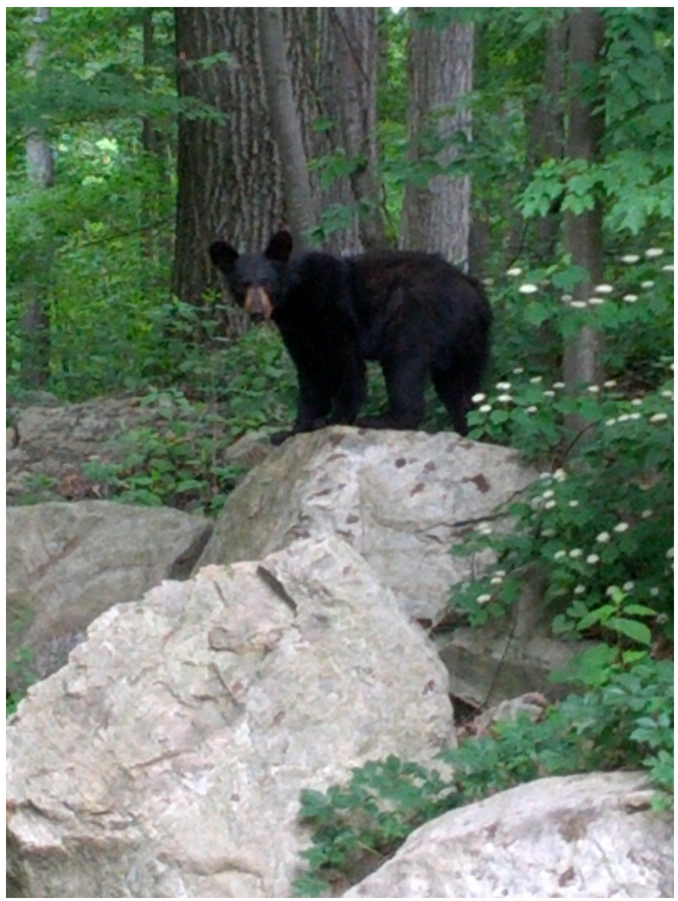
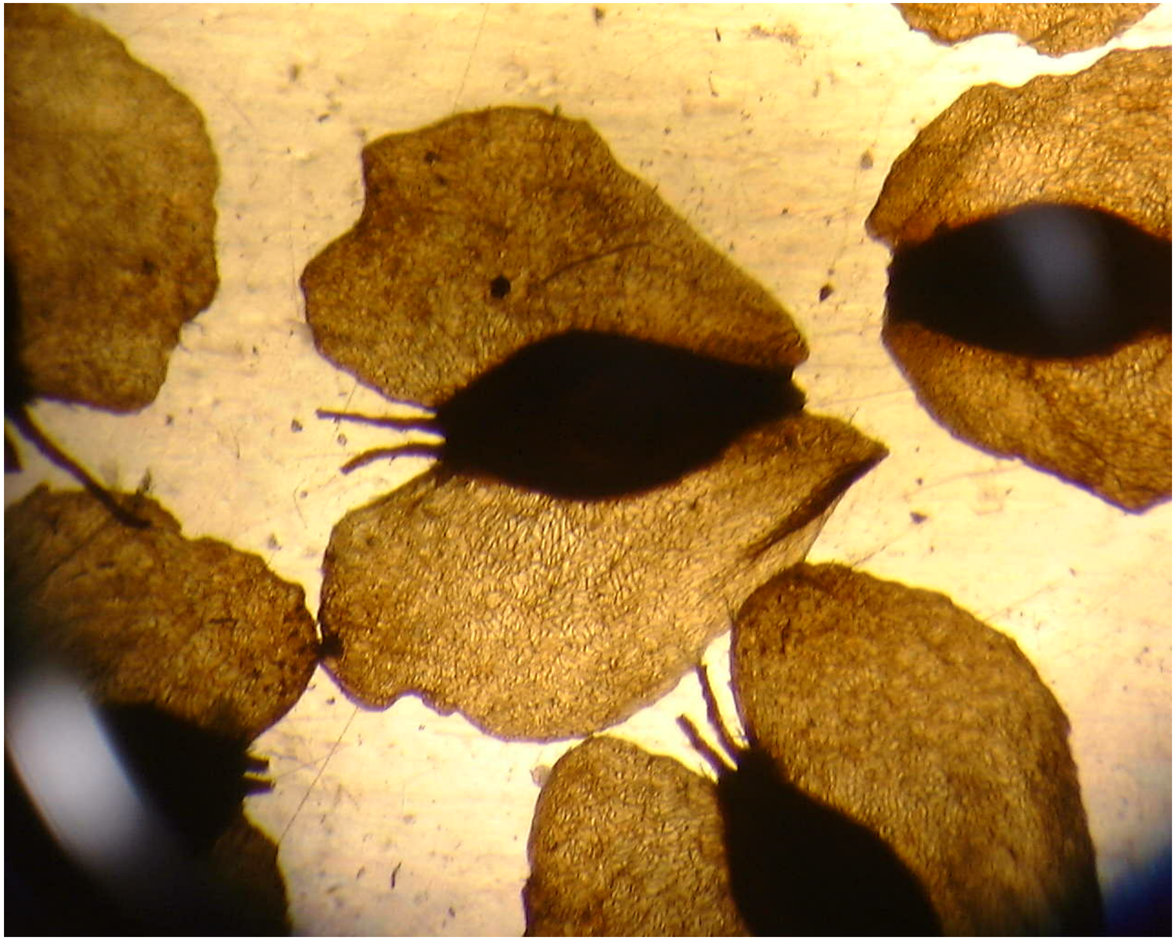
Ecology is the study of the relationships between living things and their environment.



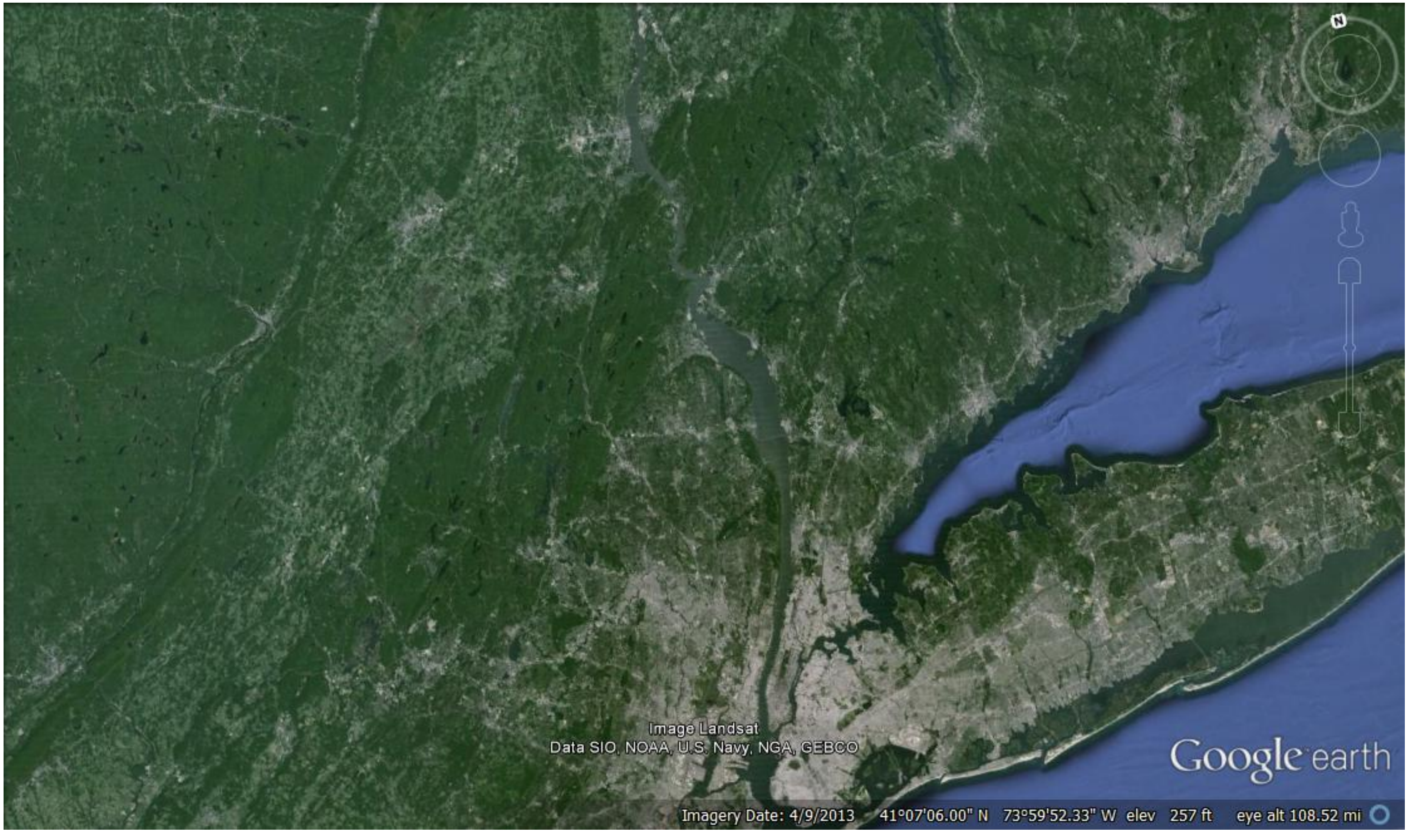
Black bear in Tuxedo, NY

Paleoecology = ecology of the past



Betula populifolia
seeds
T. Maenza-Gmelch

What was the ecology of the New York City area like 12,000 years ago?
Was it warmer or colder?
Were the plants and animals the same?
Why would we want to know this?



Knowledge from the past may help us understand what we see today.

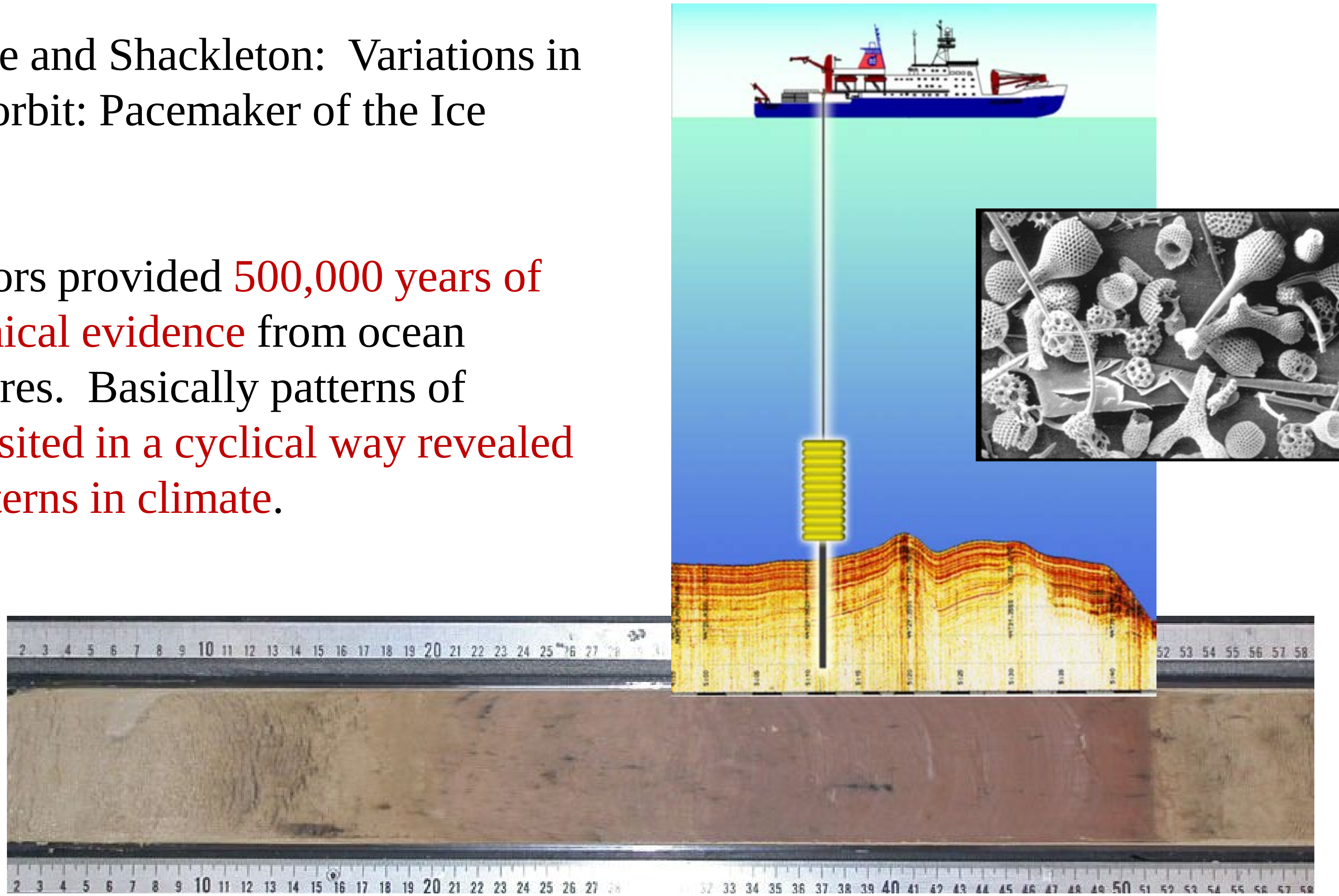
patterns of vegetation change
patterns of past climate change
evidence for insect outbreaks
past fires

Maybe we can use this information to predict or prepare for the future.

An example of famous paleoecology science paper that showed us what happened in the past so we can understand patterns and know what to expect in the future:

Hays, Imbrie and Shackleton: Variations in the Earth's orbit: Pacemaker of the Ice Ages.

These authors provided 500,000 years of biogeochemical evidence from ocean sediment cores. Basically patterns of fossils deposited in a cyclical way revealed cyclical patterns in climate.



We know that ice ages occur and last for about 100,000 years and that they are separated by warm phases that last about 10,000-20,000 years. We are in a warm phase now.

- During an ice age:
- Ice sheets grow larger
- Sea levels get lower
- Plants and animals redistribute themselves.

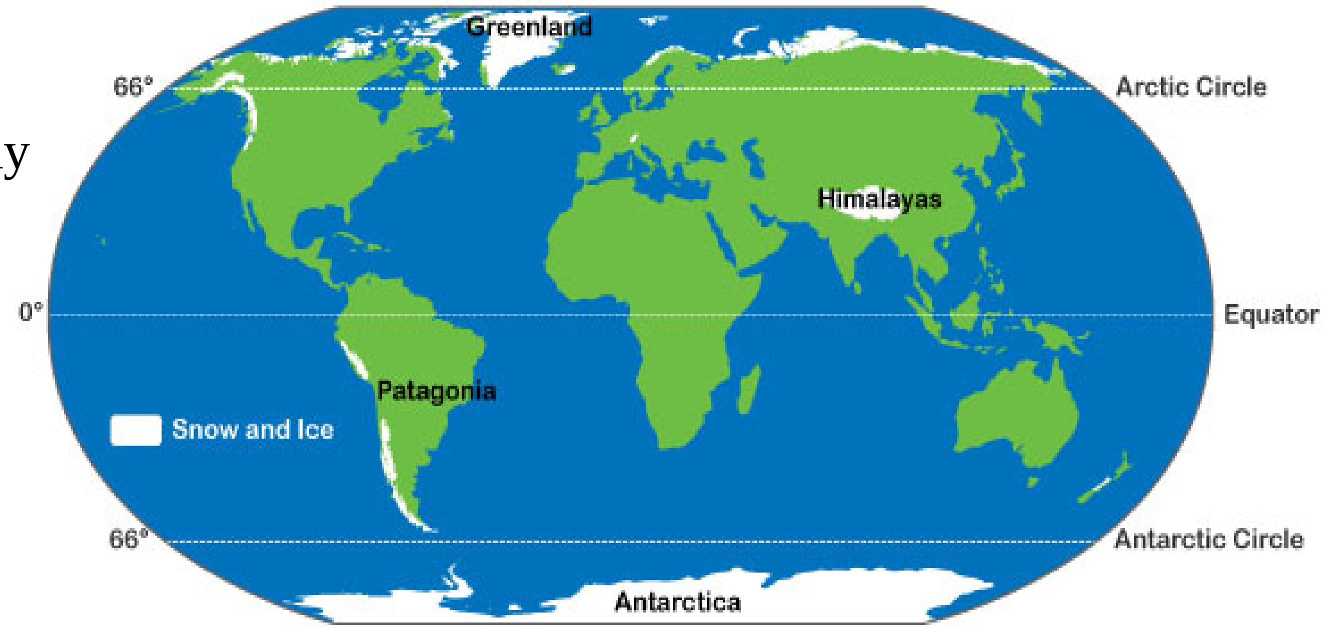
How does a glacier grow?

Glaciers begin life as snowflakes.

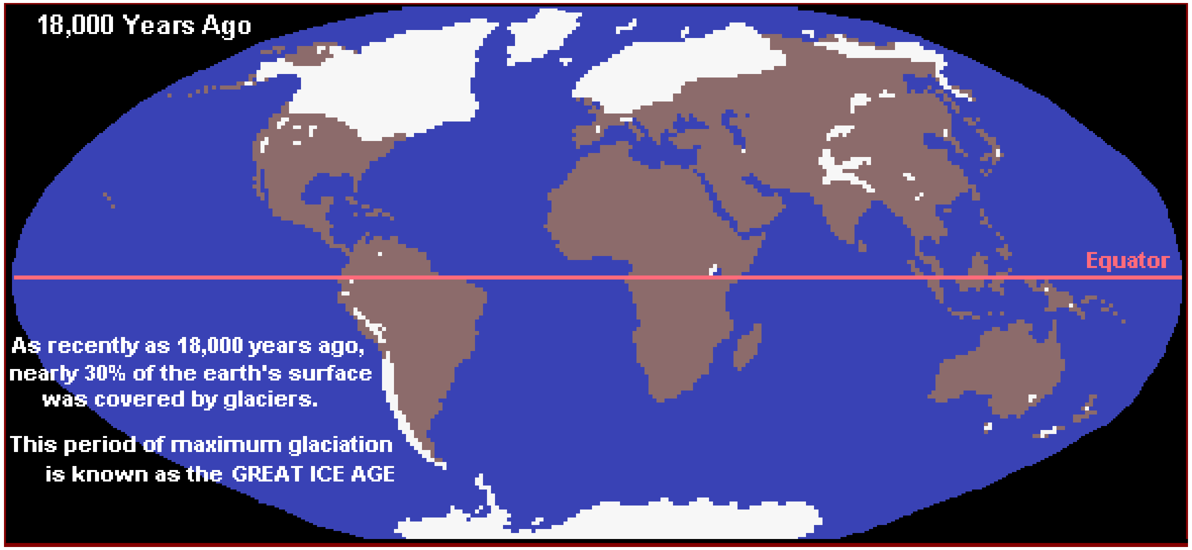
When the snowfall in an area far exceeds the melting that occurs during summer, glaciers start to form.

The weight of the accumulated snow compresses the fallen snow into ice.

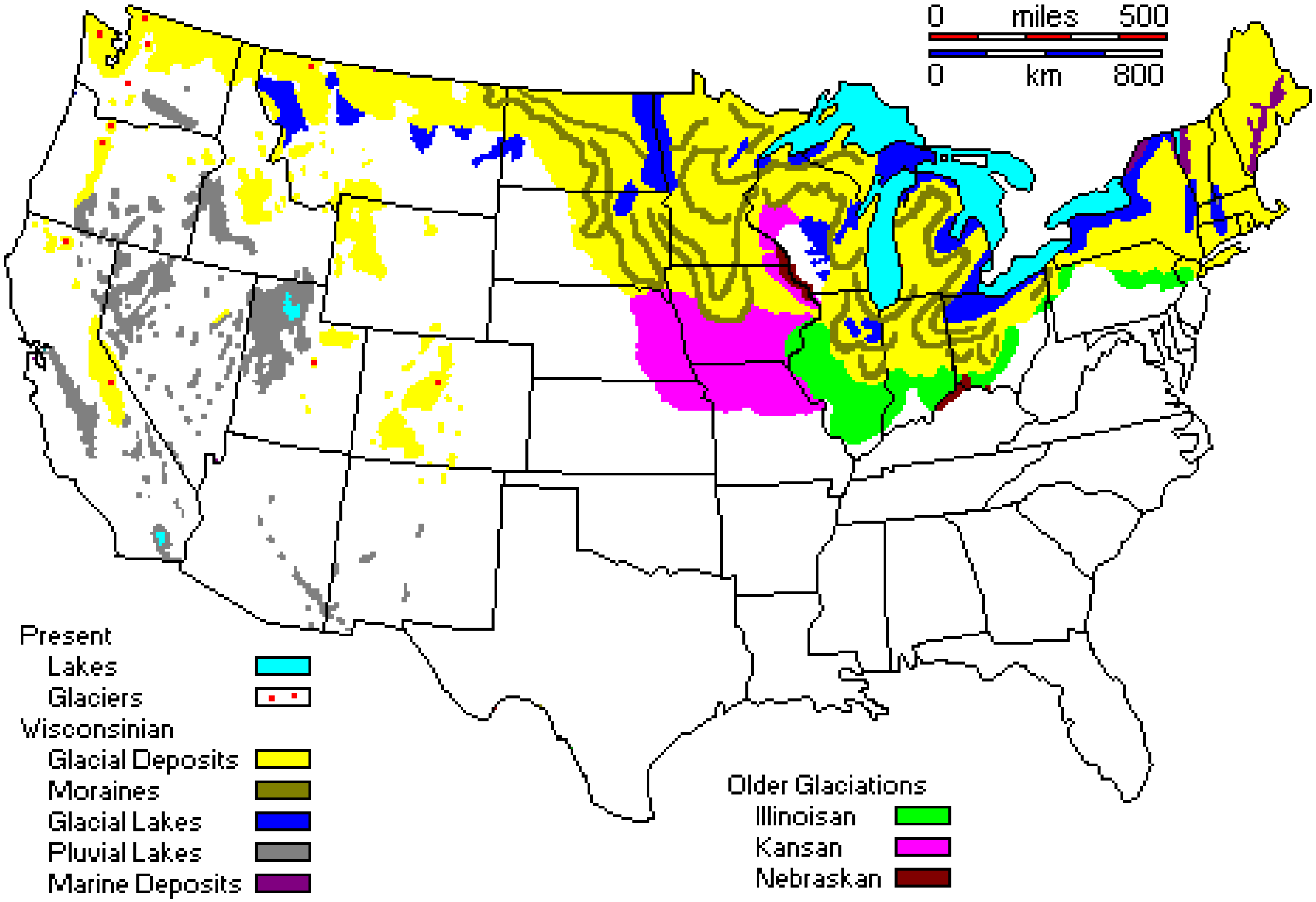
Glaciers today



Glaciers during most recent ice age



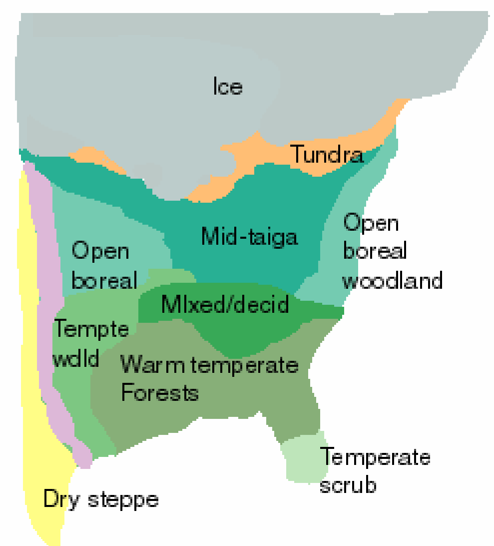
This is how much of the USA was covered with ice during the Last Glacial Maximum, 18,000 years ago.



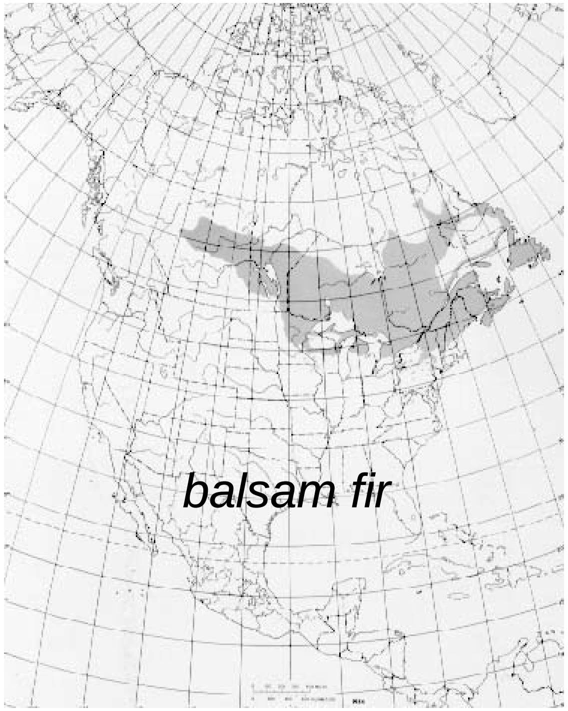
How did the plant life change?

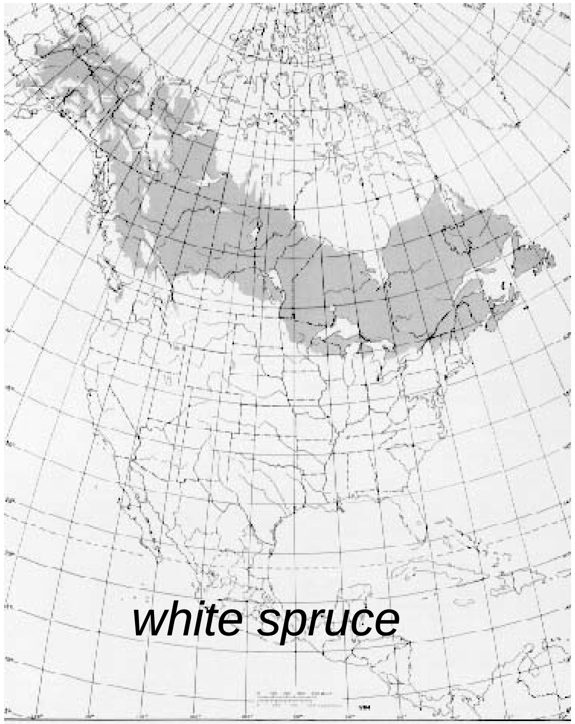
today

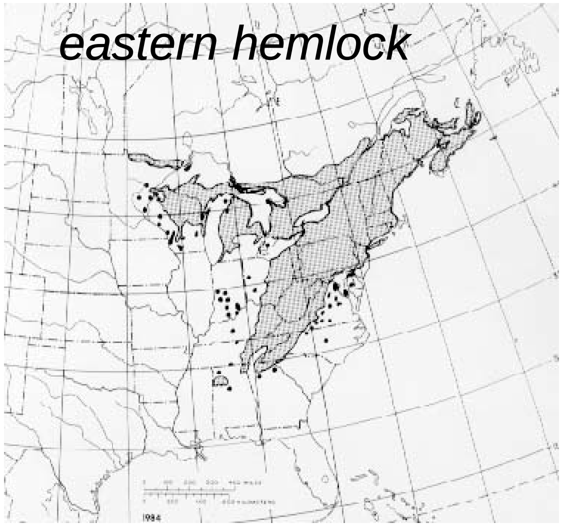
Last Glacial Maximum

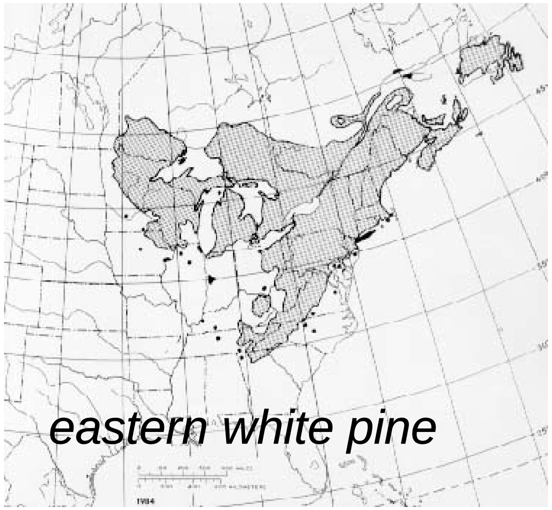


28,000-25,000 radiocarbon years ago.
From H & P Delcourt (1998)


balsam fir


white spruce


eastern hemlock


eastern white pine

What plants live here today?

<u>Trees:</u>

Oak

Maple

Birch

Hickory

Ash

Basswood

Tulip tree

Eastern hemlock

Eastern white

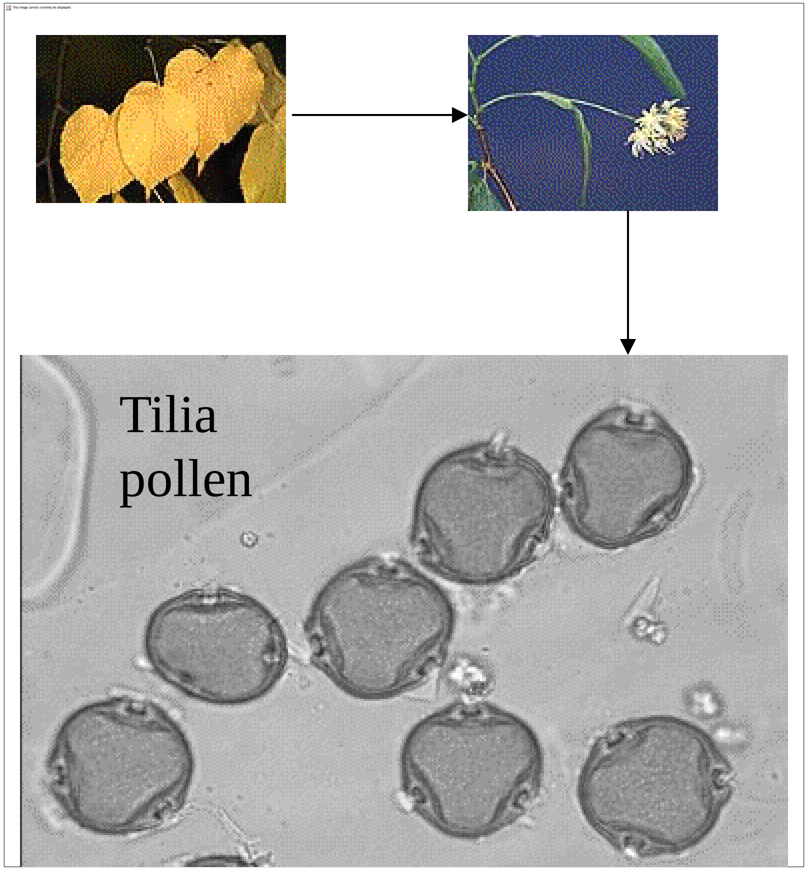
Which animals live in the region today?

Did NYC look something like this 12,000 years ago?

How can we find out?

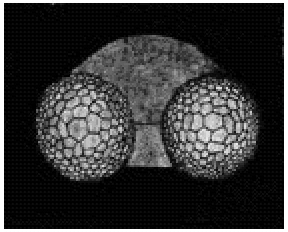
To trace the ecology of the past you need evidence

- Fossils of microscopic size (microfossils) are everywhere and abundant.
- Microfossils are biological indicators of past environments.
- If you know the ecological requirements of the various fossil species and their current geographic distributions, you can infer the environmental conditions of where you found them.

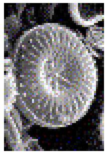


Some examples of microfossils

- Pollen grains: microscopic structures that carry male genetic material from one plant to the next; indicators of vegetation

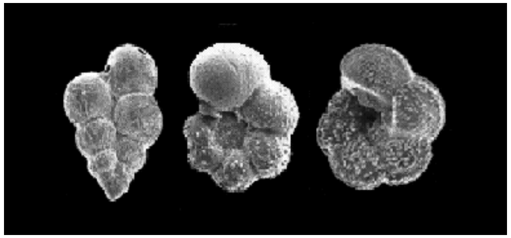


- Diatoms: microscopic, single-celled algae (most abundant in water); indicators of water pH, temp, salinity



- Foraminifera: simple, aquatic, amoeboid protozoans (mostly marine);

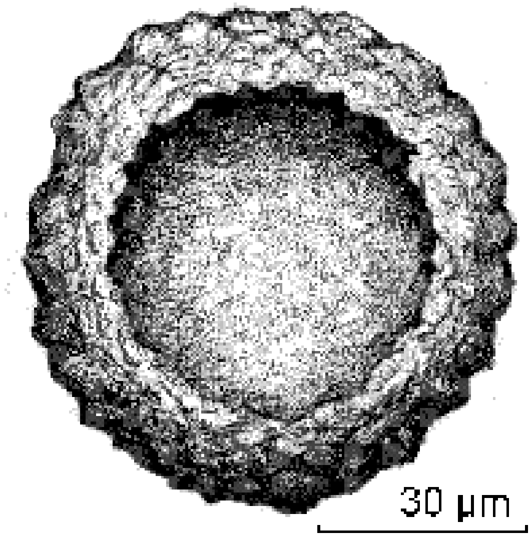
  indicators of salinity, temperature, oxygen ratios

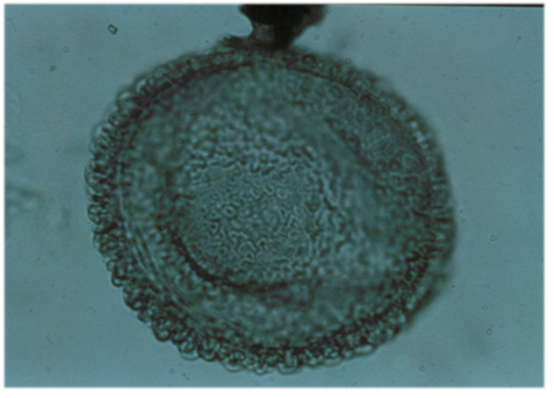


Palynology: the study of pollen and spores

- The reconstruction of a vegetation history is largely dependent on fossil pollen.
- Pollen and spores have a highly resistant outer layer that facilitates excellent preservation.

Tsuga pollen





Principles of pollen analysis

- Plants produce enormous amounts of pollen
- pollen grains have distinctive surface sculpture which permits identification of the plant species or family that produced the pollen
- each spring/summer, the pollen released into the atmosphere eventually returns to the earth's surface = pollen rain
- Pollen rain that falls on lakes/ponds/bogs gets preserved in the bottom sediments. Each year a layer of pollen is deposited, leaving a signature of the vegetation that produced it.

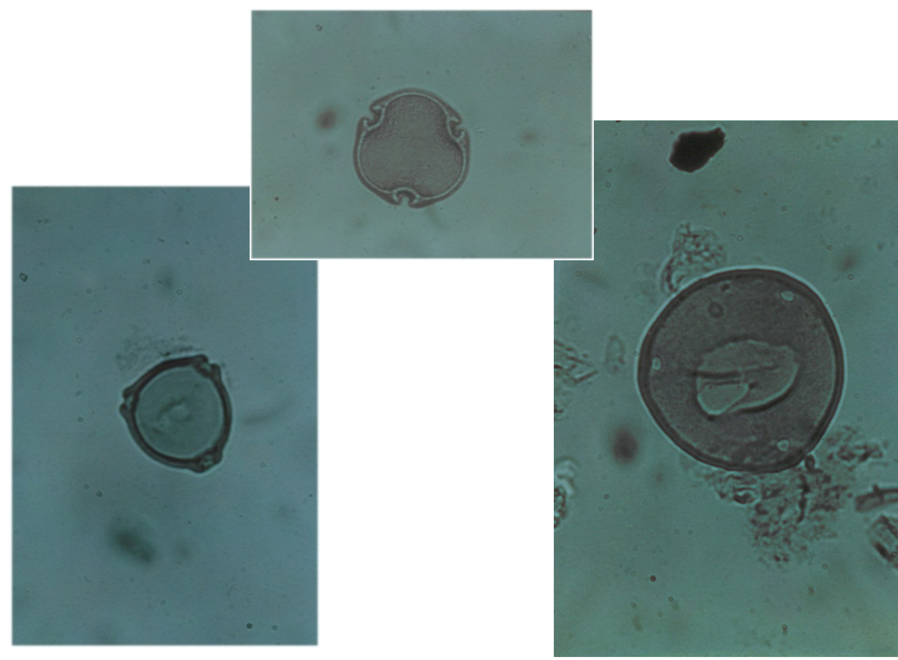
- If a palynologist locates a lake or bog that has not been disturbed, they have found a potential record of vegetation.
- The pollen analysis includes identification of no less than 300 grains per layer and the tallying of each type. For example 80 oak pollen grains, 20 hemlock grains, *etc*.

How do you get the pollen out of the lake?

- Find the deepest part of the lake, it will typically have the thickest sediments.
- Core the sediments with a hand driven piston-corer.
- Wrap and label each core segment and bring to the lab.

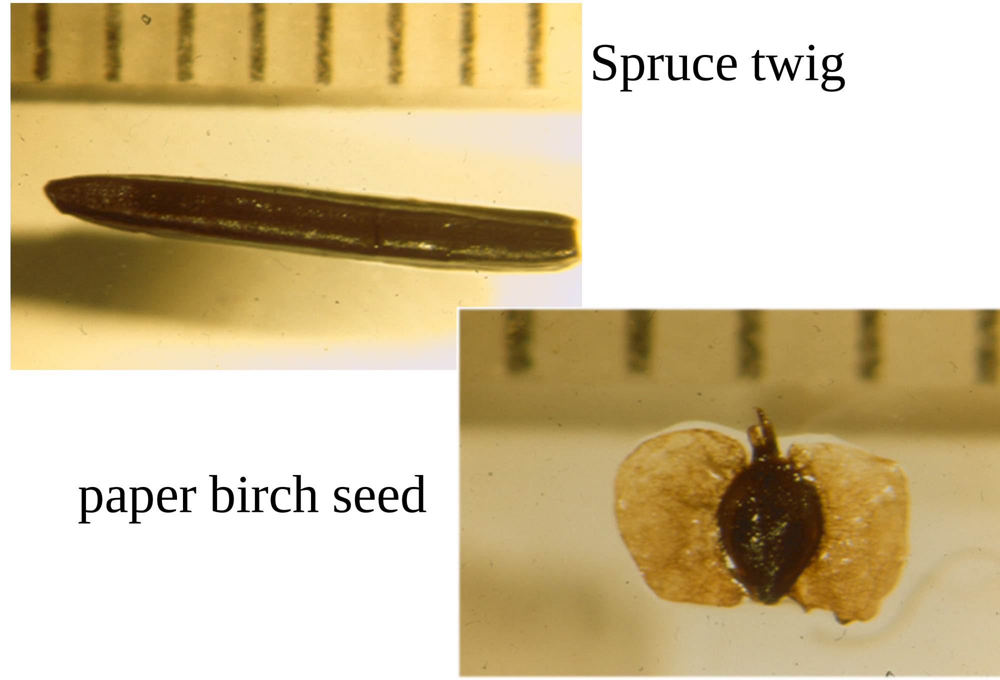
How do you isolate the pollen from the lake mud?

- Take 1cc sediment samples from the core at close intervals.
- Process using sieves and various chemicals to remove unwanted components from the sediment.
- Mount the resulting pure pollen suspension on a slide and begin microscopic analysis.



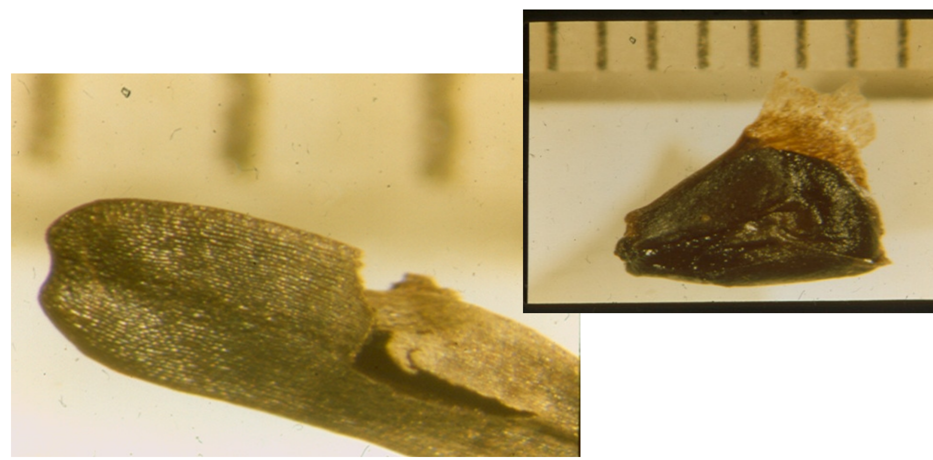
Plant macrofossils

- are fossil seeds, needles, buds, twigs, *etc*.
- can often be identified to the species level
- can confirm local presence of a taxon at the study site
- can provide valuable material for radiocarbon dating.
- can be isolated from pollen-bearing sediments by sieving and identified using a dissection microscope, reference material and pictorial keys



Spruce twig

paper birch seed

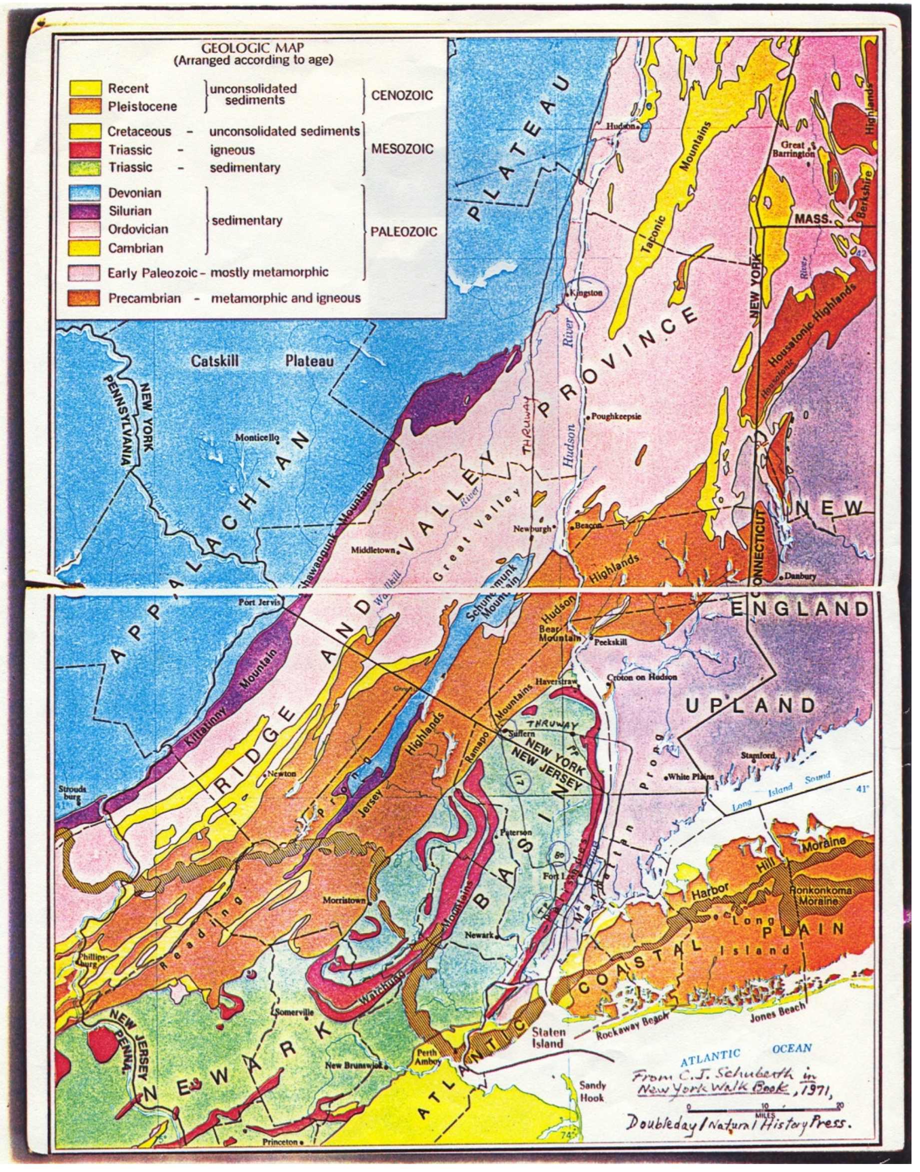


Fir needle and seed

Forest, climate, and fire history of the Hudson Highlands, southeastern New York during the last >12,500 years

Terryanne Maenza-Gmelch

Map showing Hudson Highlands Physiographic province



Core sites in the Hudson Highlands

Sutherland Pond
Black Rock Forest
Cornwall, NY

Spruce Pond

Harriman State Park

Tuxedo, NY

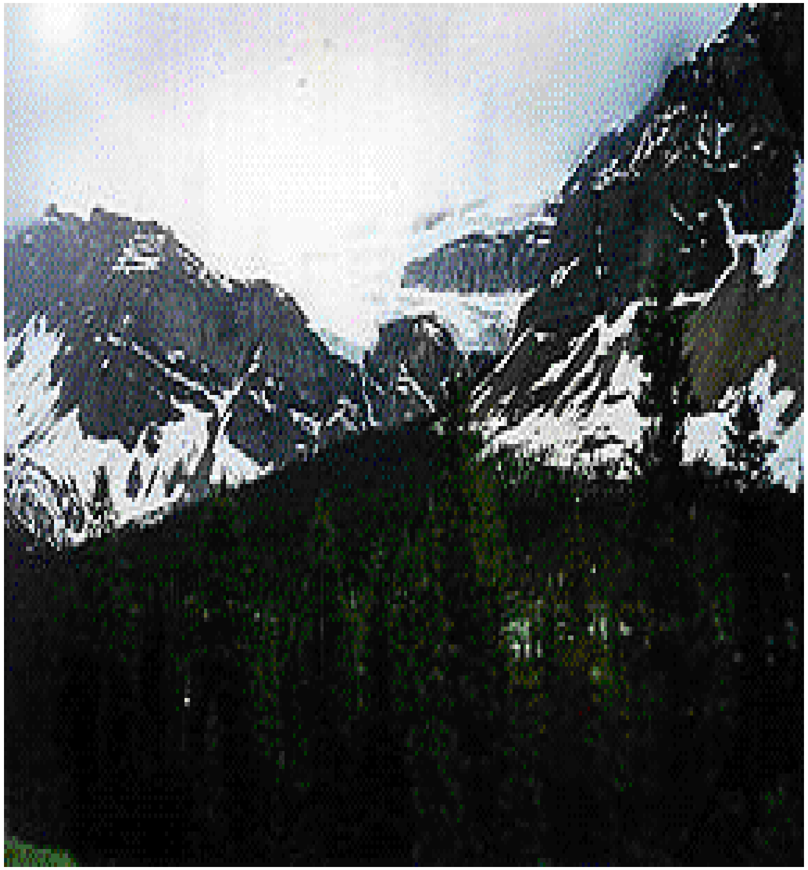
The Late-glacial (>12,500 years ago (BP))

The earliest pollen assemblages deposited after glacial retreat in the Hudson Highlands

- dominated by herbaceous and shrub types: Willow (Salix), Birch (Betula), Alder (Alnus), Heath (Ericaceae), Sedge (Cyperaceae), Grass (Gramineae), and Composites (Tubuliflorae) with some trees, Pine (Pinus) and Spruce (Picea)
- possibly represents a tundra-like environment with scattered trees.

More Late-glacial (12,500-11,000 BP)

- onset of organic deposition into each pond studied
- the first occurrence of seeds and other plant macrofossils
- large increases in pollen influx to the ponds
- development of a mixed boreal coniferous - temperate deciduous woodland (Spruce, Fir, Paper Birch,Oak, *Ostrya/Carpinus*, and Ash.
- = dramatic environmental change (climatic warming) began at 12,500 years ago.



Younger Dryas (11,000-10,000 BP)

- An abrupt climatic flip back to cold conditions occurred at approximately 11,000 years ago and lasted for roughly 1000 years.
- This cool climatic episode is inferred from the dominance of Spruce, Fir, and Alder with a reduction of Oak, Ash, and *Ostrya/Carpinus*.

The early and middle Holocene

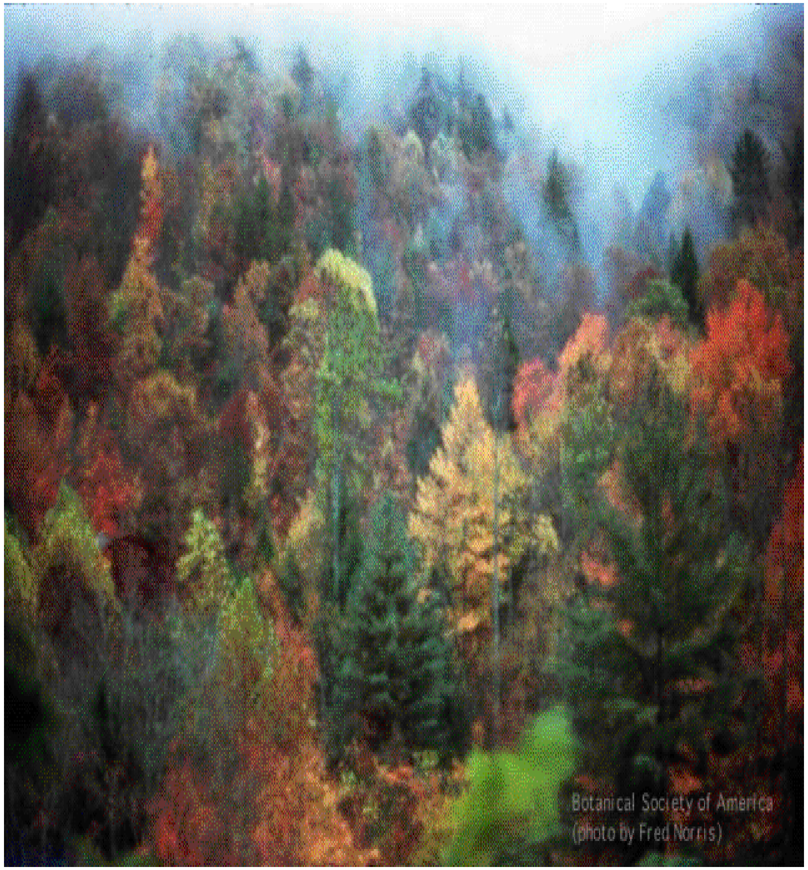
(10,000 - 2000 BP)

- Warm conditions, similar to the present, were established by 10,175 years ago. Evidence for this includes:
- expanding Oak-dominated forests
- invasion by White Pine, followed by Eastern Hemlock at 9645 years ago
- replacement of Paper Birch by Gray Birch at approximately 9575 years ago.

More Holocene

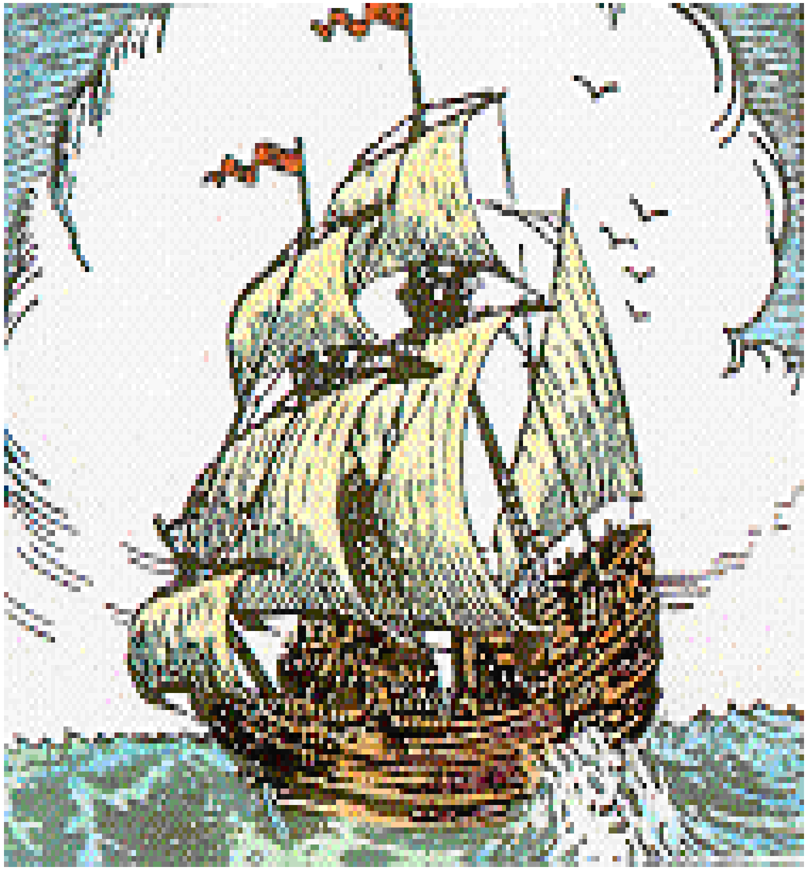
- Immigration of other tree taxa:

- American Beech (Fagus grandifolia) at 8100 BP
- Hickory (Carya) at 6200 BP
- American Chestnut (Castanea dentata) at 3600 BP



Arrival of Euroamericans (about 1700 AD)

- Euroamerican settlement of the Hudson Highlands is well-documented in the pollen record:
- rises in Ragweed, Grass, and Composites signal land clearance
- decreased percentages of Oak, Pine, and Eastern Hemlock reflect the harvest of each taxon
- Increased charcoal signals use of fire in connection with land-clearance, wood-related industries (charcoal, iron, and brick manufacturing), and operation of railroads (track fires)).



Decline of American chestnut
(Castanea dentata)

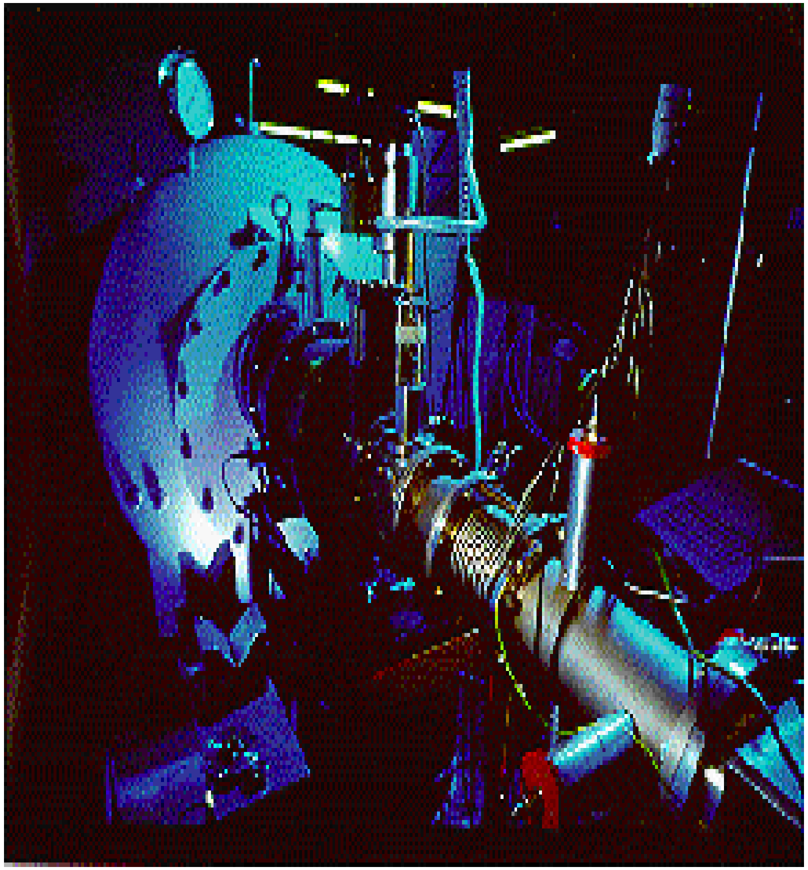
- A fungal pathogen is introduced at New York City in 1904.
- In 1909, only 1 to 2% of *Castanea* in the Hudson Highlands was affected by the pathogen; by 1915, most *Castanea* were killed.
- Prior to the blight, *Castanea* represented 35% of the trees in the forest with as much as 70% on mid-elevation slopes.
- This sequence is evident in the pollen record.

What about fire throughout this history?

- Fossil charcoal was more abundant during the last 10,000 years than between 12,500 and 10,000 years ago.
- High values of Oak pollen in association with continuous charcoal influx for some 9000 years suggest that fire played an important role in the development and maintenance of Oak forest.

How do you know the ages of these vegetation events?

- Radiocarbon dating (AMS method)
- Match ages of historical events with corresponding signals in the fossil record (for example the Ragweed Rise).



Late-glacial and early Holocene at Sutherland Pond, se NY pollen percentage diagram

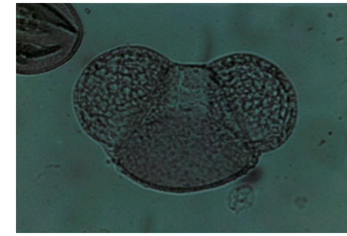
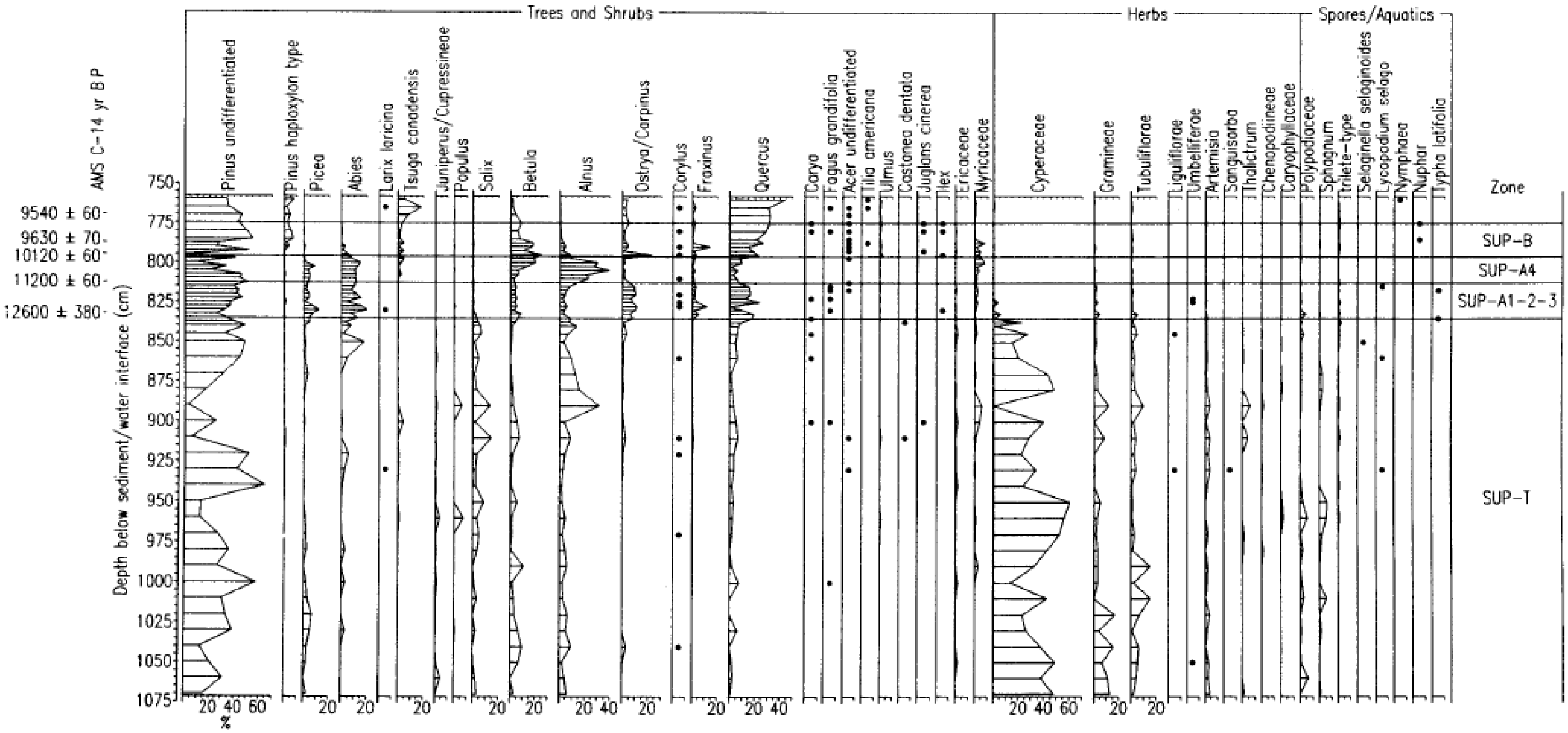
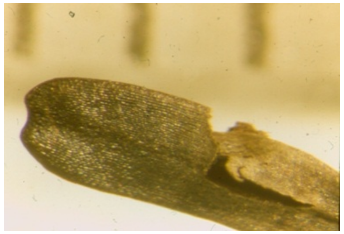
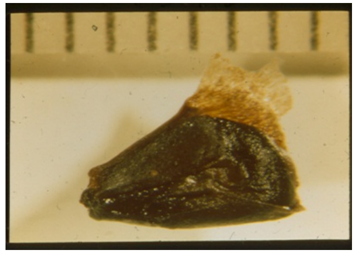


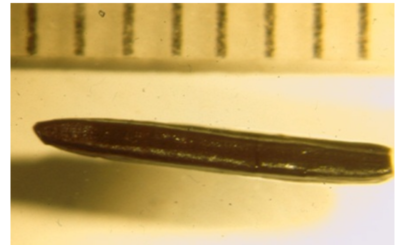
Fig. 2. Pollen and spore diagram and AMS radiocarbon chronology for the late-glacial and early Holocene at Sutherland Pond, New York. ●, values of < 1%.



Late-glacial and early Holocene plant macrofossils at Sutherland Pond







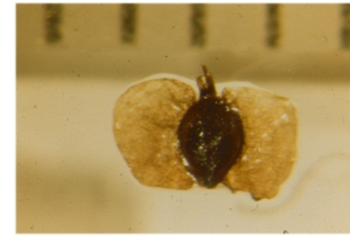
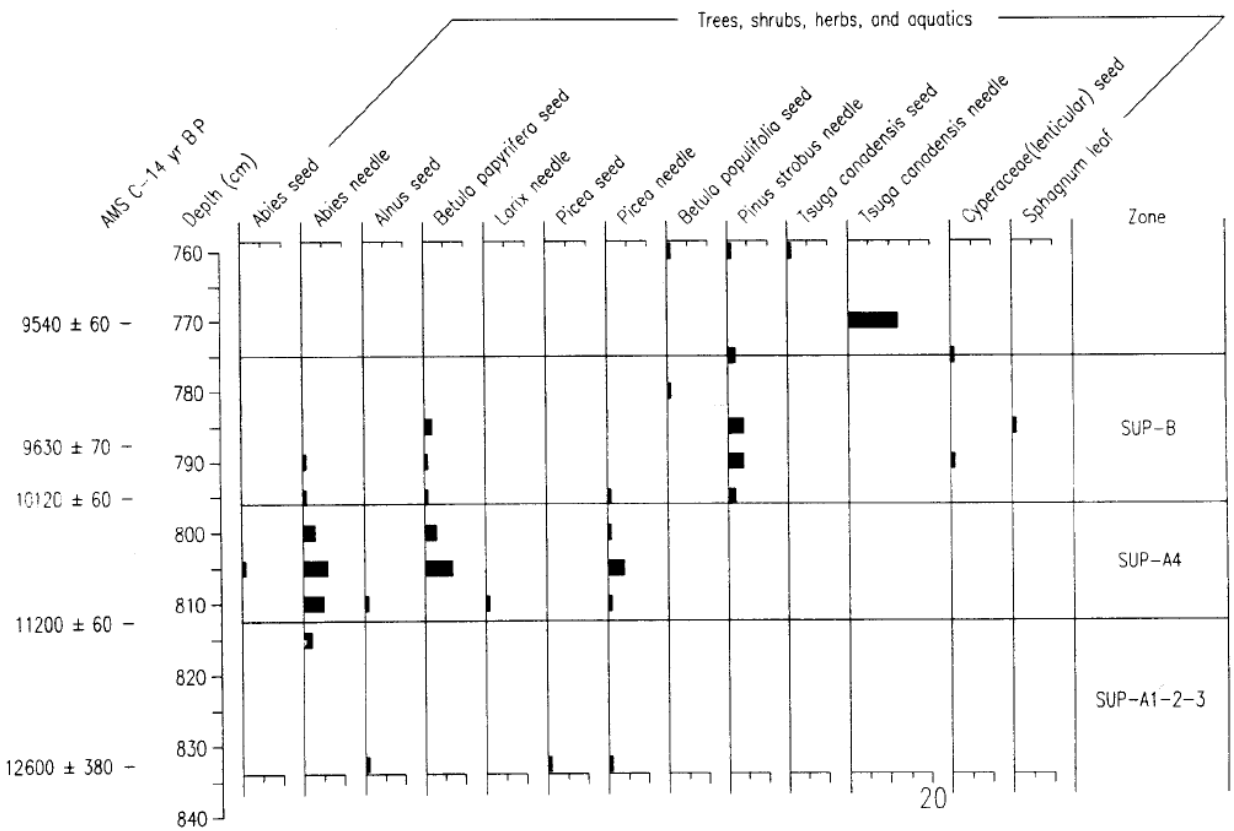


Fig. 3. Diagram of plant macrofossils (number per 50 cm^3 sediment) and AMS radiocarbon chronology for the late-glacial and early Holocene at Sutherland Pond, New York.



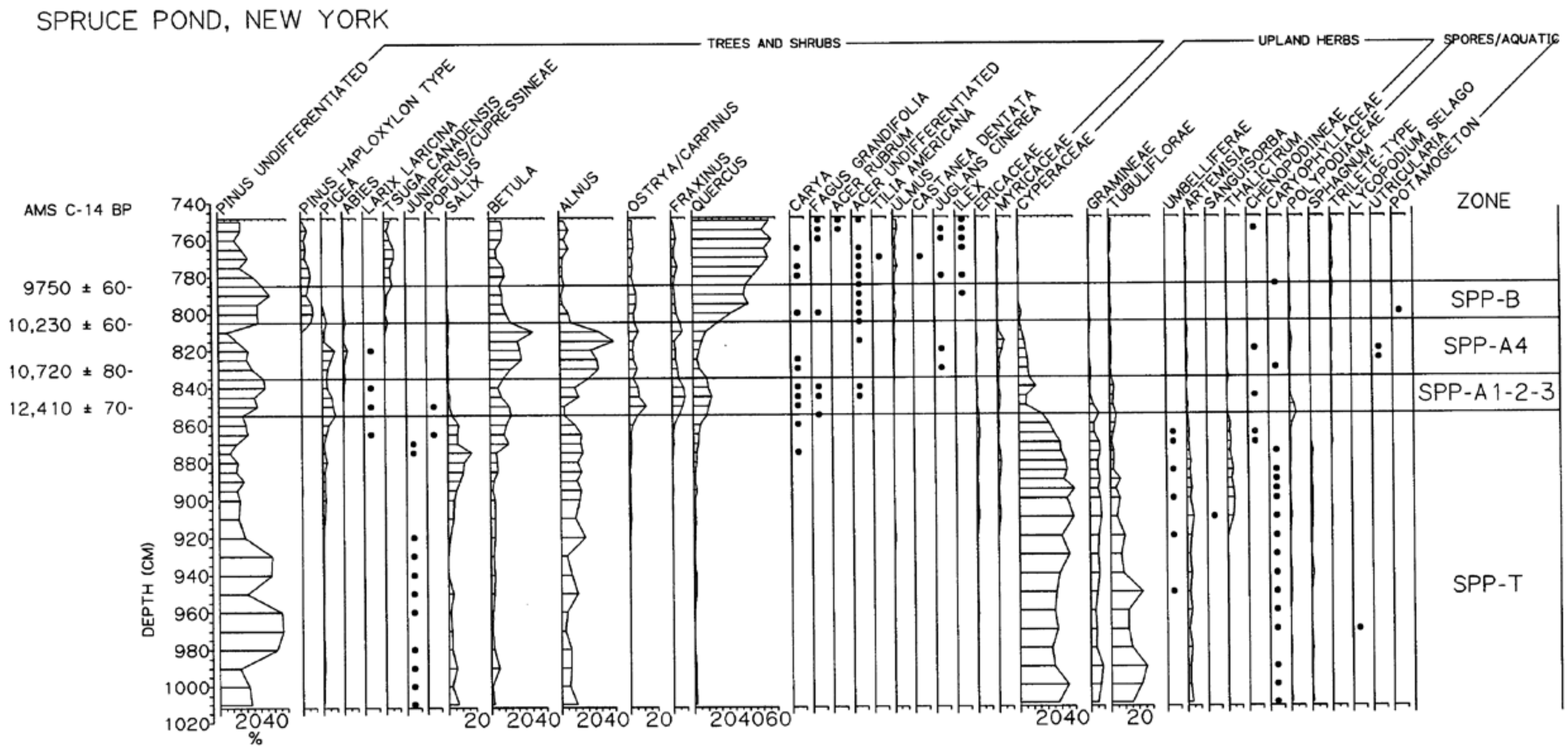


Figure 2 Pollen and spore diagram with AMS radiocarbon chronology for the late-glacial and early Holocene at Spruce Pond, New York. Closed circles indicate values of <1%.

Holocene at Sutherland Pond

pollen percentage diagram

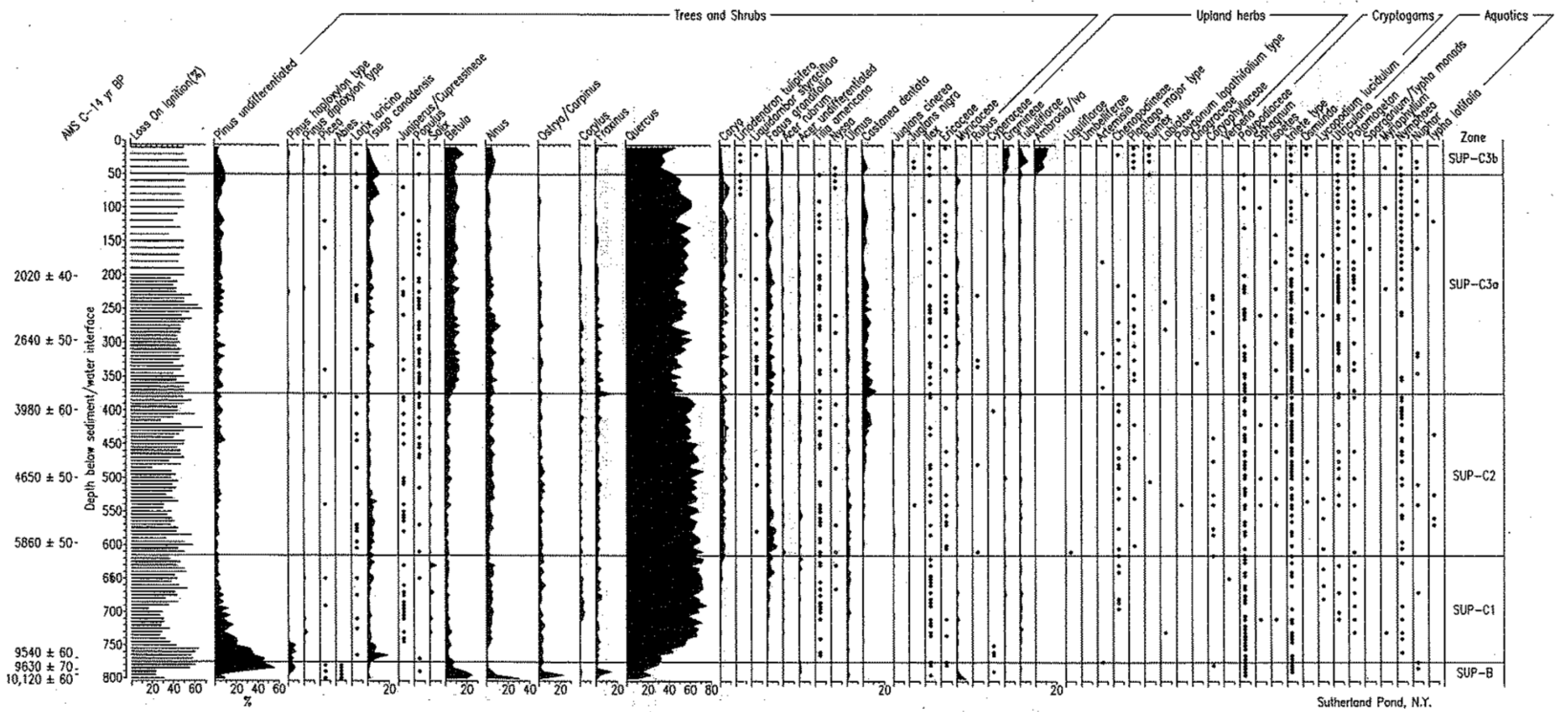


Figure 2 Pollen and spore diagram with loss-on-ignition data and AMS radiocarbon chronology for the Holocene at Sutherland Pond, New York. Closed circles indicate values of <1%.

Holocene plant macrofossils at Sutherland Pond

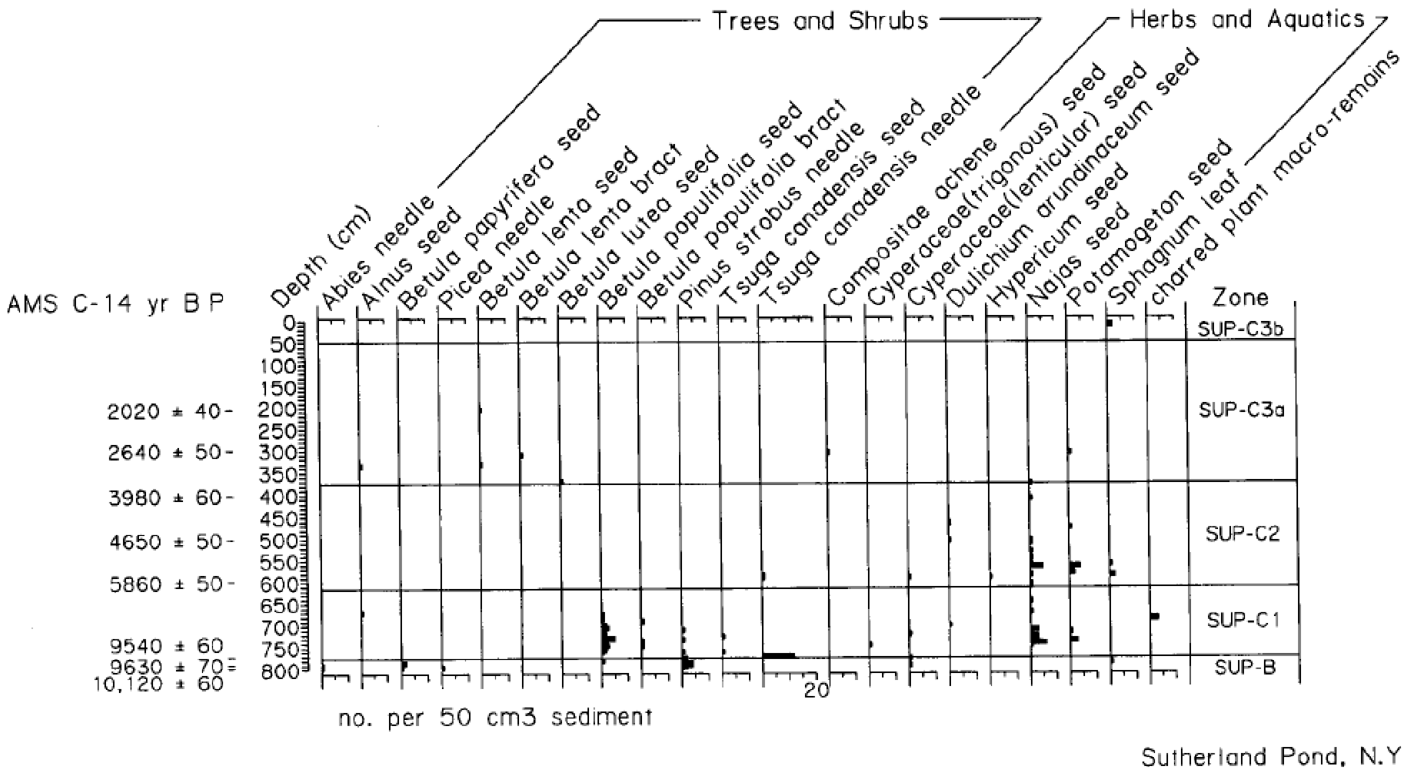
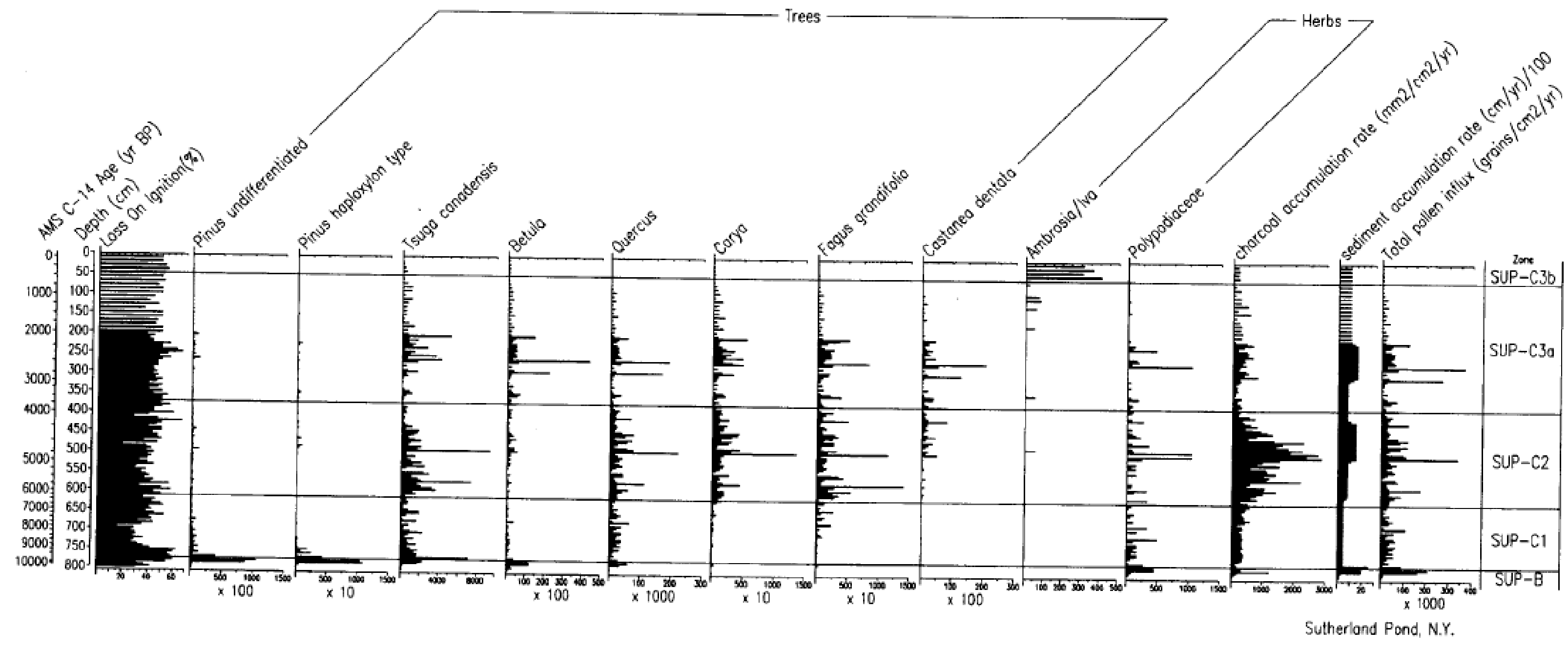


Figure 4 Diagram of plant macrofossils (number per 50 cm^3 sediment) and AMS radiocarbon chronology for the Holocene at Sutherland Pond, New York.

Pollen influx at Sutherland Pond (Holocene)

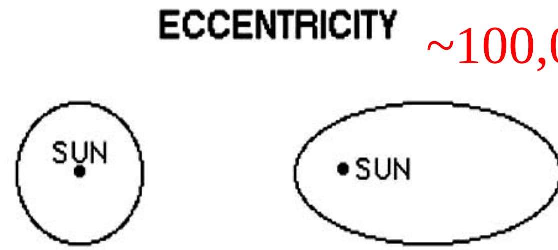


igure 3 Diagram of pollen influx (grains cm^{-2} yr^{-1}) for selected taxa, AMS radiocarbon chronology, loss-on-ignition, charcoal accumulation rates (mm^2 cm^{-2} yr^{-1}), sediment-accumulation rates (cm yr^{-1}), and total pollen flux (grains cm^{-2} yr^{-1}) for the Holocene at Sutherland Pond, New York.

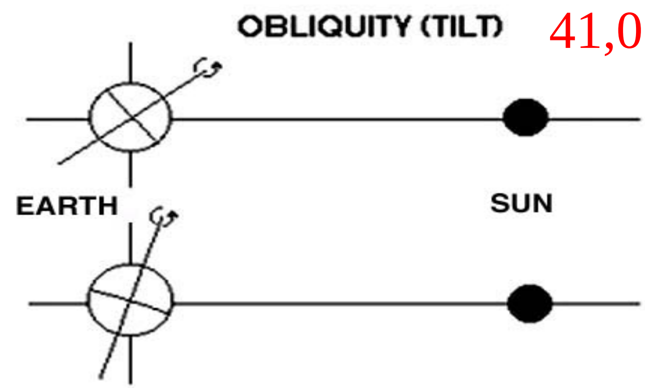
What is the cause of the observed pattern of glaciations?

The most widely accepted theory is the Milankovitch Theory of Orbital Forcing:

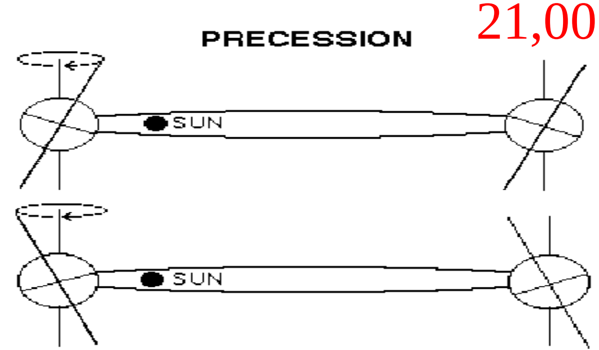
- Milankovitch proposed that cyclical changes in the relative positions in the earth and the sun (orbital geometry) influence the amount of solar radiation received on earth.
- These variations in solar radiation affect the contrast between summer and winter temperatures. If summers are not warm enough to melt the previous year's snow then ice sheets grow.



~100,000 year cycle

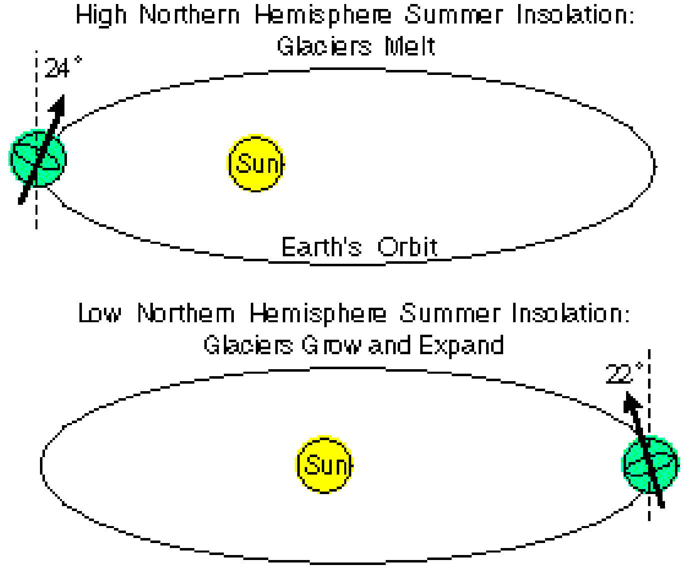


41,000 year cycle



21,000 year cycle

Milankovitch's Orbital Parameter Theory



When Earth's orbit is eccentric, the tilt of Earth's axis of rotation is large, and Northern Hemisphere summer occurs when Earth is closest to the sun; High latitude summertime insolation is large and the Milankovitch theory predicts warmer climate.

When Earth's orbit is less eccentric, the tilt of Earth's axis of rotation is less, and Northern Hemisphere summer occurs when Earth is farthest from the sun: High northern latitude summertime insolation is less and the Milankovitch theory predicts ice ages.