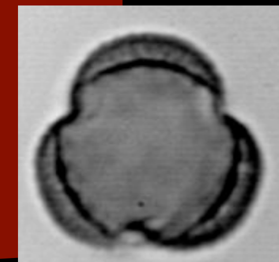
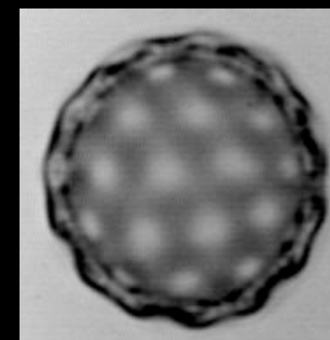
# Palynology:
## A brief introduction

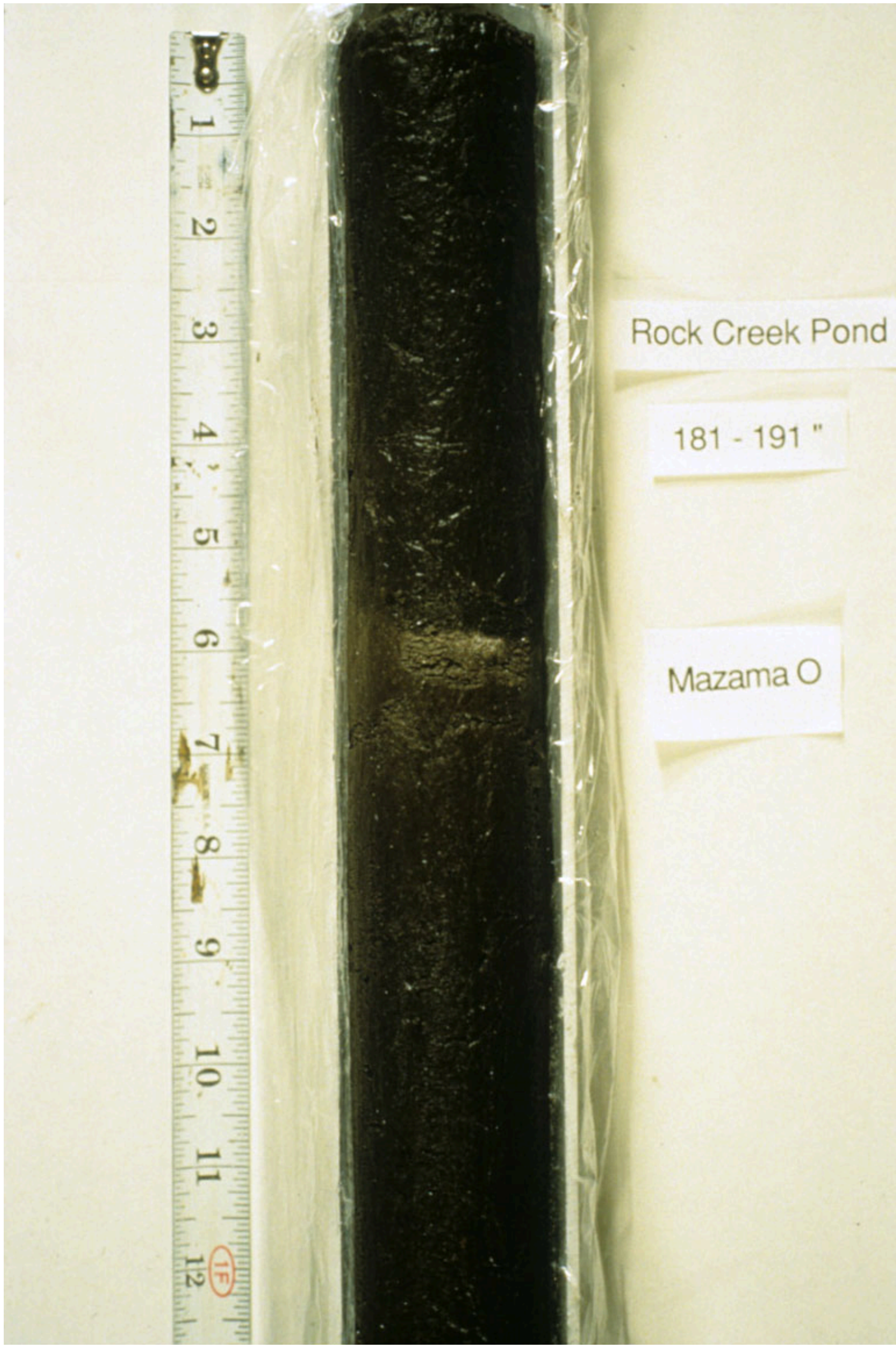




- Why are pollen grains and spores valuable indicators of past conditions?
  - Preservation due to structural chemistry
    - Exine is chemically resistant – prevents degradation within anoxic environments.
  - Abundance in sediments
  - Transportation/dispersion
  - Recognition and identification – usually only to family or genus level

Extracting sediment cores from smaller lakes or ponds, such as Rock Creek Lake Sierra Nevada, California, will provide a local record of vegetation change.

Coring Rock Creek pond Sierra Nevada with a hand-driven Livingston piston corer. A 10 meter record was extracted, dating back 12,000 yr B.P.



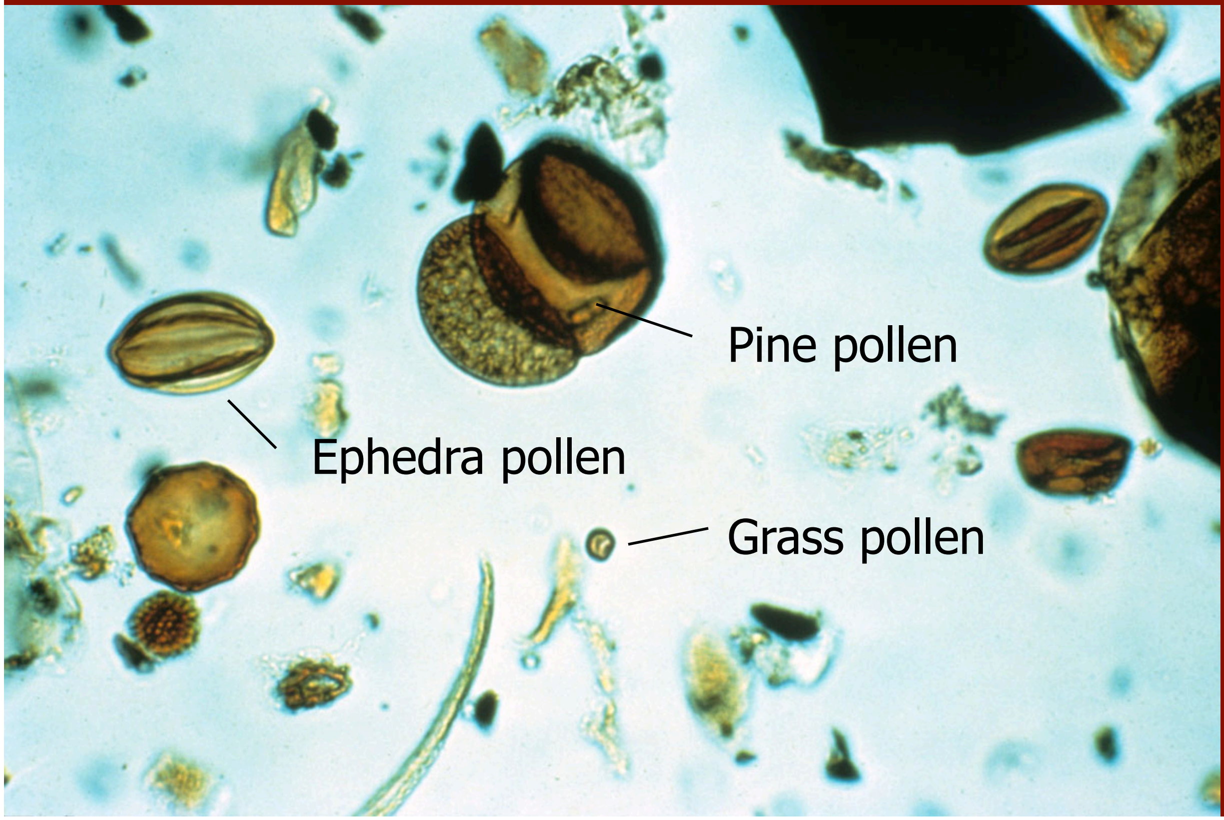

Sediment cores extracted from lacustrine or bog environments provide a wealth of paleo-ecological and chronological data.

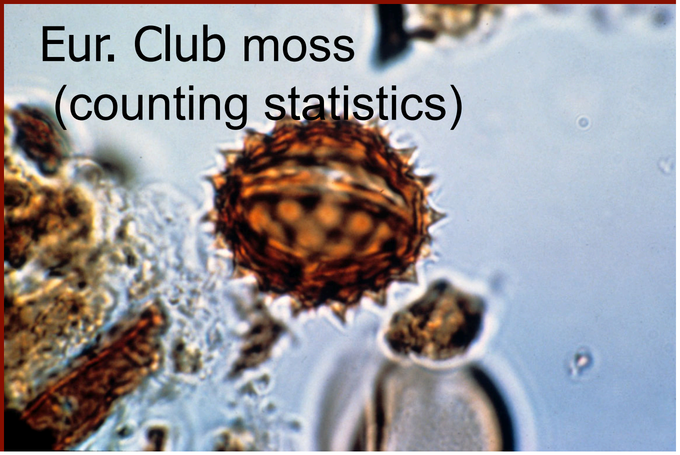
Chronology is typically provided by $^{14}C$ dating of organic matter (dark coloration) collected from sediment records that are yonger than 45,000 years. Macro-fossils, such as seeds or other plant parts provide the most reliable ages.

Many cores extracted from bogs, lakes or ponds within the Cascades or Sierra Nevada also contain tephra layers that have been independently dated (e.g., Mazma O layer is dated at 6800 yr B.P.).

Fossil pollen is separated from the lacustrine or bog sediment using a series of acid and base washes.  The exine of the pollen grains is resistant to decomposition in extreme acidic or basic solutions.  Silicate minerals and extraneous organic matter are dissolved during this process leaving concentrated pollen samples which can be preserved onto a glass slide for viewing under a standard binocular microscope.

Pollen may be sampled at 1 - 10 cm intervals from sediment cores depending upon sedimentation rate and resolution of the record being measured.  Sedimentation rates in local lakes are typically ~1 mm per year, but will vary depending upon inflow of sediment into the basin.



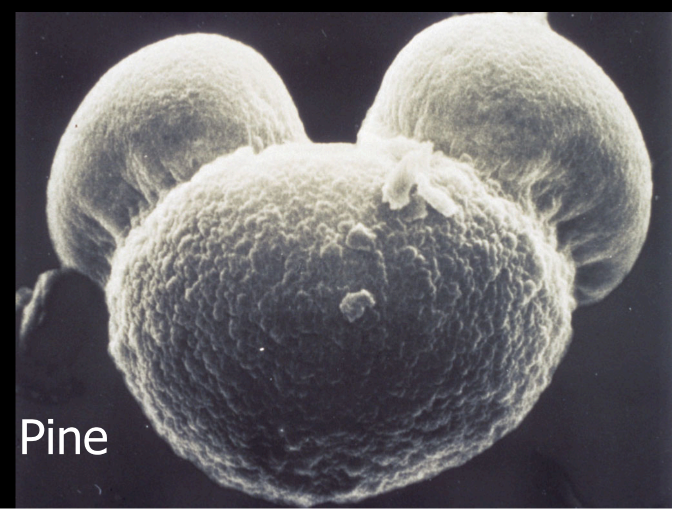



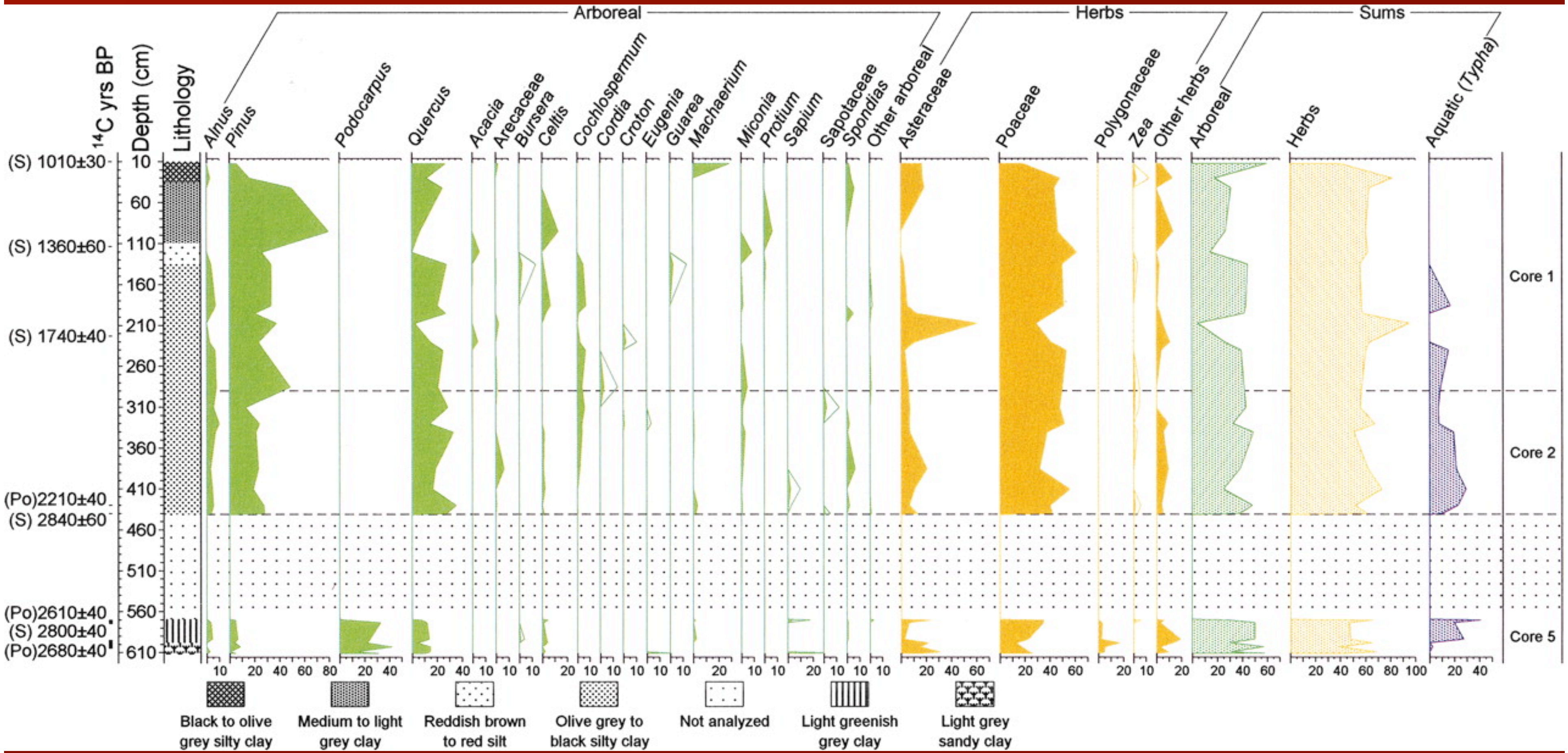
Fossil pollen can be identified at the generic or family taxonomic level.

Scanning Electron Microscope (SEM) images of oak, maple and pine pollen. Note the two bladders of the pine pollen look like "Micky Mouse ears." Because of the these bladders pine pollen is transported greater distances by wind. How might this attribute of pine pollen cause problems when interpreting pollen records.

Individual pollen grains are counted from each sampled interval using a standard binocular microscope (400 X's magnification). Typically 100 to 1000 grains are counted from each sampling interval.

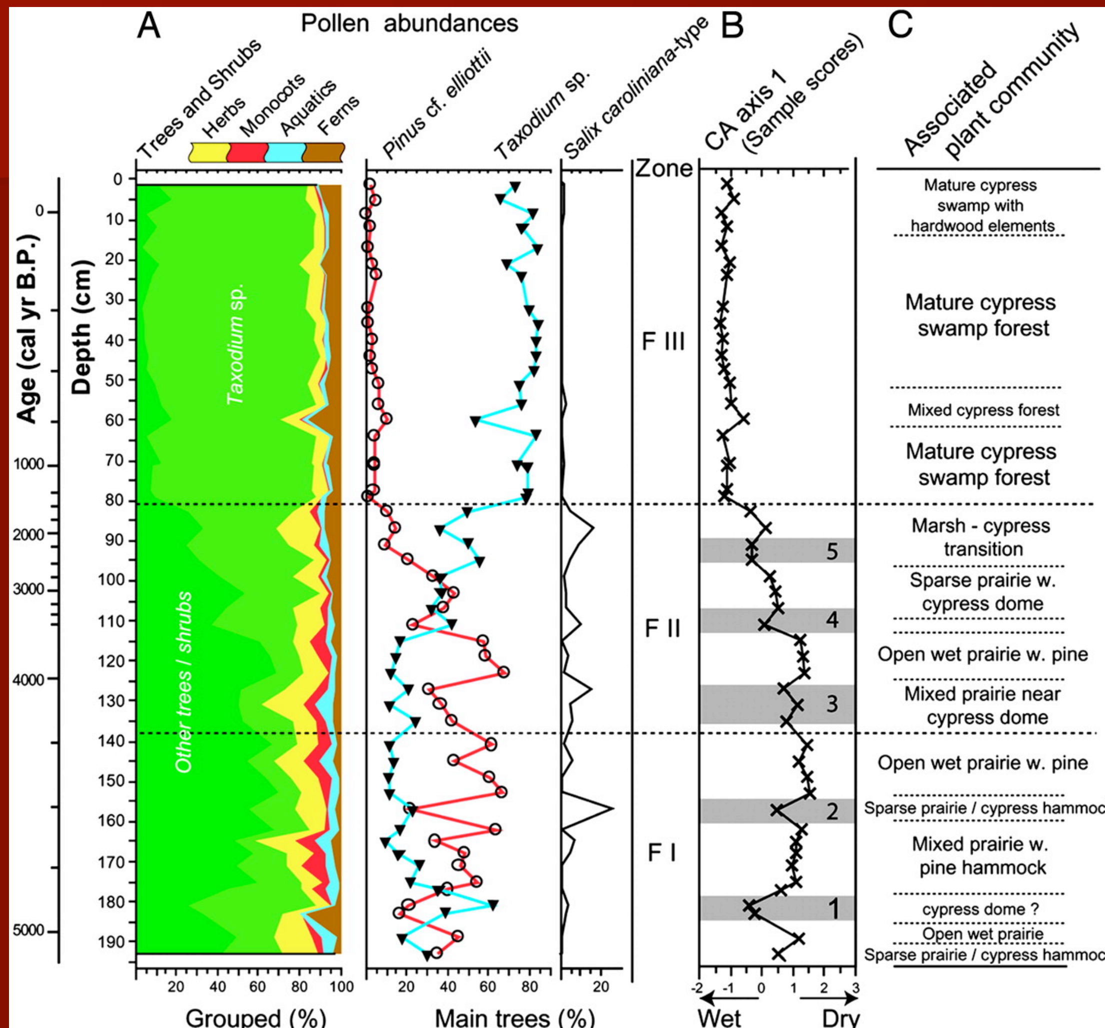







Individual pollen grain counts from each sampling interval are organized within pollen diagrams. Pollen diagrams trypically show pollen counts by relative abundance (%) of arboreal and herbs genera. Chronology is shown vertically with oldest ages on the bottom of the diagram.

# Pollen percentage diagram and reconstructed past vegetation from the FSPSP wetland in Florida




Donders T H et al. PNAS 2005;102:10904-10908

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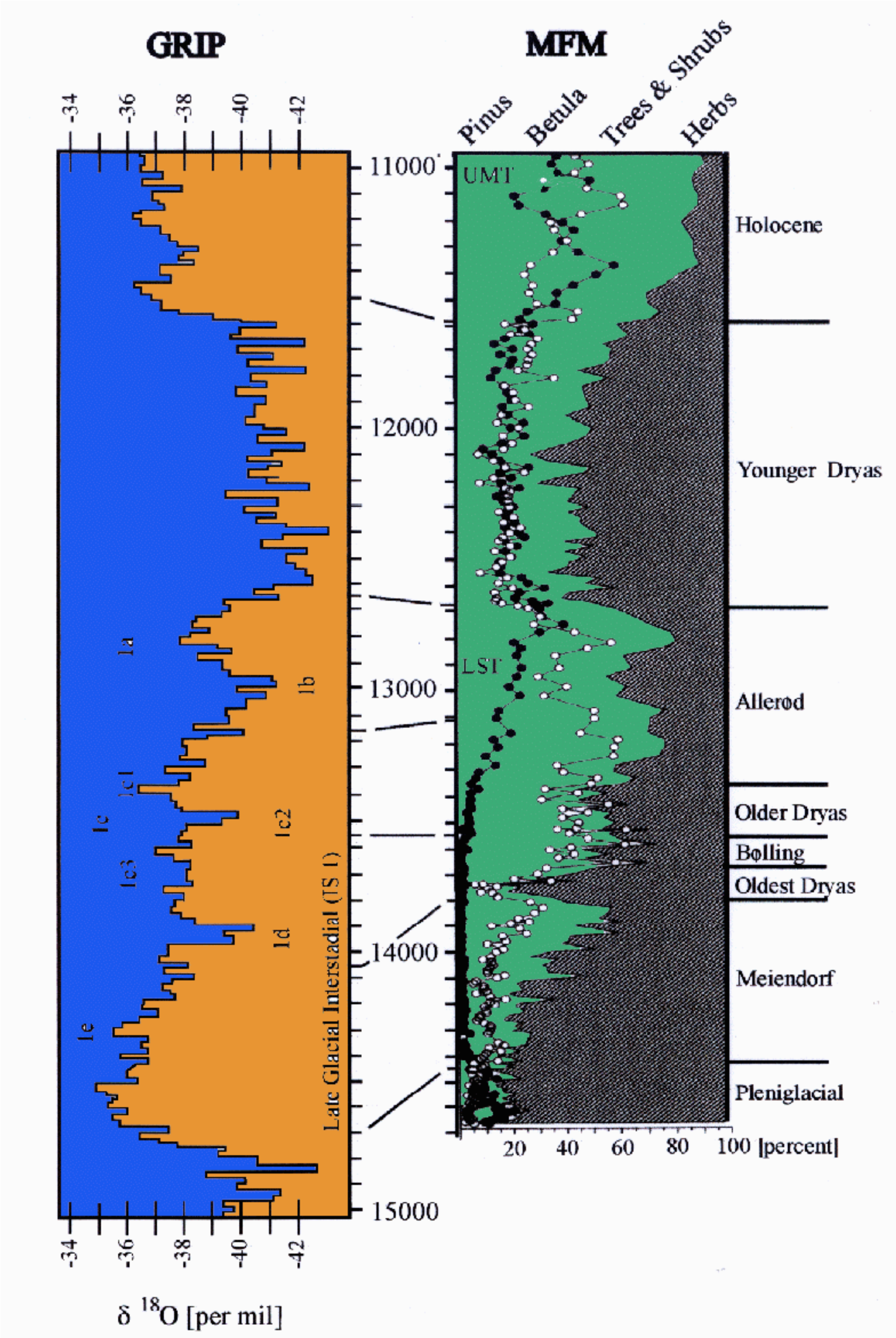
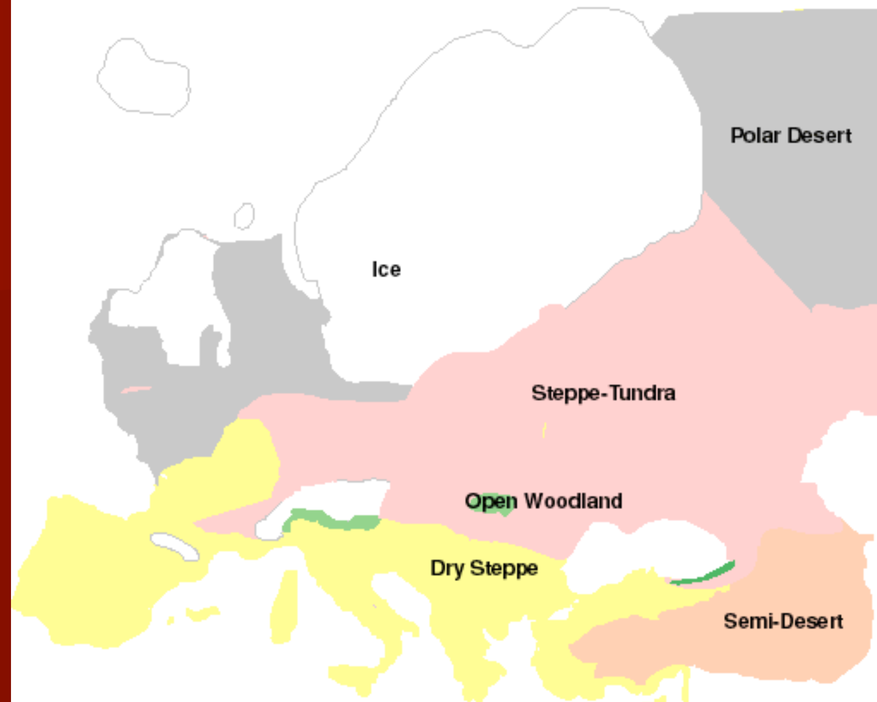



European pollen records are consistent with the Greenland ice core (Grip) record. During the YD interval arctic herbs dominate the pollen record as glacial conditions returned to Europe. The YD interval ended abruptly and warm conditions returned to Europe.

Present Potential Vegetation

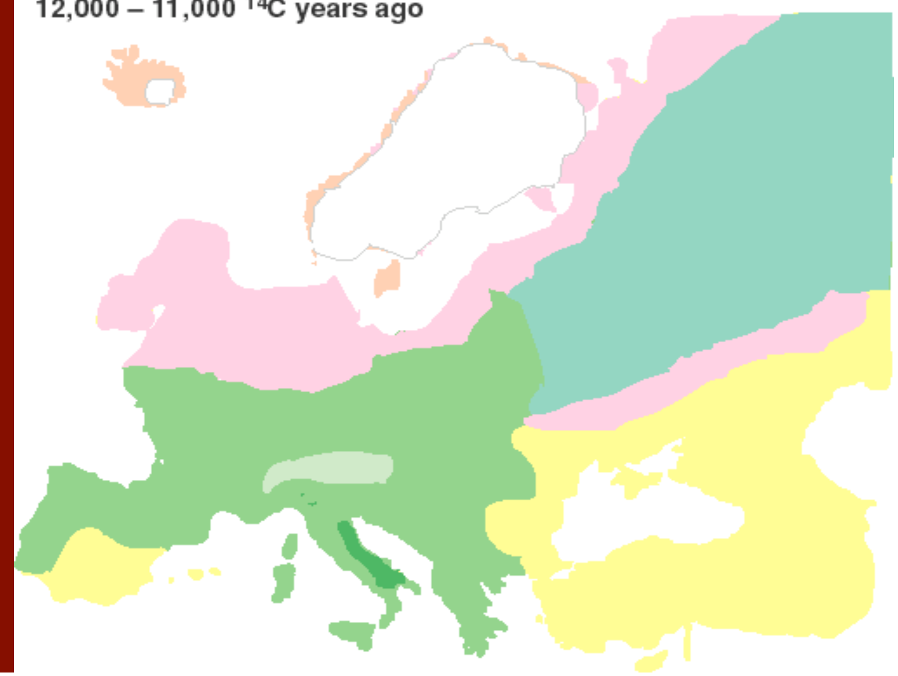

22,000 – 14,000 $^{14}C$ years ago



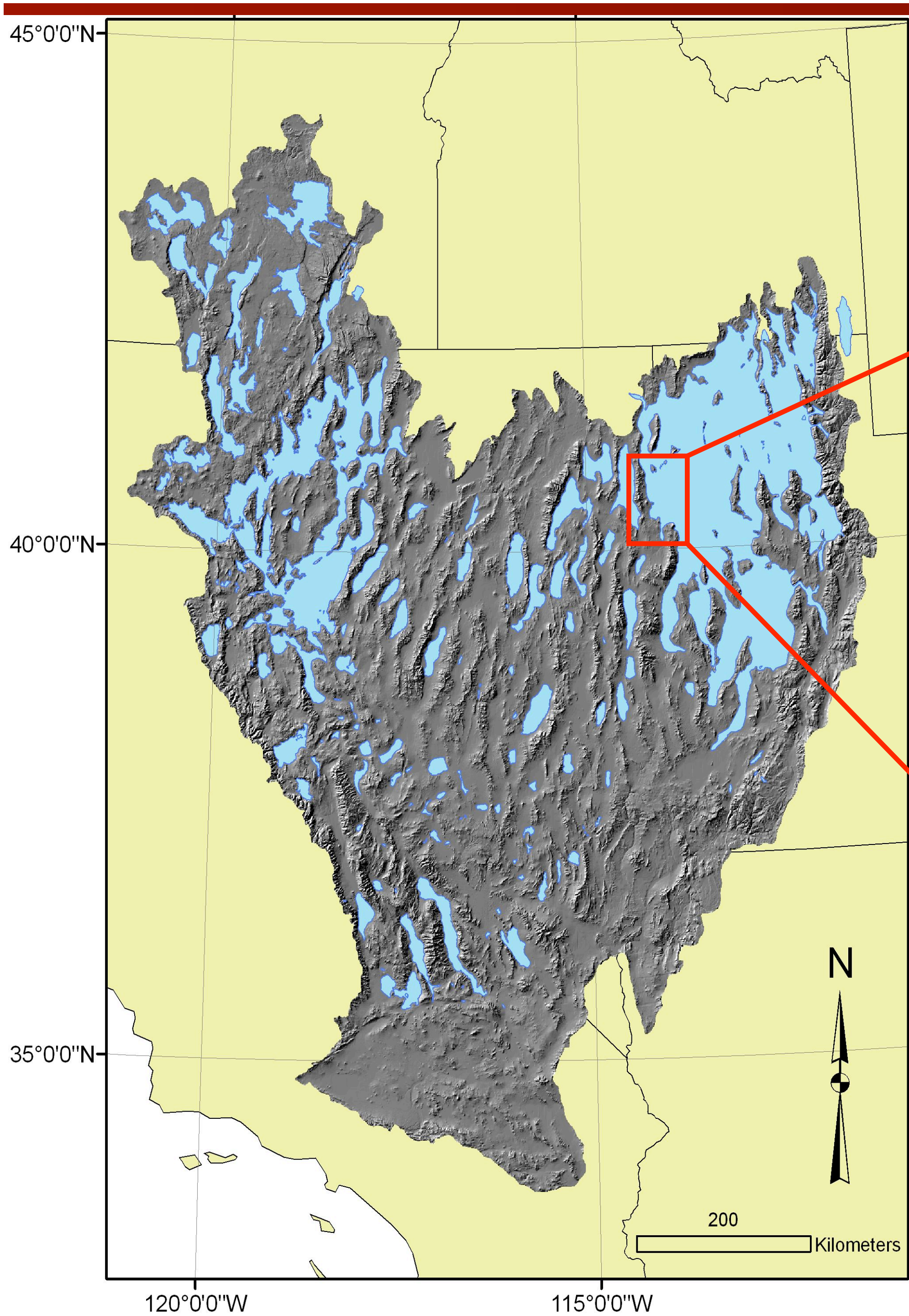

11,000 – 10,000 $^{14}C$ years ago

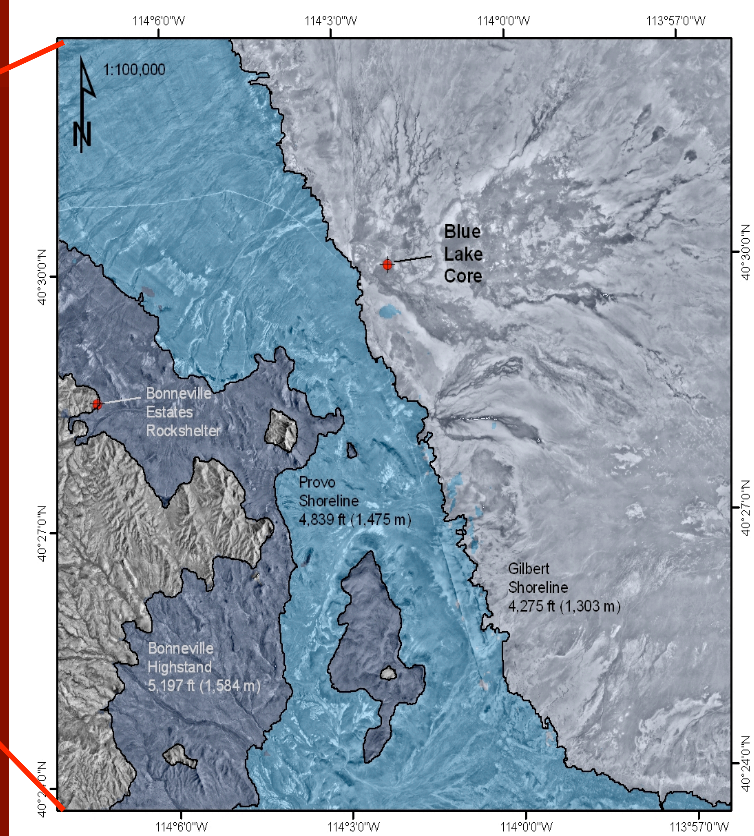


12,000 – 11,000 $^{14}C$ years ago

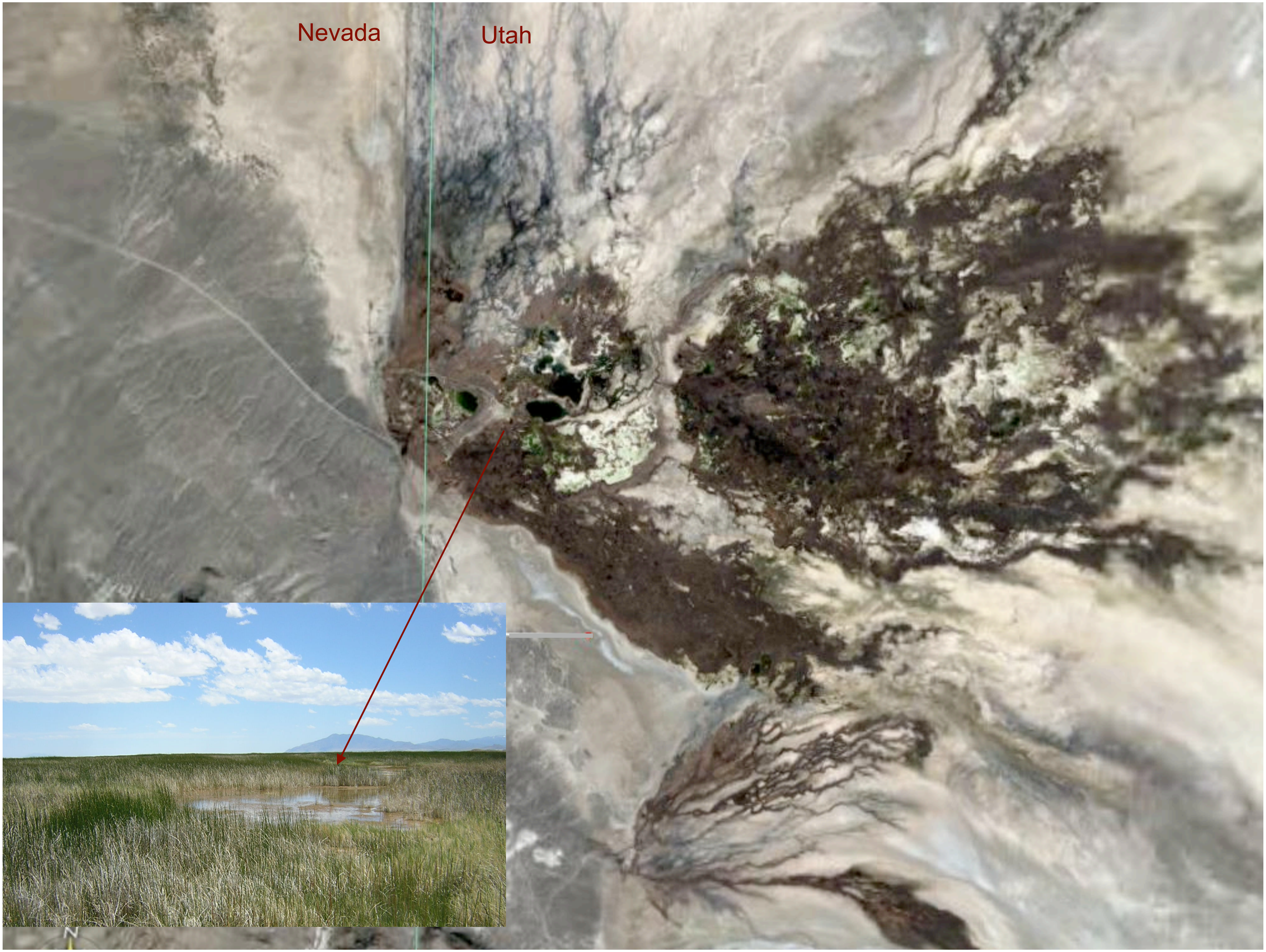


# Blue Lake

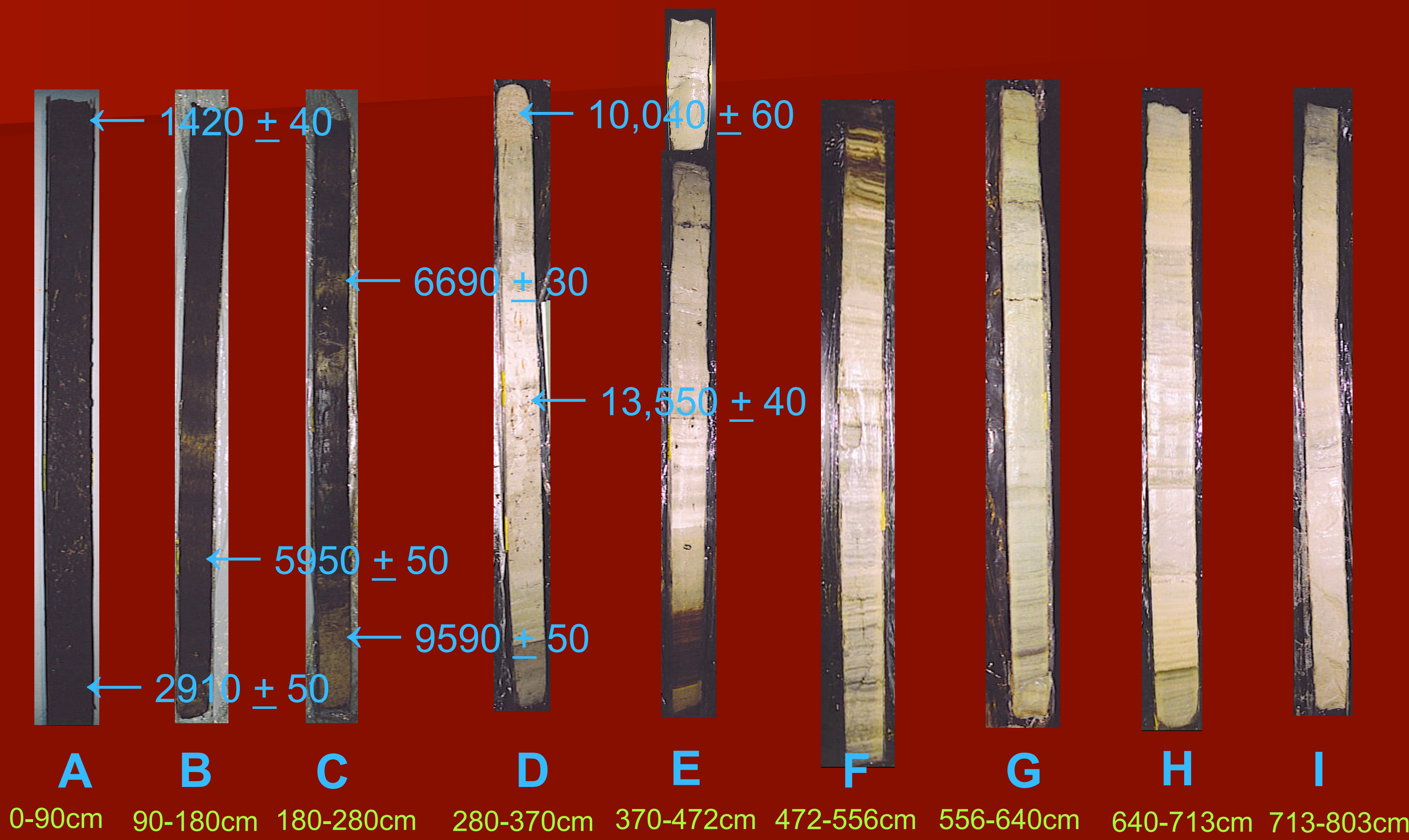



Paleoclimate reconstruction of the Lake Bonneville region (Blue Lake paleoclimate research and powerpoint slides provided by Lisbeth Louderback).

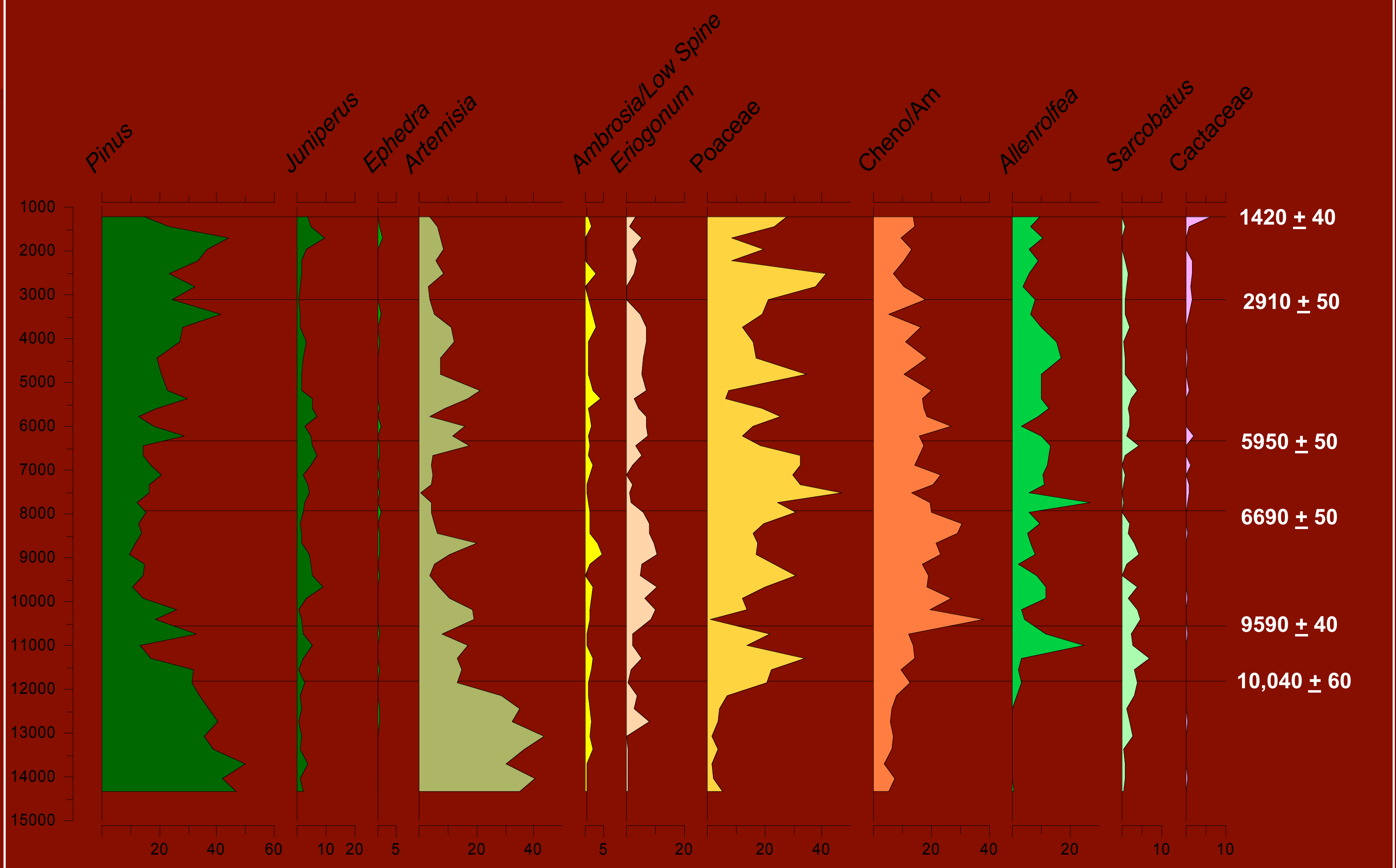

Nevada
Utah

# Core BL04-4

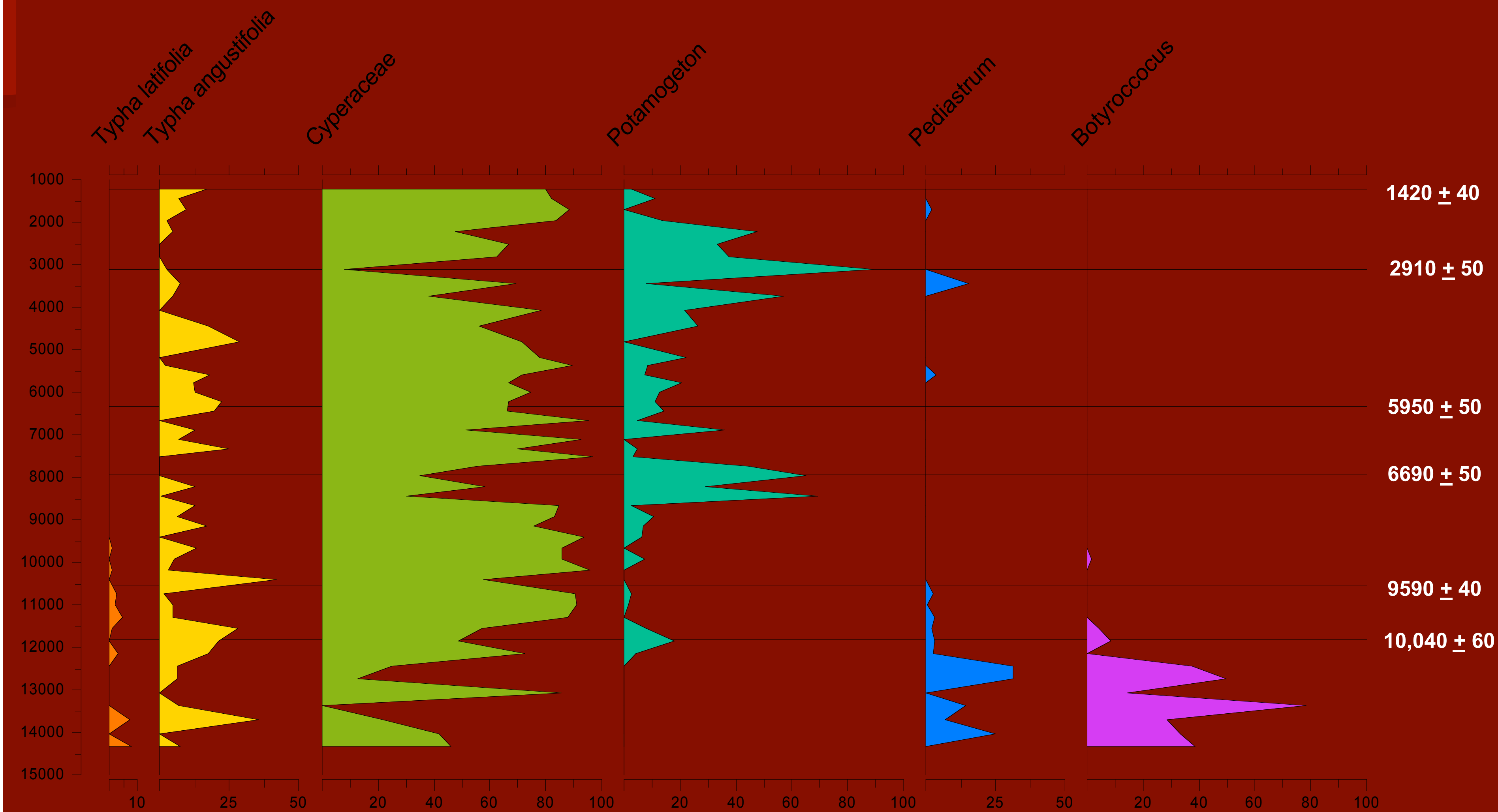


1420 ± 40
10,040 ± 60
6690 ± 30
13,550 ± 40
5950 ± 50
9590 ± 50
2910 ± 50
A
0-90cm
B
90-180cm
C
180-280cm
D
280-370cm
E
370-472cm
F
472-556cm
G
556-640cm
H
640-713cm
I
713-803cm

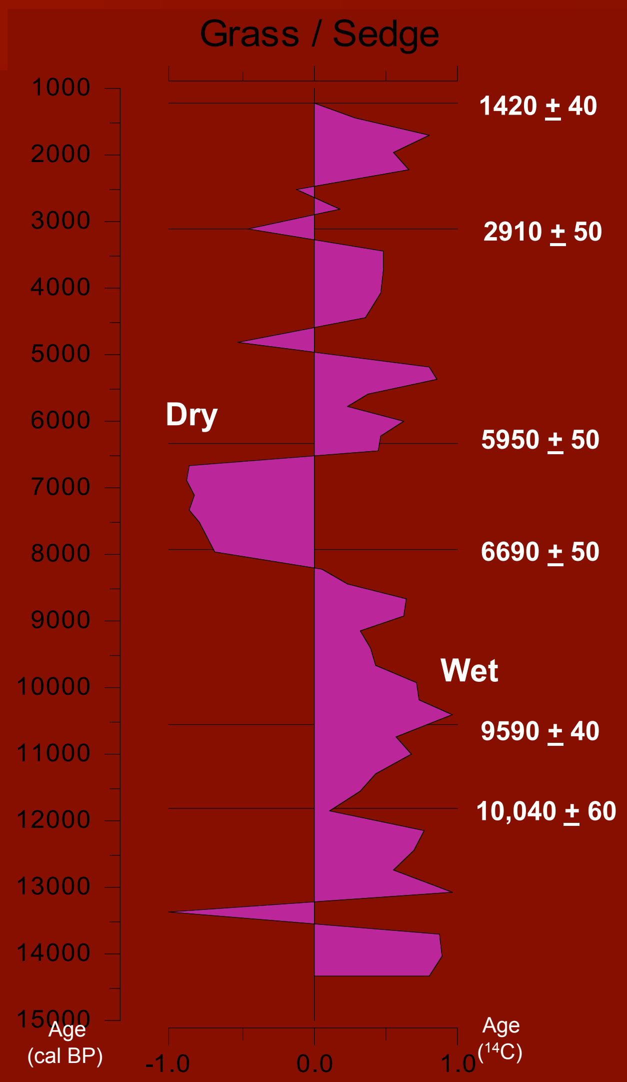
# Blue Lake Terrestrial Pollen



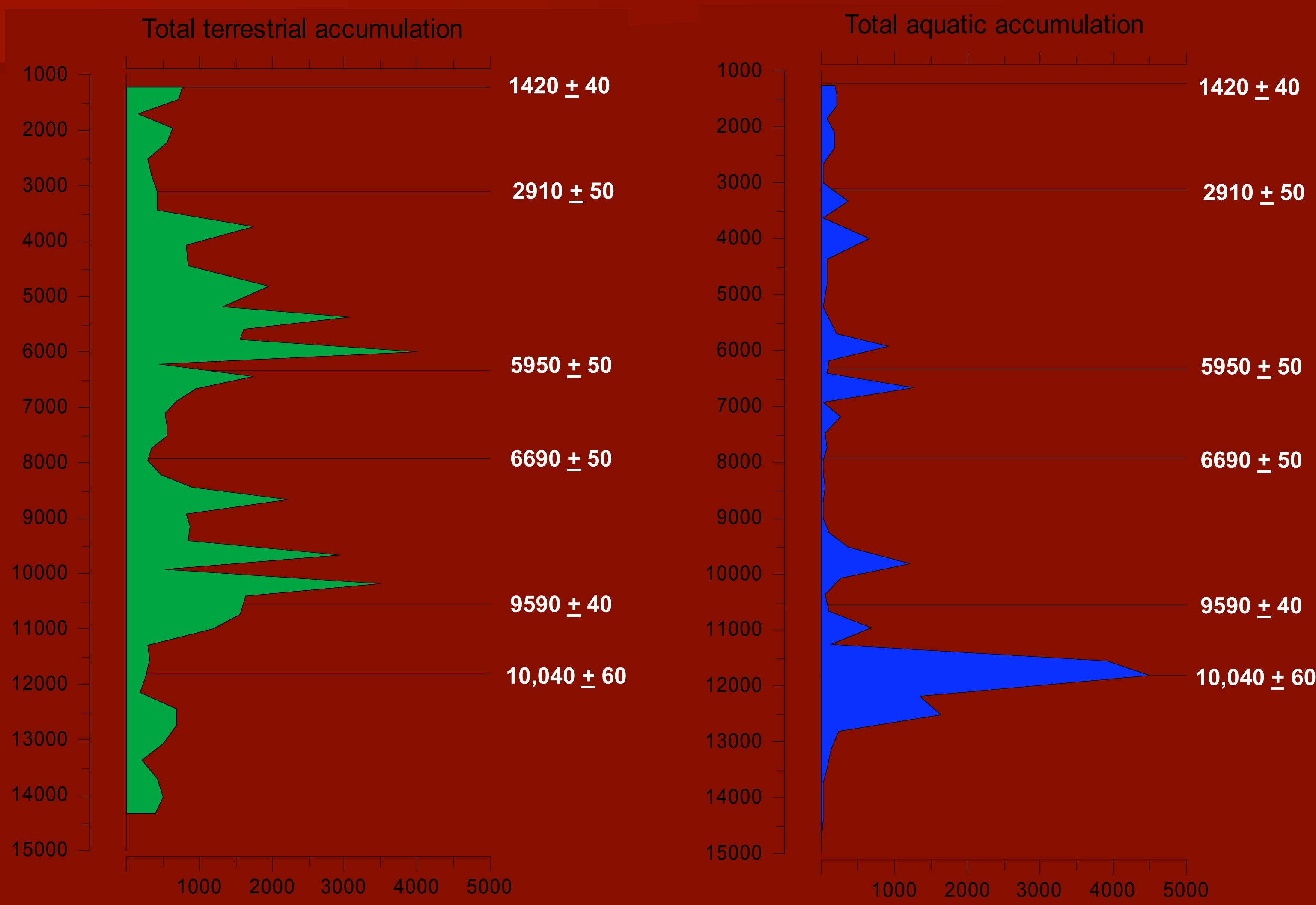
# Blue Lake Aquatic Pollen



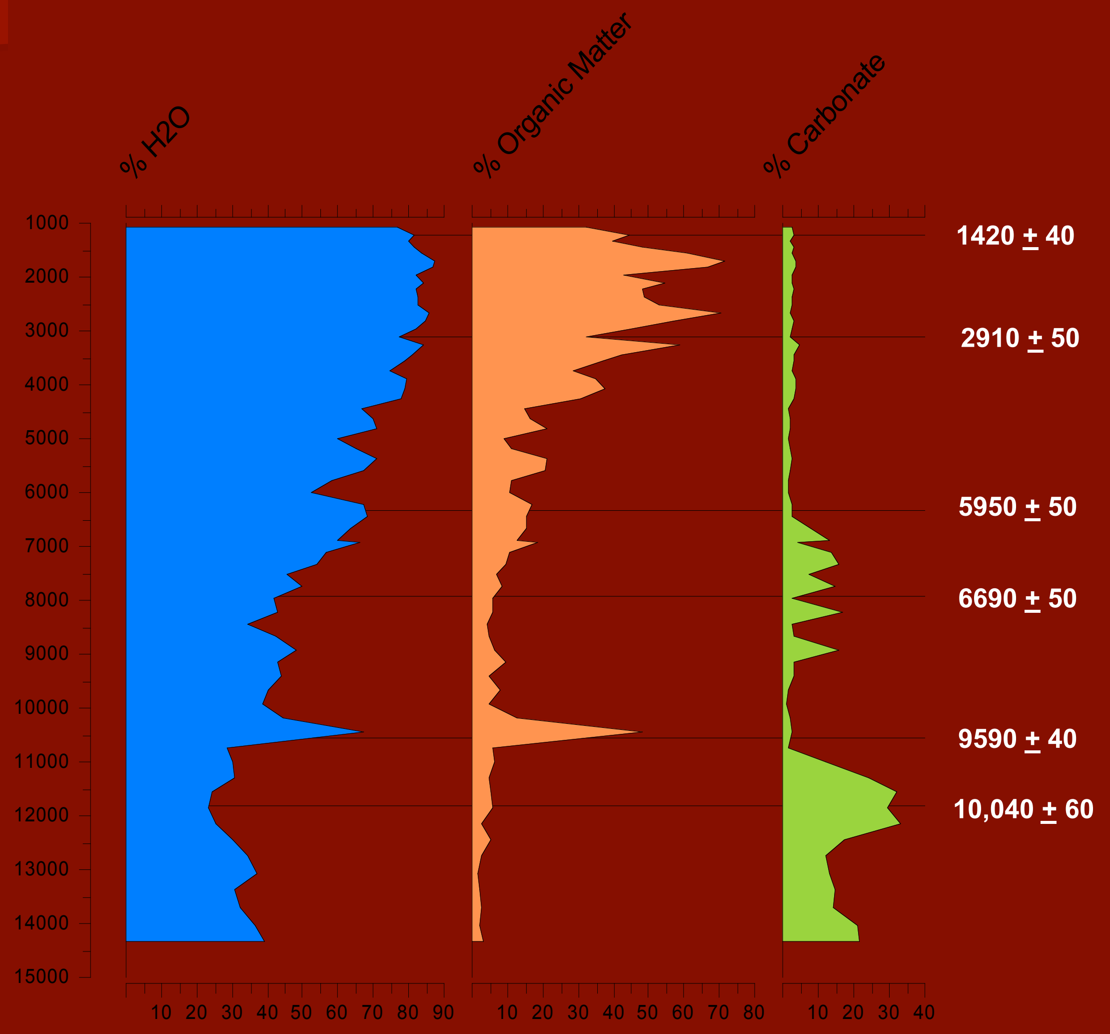
# Blue Lake Sedge/Grass Ratio



# Blue Lake Total Pollen Accumulation



# Blue Lake Sediment Composition



- **Blue Lake Pollen Record**
  - Vegetation changes
- **Major Shifts in Bonneville Basin**
  - Environmental shifts
    - Wetland establishment
    - Wetland desiccation
  - Human adaptive shifts
    - Hiatuses in human occupation
    - Small-seed intensification

# Vegetational and Climatic History of the Pacific Northwest during the Last 20,000 Years: Implications for Understanding Present-day Biodiversity

A Review of Cathy Whitlock's Paper

# The Last 20,000 Years Worldwide:

- Glacial State → Interglaciation (Holocene)
- Continental ice sheets disappeared
- Sea level rose worldwide
- Land and ocean surfaces warmed
- Moisture became redistributed

# In the Pacific NW:

- Retreat of glacial ice created stagnant ice
- Created meltwater debris in northern Washington, Idaho, and western Montana
- Colonized by biota surviving in the unglaciated region to the South

# Questions to Consider

- What was the nature of the vegetation in the unglaciated region?
- How did glacial-age communities respond as climates changed and new species entered the region?
- What environmental controls shaped the subsequent development of modern forests within both the glaciated and unglaciated regions?
- In what ways have present-day vegetation and plant communities in the pacific NW been influenced by long-term changes in climate, substrate, biological interactions, and natural disturbance?

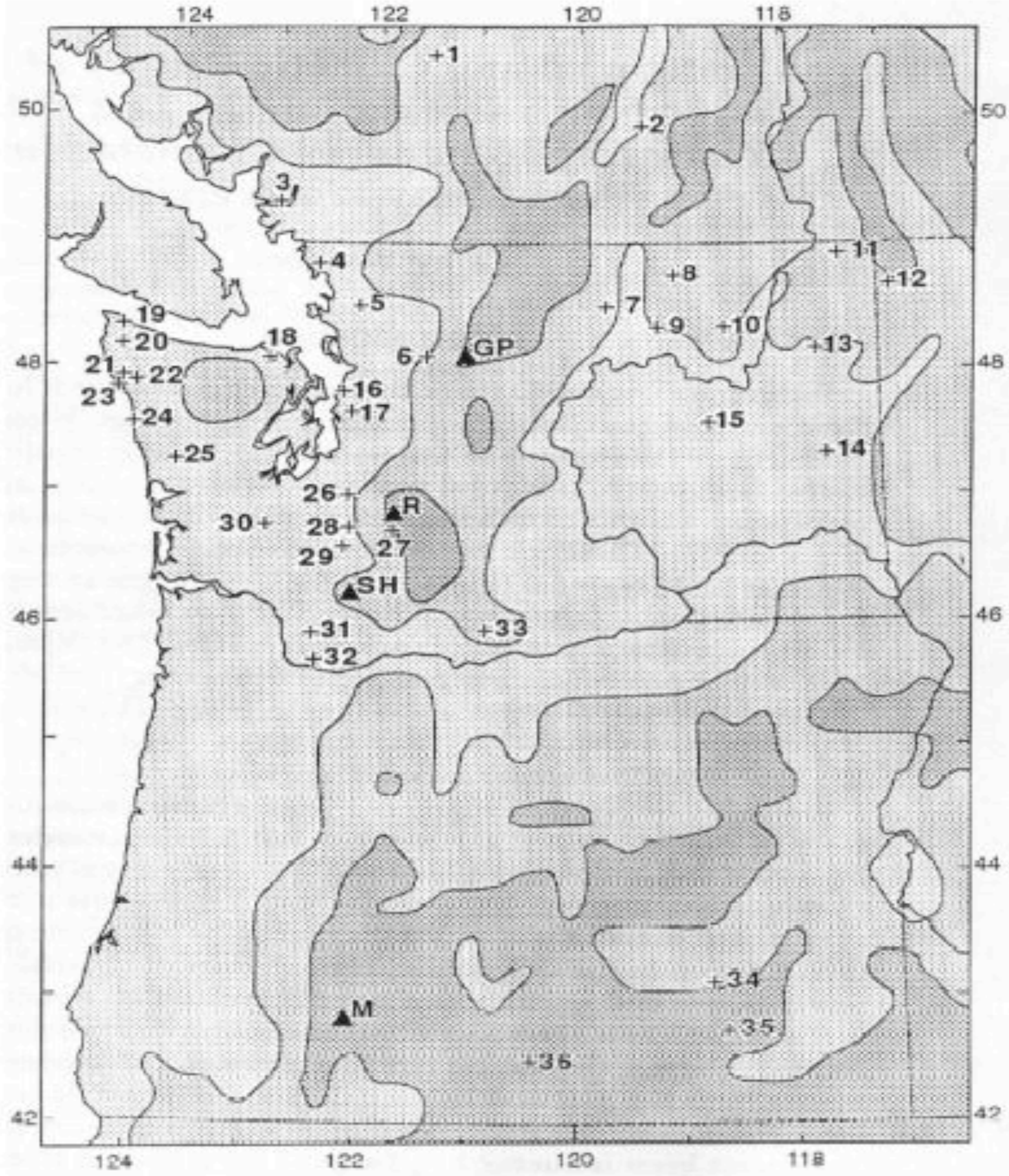
Location of Radiocarbon -dated pollen sites in NW

M=Mt. Mazama

SH=Mt. Saint Helens

R=Mt. Rainer

GP=Glacier Peak



# Objective:

- Describe the vegetational and climatic history of the Pacific NW during the late-Quarternary period from 20 ka to present day.

# Pacific NW: Suitable Source for Stocked Samples?

- Yes! Large number of lakes and bogs for paleoecological research.
- Glacier fed soils contain Holocene sediment rich in pollen and macrofossils.

# Pollen Samples

- Extracted from sediment cores at individual sites.
- Compared with other sites to infer broad changes in regional vegetation and climate
- Further dated by ash layers found in lake sediment  (i.e. Mazama ash appears in nearly every sample site.  Took place 6.7-7 ka)

# Pollen Collection

- Small-Medium sized lakes (1-50 ha) collect pollen from 100-1,000$km^2$
- Stratiographic interval that represents one sample for every 300-1,000 years of sediment accumulation
- Good for large scale inferences but leaves short-term changes and specifics in the dark.
- Using macrofossils from same strata greatly improves faunal reconstruction (seeds, needles, etc.)
- Charcoal particulates reflect past fire data.

# Past Pollen Projects

- From the Pacific NW: 1930's and '40s
- Used peat samples
- Evidence for a change from tundra to modern forests and steadily warming
- Xeryophytic (dry-loving) taxa evidence for drier/ warmer climate than present.
- Even without radiocarbon dating, information lead scientific community to accept a significant change in vegetation since last ice age.M

# Pacific NW: 20-14 ka

- Extensive alpine glaciation
- Cordillian small and little glacial ice in the lowlands
- Laurentide ice sheet at its greatest extent
- 15-14 ka: alpine glaciers getting smaller
- Olympic Peninsula covered with tundra and parkland vegetation (spruce, alder, pine, mountain hemlock, etc.)
- Alpine margins covered with grass and alpine herbs
- Annual Temp. 5-7 degrees C cooler
- 1,000 mm less precipitation
- Lacking pollen samples point to cold/dry tundra (23.5 to 10 ka)

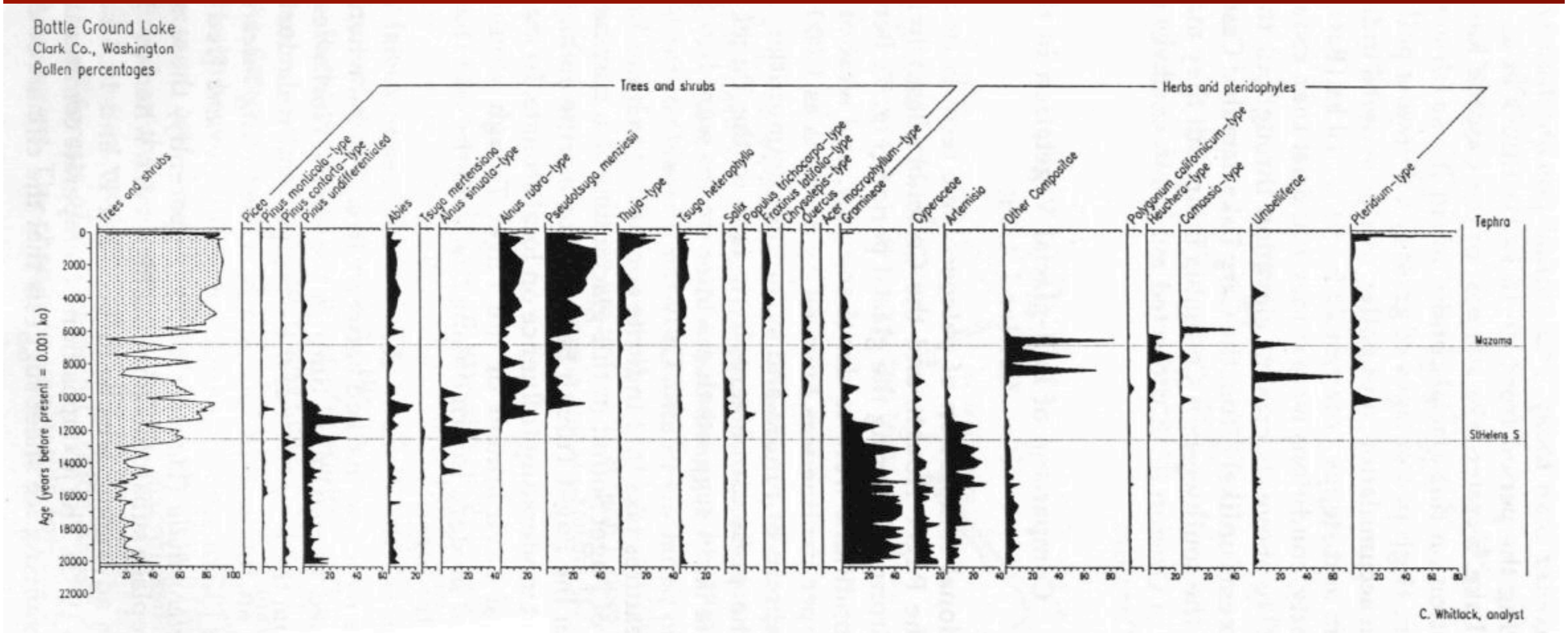



Fig. 2. Pollen abundance of selected plant taxa obtained from the analysis of a sediment core from Battle Ground Lake, Clark County, Washington. Changes in pollen percentages through time at Battle Ground Lake and other sites provide evidence of vegetational changes in the southern Puget Trough during the last 20,000 years (see text for further discussion). The vertical scale represents years before present (yr B.P.; 1,000 yr B.P. =ka), based on radiocarbon age determinations and the occurrence of known-age volcano debris (tephras) in the core (after Barnosky 1985*a*).

# General Circulation Computer Models (GCMs)

- Input with full-sized Laurentide ice sheet:
- Cooling throughout the northern mid-latitudes
- Split North American Jet Stream, causing winter storm tracks south of their present position and leaving Pac NW without winter moisture
- Strengthening of easterly surface winds=enhanced cold and arid conditions in Pac NW

# Pacific NW 16-15 ka

- Mesophytic (wet-loving) climate
- Puget Trough, grass and herbs less dominant (analogous to present day western cascades range and eastern Olympic Mtns.)
- Present precipitation values but 2-6 deg C cooler…increased humidity
- Laurentide ice diminished and no longer split the jet stream (16-13 ka), directing winter storms to Pac NW

# Pac NW 14-10 ka

- Pine trees reclaim land once covered by the Juan de Fuca and Puget lobes and grow steadily and rapidly on infertile soils
- Communities of herbs and shrubs dominate over forests
- Drier conditions and coarse-textured soils on glacial outwash maintain open vegetation simiilar to the present
- Warmer temperatures coax firs, cottonwood, and alder to grow
- Very diverse collection of settings
- Still cooler than today

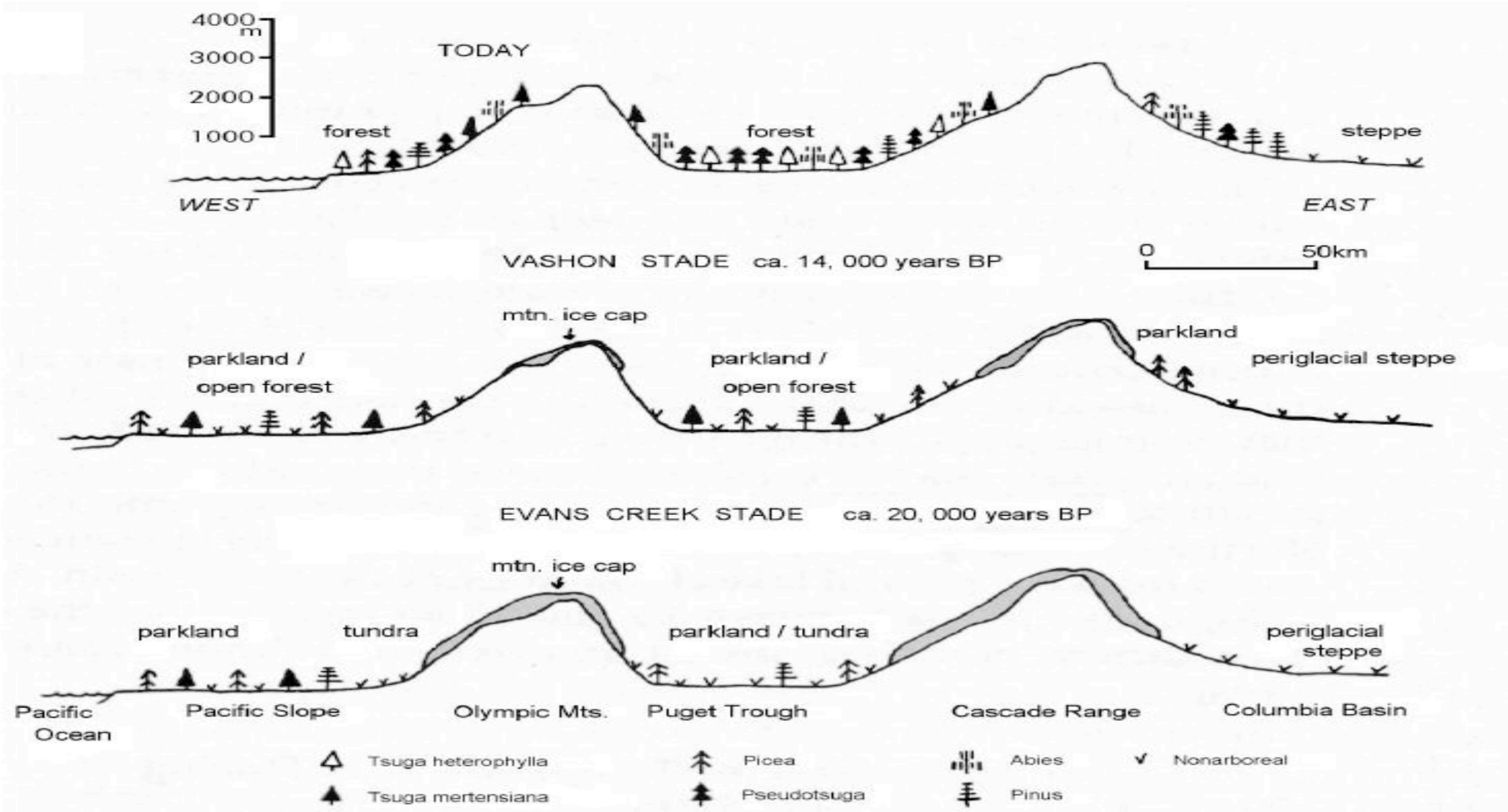



Fig. 3. Schematic transects across southwestern Washington show dominant vegetation and ice distribution today, during the full-glacial period (Evans Creek Stade, Ca. 20 ka), and during the maximum advance of Cordilleran ice (Vashon Stade, ca. 14 ka). During the Vashon Stade, Cordilleran ice occupied lowlands north of this transect, and throughout glacial time the coastline lay 20—50 km farther west than it does today (from Barnosky 1984). Note: 1,000 yr B.P. equals one kiloannum (ka).

# Pac NW 10-5 ka

- Computer simulations suggest increased summer radiation, increasing temp. and lower effective moisture ensue
- 8% more in the summer and 10% lower in the winter
- Expansion of eastern Pacific subtropical- high pressure system of the Pac NW (intensified summer draught)
- 40-50% less precipitation 9.5-4.5 ka, annual temp increased 1-3 deg C

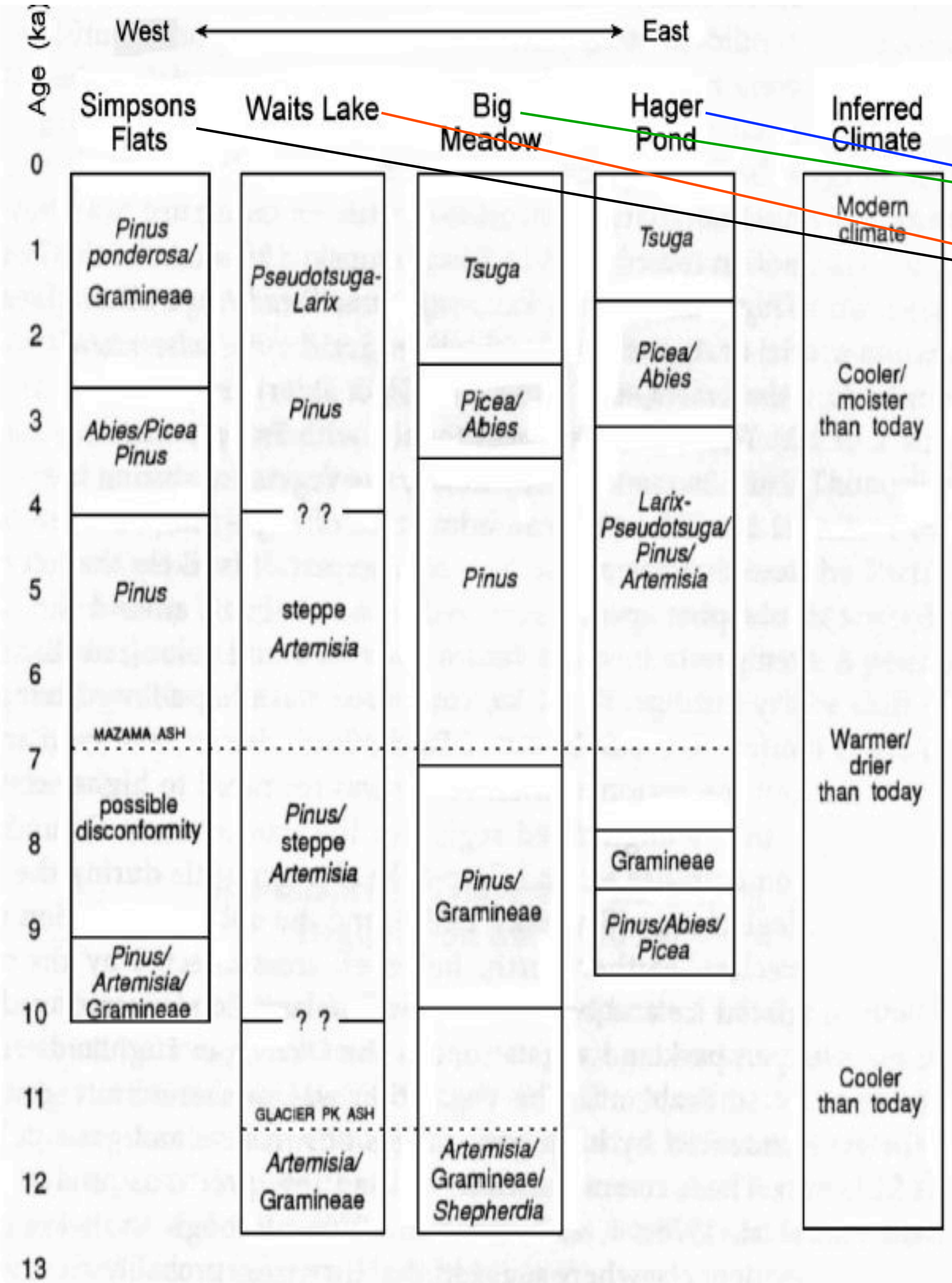
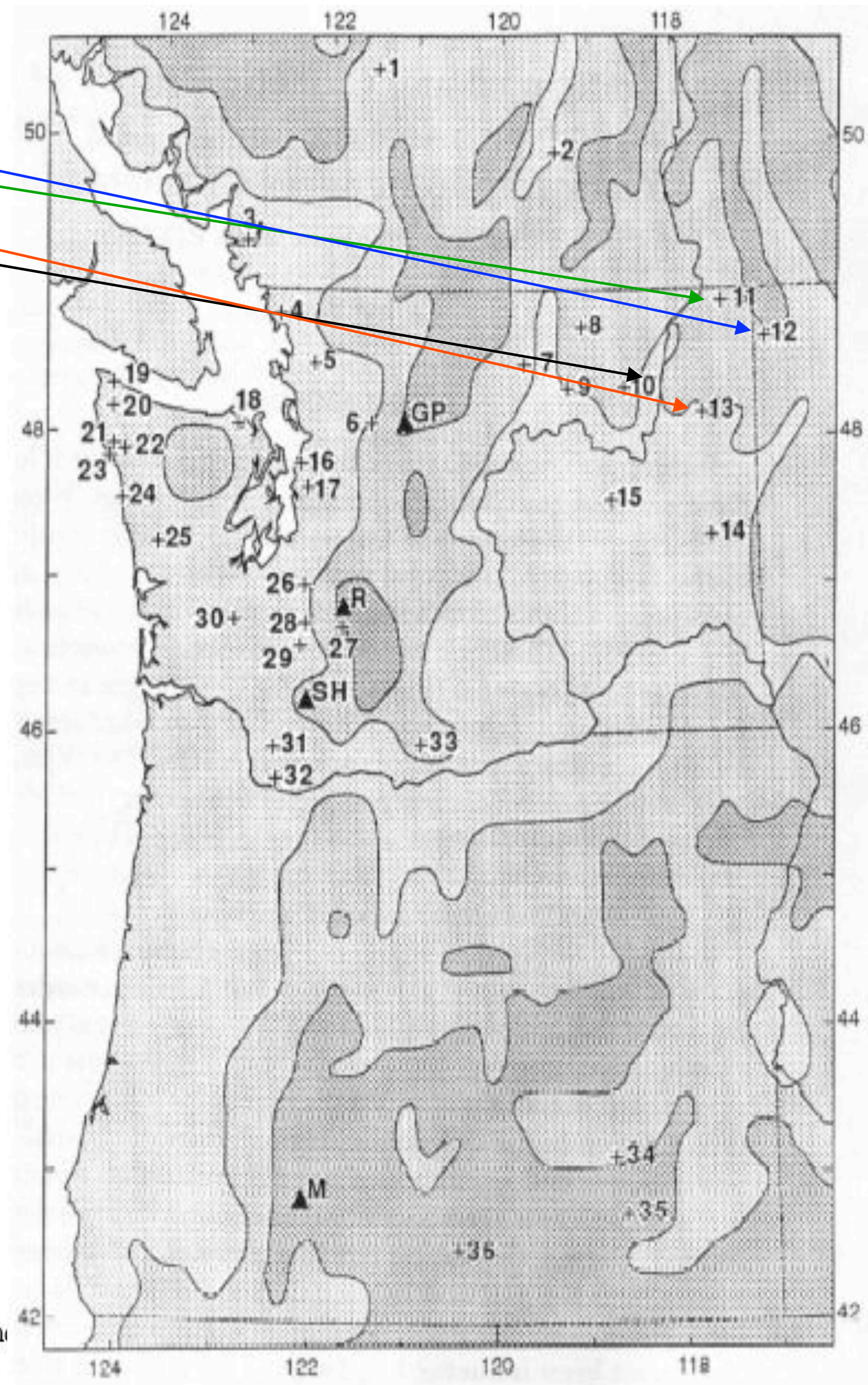



Fig. 4. Vegetational changes and inferred climatic conditions in northeastern Washington and northern Idaho during the last 10,000 years, based on pollen analysis (after Mack et al. 1978a).



# Pac NW 5 ka – Present

- Summer draught less intense, lower temps and greater precipitation
- Vegetational response varied
- Warmer with increased rate of forest fires (lake sediments from Rainer)
- Neoglaciation creates cooler/moister environment and reduces fire frequency, allowing forests to mature

# Implications of the Paleoecological Record for ecology and Biogeography

- Variations on latitudinal and seasonal distribution of solar radiation and ice-sheet size have governed the overall pattern of change during the last 20 ka
- Cold conditions occurred in response to cold ice sheets
- Aridity resulted in displacement of Jet stream
- After 16 ka Laurentide shrank in height and led to development of mesophytic subalpine vegetation
- Warm-loving (thermophilous) taxa at 12 ka and drought-adapted vegetation at 10-9 ka due to amplified seasonal cycle of solar radiation.
- Enhancement of Subtropical high between 12 and 6 ka shift position of forest/steppe ecotone

# Implications of the Paleoecological Record for ecology and Biogeography II

- Direct Cordilleran activity minimal compared to that of the Laurentide
- Higher sea surface temperatures more effective than Cordilleran
- High percentages of Alnus and Pinus suggest trees were near and even on the glacier in high percentages (periglacial tundra restricted at the time of Cordillerian advance)
- Glaciers retreated rapidly after 14.5 ka but temperate taxa not present until 2,000 years later
- Fire frequency and local variation further influenced biotic growth
- Fires were more frequent during the early Holocene warm/dry period than today → cause for early-succesional species and forest openings being more abundant, but could have been from Native Americans deliberately setting fire to these areas for hunting and berry gathering (needs to be explored further)
- More information (only based on few charcoal records)
- Coarse outwash and draught conditions effecting northeastern taxa coverage

# Implications of the Paleoecological Record for ecology and Biogeography III

- Development of modern forest communities didn't occur until last few millennia
- Caused by intensified draught shortly after deglaciation.
- Lags of vegetational response to climatic forcing were very short (1,000-500 years)
- No millenia has been exactly like this in 20,000 years
- Periods of rapid environmental change characterized by increase in species richness creating specific communities and vegetation types
- Subalpine → Temperate
- Species with ability to adapt quickly during rapid climate change faired the best

# Implications of Global Warming

- Present-day reserves will most likely be the source for future communities while species respond to increased draught and warming
- Species that live in warmer climates will move northward and into higher elevations
- Temp transition will resemble that of the late-glacial to Holocene (temps warming 4-5 deg C higher)