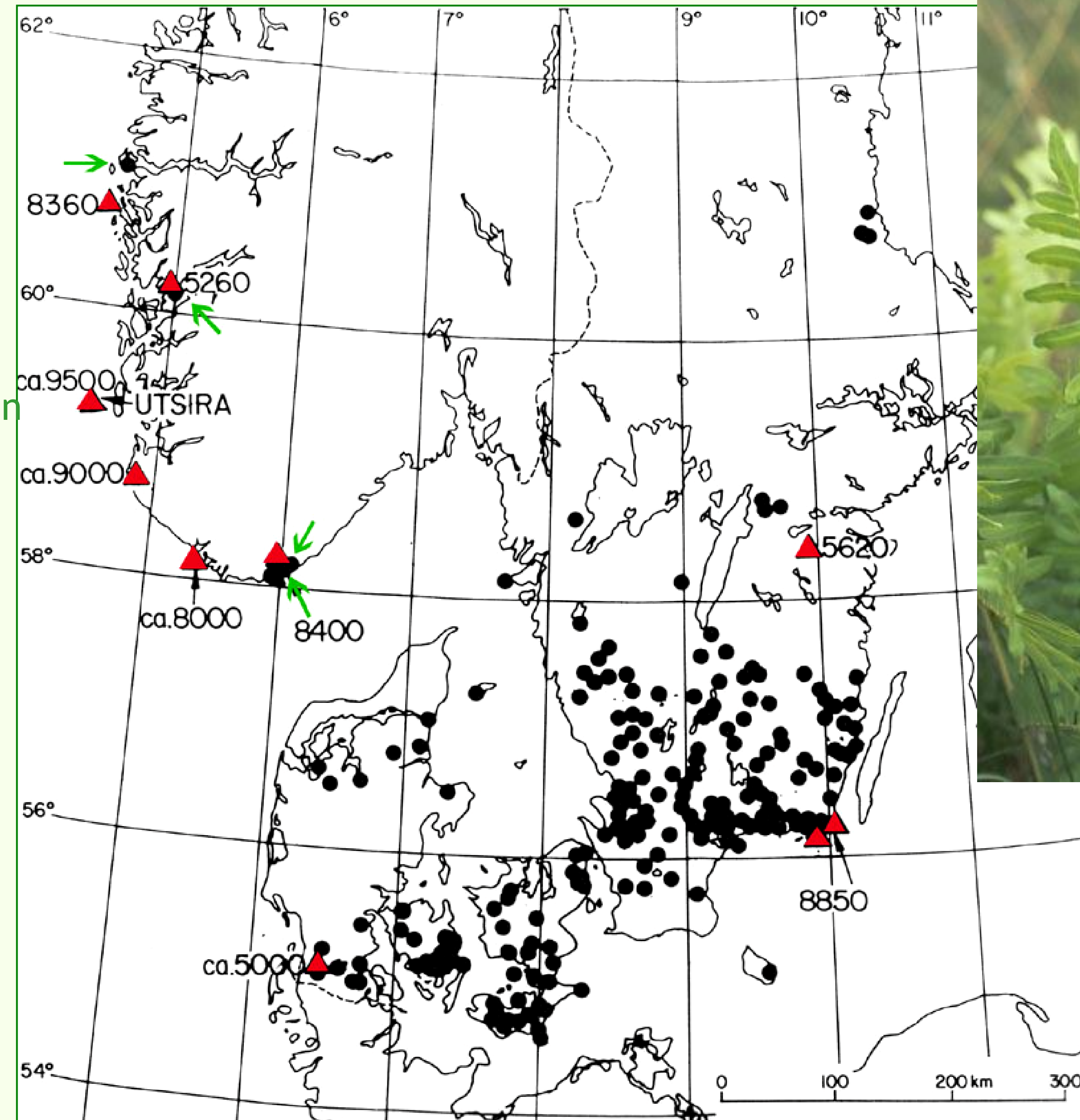
Jackson *et al.* (1997)

Holocene spread of *Osmunda regalis* (royal fern)

● Present range

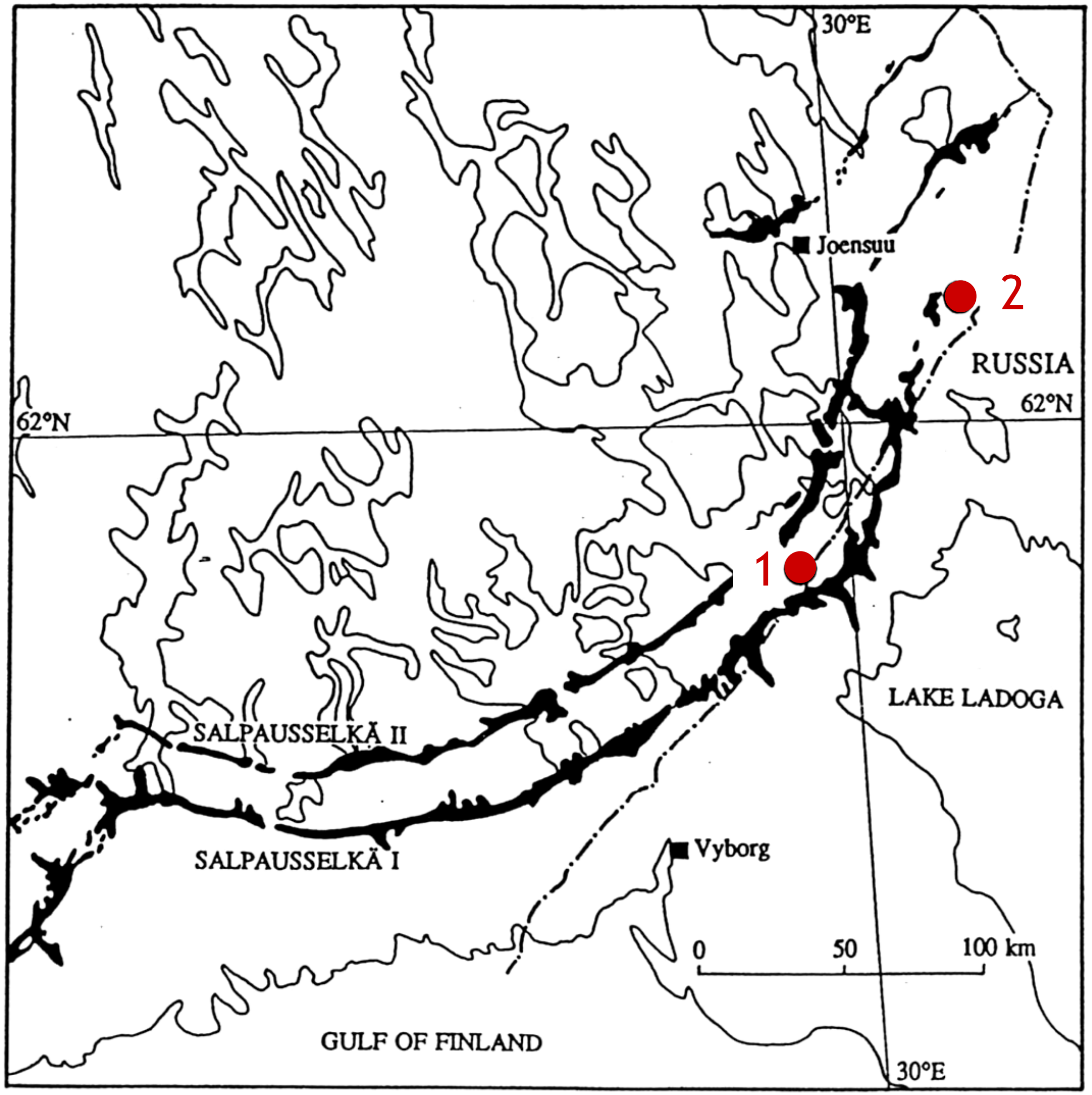
▲ Fossil localities

➔ Norwegian outliers today



Birks & Paus (1991)

Vegetation Change: Succession



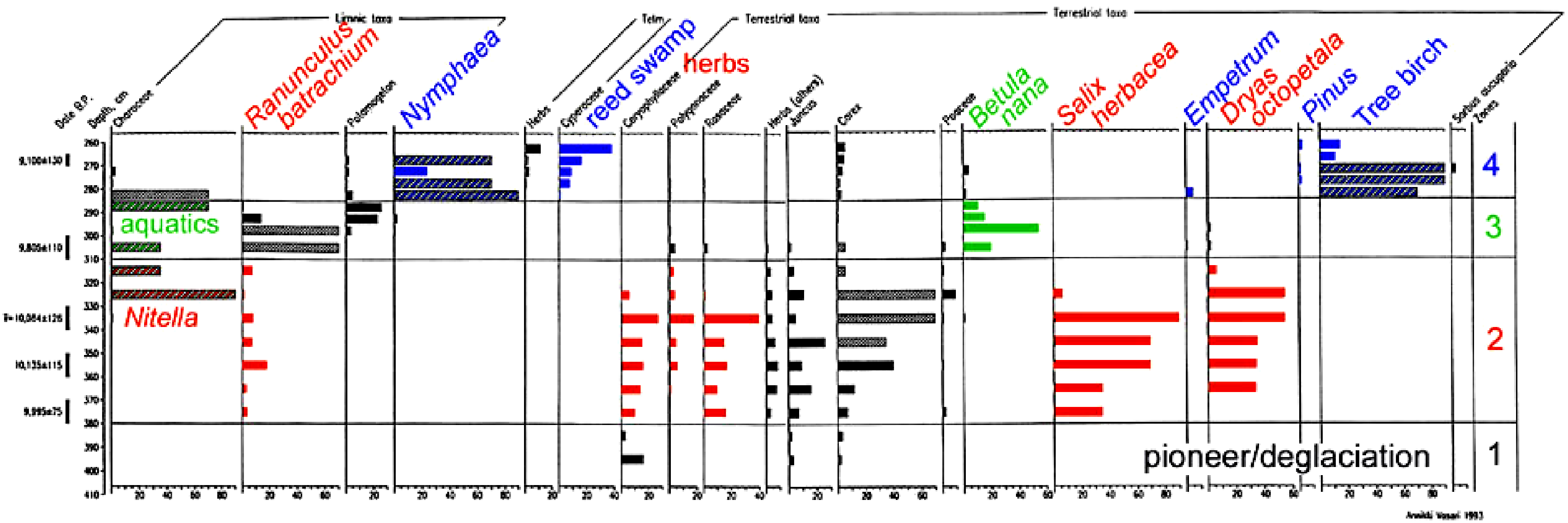
SE Finland

Early Holocene

Bondestam *et al.* (1994)

Map of south eastern Finland. 1 = Koivusilta, 2 = Mustalampi

Koivusilta, Saari

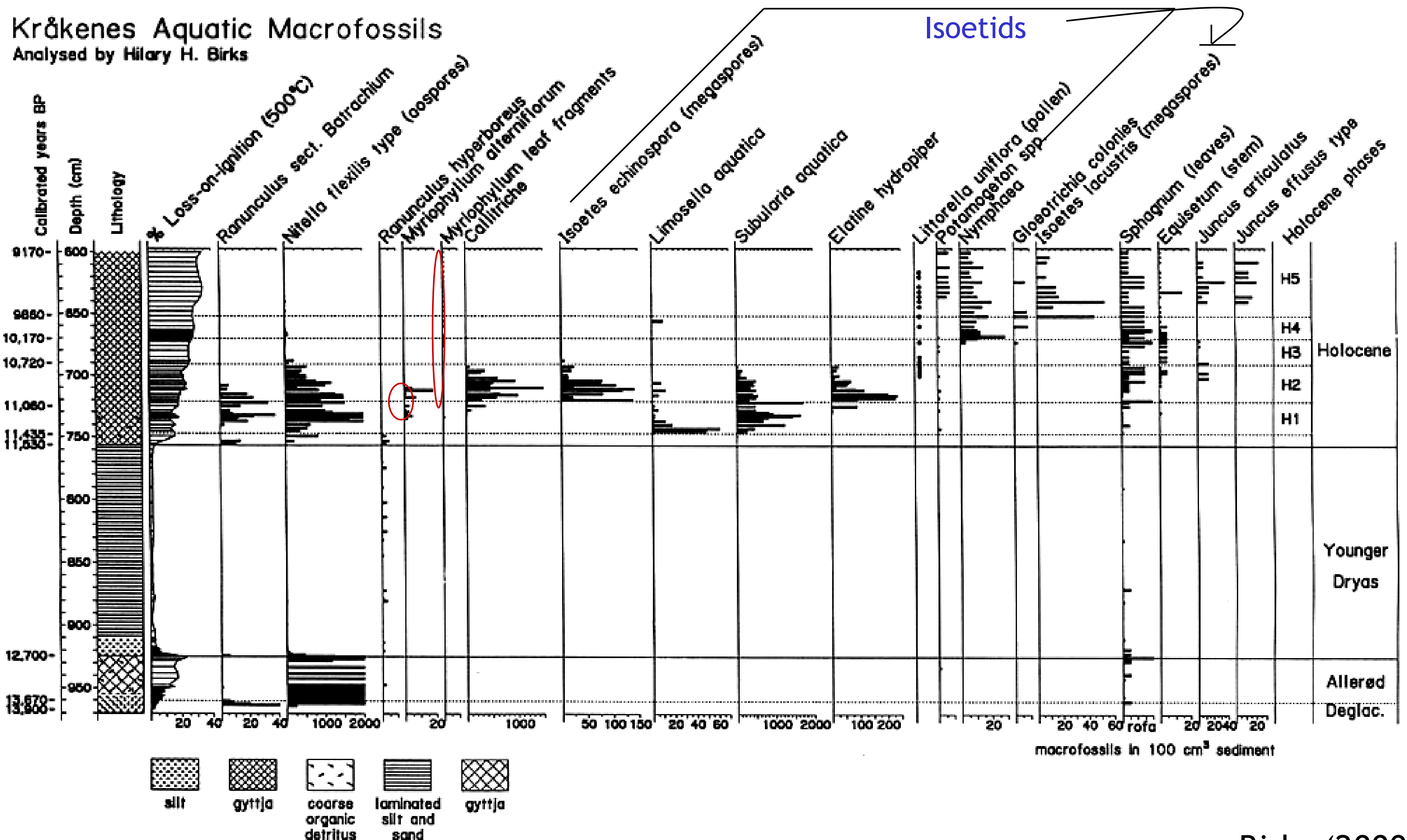


Zone 2: *S. herbacea*, *Dryas* dwarf-shrubs; *Potentilla*, *Draba*, *Cerastium alpinum*, *Minuartia*, *Rumex acetosella*, *Polygonum aviculare*, *Oxyria*, *Gramineae*. Mosses indicate meso-eutrophic fens. Pioneer aquatics.

Zone 3: *Betula nana*. Expansion of aquatics.

Zone 4: *Betula* tree-type, *Pinus*, *Empetrum* (at transition), *Populus*, *Sorbus aucuparia* – woodland development. Lake maturation with *Nymphaea;* fens with *Schoenoplectus*, poor-fen mosses.

Early Holocene Aquatic Succession



Birks (2000)

Allerød plants

Ranunculus Sect. Batrachium

Nitella

Younger Dryas

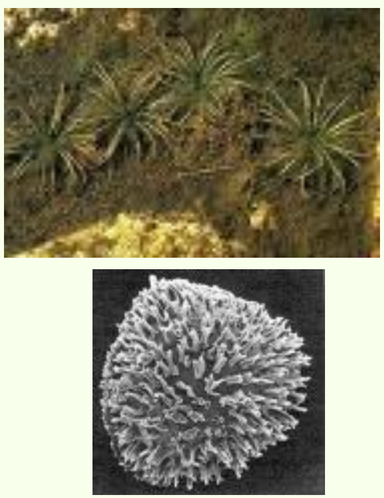
Ranunculus hyperboreus

Early Holocene - isoetid succession

Limosella aquatica

Subularia aquatica

Elatine hydropipper

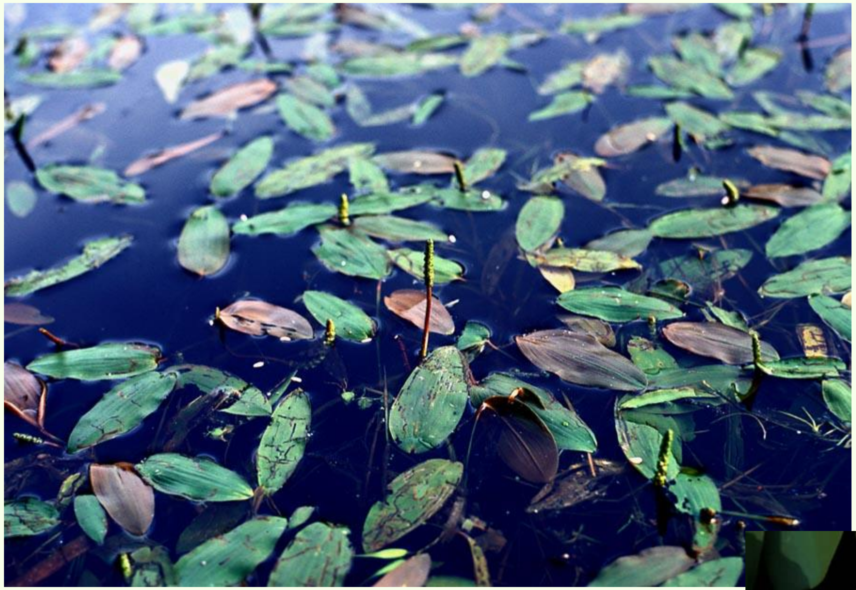


Isoetes echinospora

Littorella uniflora (pollen)

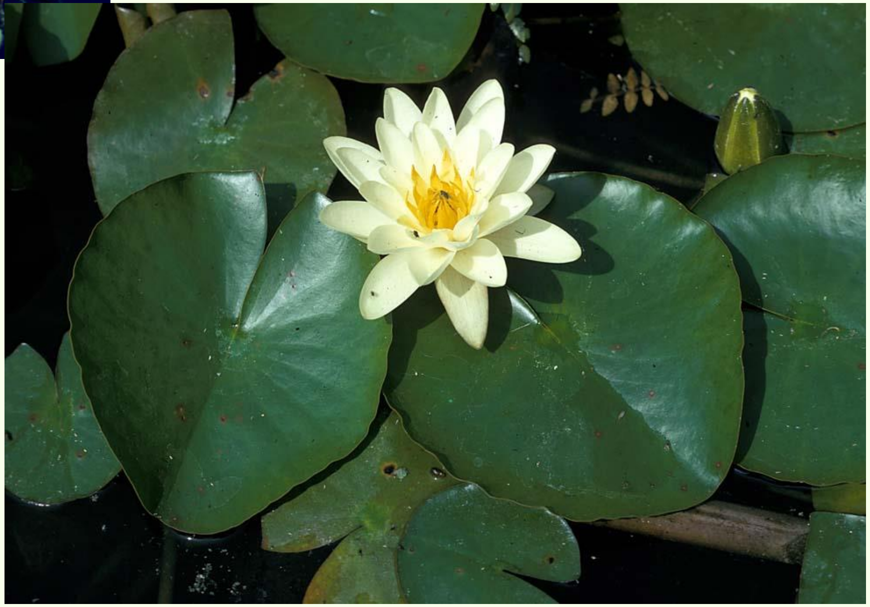
Isoetes lacustris

Early Holocene - nymphaeids

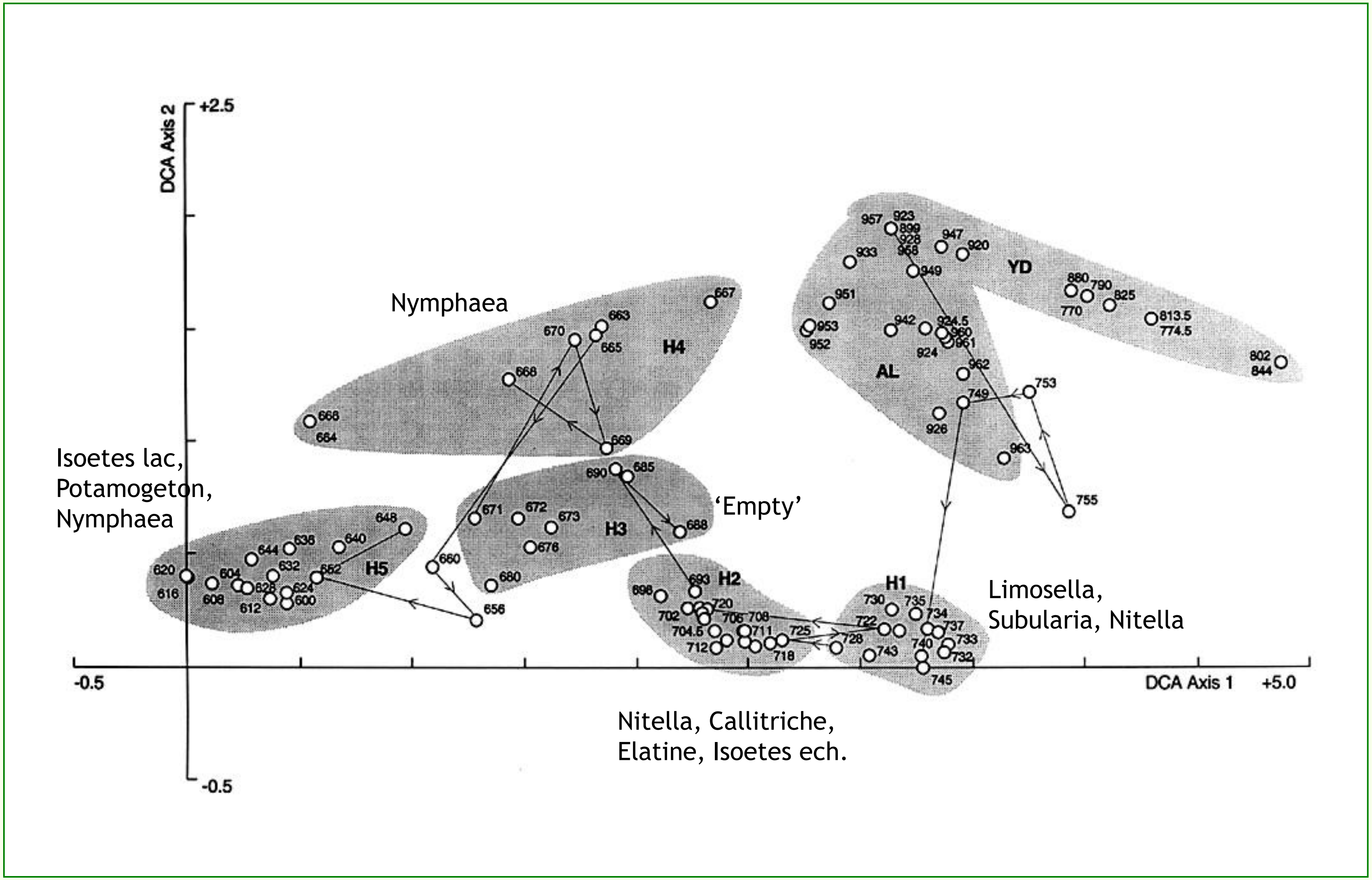


Potamogeton natans

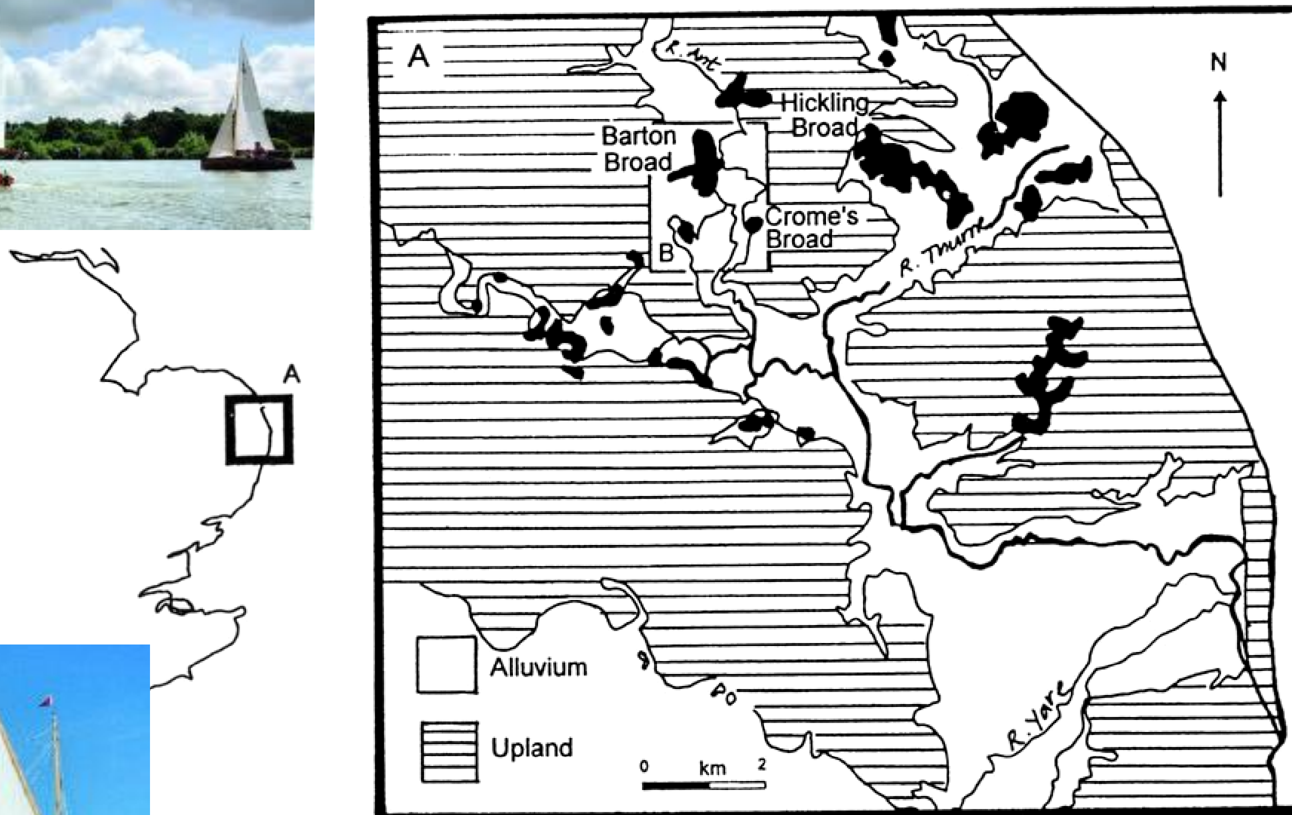
Nymphaea alba



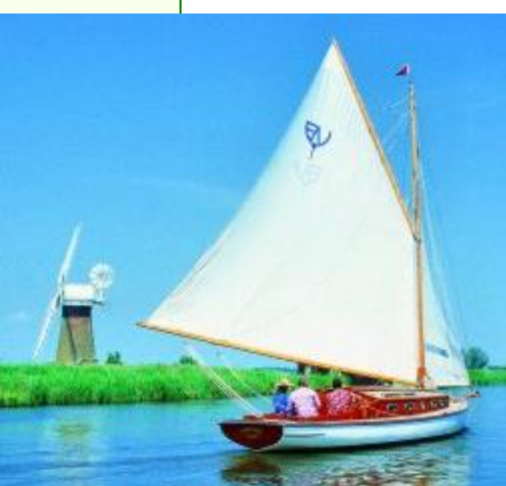
DCA of Kråkenes Sequence



Norfolk Broads, SE England

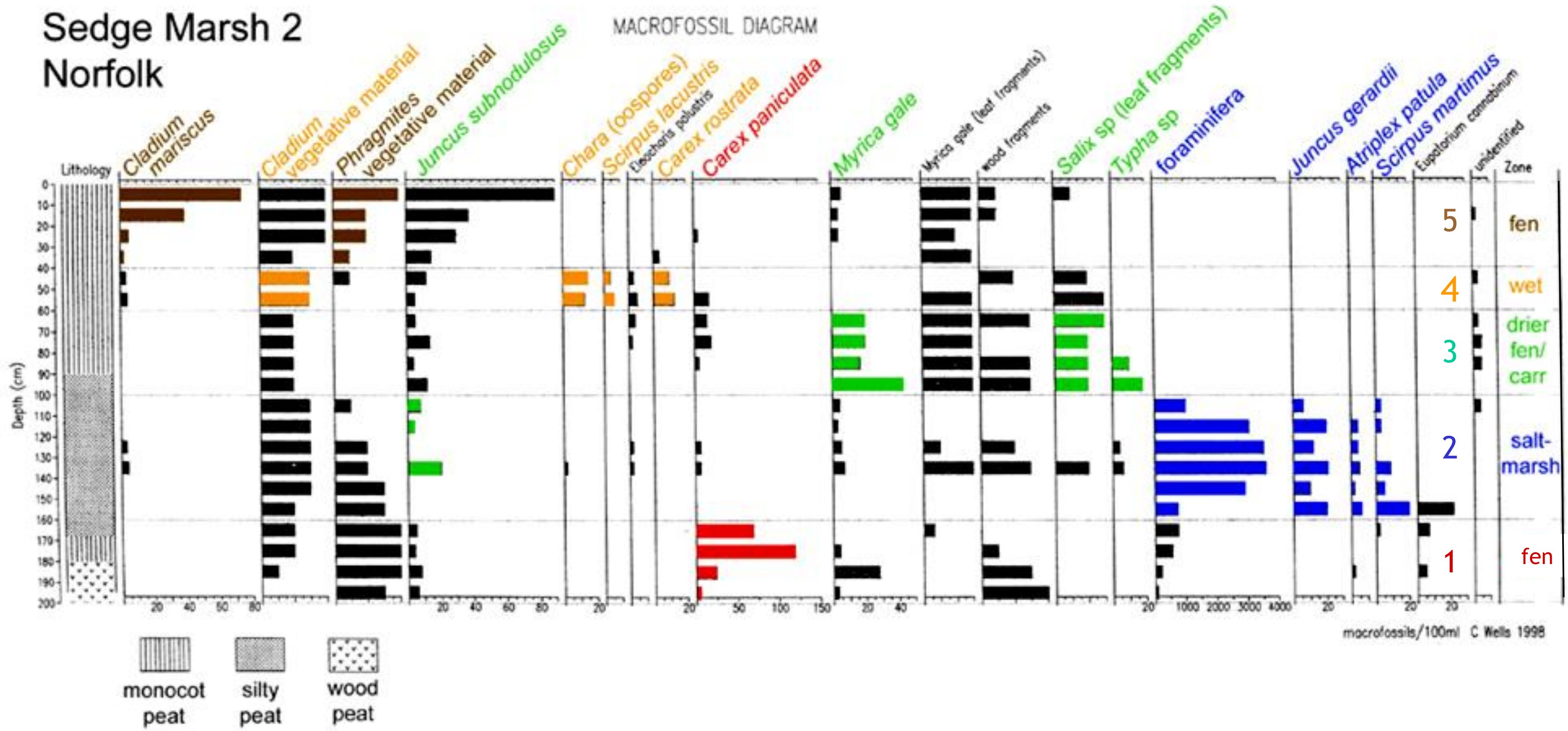


Wells & Wheeler (1999)



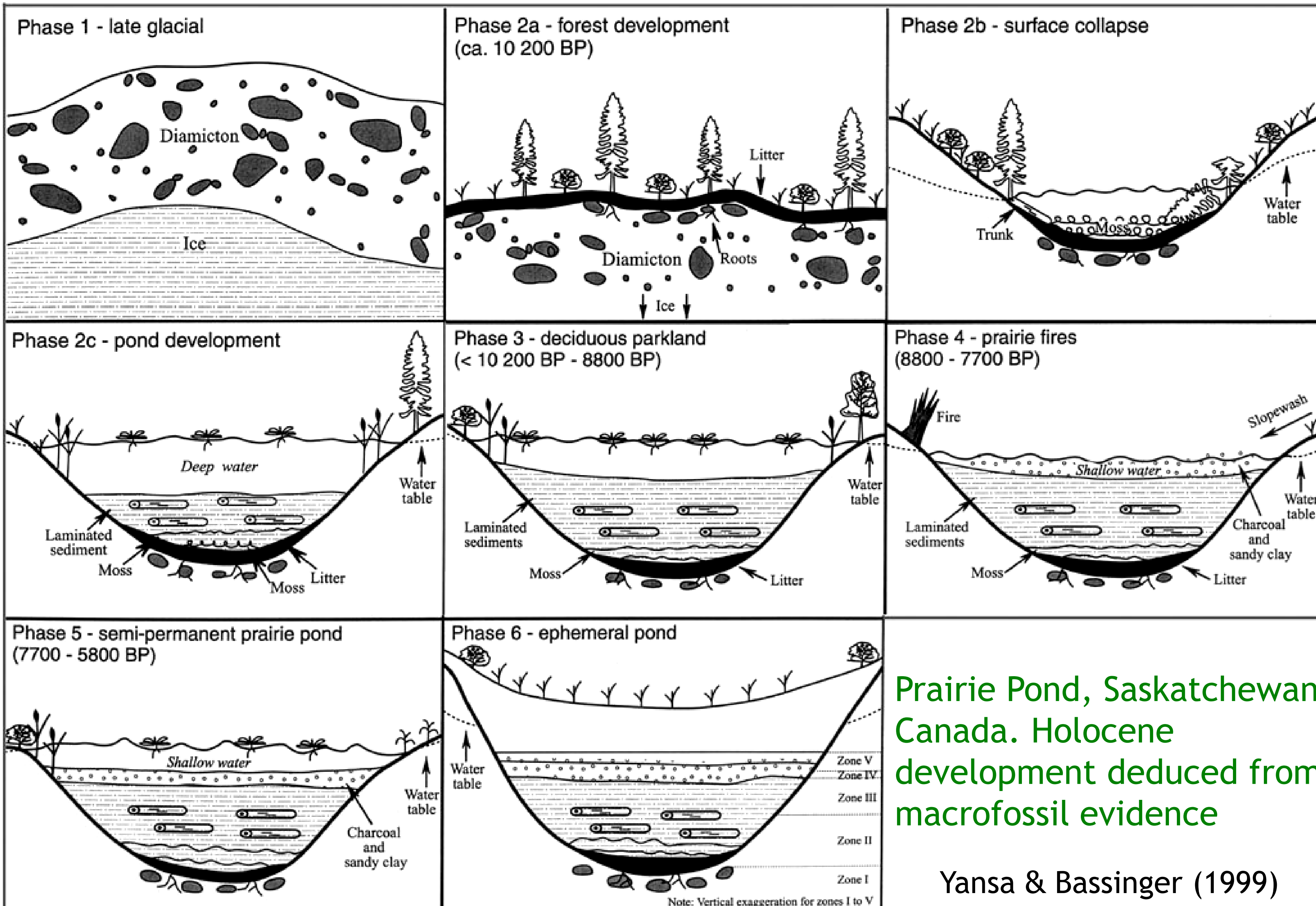
Location of Norfolk Broadland and the Ant Valley

Formation of the Norfolk Broads (lakes) – are they natural or man-made?



Changes in sea-level flooded the fen and then allowed the fen to recolonise 1,2,3. The peat accumulation during a dry period was mined by Medieval monks 3. Climate became wetter 4 and flooded the turf pits, preventing peat-mining; the Broads lakes were formed in the turf pits and fens were flooded. Fen plants recolonised 5. Reed marshes were maintained by people for thatching material and for wild-fowl.

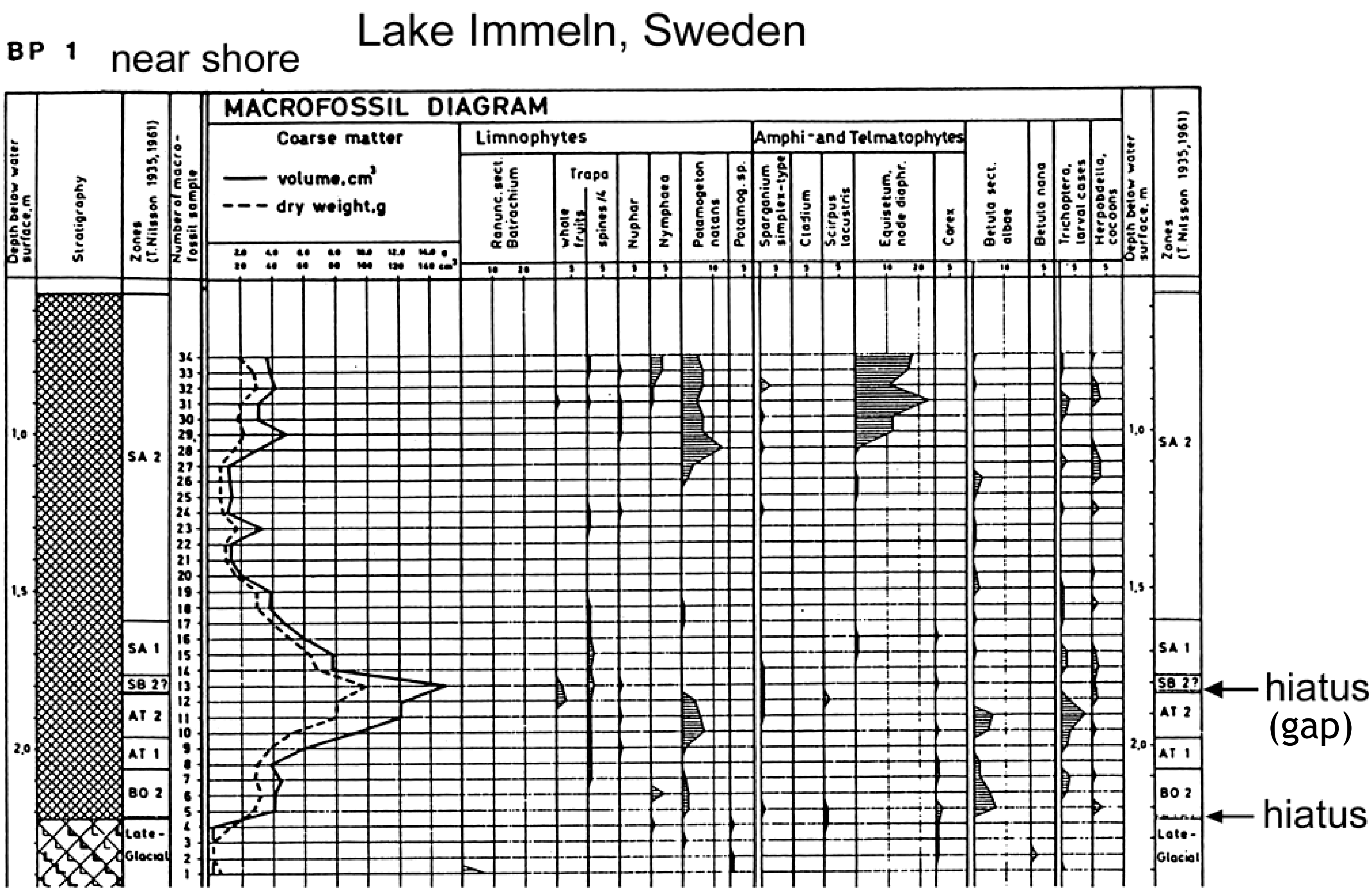
Development of an ephemeral prairie pond, Saskatchewan



Prairie Pond, Saskatchewan, Canada. Holocene development deduced from macrofossil evidence

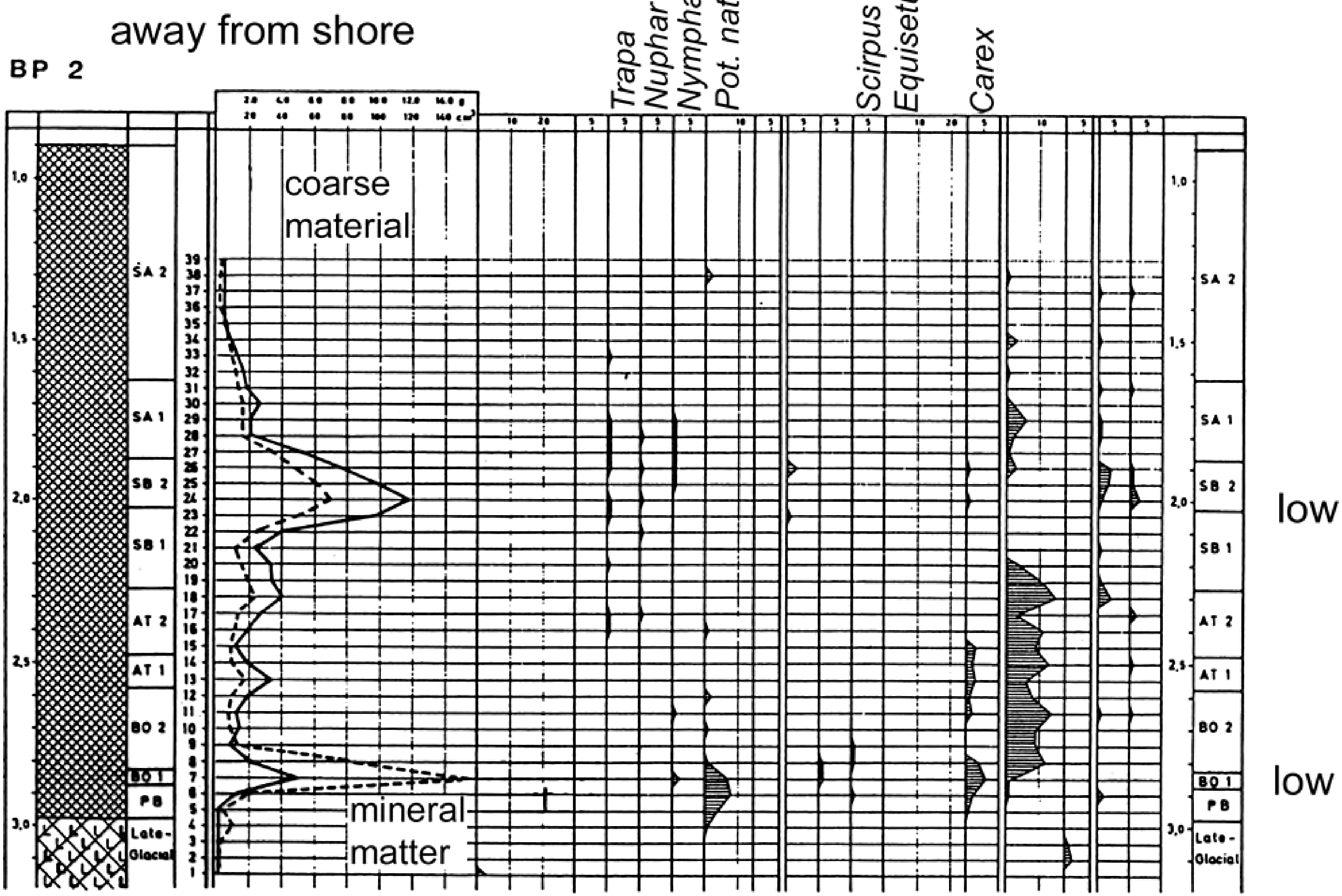
Yansa & Bassinger (1999)

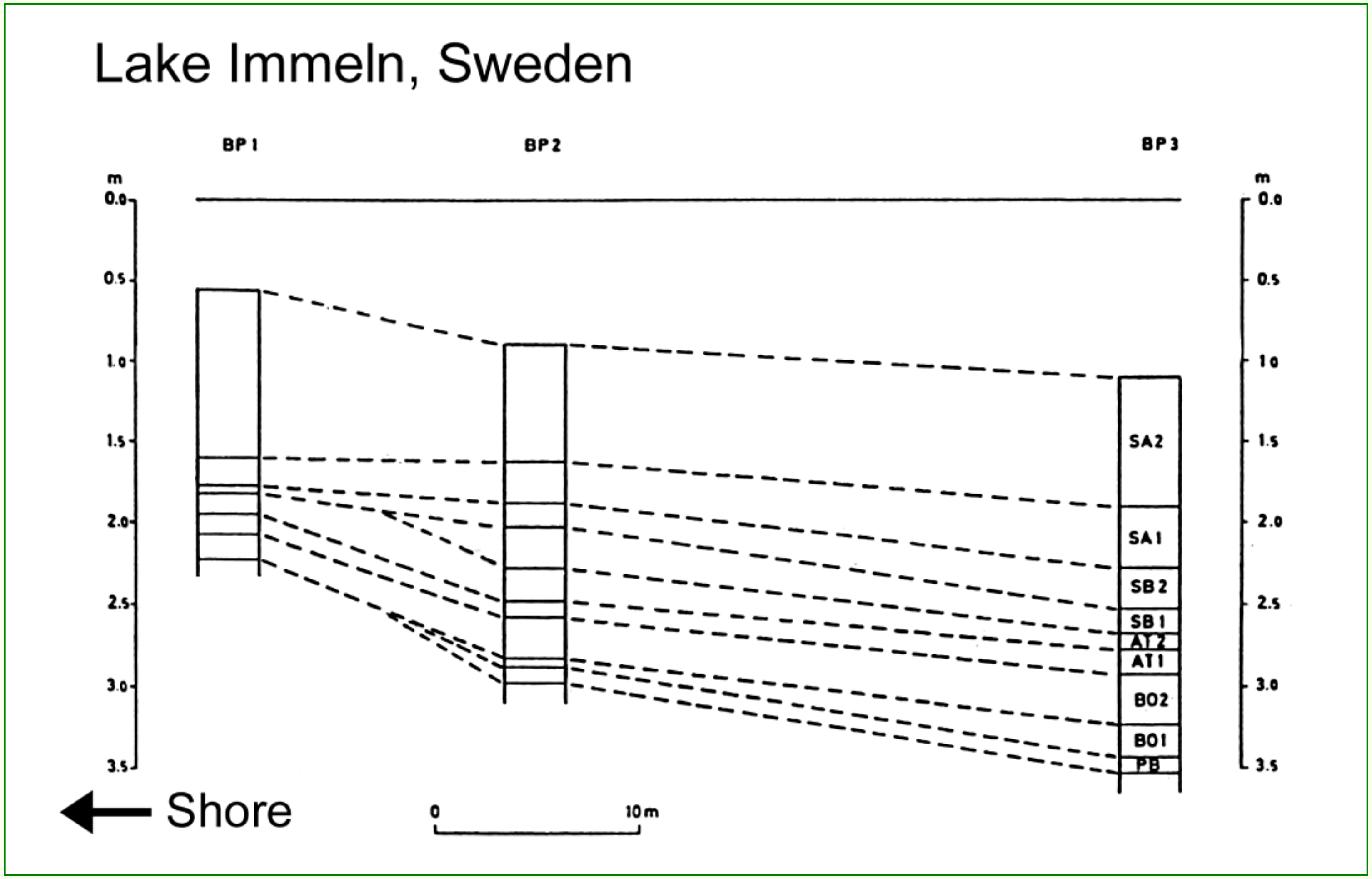
Lake Water-Level Changes



Digerfeldt (1986)

Lake Immeln, Sweden





Sediment limit moved away from shore and there are hiatuses in PB/BO1 and SB1, i.e. lower lake level at these times.

Conclusions Hannon & Gaillard (1997)

1. Plant-macrofossil analysis is a sensitive biostratigraphical method for the detection of lake-level changes.

2. The type and distribution of the submerged, floating-leaved and emergent lake-shore vegetation is highly dependent on lake water-depth, but water chemistry and nutrient status are two major factors which must be taken into consideration.

3. Mesotrophic to eutrophic lakes are best suited for lake-level studies because of their rich littoral vegetation and well defined, water-depth related vegetation zones. Oligotrophic and dystrophic lakes are less suitable, but careful analysis of the macrofossil material and changes in the amount of coarse organic matter may provide helpful information.

4. Lake-shore species (eulittoral and sublittoral) seldom have very narrow water-depth ranges within any one lake, and these ranges may differ among lakes. Therefore, it is inappropriate to interpret the occurrence of single species from a single coring point, in terms of absolute water-depths.

5. Within any one lake, for any given stage in the lake development, the depth ranges of plants are relatively consistent. Fluctuations in the abundance of individual taxa or species associations, or their replacement by a different group of plants, primarily records the movements of the littoral belts through time.

6. The interpretation of the macrofossil record from a single core in terms of water-depth and lake-level changes will always be subject to alternative interpretations such as natural infilling, changes in sediment focusing and trophic status.

7. A reliable reconstruction of the changes in water-depth through time should be based on several littoral cores, in order to ensure that changes observed in macrofossils in one core result from the movement of the littoral vegetation zones.

8. A decrease in water-depth resulting from natural infilling may be difficult to separate from a lake-level lowering on the basis of plant macrofossils alone. The reconstruction of changes in the sediment limit through time is essential for separation of these two factors (Digerfeldt, 1986, submitted).

9. A convincing reconstruction of past lake-level changes should be based on complementary lines of evidence from transect of littoral cores. Furthermore, the multidisciplinary approach helps to rule out alternative interpretations of stratigraphic changes in macrofossils, such as changes in the nutrient status and water chemistry, erosion from the catchment, natural infilling and other factors.

10. The macrofossil identification of the major genera, species groups, and individual species included in the lake-shore vegetation is often sufficient for a reliable interpretation. However, in some cases, identification of species of more difficult groups such as e.g. *Potamogeton*, *Carex*, Umbelliferae, Gramineae, *Chara* may allow a more precise reconstruction, or may even be essential for any lake-level reconstruction. The justification of the level of detail in the macrofossil analysis should be evaluated for each case.

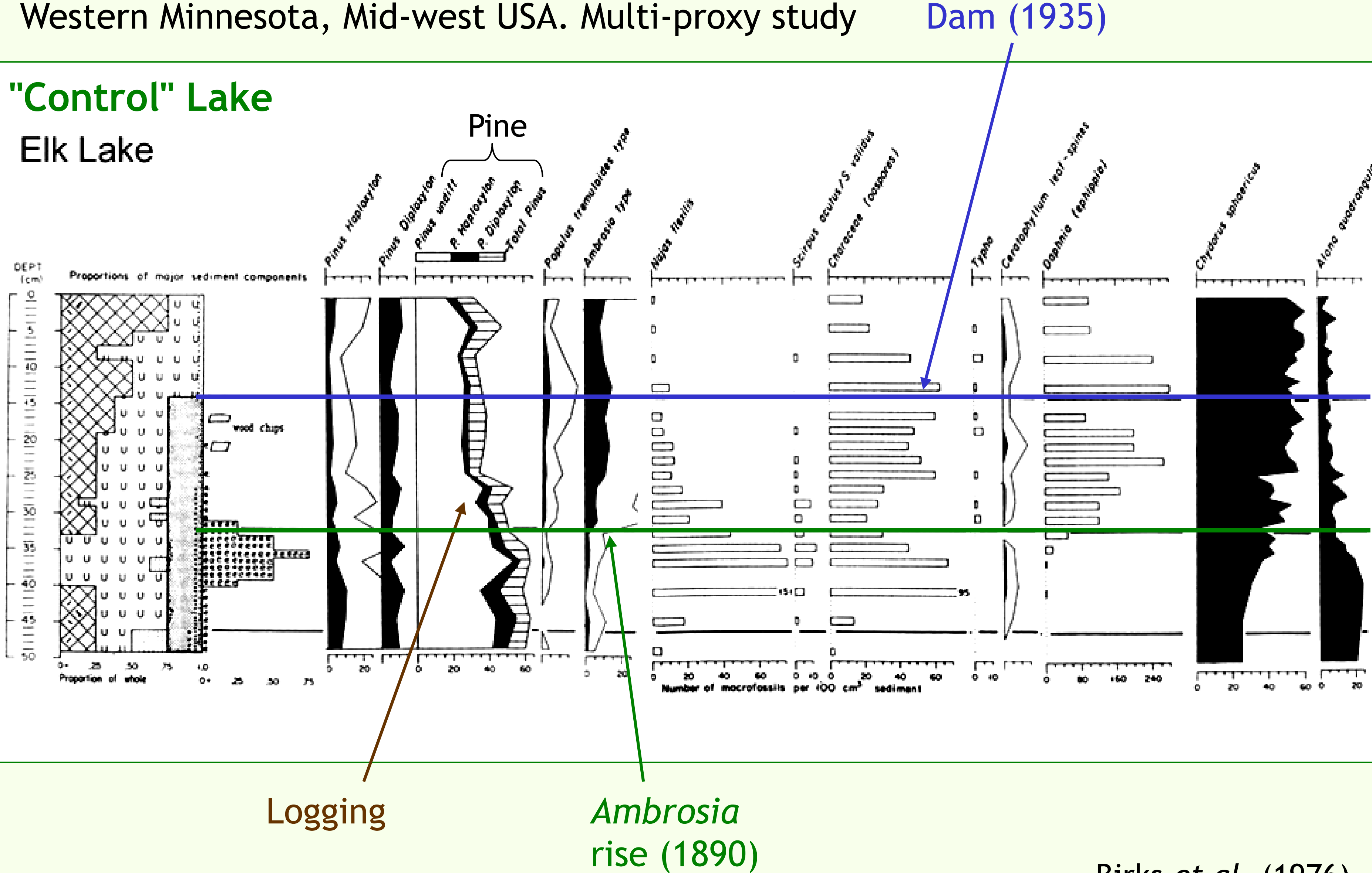
Compare with Dieffenbaker-Krall & Halteman (2000)

Eutrophication (palaeolimnology)

Western Minnesota, Mid-west USA. Multi-proxy study

"Control" Lake

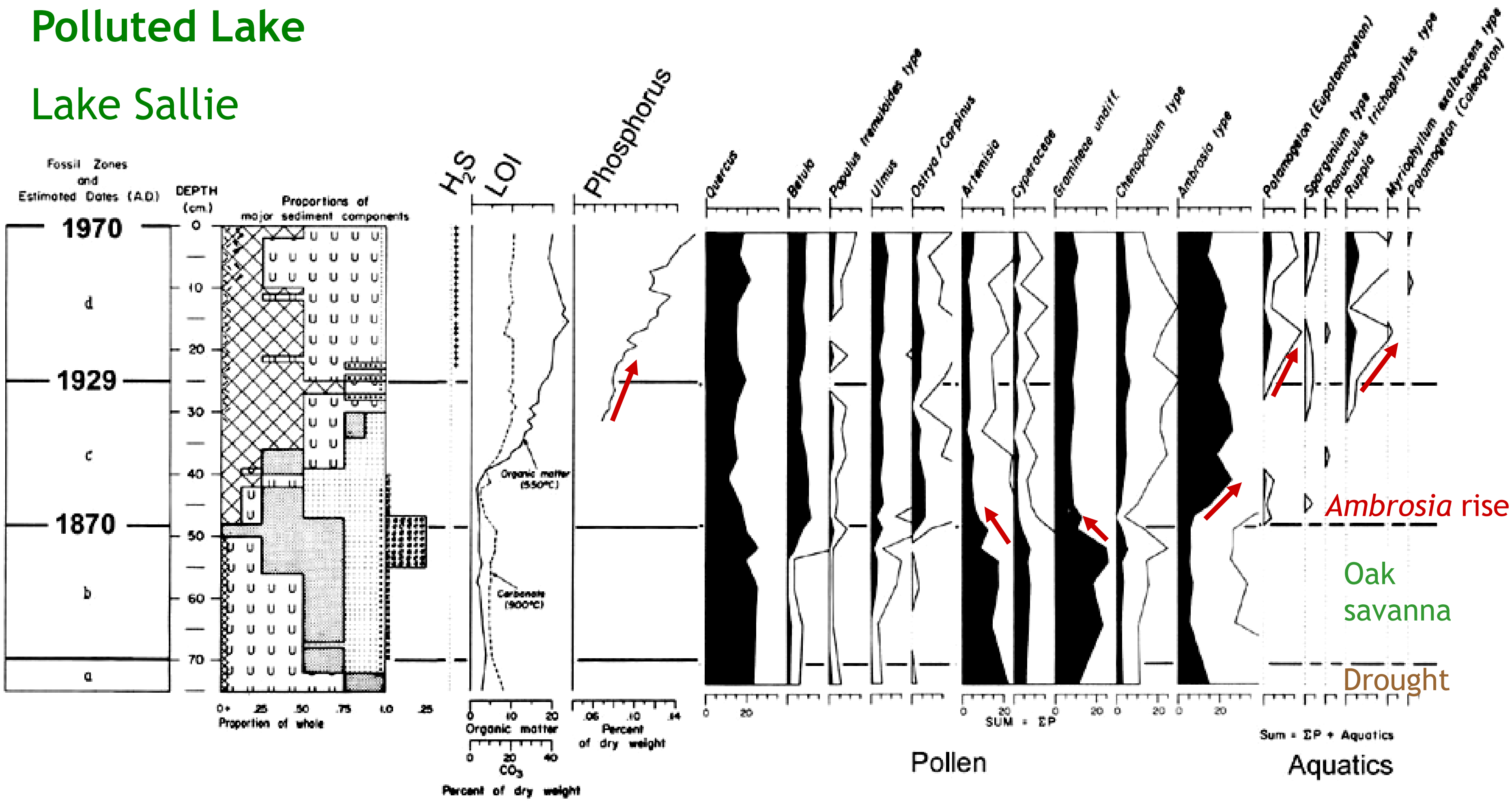
Elk Lake



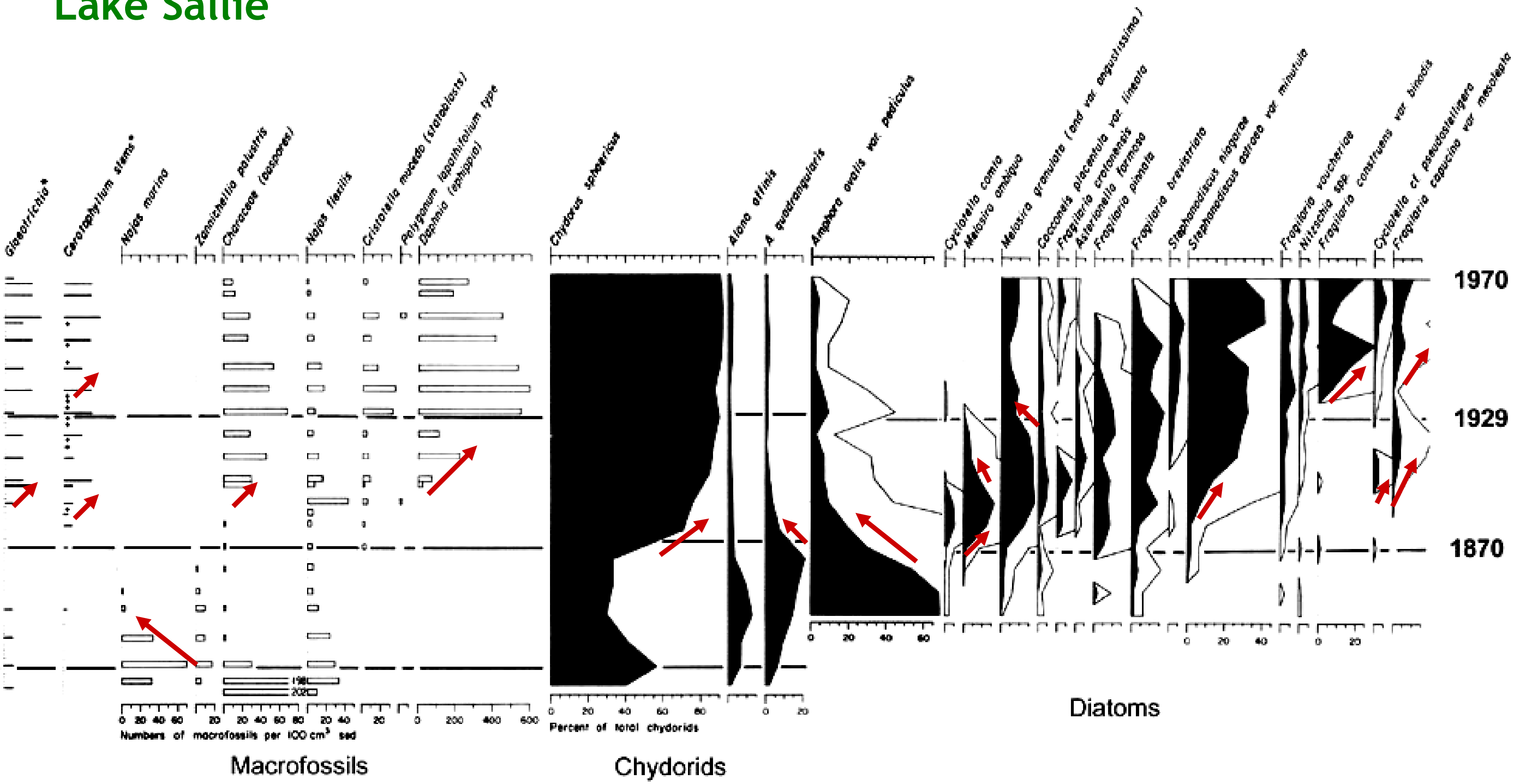
Birks *et al.* (1976)

Polluted Lake

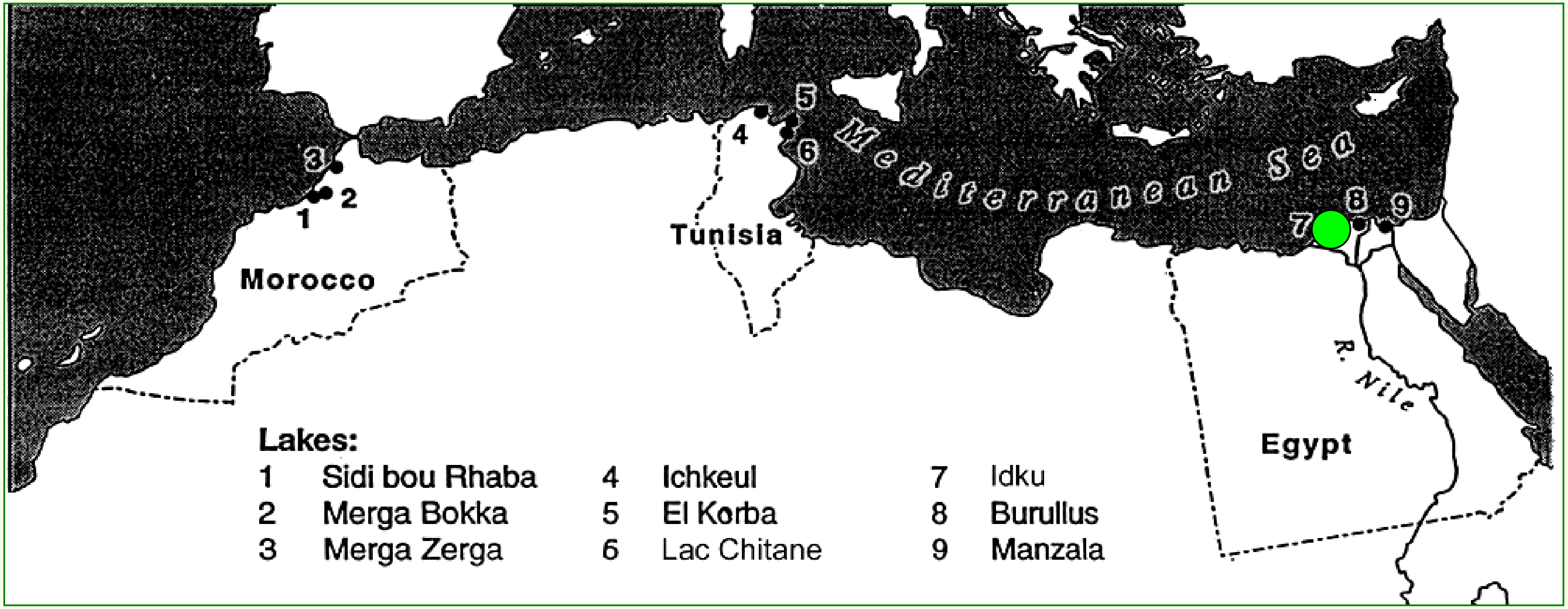
Lake Sallie



Lake Sallie



Gloeotrichia*
Ceratophyllum stems*
Najas marina
Zannichellia palustris
Characeae (oospores)
Najas flexilis
Cristatella mucedo (statoblasts)
Polygonum lapathifolium type
Daphnia (ephippia)
Chydorus sphaericus
Alona affinis
A. quadrangularis
Amphora ovalis var. pediculus
Cyclotella comta
Melosira ambigua
Melosira granulata (and var. angustissima)
Cocconeis placentula var. lineata
Fragilaria crotonensis
Asterionella formosa
Fragilaria pinnata
Fragilaria brevistriata
Stephanodiscus niagarae
Stephanodiscus astraea var. minutula
Fragilaria vaucheriae
Nitzschia spp.
Fragilaria construens var. binodis
Cyclotella cf. pseudostelligera
Fragilaria capucina var. mesolepta
1970
1929
1870
Numbers of macrofossils per 100 cm³ sed
Percent of total chydorids
Macrofossils
Chydorids
Diatoms

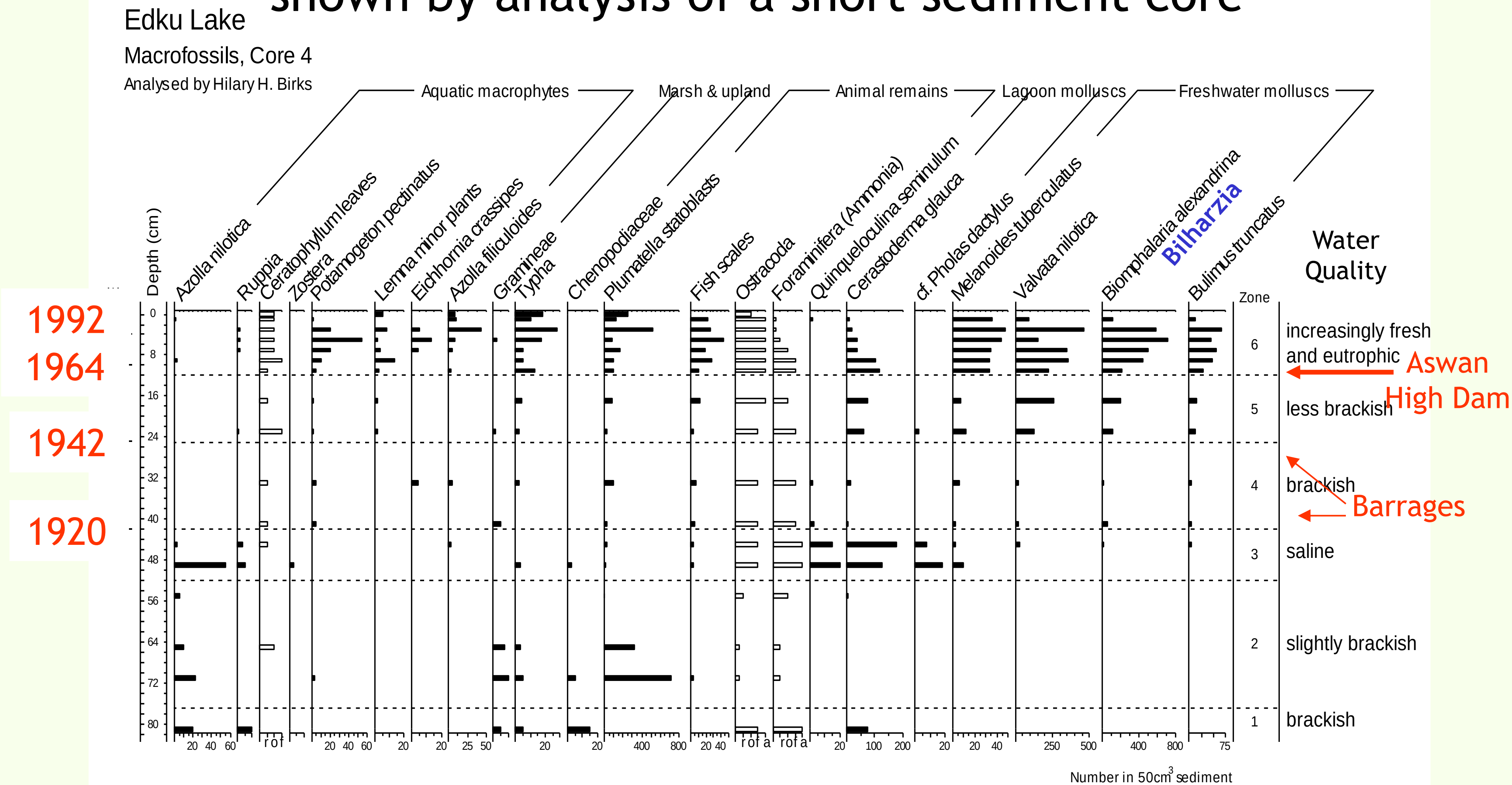


CASSARINA Project - Change, Stress and Sustainability:
Aquatic Ecosystem Resilience in North Africa

Birks et al. 2001, Birks & Birks 2001

How fast can aquatic plant communities change?

Aquatic vegetation changes in Nile Delta over last 100 years shown by analysis of a short sediment core



Late-Glacial Multidisciplinary Studies

Pine Ridge Pond, SE Canada

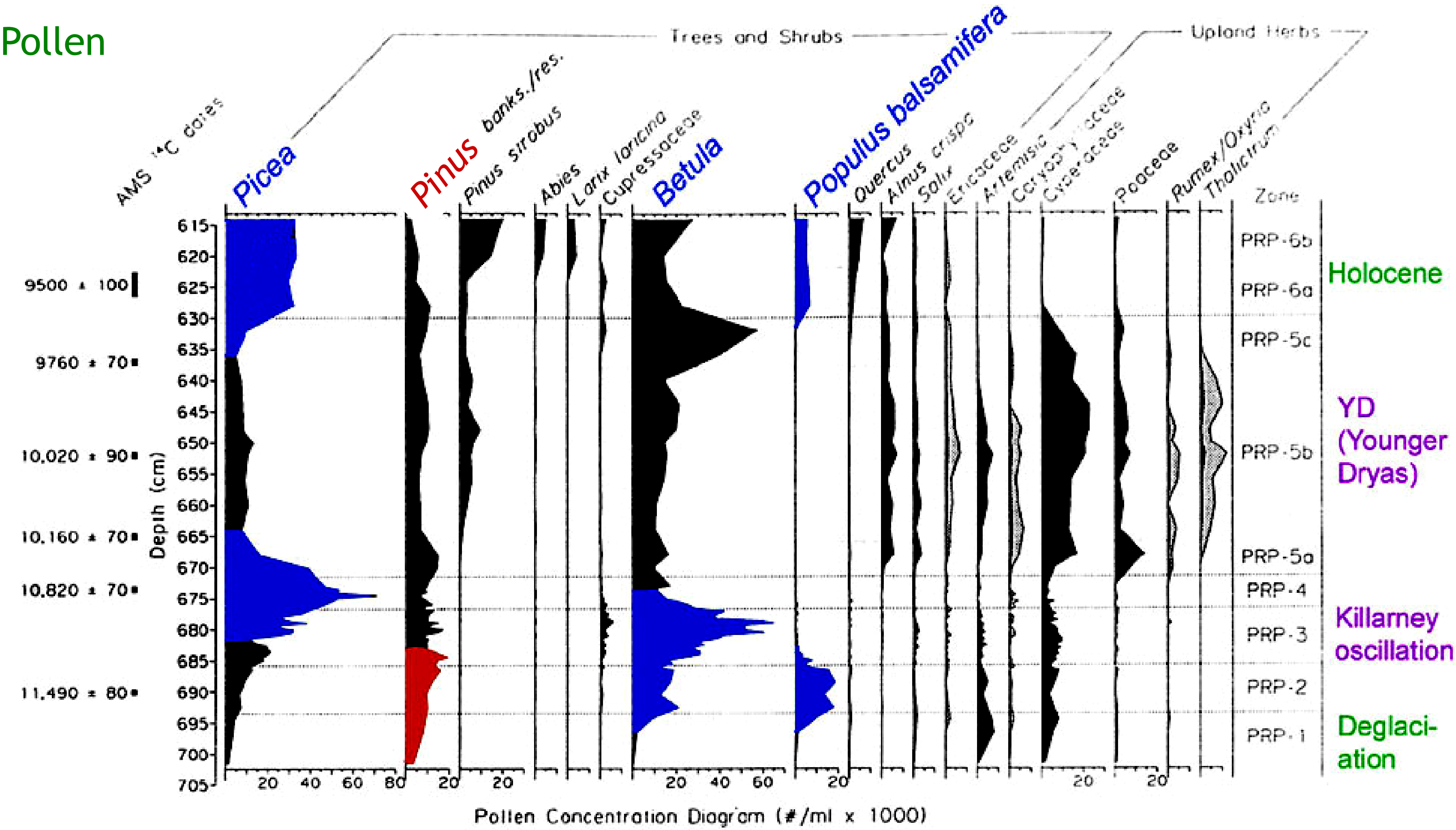
Core from Pine Ridge Pond

KO

YD AL bottom

Levesque *et al.* (1994)

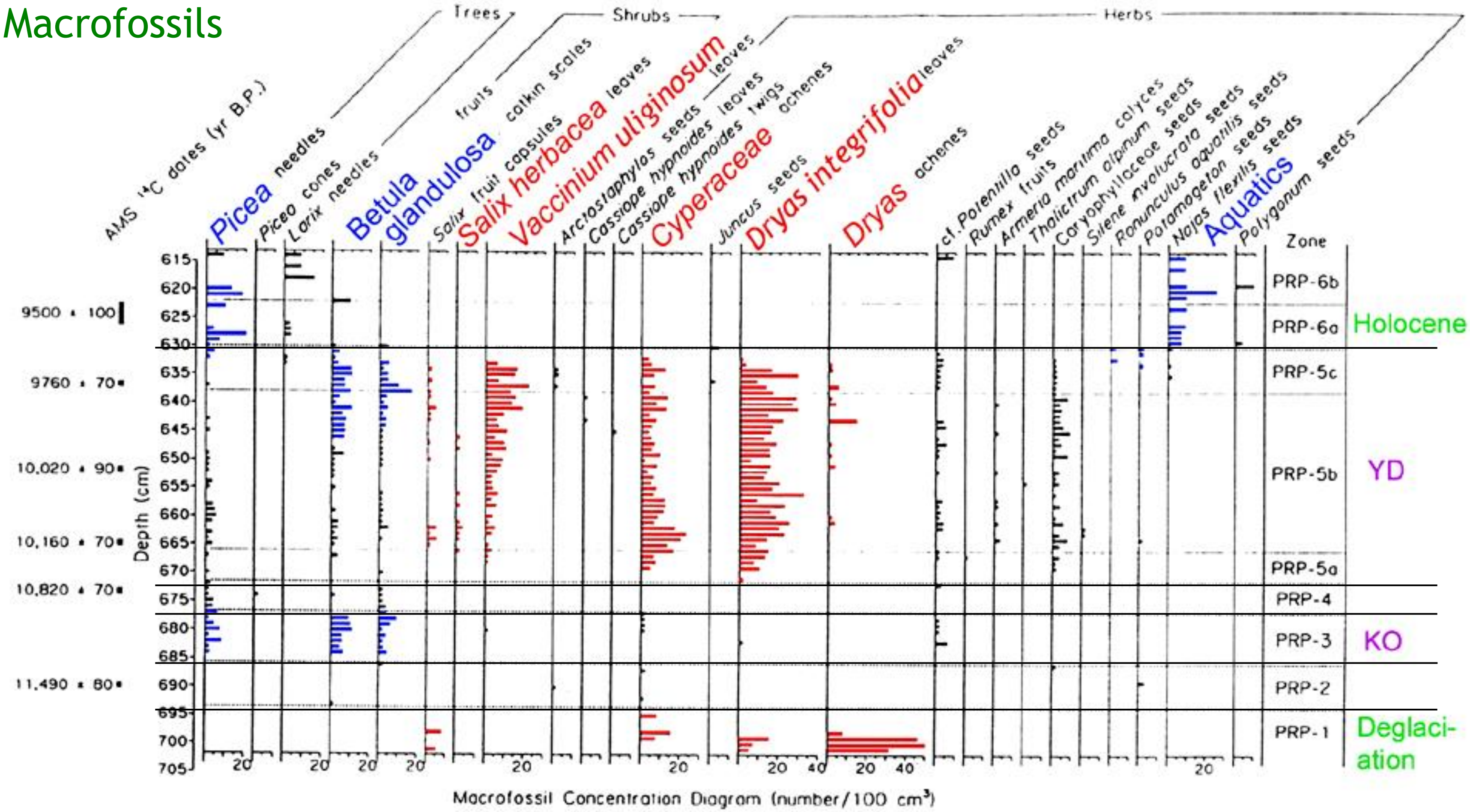
Pollen



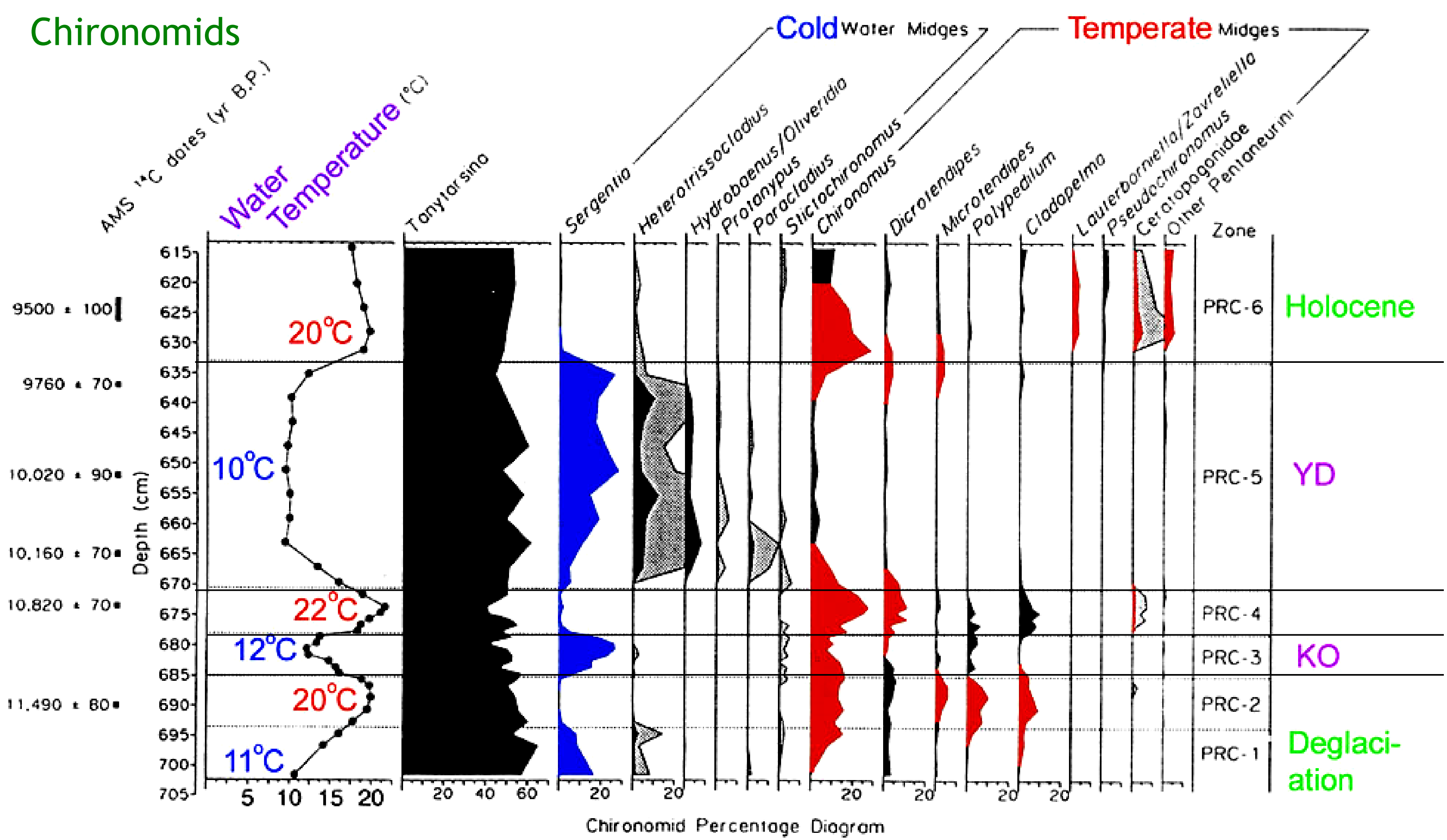
Trees and Shrubs
Upland Herbs
AMS 14C dates
Picea
Pinus
Pinus banks./res.
Pinus strobus
Abies
Larix laricina
Cupressaceae
Betula
Populus balsamifera
Quercus
Alnus crispa
Salix
Ericaceae
Artemisia
Caryophyllaceae
Cyperaceae
Poaceae
Rumex/Oxyria
Thalictrum
Zone
9500 ± 100
9760 ± 70
10,020 ± 90
10,160 ± 70
10,820 ± 70
11,490 ± 80
Depth (cm)
615
620
625
630
635
640
645
650
655
660
665
670
675
680
685
690
695
700
705
PRP-6b
PRP-6a
PRP-5c
PRP-5b
PRP-5a
PRP-4
PRP-3
PRP-2
PRP-1
Holocene
YD (Younger Dryas)
Killarney oscillation
Deglaci-ation
20
40
60
80
Pollen Concentration Diagram (#/ml x 1000)

Pine Ridge Pond

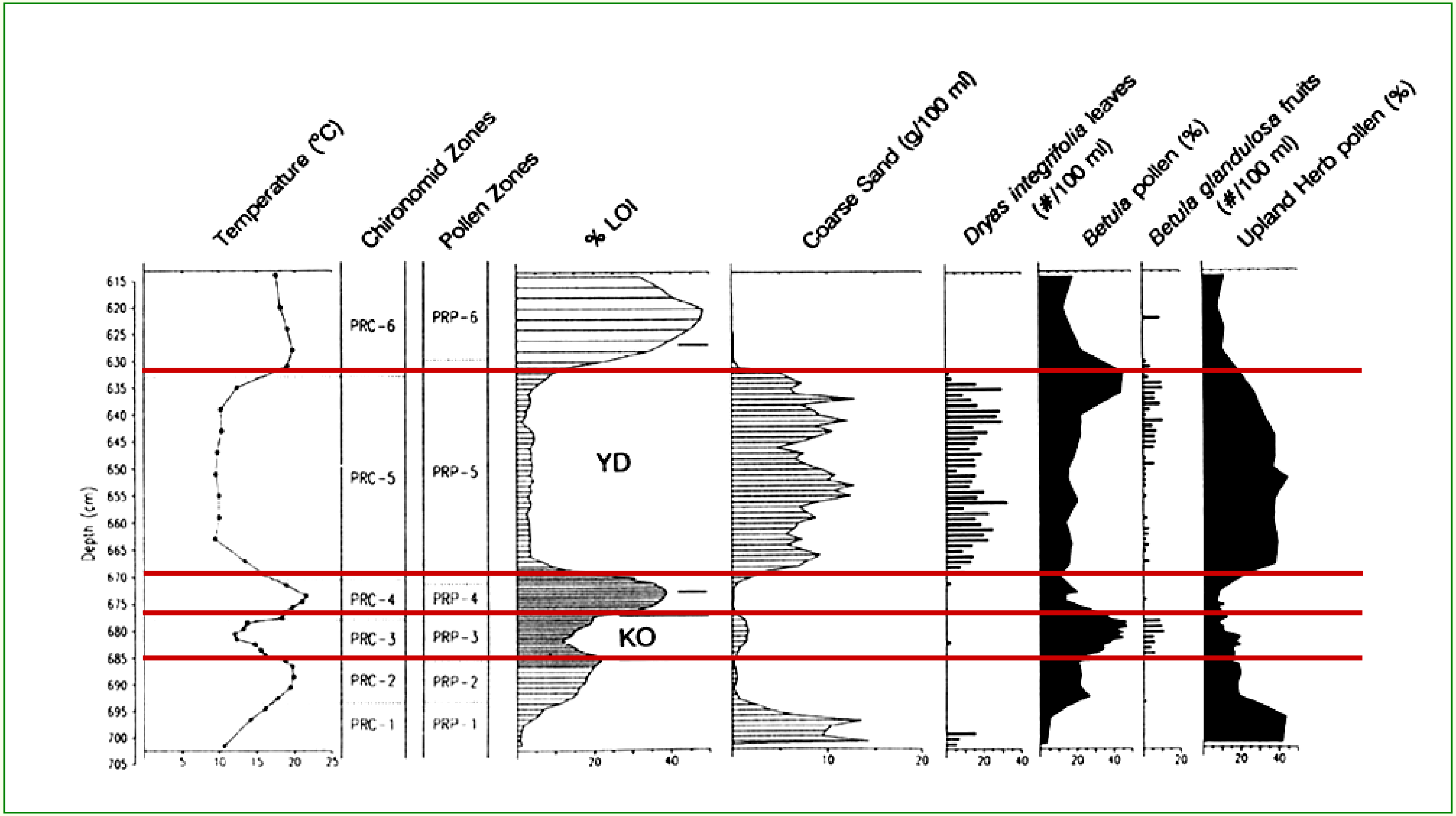
Macrofossils



Pine Ridge Pond



Pine Ridge Pond, Summary



Summary diagram displaying the synchronicity of changes in the various proxy records. KO: Killarney Oscillation, YD: Younger Dryas.

Levesque *et al.* (1994)

The Kråkenes Project

Late-glacial and Early Holocene environment and ecosystem reconstructions –

a multiproxy study

Kråkenes Project

multiproxy project focussed on late-glacial changes in the terrestrial and aquatic ecosystems

Kråkenes Project

multiproxy project focussed on late-glacial changes in the terrestrial and aquatic ecosystems

proxies represent different spatial scales

Terrestrial ecosystem

Scales: local lake shore, the catchment, the region

plants:

pollen (local, catchment, region)
macrofossils and mosses (local, catchment)

animals:

Oribatid mites (local, catchment)
beetles (Coleoptera) (local, catchment)0

Aquatic ecosystem – the lake itself, streams

plants:

pollen, macrofossils, mosses, diatoms, green algae

animals:

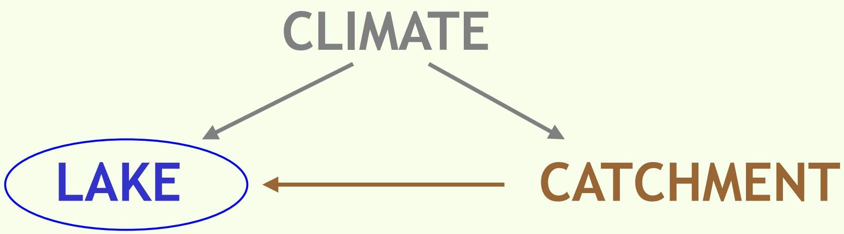
chironomids, oribatid mites, beetles, cladocera, trichoptera, bryozoa

KRÅKENES PROJECT

Special issue - Journal of Paleolimnology 23 (1) (2000)

Late-Glacial and Early-Holocene Ecosystem Reconstructions at Kråkenes

Consider the ecosystem



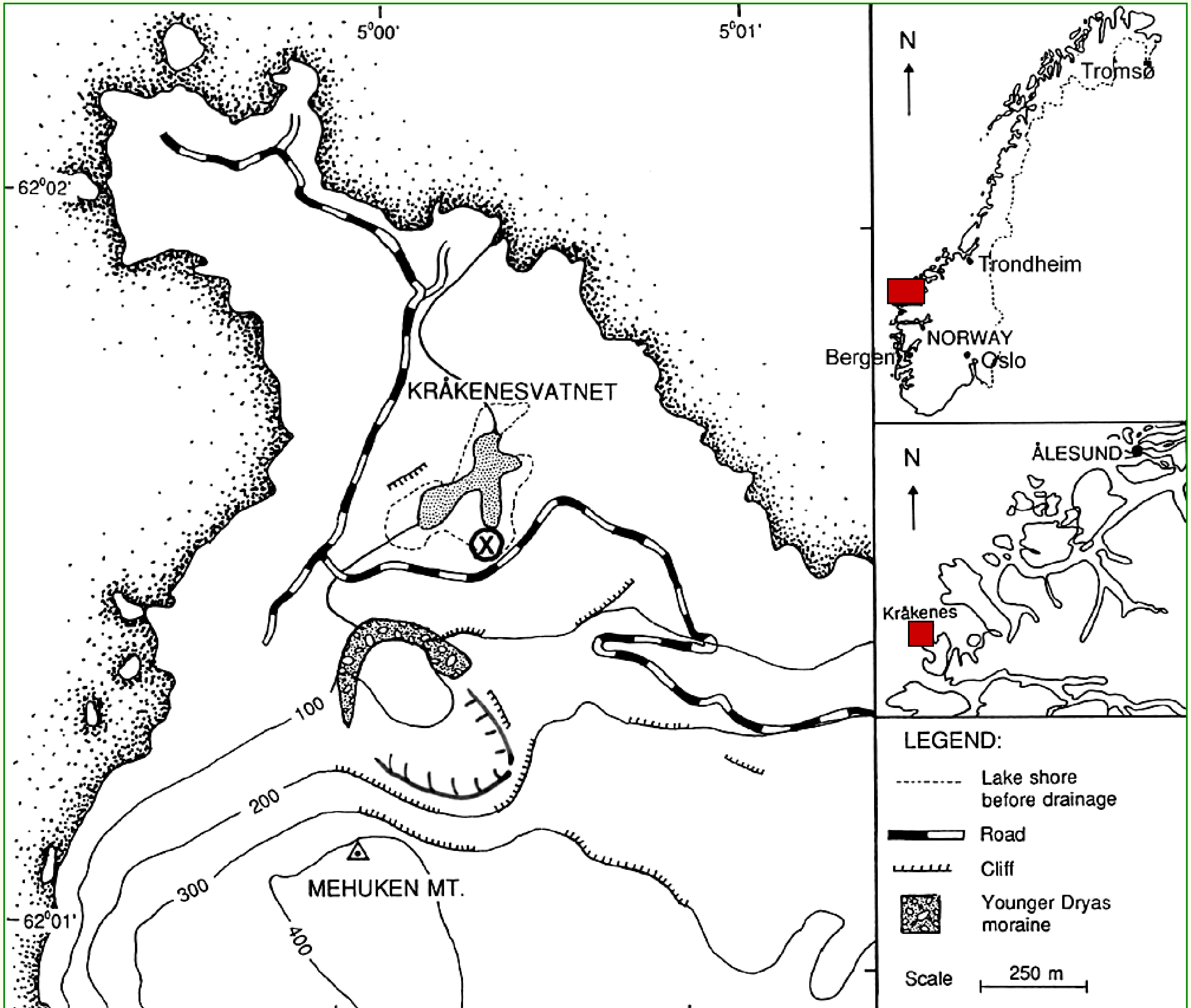
Multi-disciplinary study

- Chronology
- palaeoenvironmental reconstructions
  - terrestrial organisms
  - aquatic organisms
- climate reconstructions

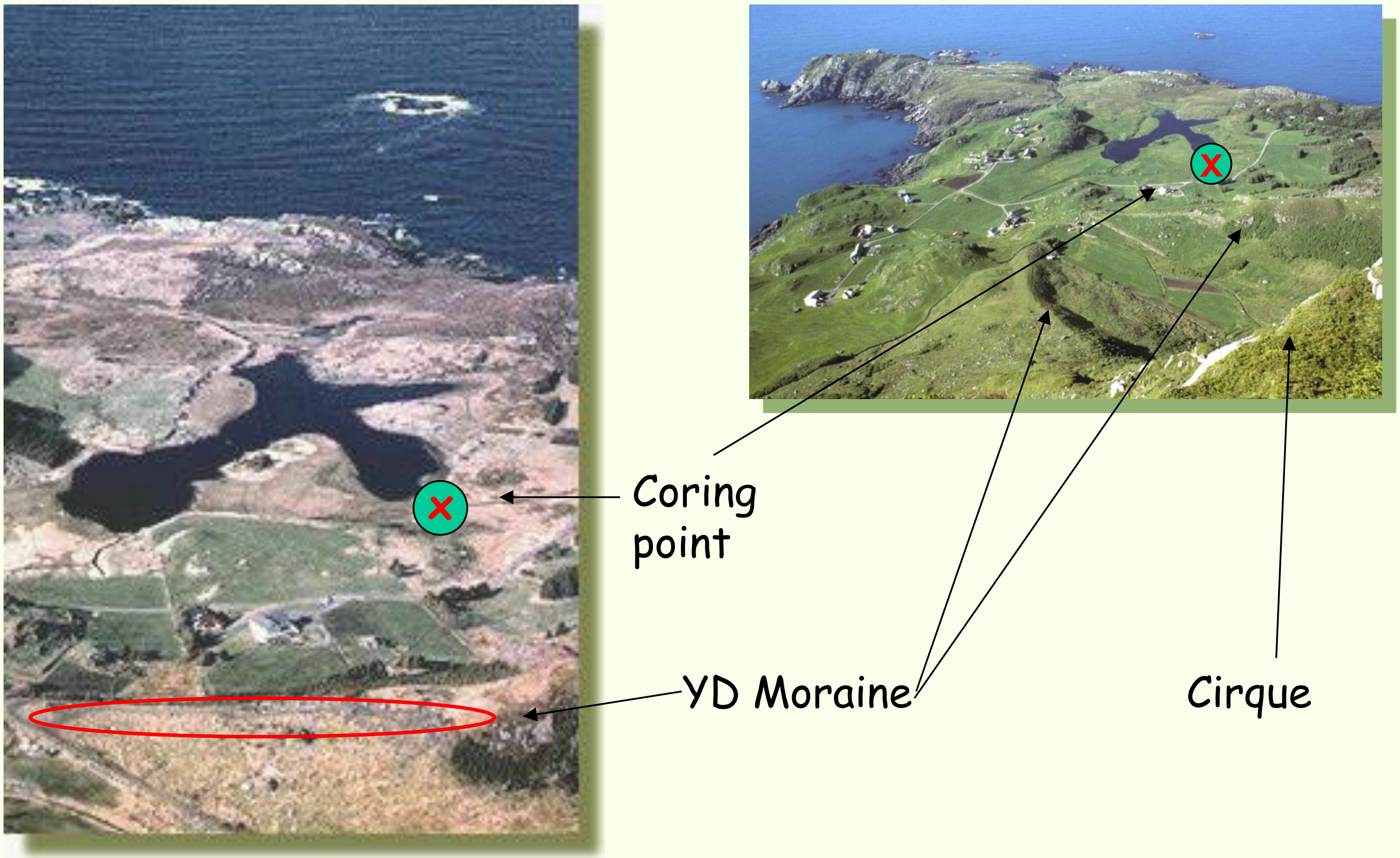
Numerical analyses (tools)

- DCA
- rate-of-change
- climate reconstruction

Kråkenes Lake, W Norway



Kråkenes Lake
from Mehuken Mountain

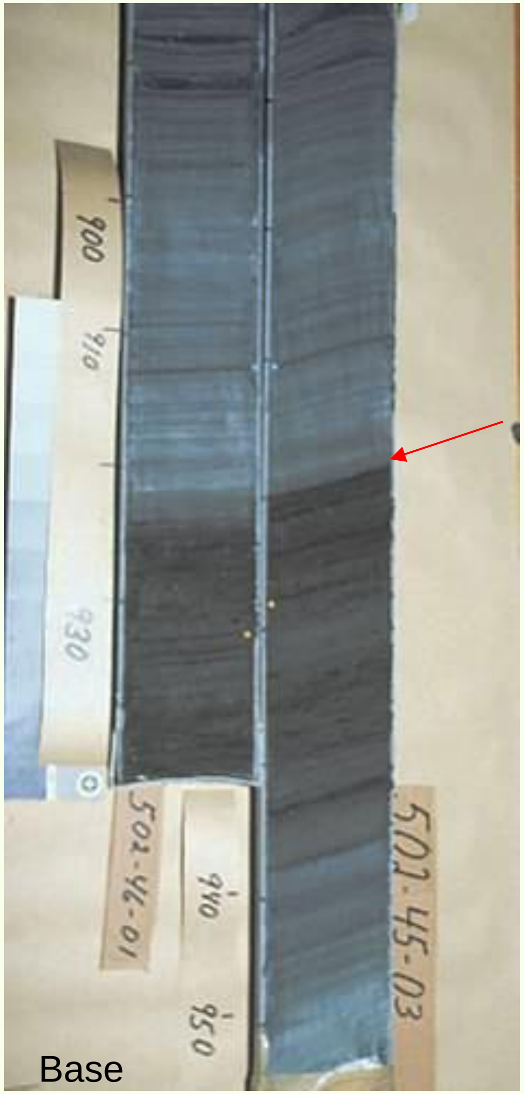


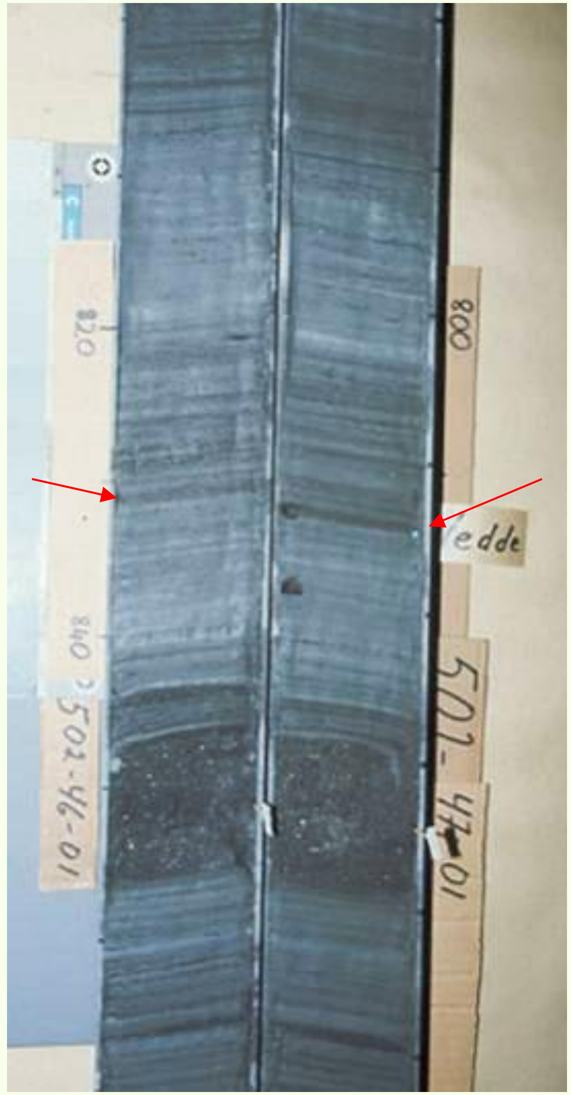
Kråkenes Lake and cirque with YD moraine in Mehuken Mountain behind

moraine

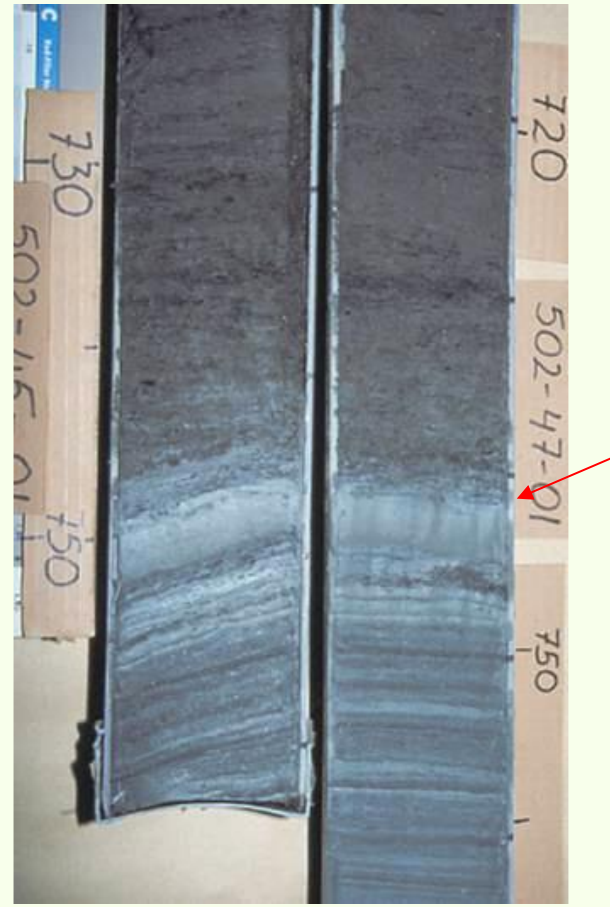
Coring

Kråkenes Cores Late glacial is 2 metres long



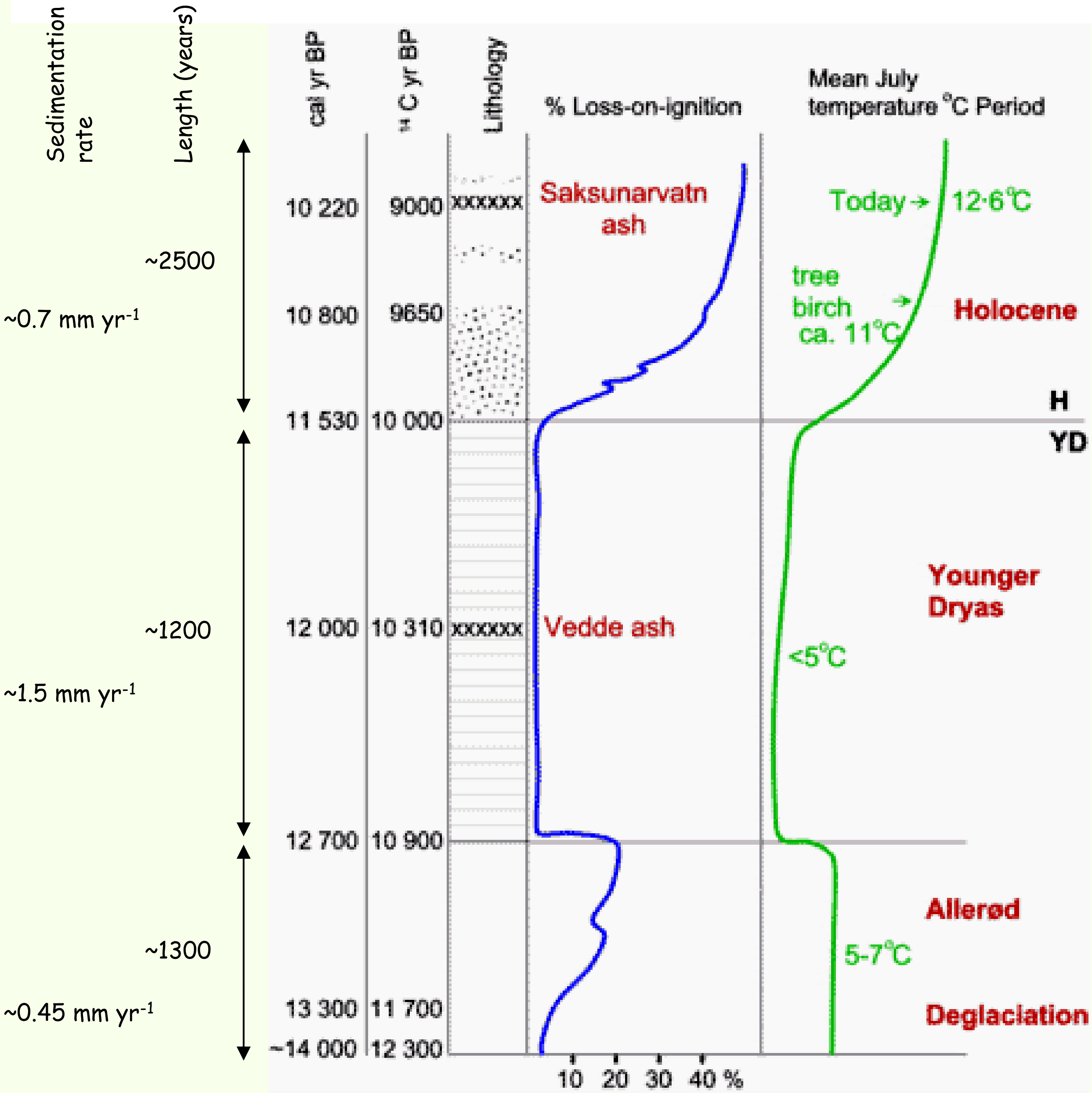


Top



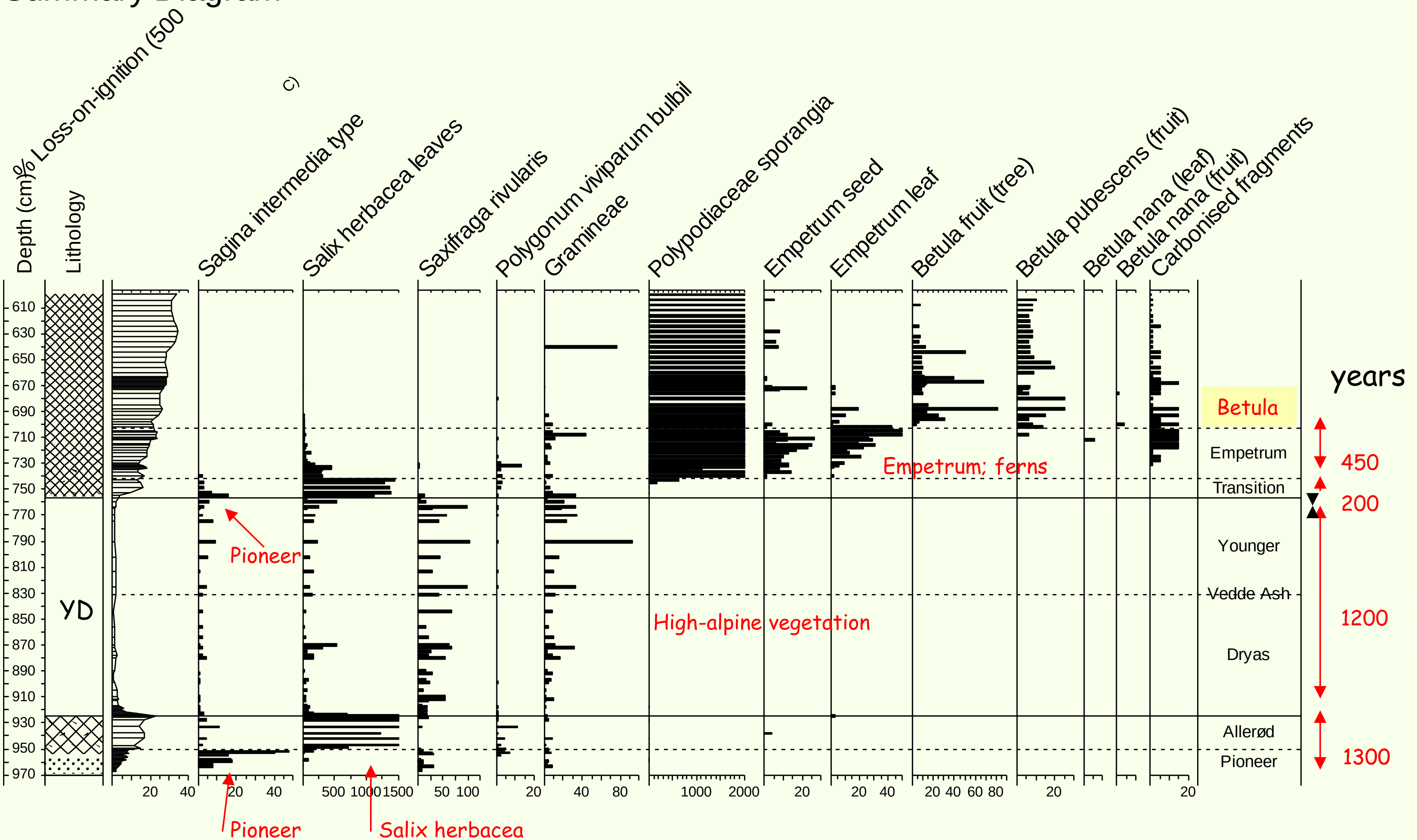
Allerød/Younger Dryas → Mid Younger Dryas with Vedde Ash → Younger Dryas/Holocene boundary

Overview of the late-glacial at Kråkenes

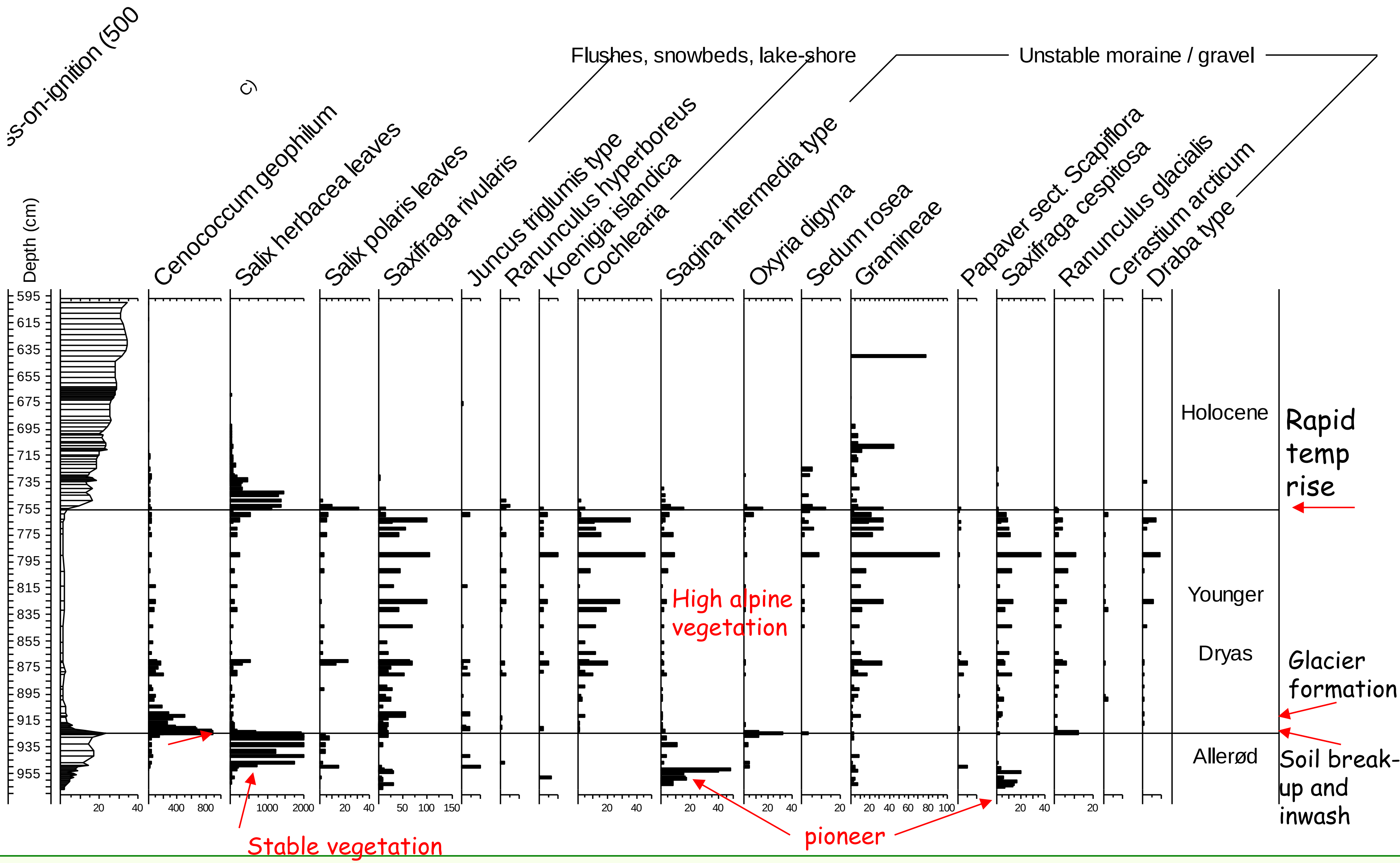


Terrestrial Ecosystem: Macrofossil Data

Kråkenes Terrestrial Macrofossils
Summary Diagram



Kråkenes macrofossils, Allerød and Younger Dryas



The Allerød landscape

Snow beds

Salix herbacea

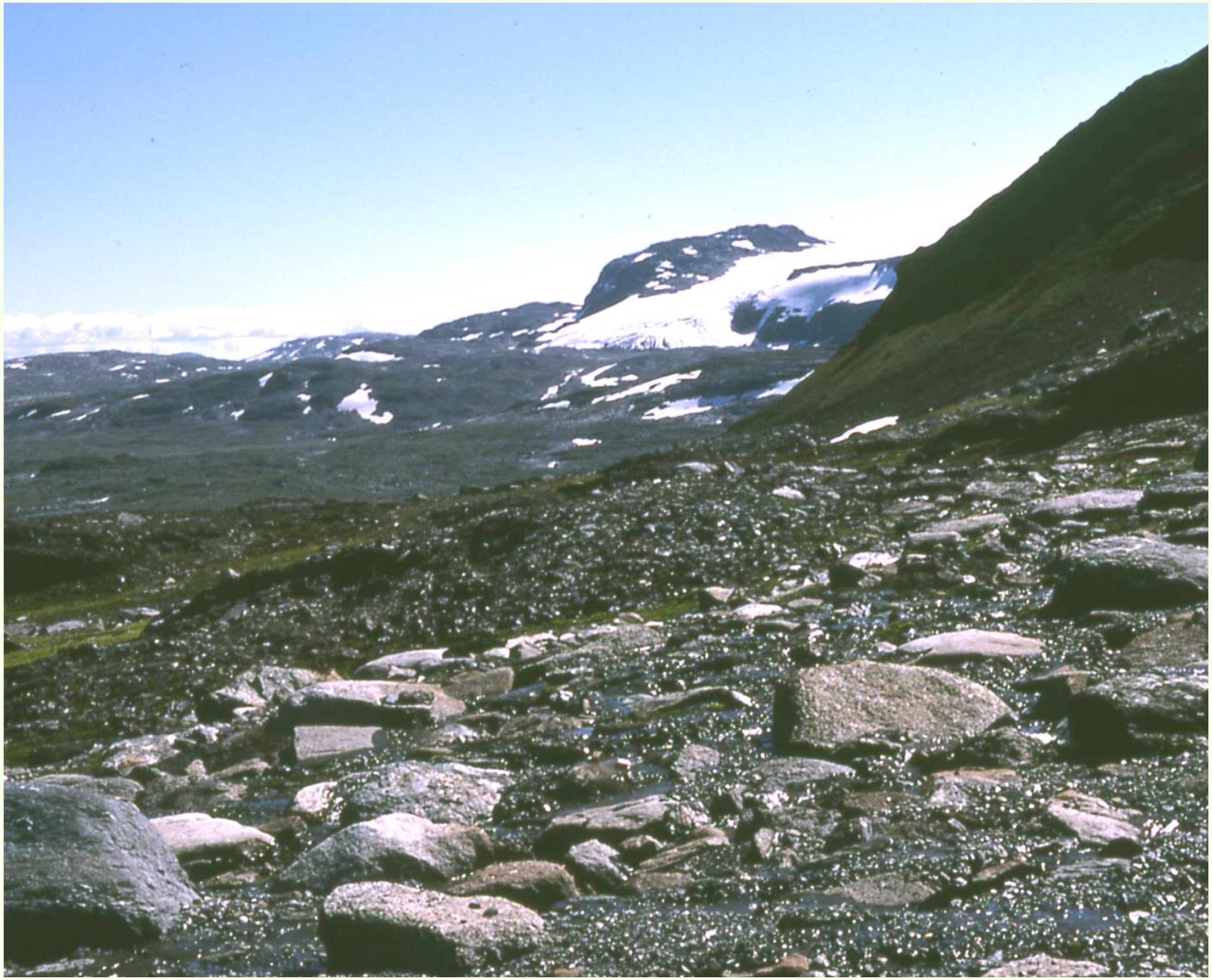
Dry stoney soils

Empetrum (krekling), pioneer herbs and grasses

Wet areas (snow-melt)

Low Salix shrubs, Carex, grasses, herbs

The Younger Dryas landscape



Glacier

Dry open soils

Pioneer herbs, e.g. Sagina, Papaver, mosses.

Salix herbacea snow-beds

Wet soils (snow-melt)

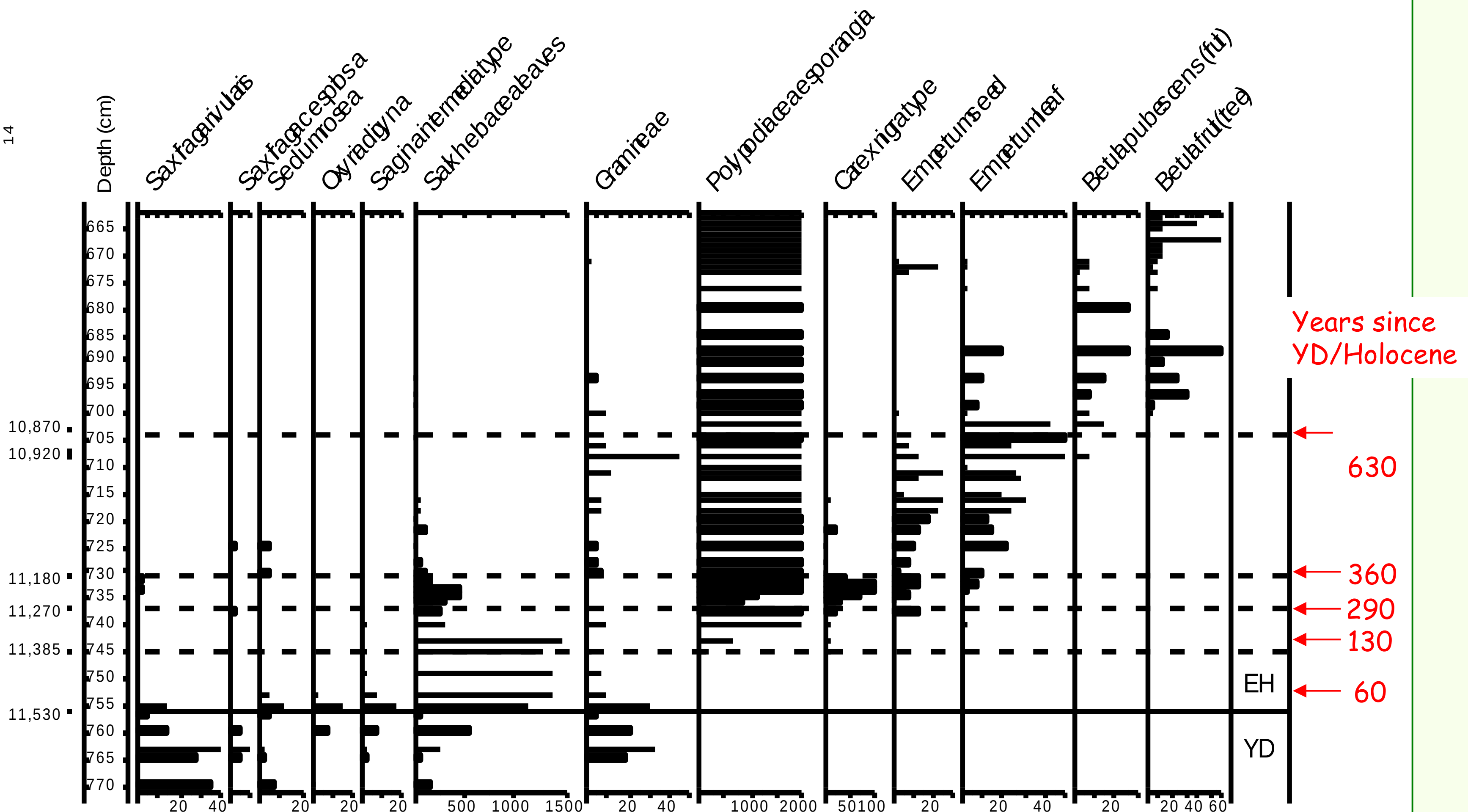
Saxifraga, Ranunculus glacialis, Koenigia

Detail of transition into the Holocene

Kråkenes YD/Holocene

Selected plant macrofossil taxa

Analysed by Hilary H. Birks



See Birks HJB & Birks HH (2008). Biological responses to rapid climate changes at the Younger Dryas-Holocene transition at Kråkenes, western Norway. The Holocene 18: 19-30

The Early Holocene landscape

Pioneer succession on recent moraines

Empetrum heath on dry soils; Salix shrubs with ferns on damp soils

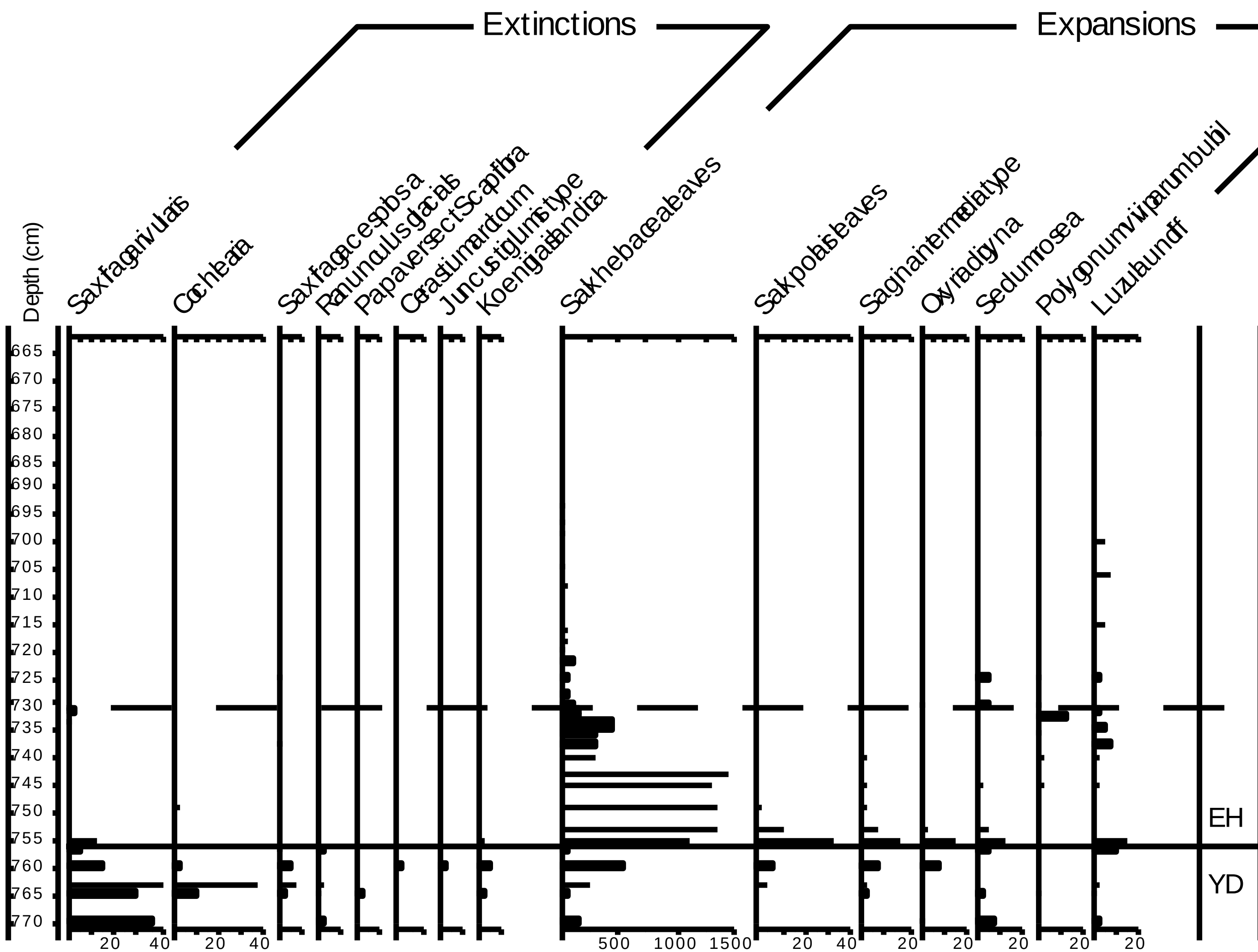
Tree Betula

Berdalsbreen, Norway

Kråkenes YD/Holocene

Impact of Holocene on YD plants

Species dynamics driven by temperature rise



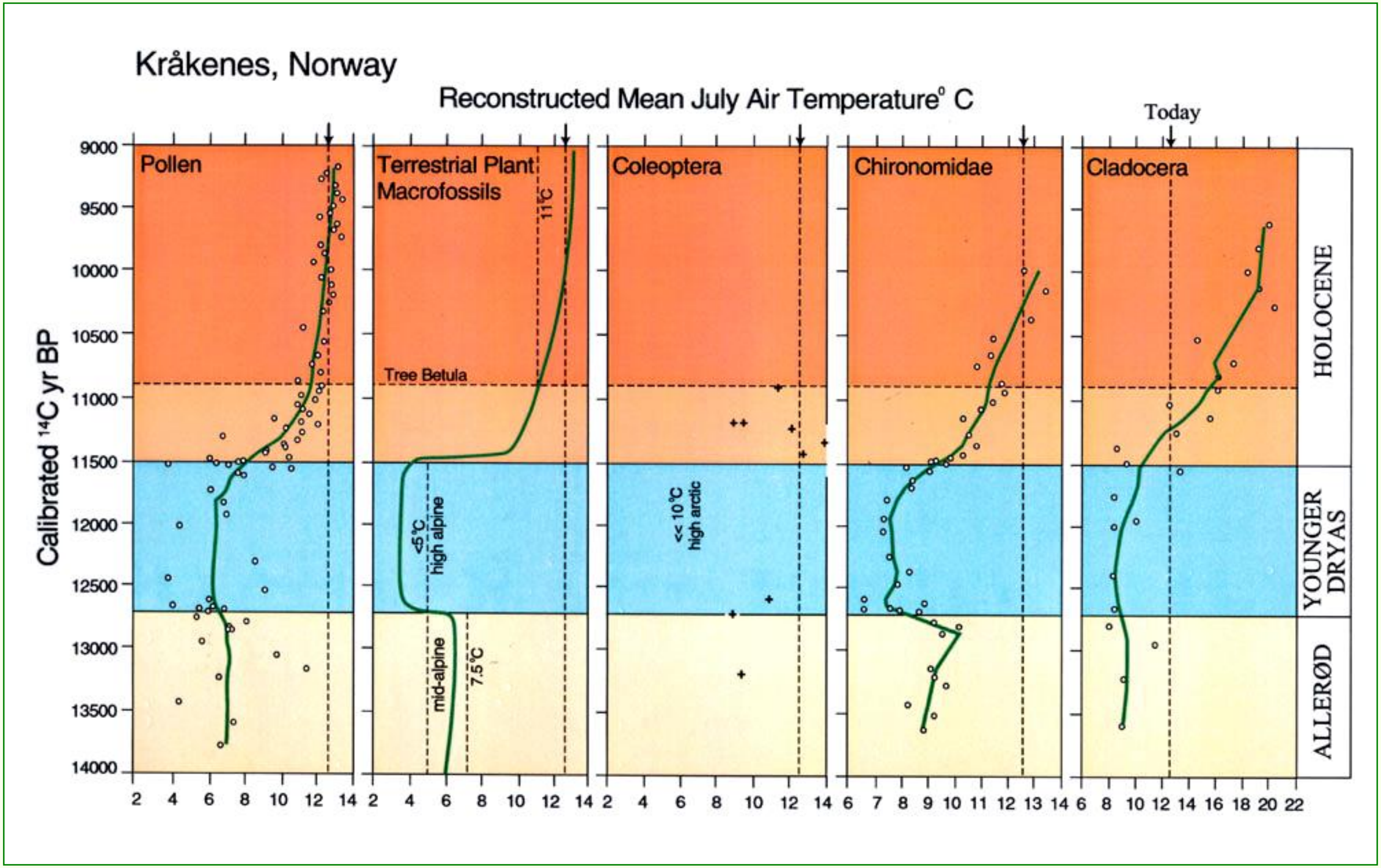
How fast?

350 years

competition

60 years

temperature



Birks & Ammann (2000)

Rates of temperature change

	Mean AL °C	Al – YD drop	Rate per 25 yr	Mean YD °C	Incr. in Hol 500 yr	Rate per 25 yr
Pollen	7	1°C	0.7°C	6	6°C	0.3°C
Chironomids	9-10	1.5-2.5°C	0.7°C	7.5	3.5°C	0.2°C
Cladocera	9	1°C		8	6°C	0.3°C
Macrofossils	~6	1°C	~1°C	<5	6°C	0.3°C
Coleoptera	9.6	~2°C		<<10	~5°C	

Kråkenes paper in Nature Geoscience: uses the plant record in the reconstruction of atmospheric circulation changes through the YD

'Rapid oceanic and atmospheric changes during the Younger Dryas cold period'

Bakke, J., Lie, Ø., Heegaard, E., Dokken T., Haug, G.H., Birks, H.H., Dulski, P., Nilsen, T. (2009).