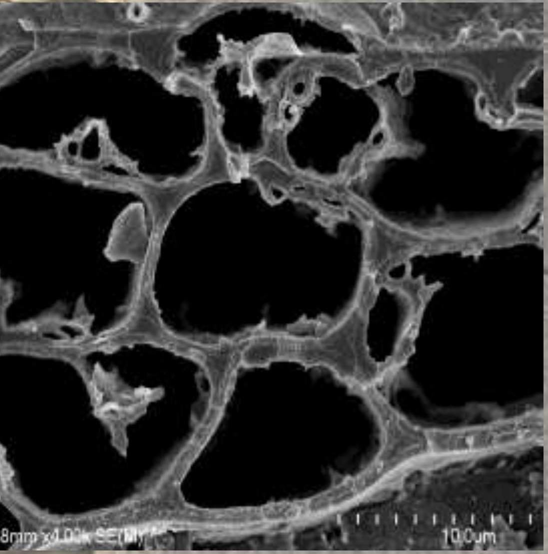
Oaks & Oceans

a 14,000 year coupling of mid continental and ocean climates



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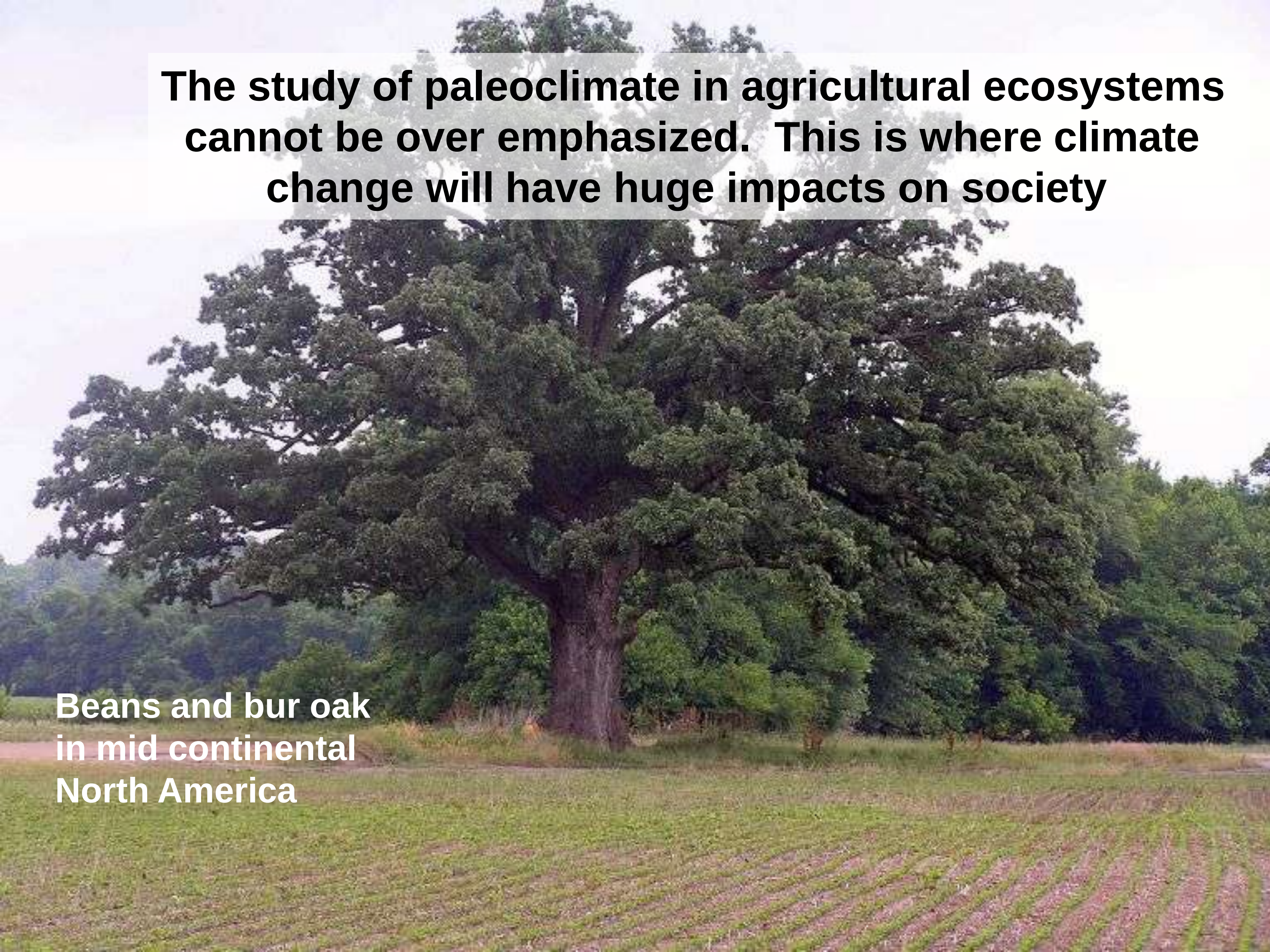
University of Missouri

Presentation Objectives

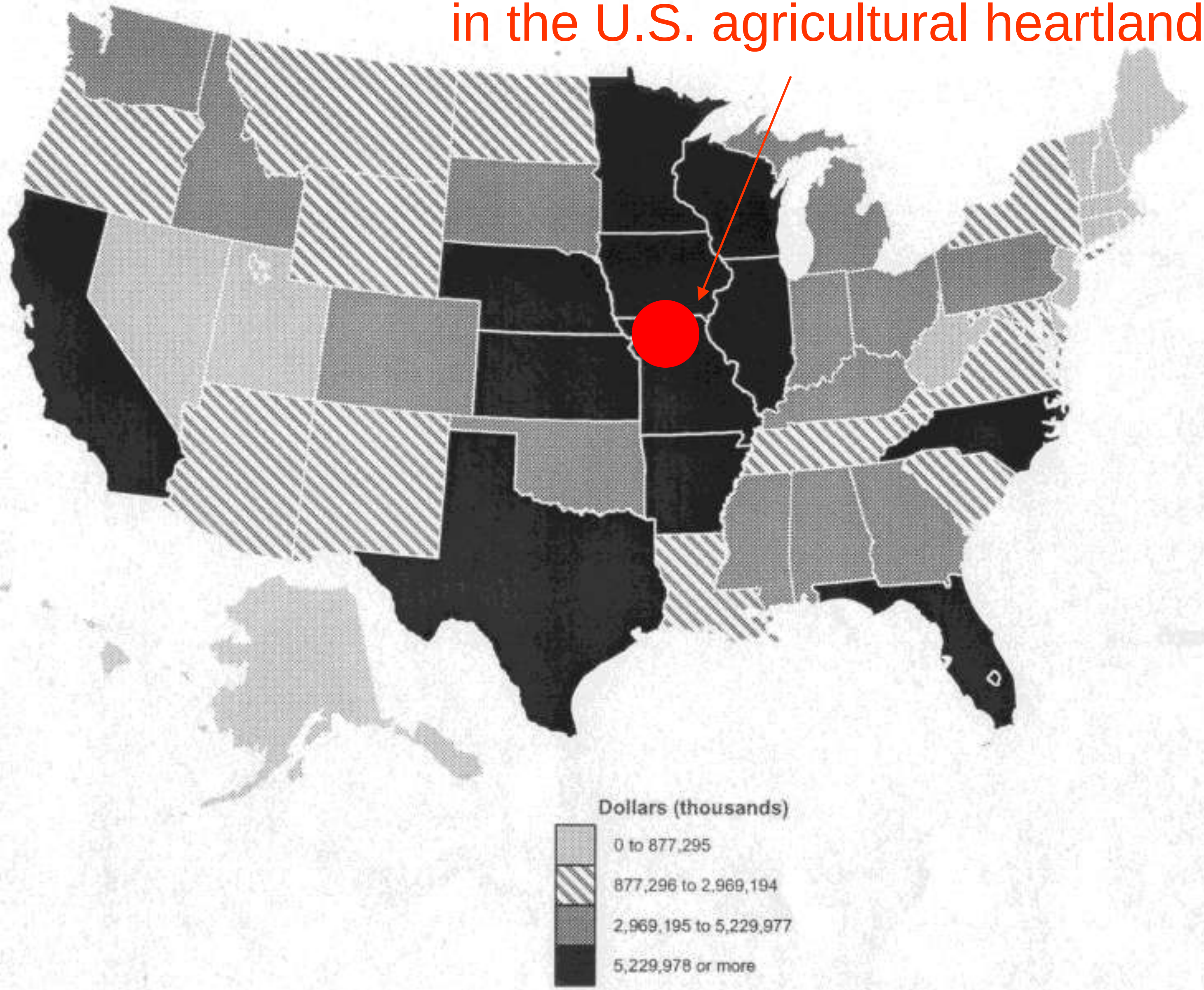
1. Address the importance of climate in the mid west
2. Present the climate proxy resource and data
3. A minimal description of methods
4. Compare mid-continental and ocean climates


The study of paleoclimate in agricultural ecosystems cannot be over emphasized. This is where climate change will have huge impacts on society
Beans and bur oak in mid continental North America

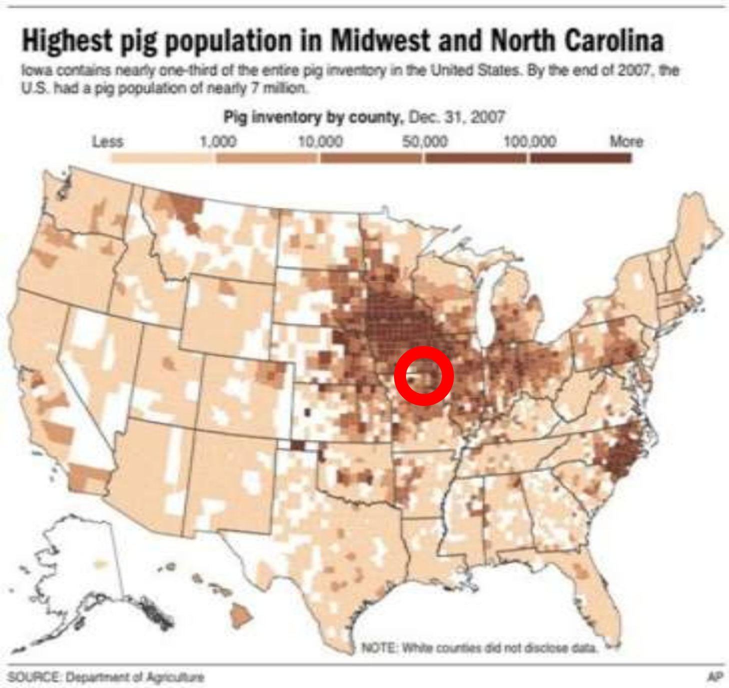
Paleoclimate in an agricultural ecosystem
Old wood under tomorrow's breakfast (grains)

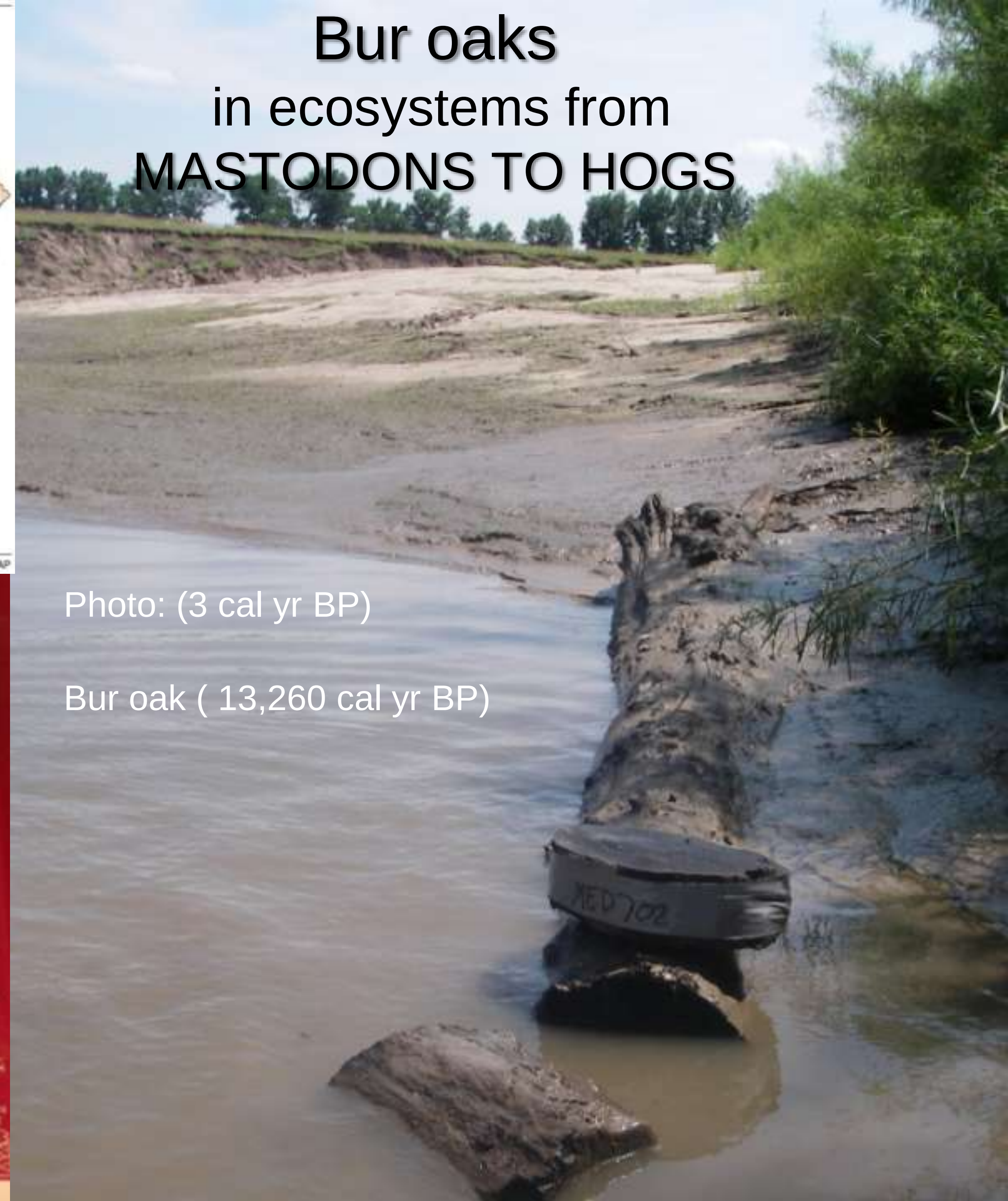
Pulling the canoe by a 'cut bank'
in a shallow river loaded with hundreds
of pounds of wood and equipment

Ancient oak ring climate proxy is in the U.S. agricultural heartland

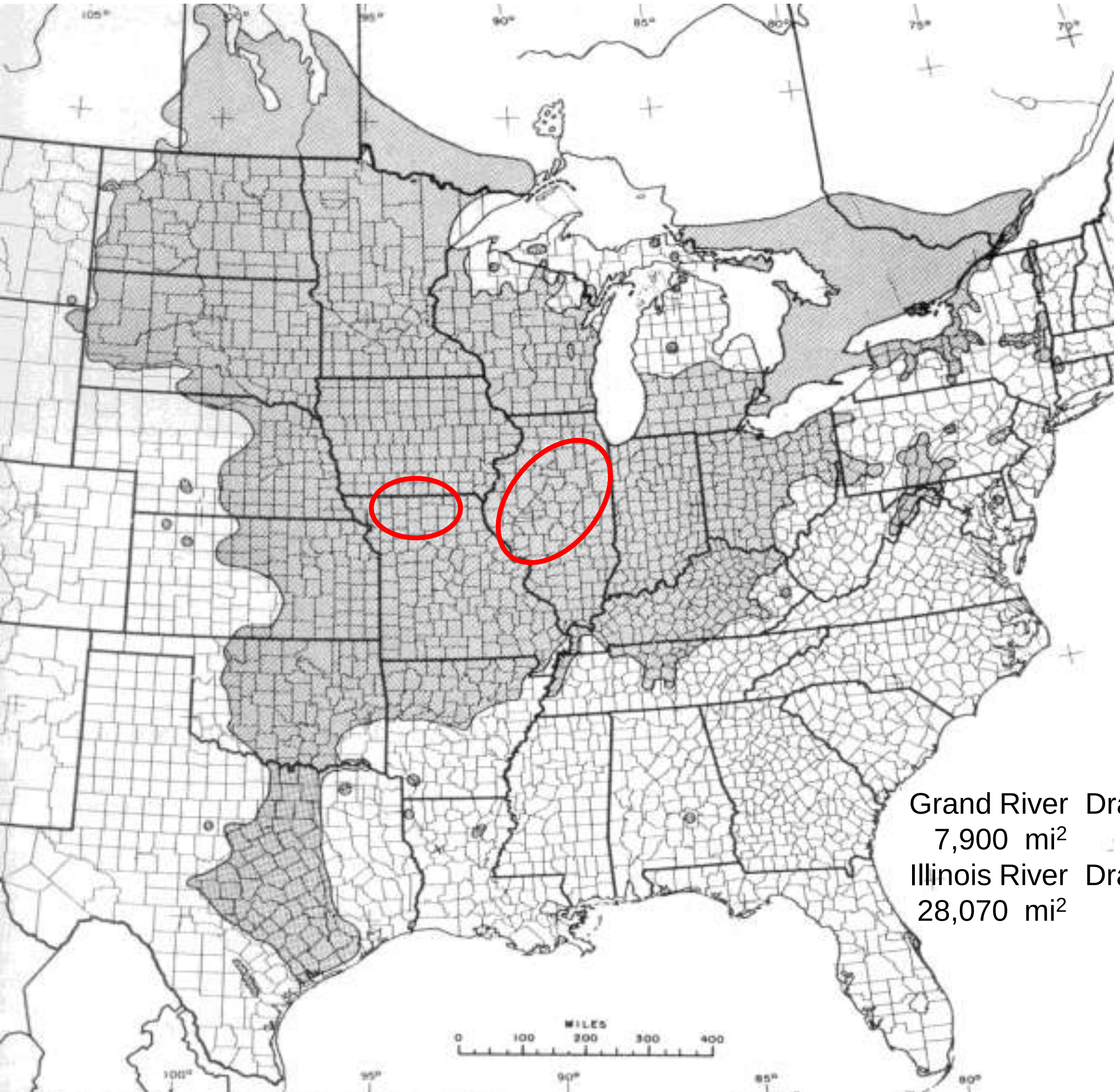


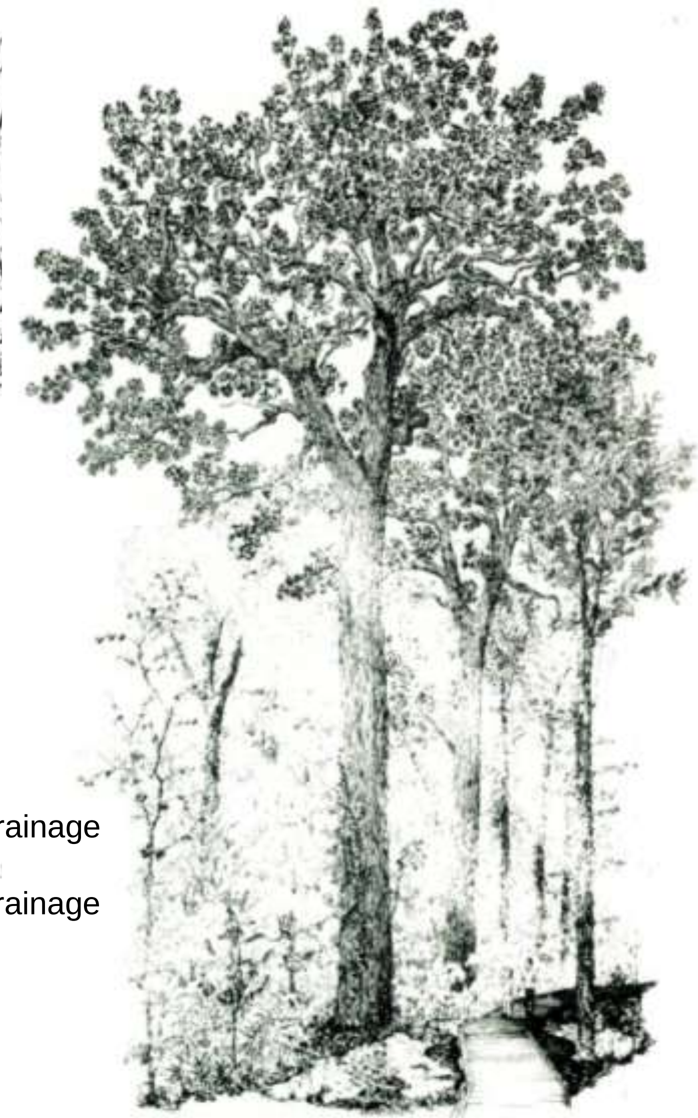
Bur oaks
in ecosystems from
MASTODONS TO HOGS

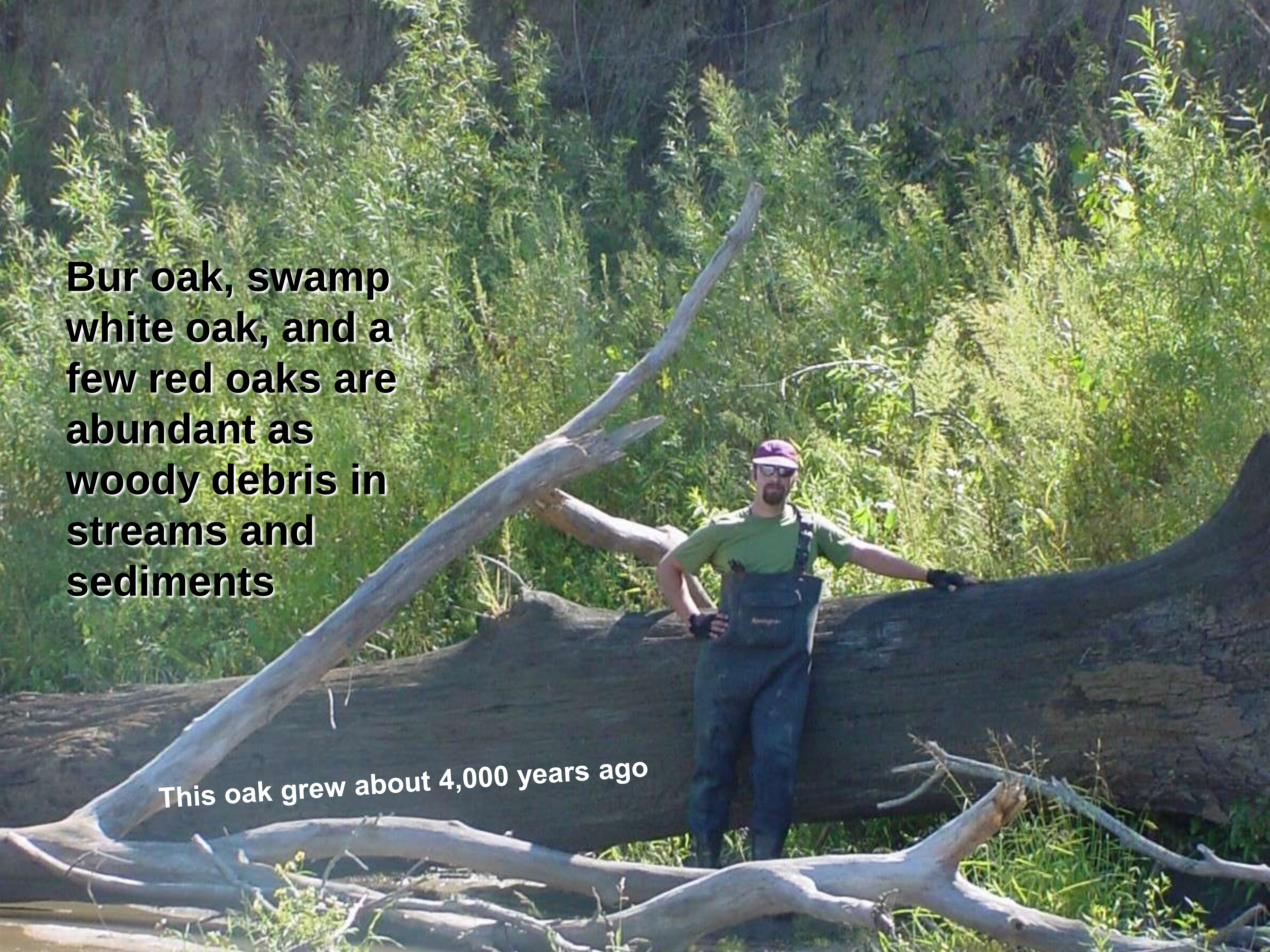




Bur oak (*Quercus macrocarpa*) has a very ***large ecological amplitude*** with respect to climate: along its ***2,700 km north-south*** distribution it has a ***range of 25 ºC*** in annual mean minimum temperature and ***100 cm/yr*** in precipitation



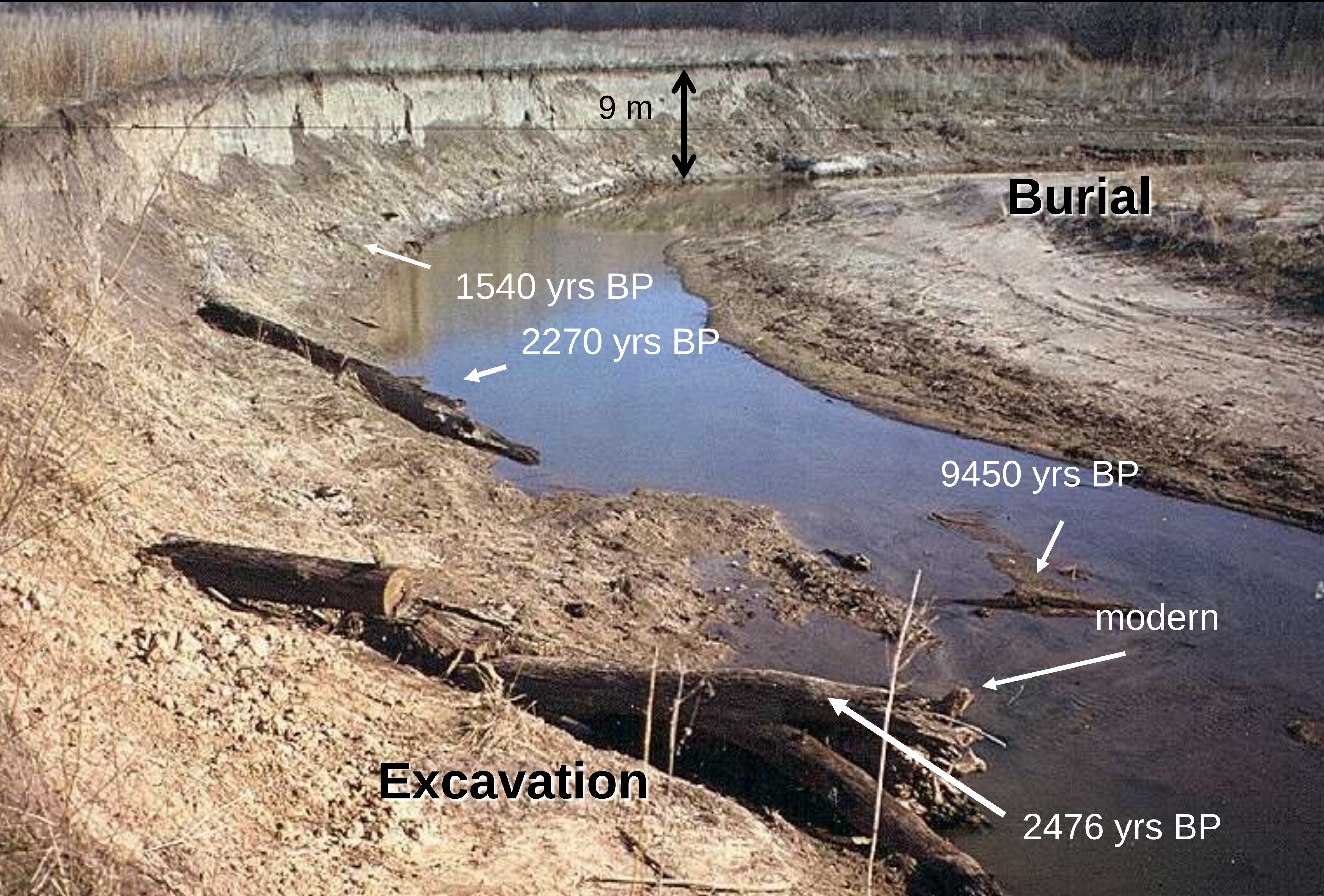



Bur oak, swamp white oak, and a few red oaks are abundant as woody debris in streams and sediments
This oak grew about 4,000 years ago

Buried trees are *Quercus, Fraxinus, Acer, Ulmus, Juglans, and other spp*.)


Samples are waterlogged, of variable size, weight, and density
1,820 cal yr BP

Involvement of large wood in sediments



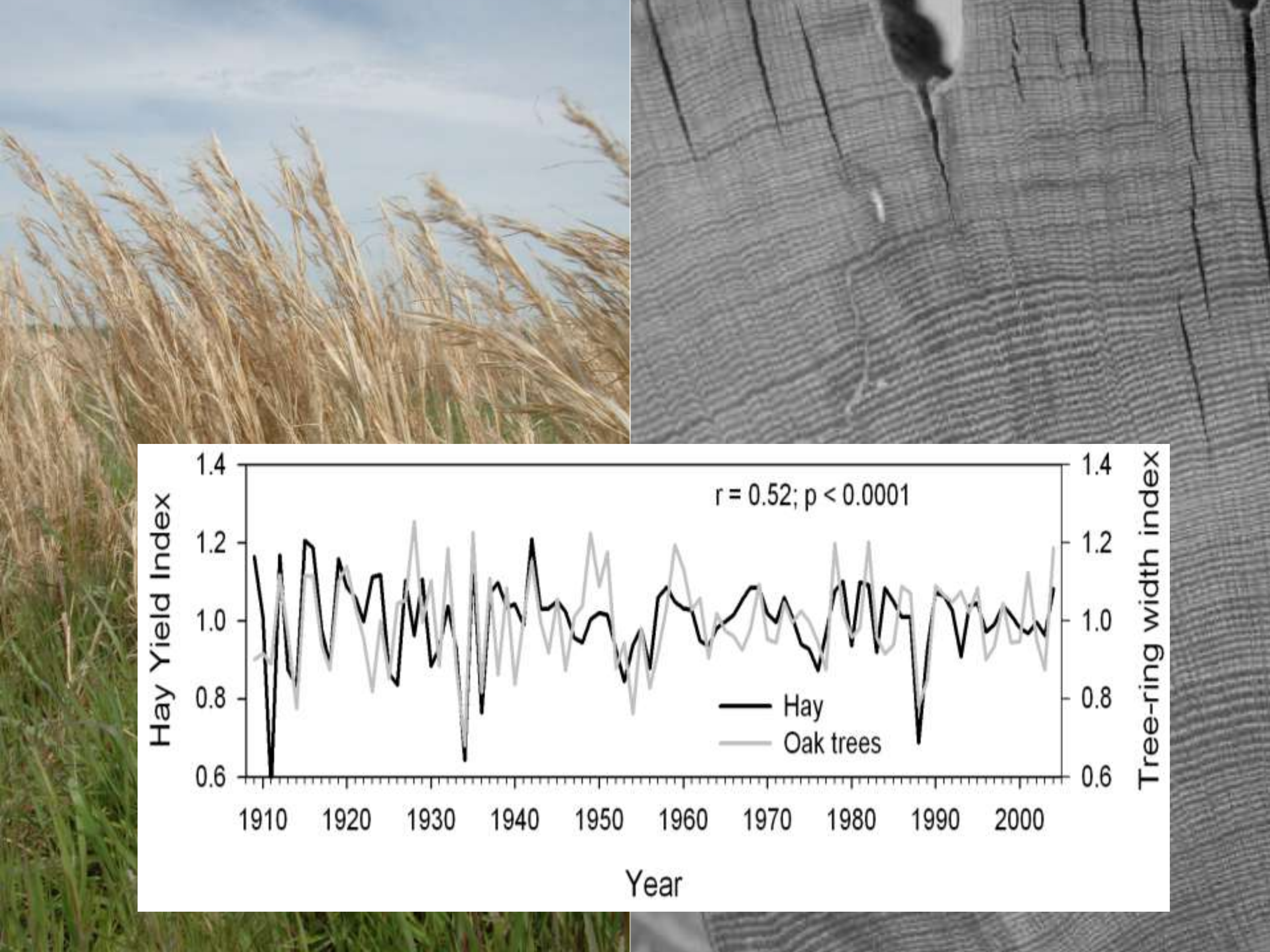
Each sample tree is cut, photographed and geo-referenced. This is the only permanent record other than the wood itself.

Riparian oak trees in a North Missouri floodplain

Oaks (*Quercus bicolor and macrocarpa*) in a floodplain pasture


7,745 Cal yr BP
WLD38


Private lands, oak washing out at the Peterson Ranch
(3, 601 years BP)



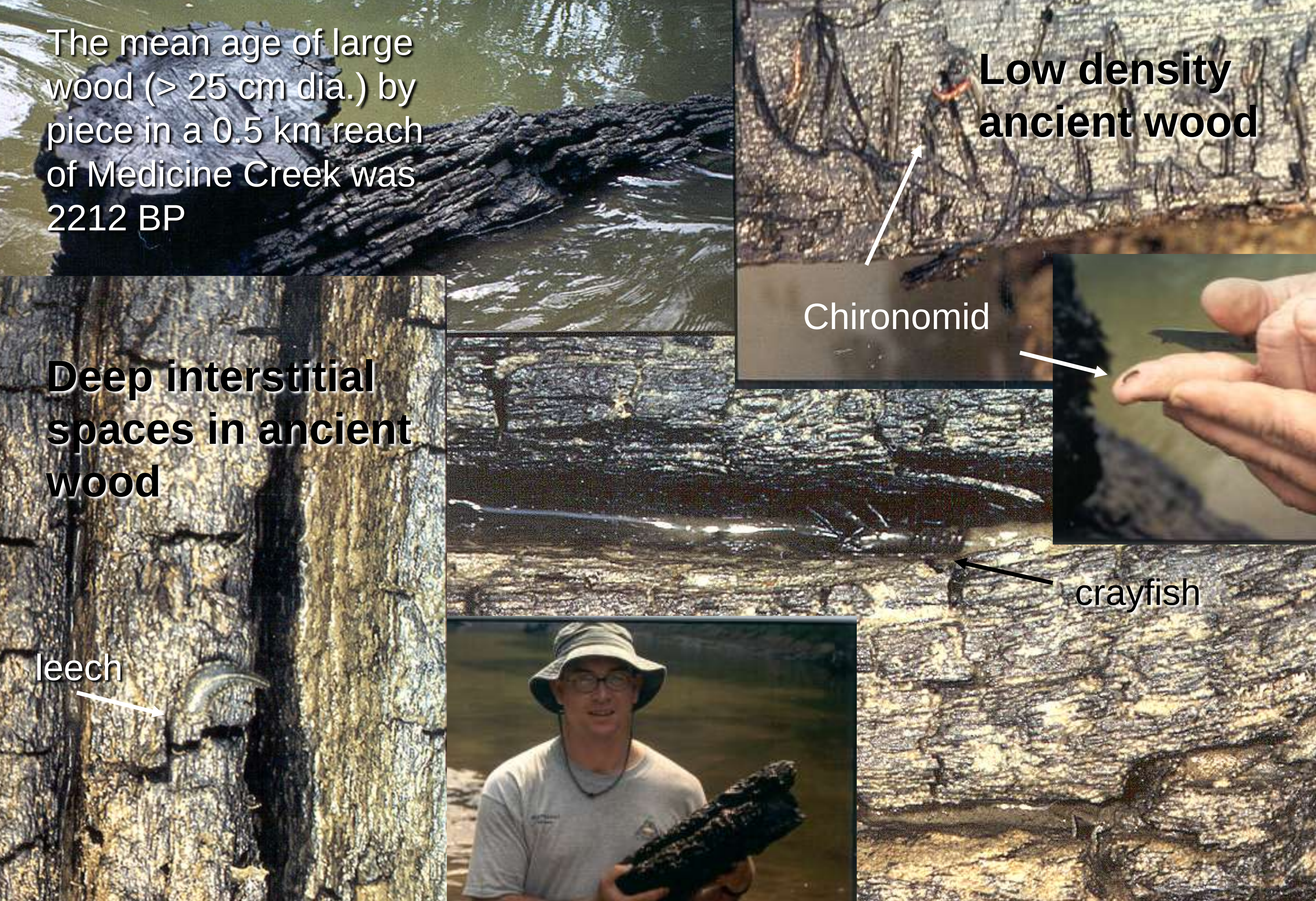
r = 0.52; p < 0.0001
Hay Yield Index
Tree-ring width index
1.4
1.2
1.0
0.8
0.6
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
Year
Hay
Oak trees


TMP035
2,020 cal yr BP
TMP041
2,780 cal yr BP
TMP039
920 cal yr BP

Some caddisflies (*Lype diversa*) prefer large wood with interstitial spaces (Phillips 1994)

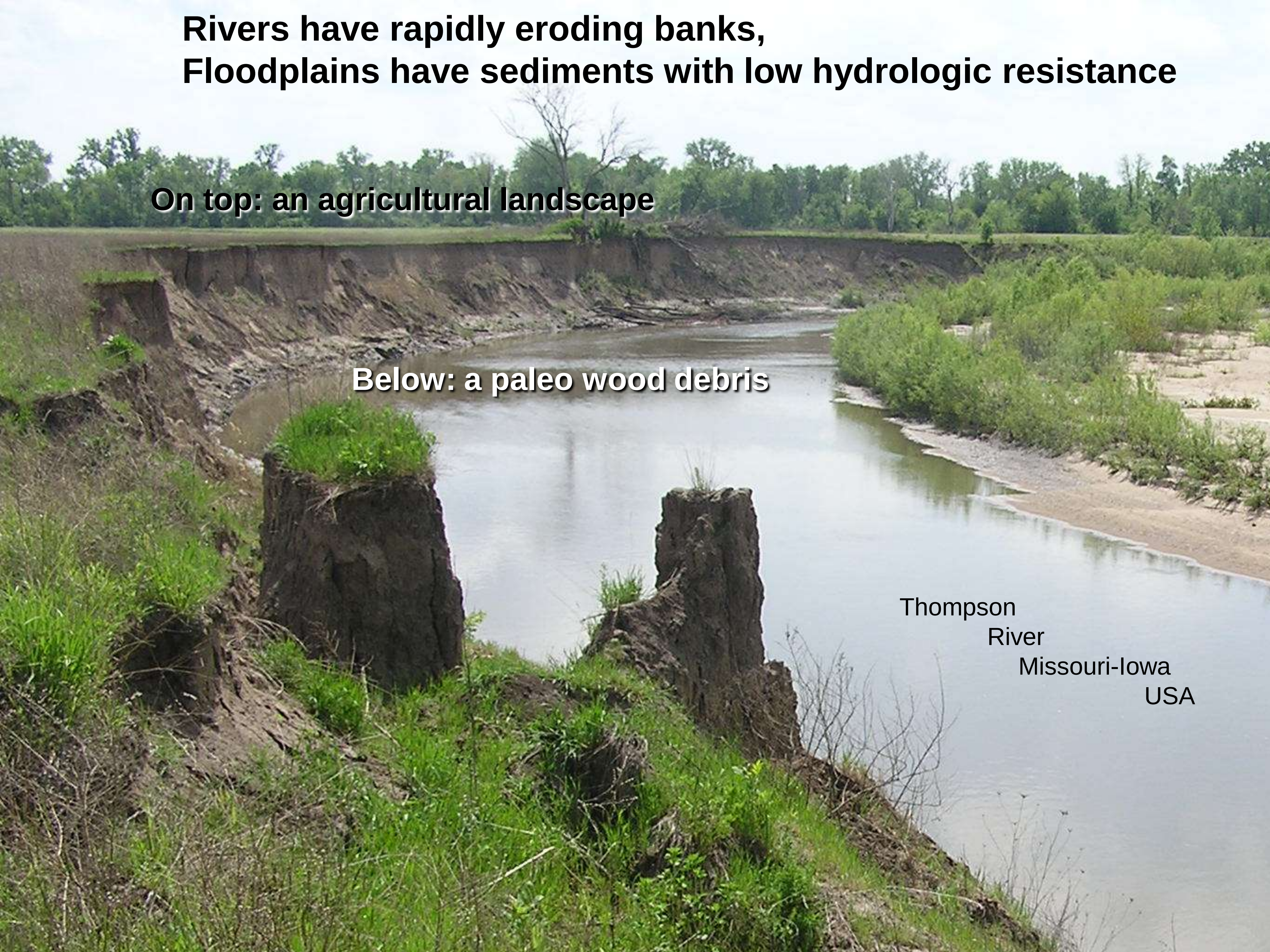
Invertebrates on ancient wood

The mean age of large wood (> 25 cm dia.) by piece in a 0.5 km reach of Medicine Creek was 2212 BP

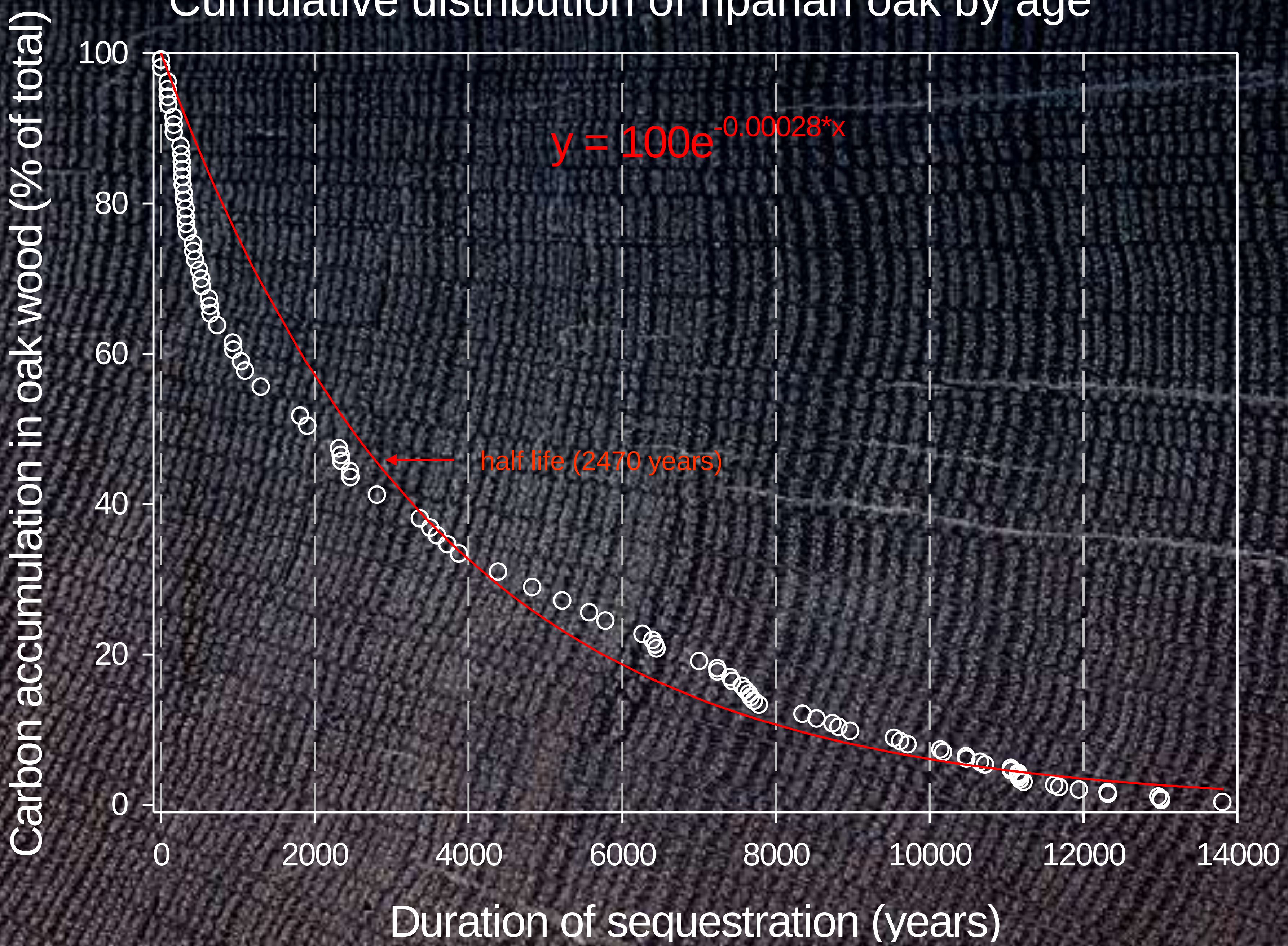



bur oak
1980 cal yr BP
Riparian forests of maple, oak,
sycamore, ash, and cottonwood

Rivers have rapidly eroding banks, Floodplains have sediments with low hydrologic resistance

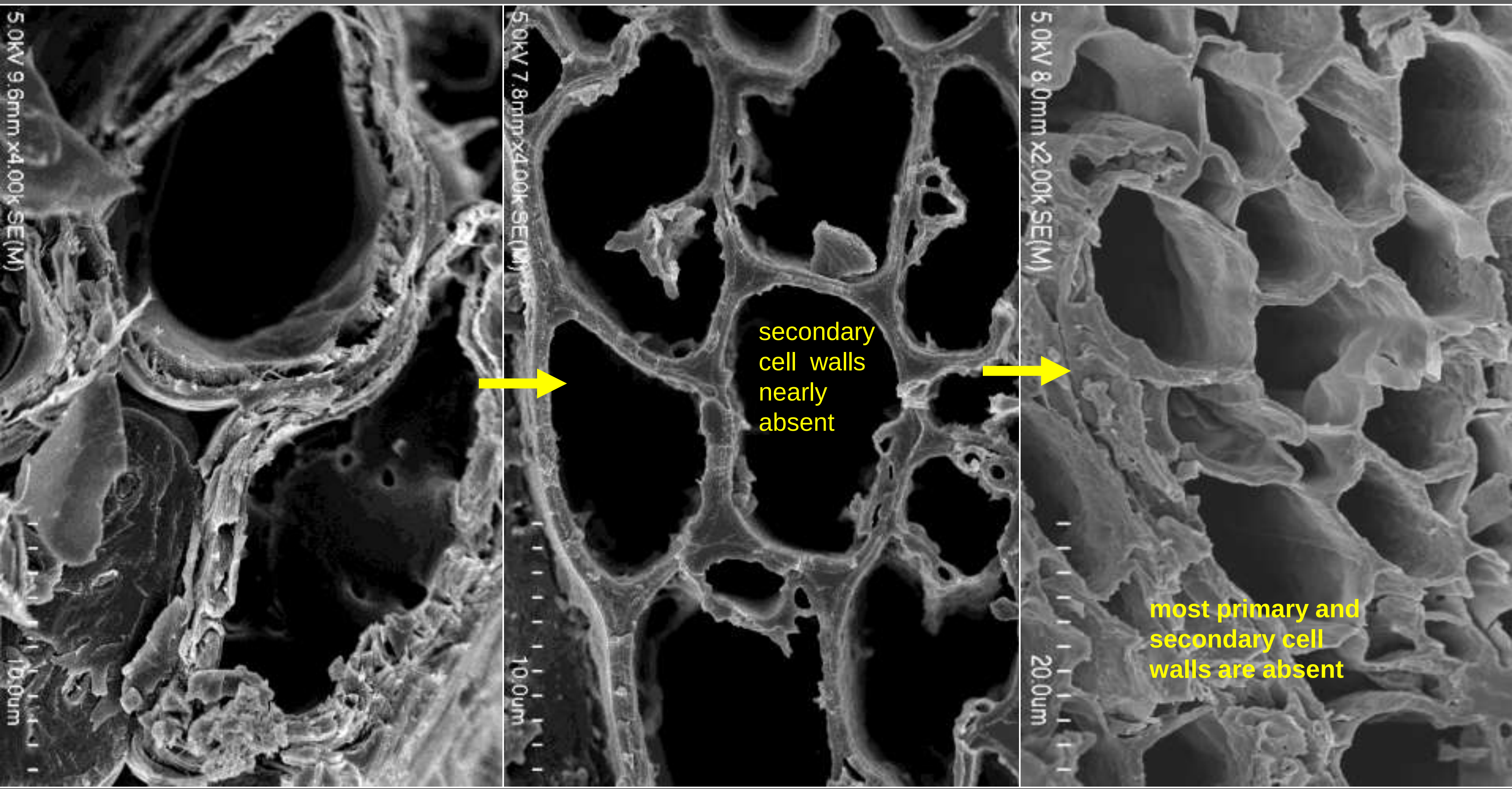


Cumulative distribution of riparian oak by age



Ancient oak wood dries and shrinks when exposed to ambient atmospheric conditions, thus we measure the wood when it is still wet and we don't let it dry out.

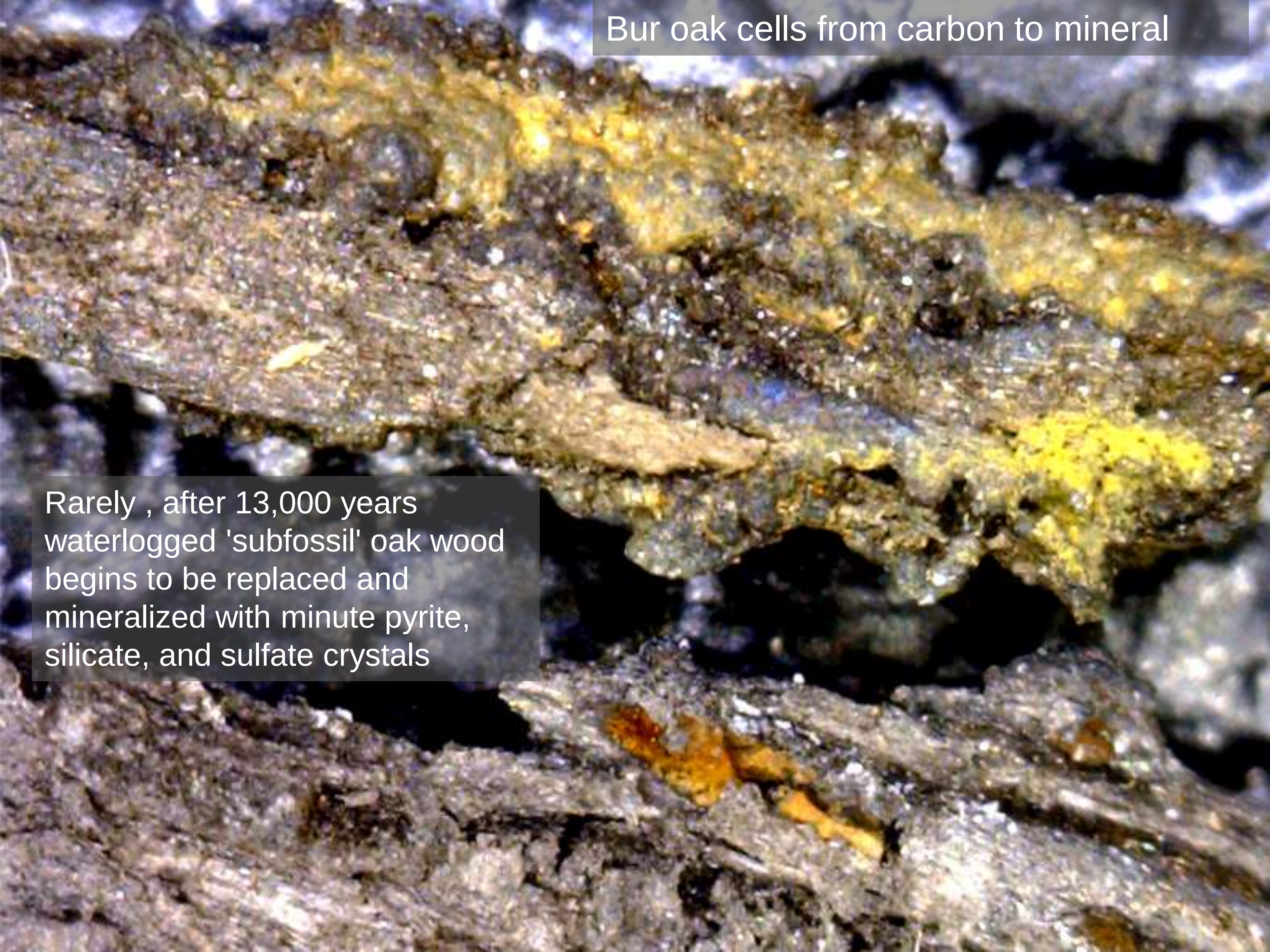
Cell wall structure and thickness change with time when stored in floodplain sediments

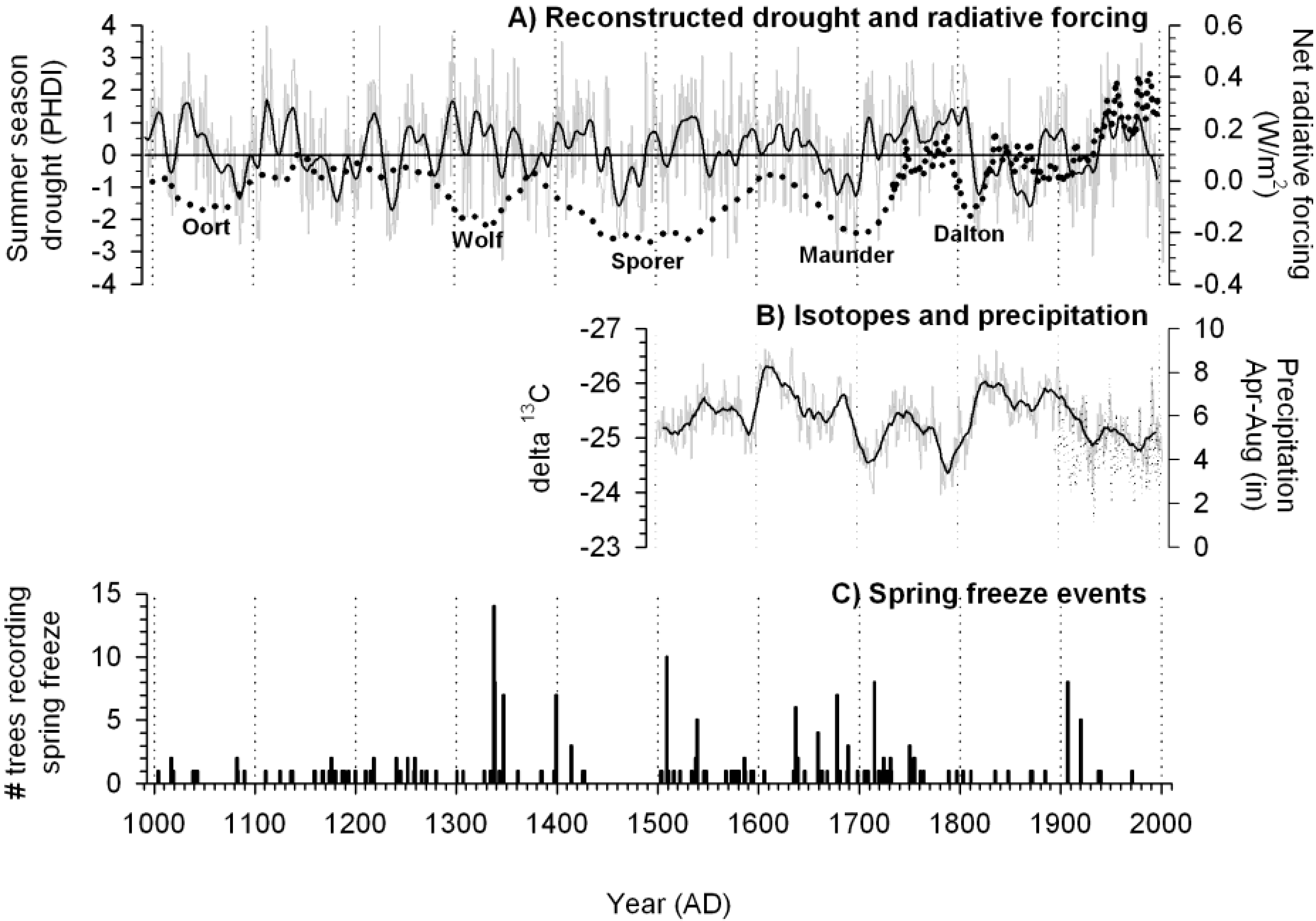


Modern (< 100 years) oak cell walls

Oak cell walls after 11,000 years

Cell walls after 14,000 years)


Bur oak cells from carbon to mineral
Rarely , after 13,000 years waterlogged 'subfossil' oak wood begins to be replaced and mineralized with minute pyrite, silicate, and sulfate crystals

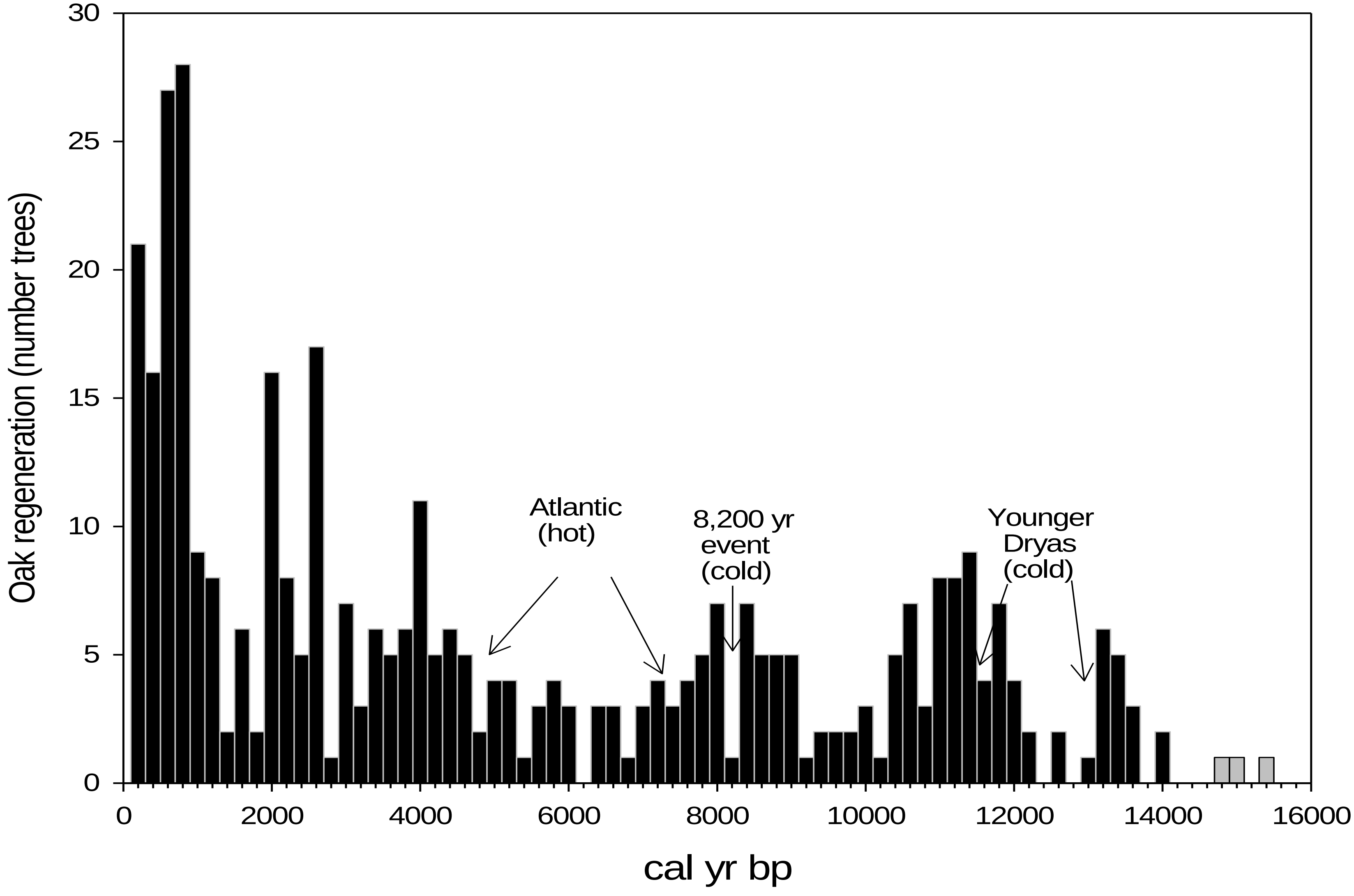


A) Reconstructed drought and radiative forcing
Summer season drought (PHDI)
Net radiative forcing (W/m^2)
Oort
Wolf
Sporer
Maunder
Dalton
B) Isotopes and precipitation
delta ^{13}C
Precipitation Apr-Aug (in)
C) Spring freeze events
trees recording spring freeze
Year (AD)

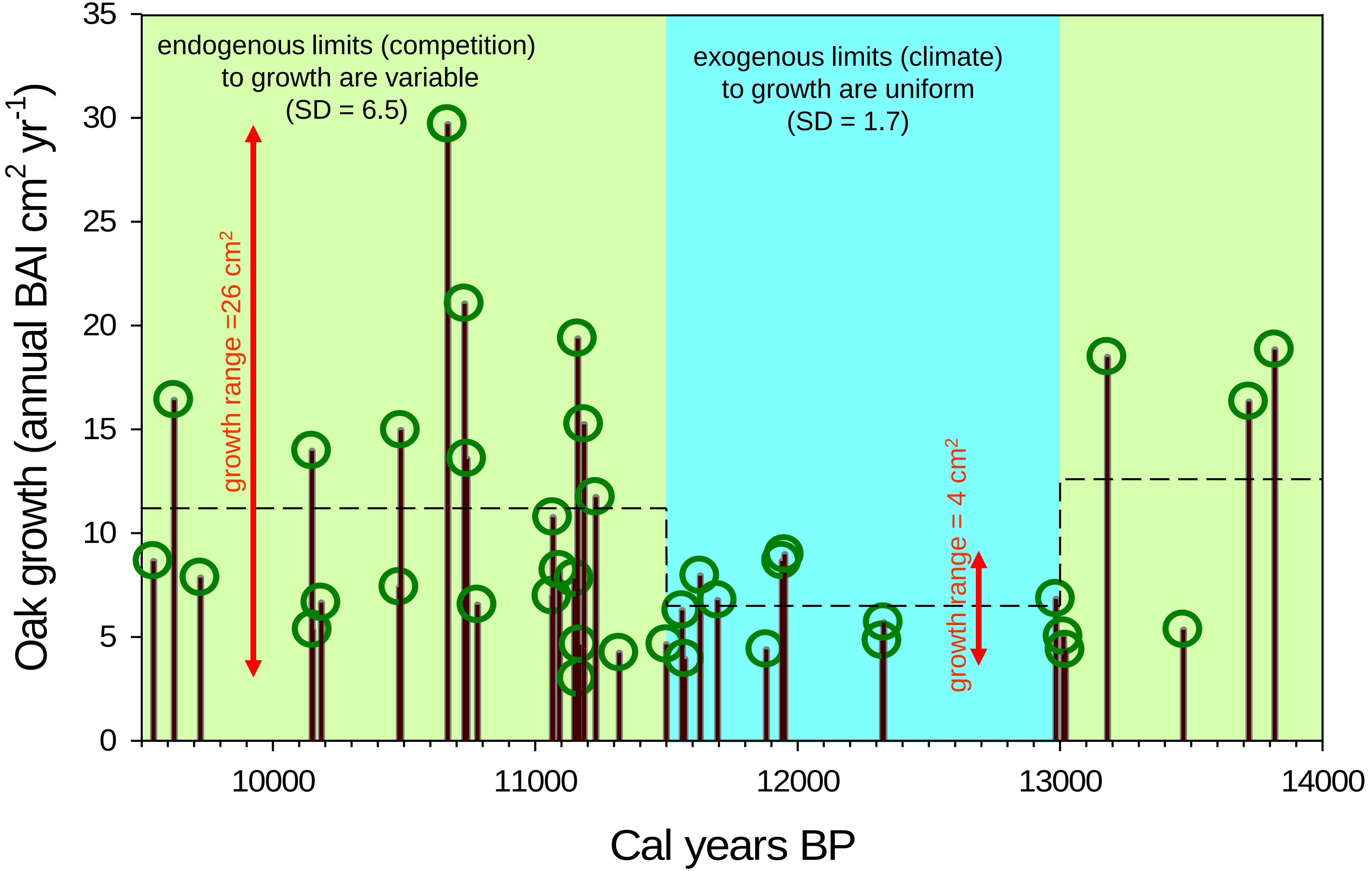
The '8.2- kyr event' is recorded in the ^{13}C of oaks in Northern Missouri

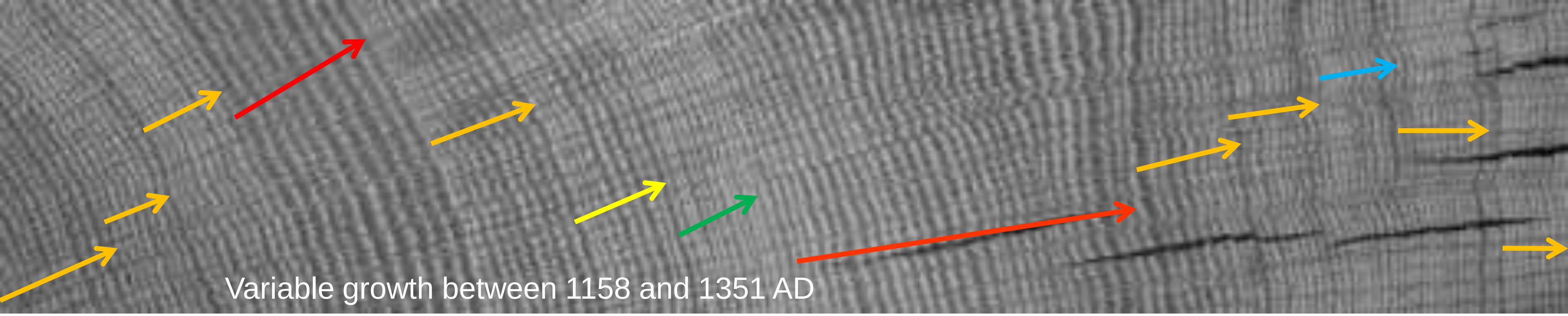
*This abrupt event, recorded in marine sediments was caused by the abrupt disintegration of the **Hudson Bay ice mass** and fresh water flux into the North Atlantic.*

Oak recruitment in the floodplain and rivers

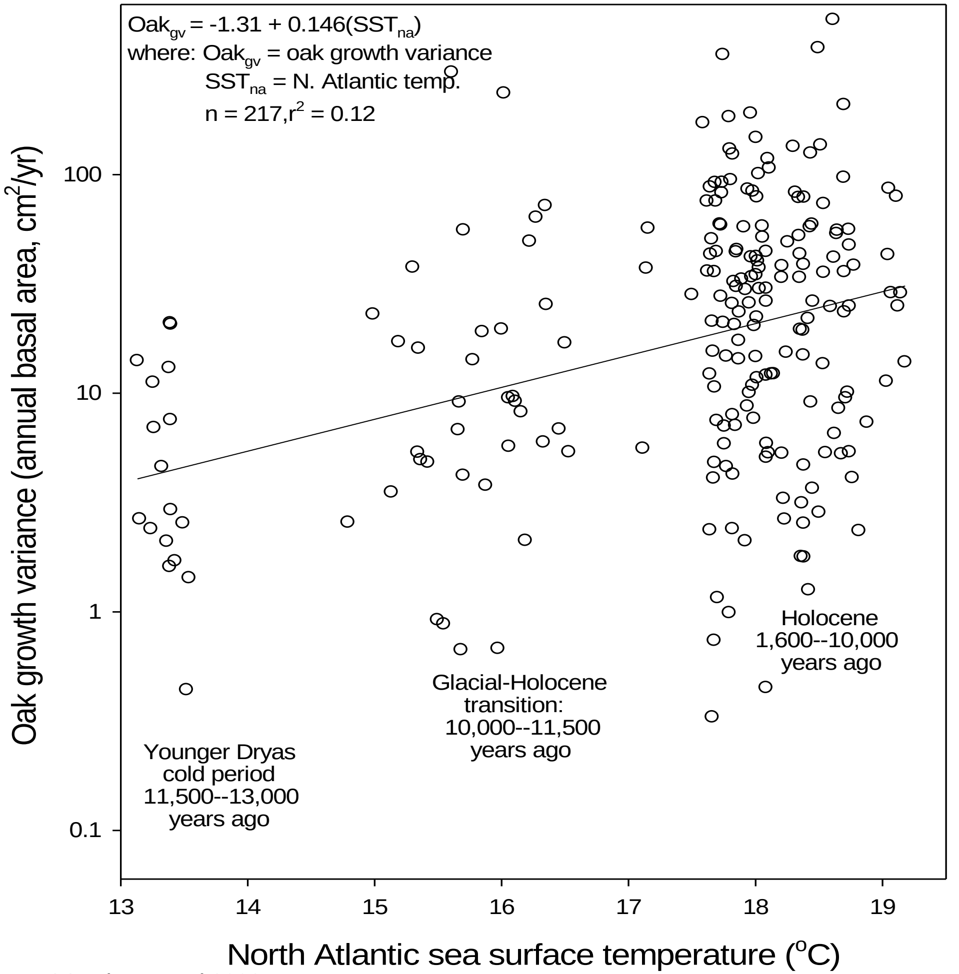


A reduction in between tree growth variance within a tree population would be expected if the limits on growth switch from highly variable endogenous factors such as competition for light to exogenous limits on growth such as climate





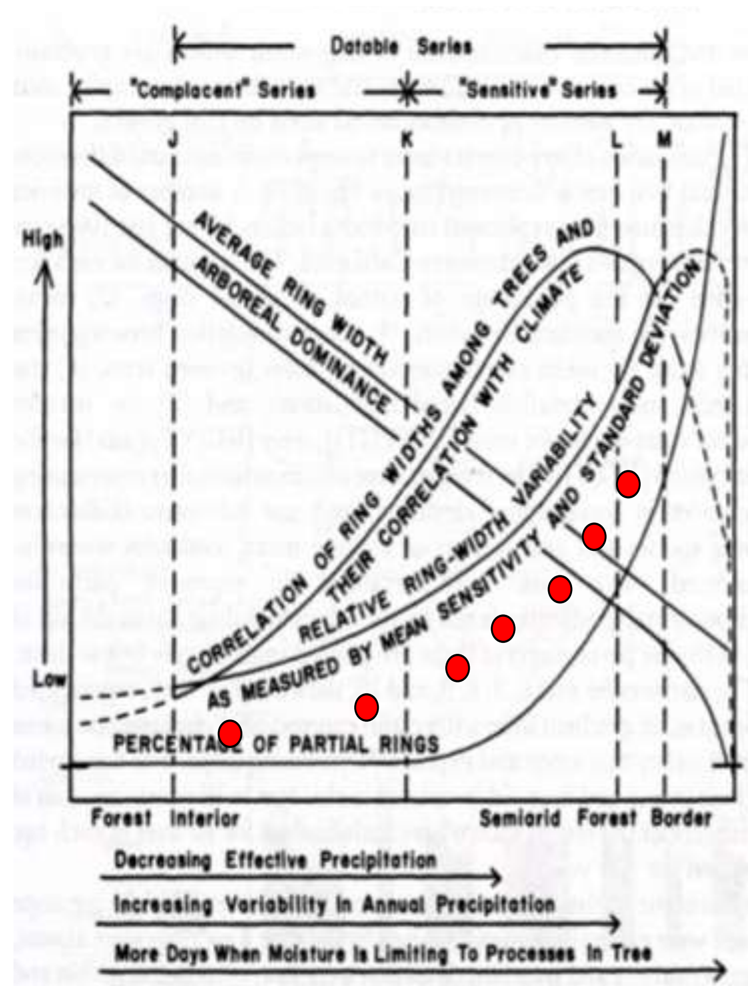
The modeling of climate and growth variance is an important aspect of ecological climatology. Extremes and variance are often more significant than averages for species diversity, richness, change, and in many aspects of ecosystems.



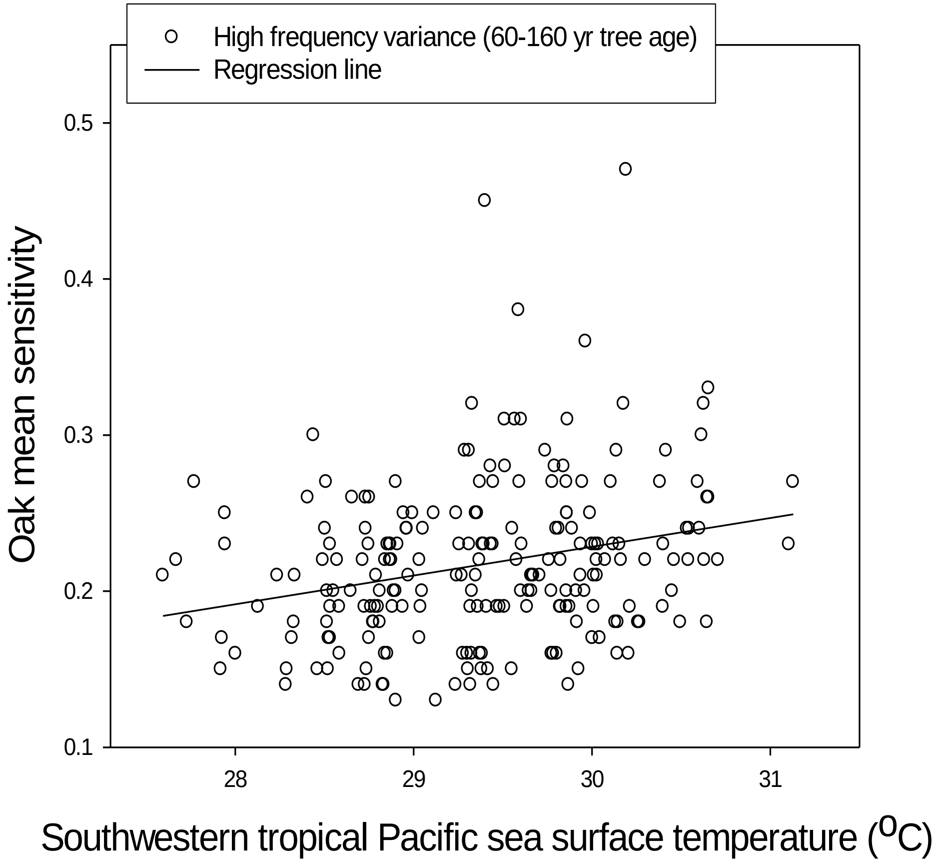
SST data: Bard 2002

High year to year climate variance
(measured as mean sensitivity, ms_x)

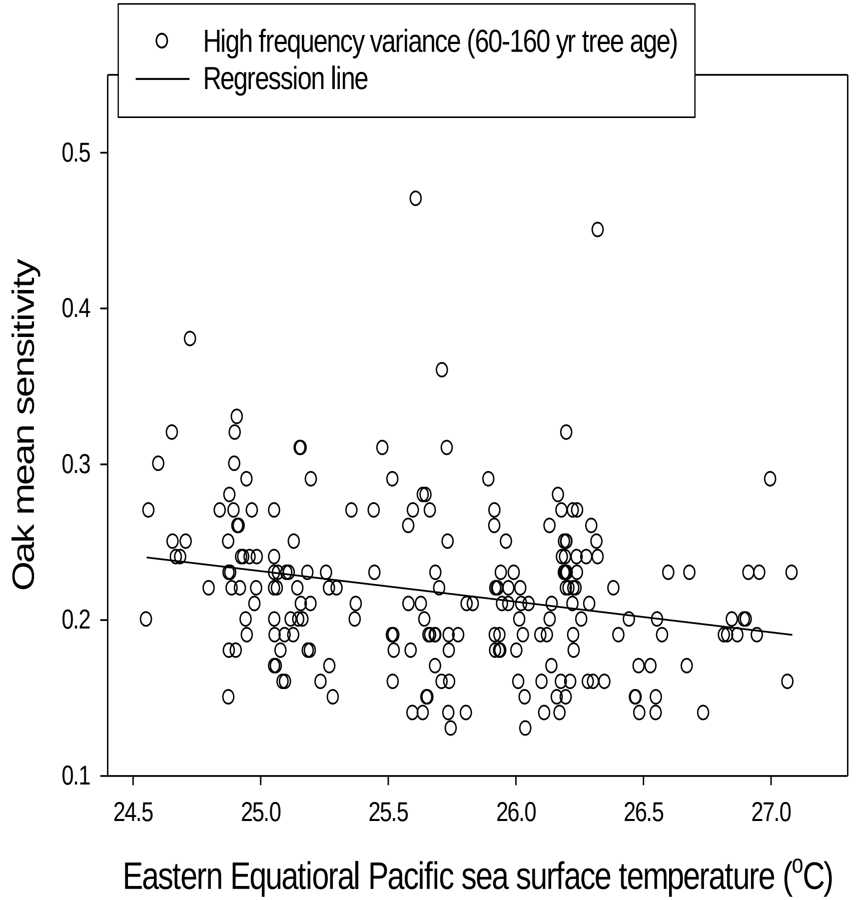
Mean sensitivity (ms_x) is the averaged relative difference in width from one ring to the next. Climatic and physiological conditions vary along the mean sensitivity gradient (Fritts 1976). (Right) Dots on graph represent the expected range of subfossil oak mean sensitivity considering northern Missouri and southern Iowa climate changes during the last 14,000 years. (Left photos) ‘Complacent’ annual rings (top) represent low year to year climate variability while ‘sensitive’ rings (bottom) result from high year to year variability



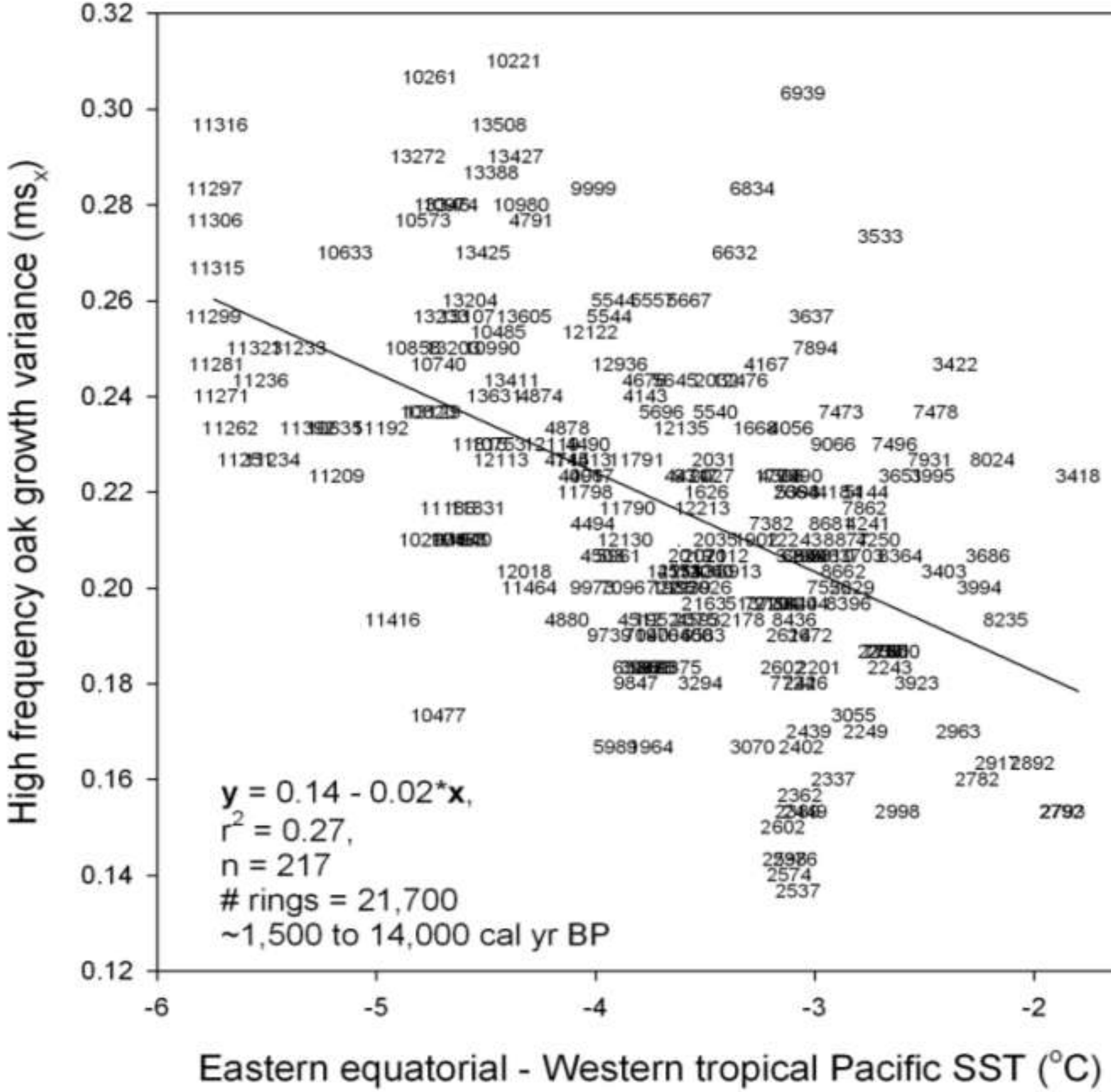
Effects of eastern and western Equatorial Pacific sea surface temperatures (ENSO) on high frequency oak growth variability between 1,600 and 14,000 years BP



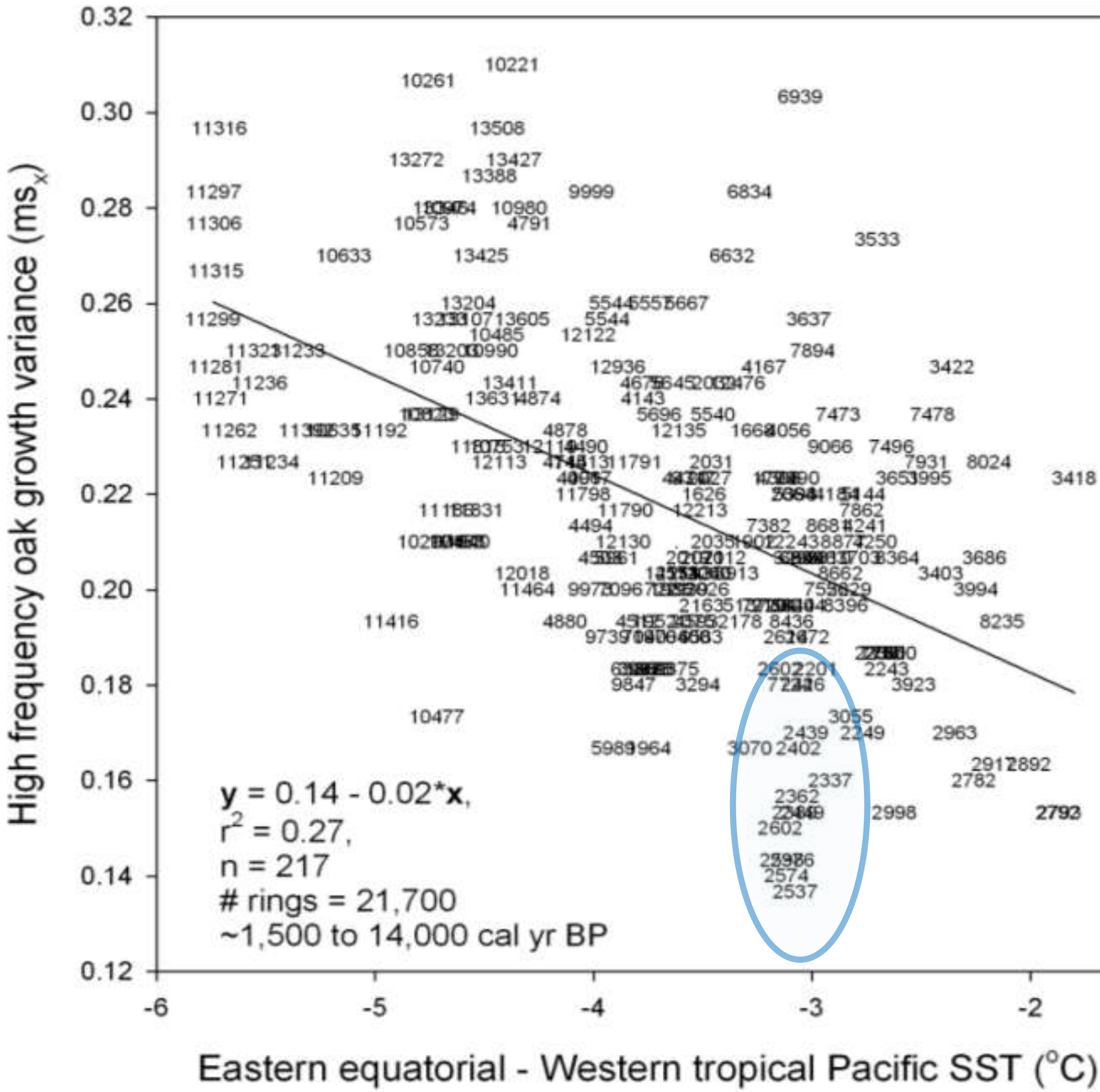
SST data: Stott et al. 2004



SST data: Lea et al. 2000

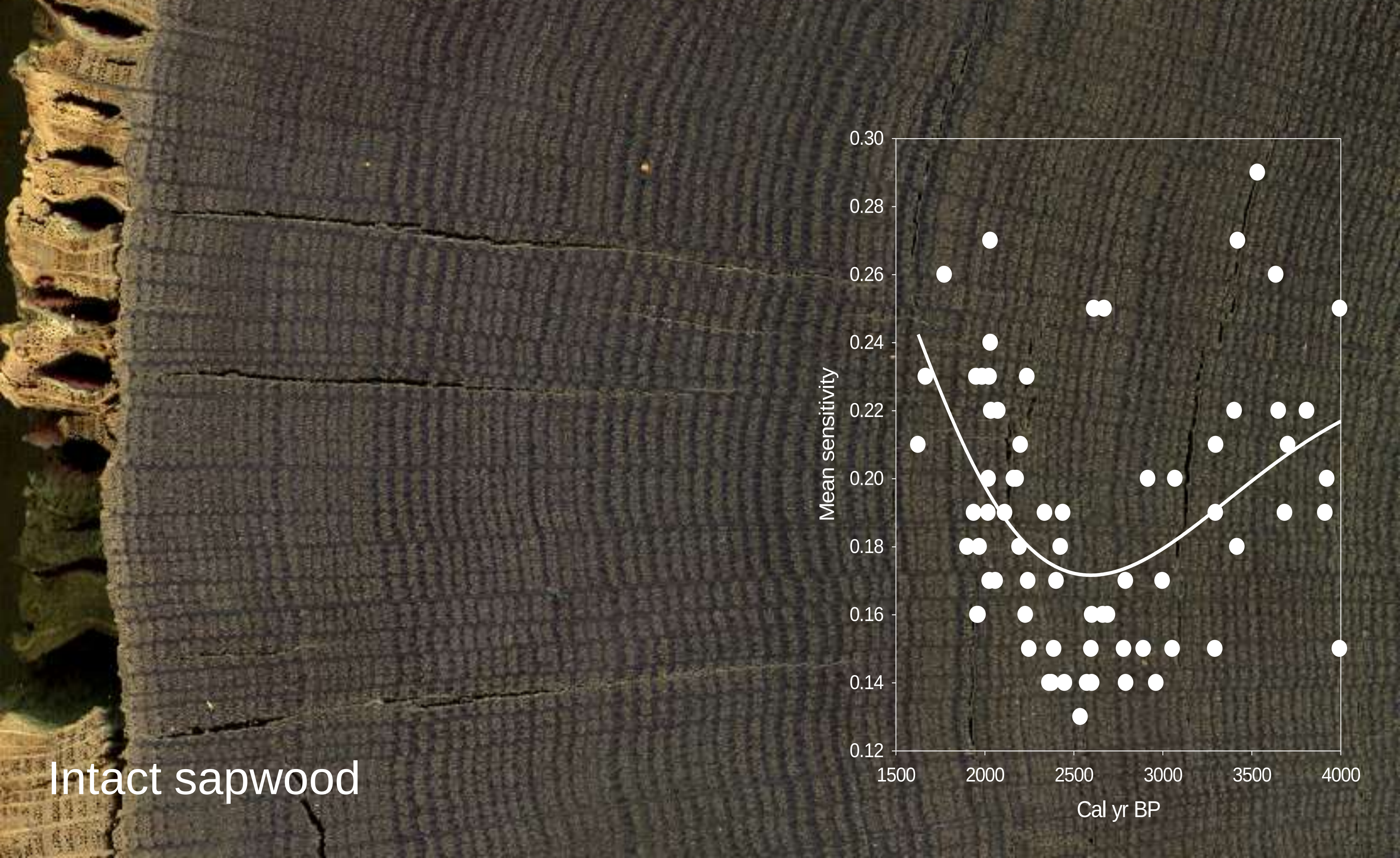


SST data: Stott et al. 2004
Lea et al. 2000

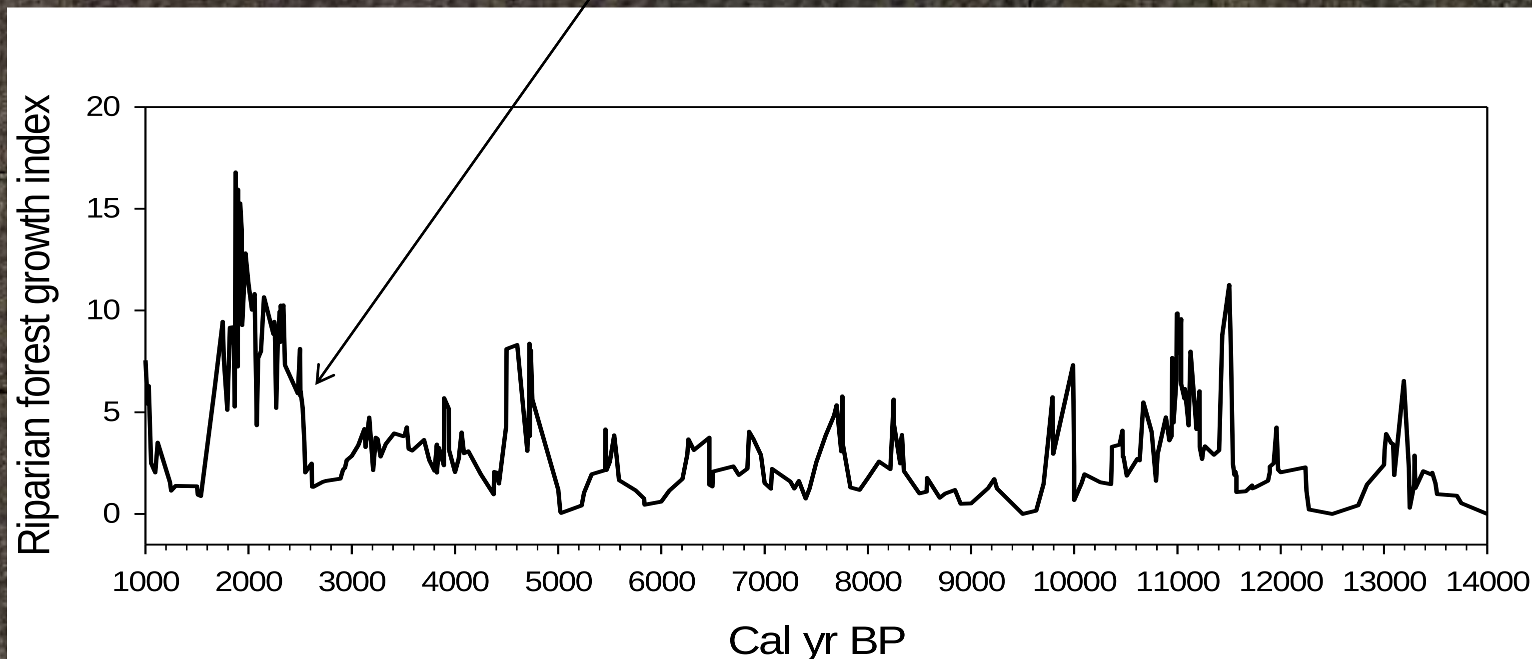


SST data: Stott et al. 2004
Lea et al. 2000

Bur oak PTR032 dates to 2,476 cal yr BP, a wet period with low annual ring mean sensitivity

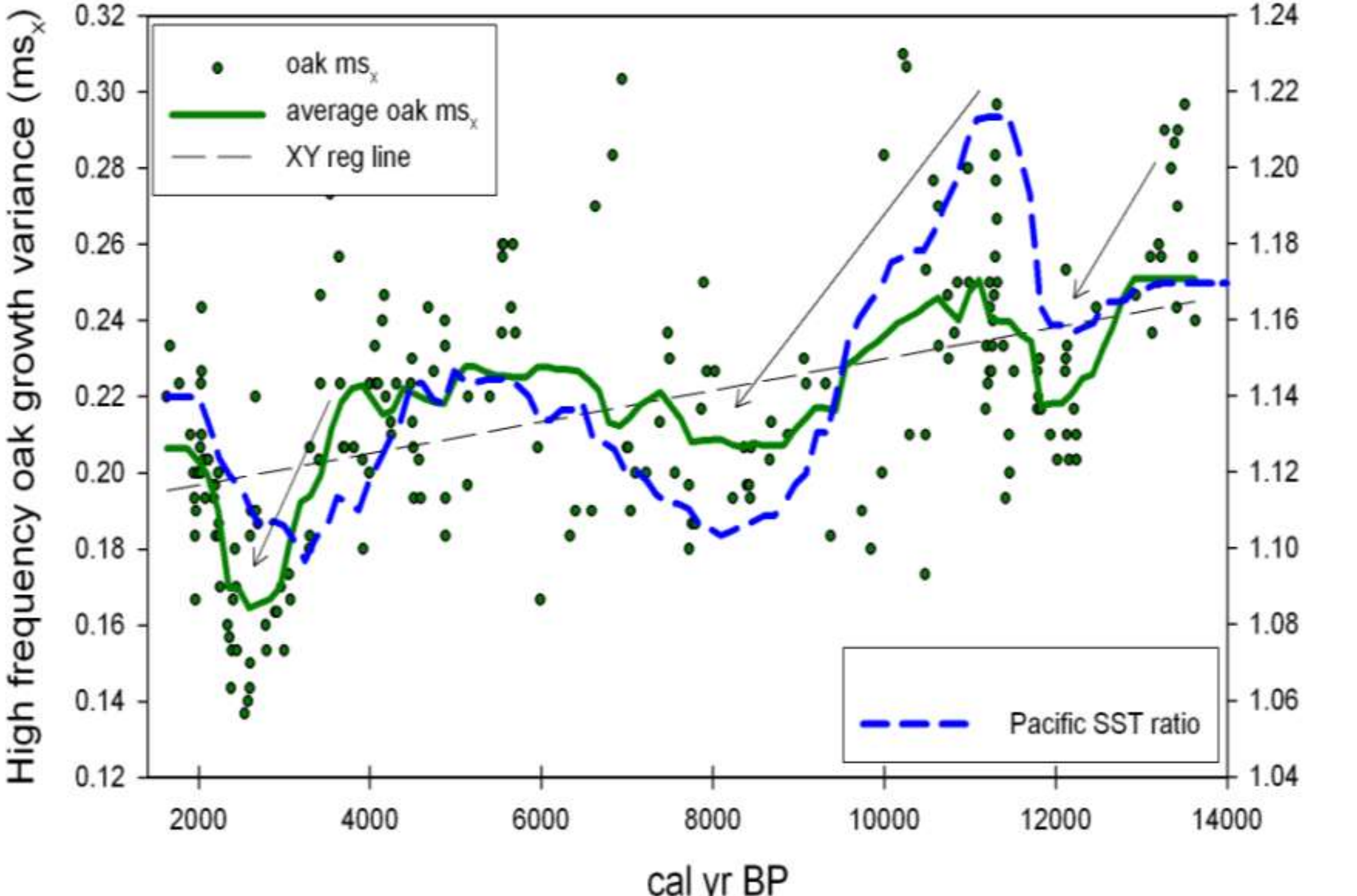


Bur oak PTR032 dates to 2,476 cal yr BP, a wet period with low annual ring mean sensitivity

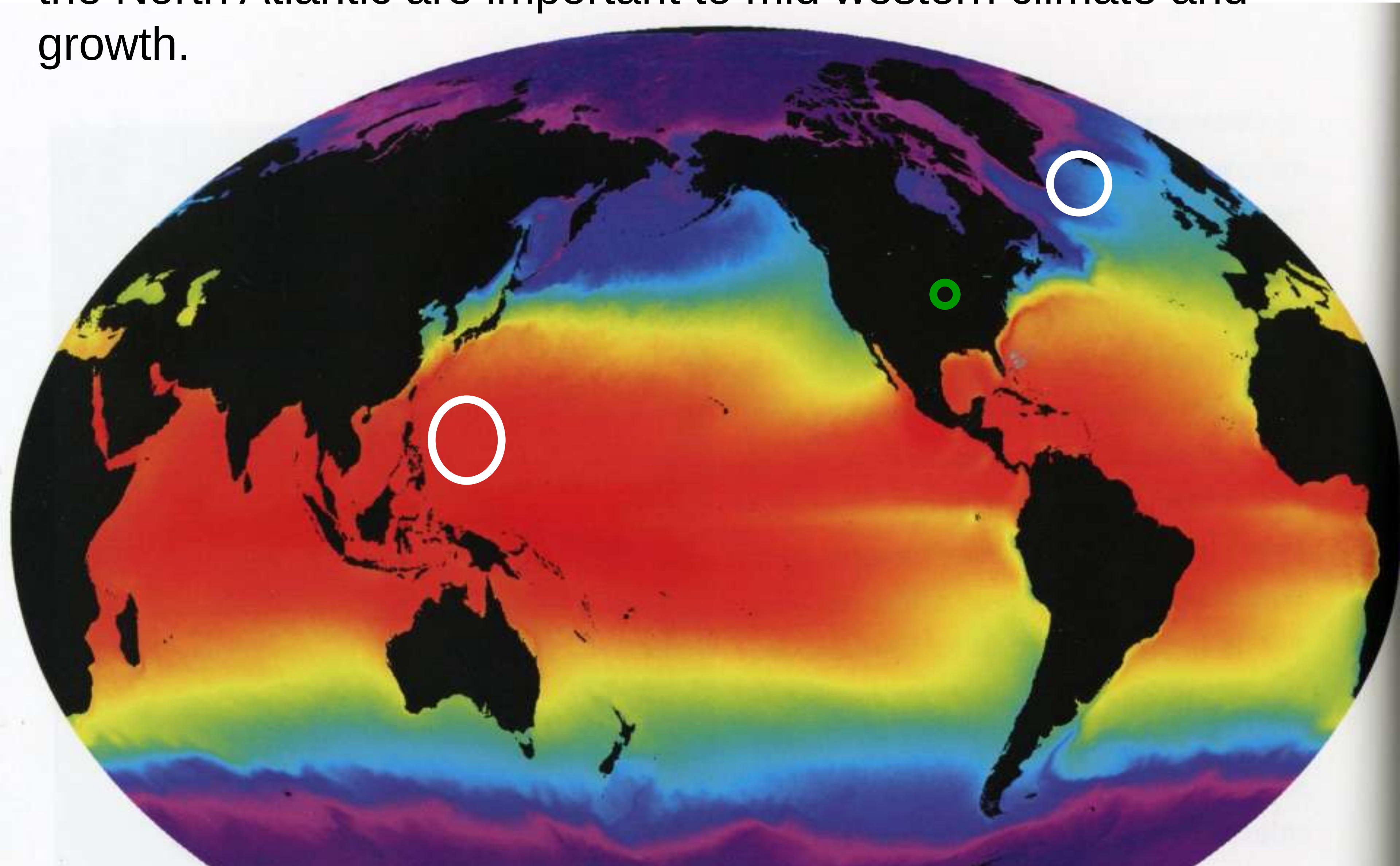


Intact sapwood

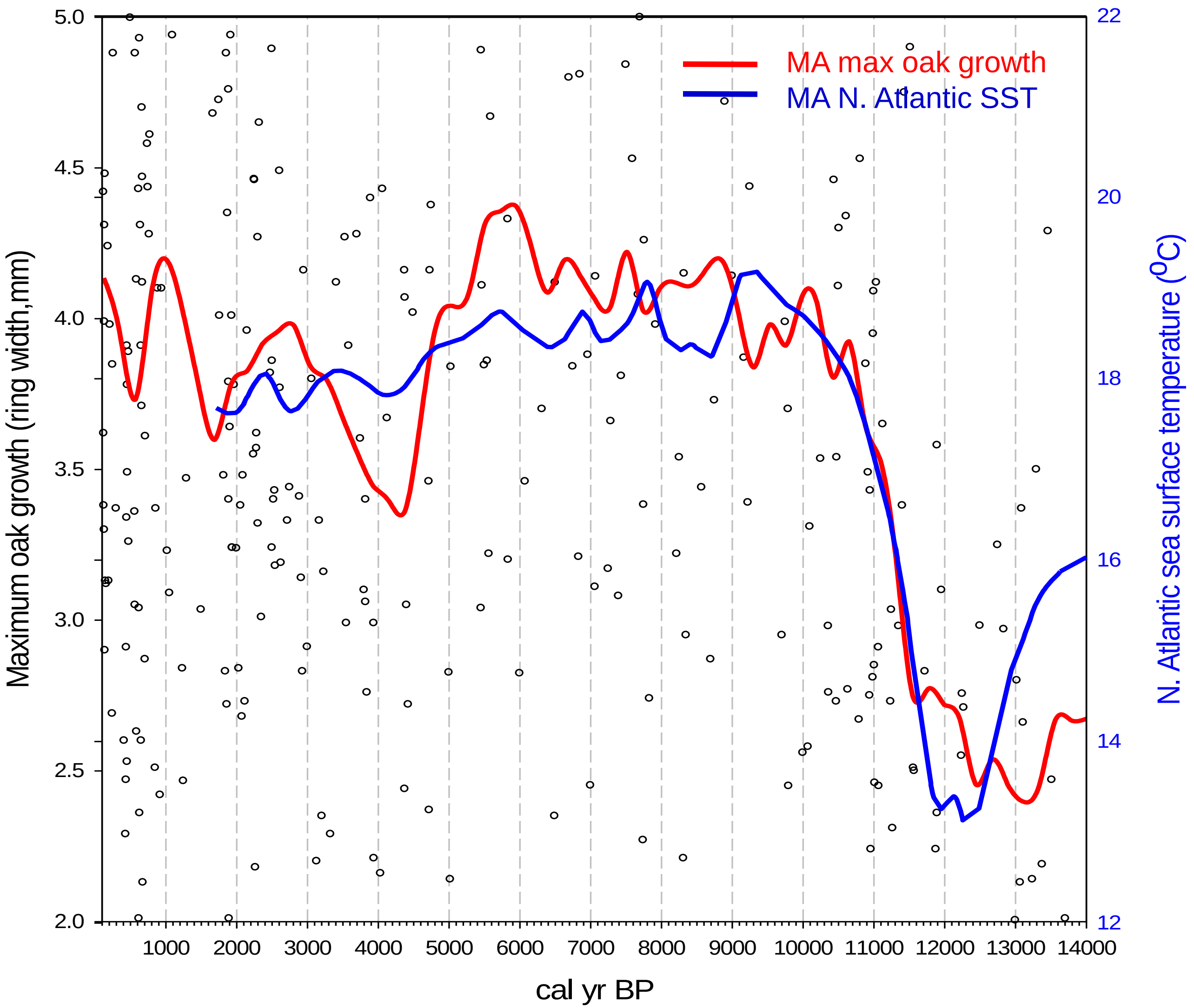
Time series plot of year to year oak tree growth variance (msx) and equatorial Pacific sea surface temperature ratio using smoothed data. SST data: Stott et al. 2004, Lea et al. 2000. Arrows show periods of declining SST gradients and oak high frequency variance.



Ocean sediment proxies of sea surface temperature (SST) are correlated with mid-continental climates. The tropical Pacific and the North Atlantic are important to mid western climate and growth.



Century+ scale exogenous climate influences on tree growth may better be reflected by maximum ring width than by minimum ring widths that are more strongly influenced by endogenous non-climatic factors such as competition



Roughly: 1 °C change in SST   1.0 mm change in ring width

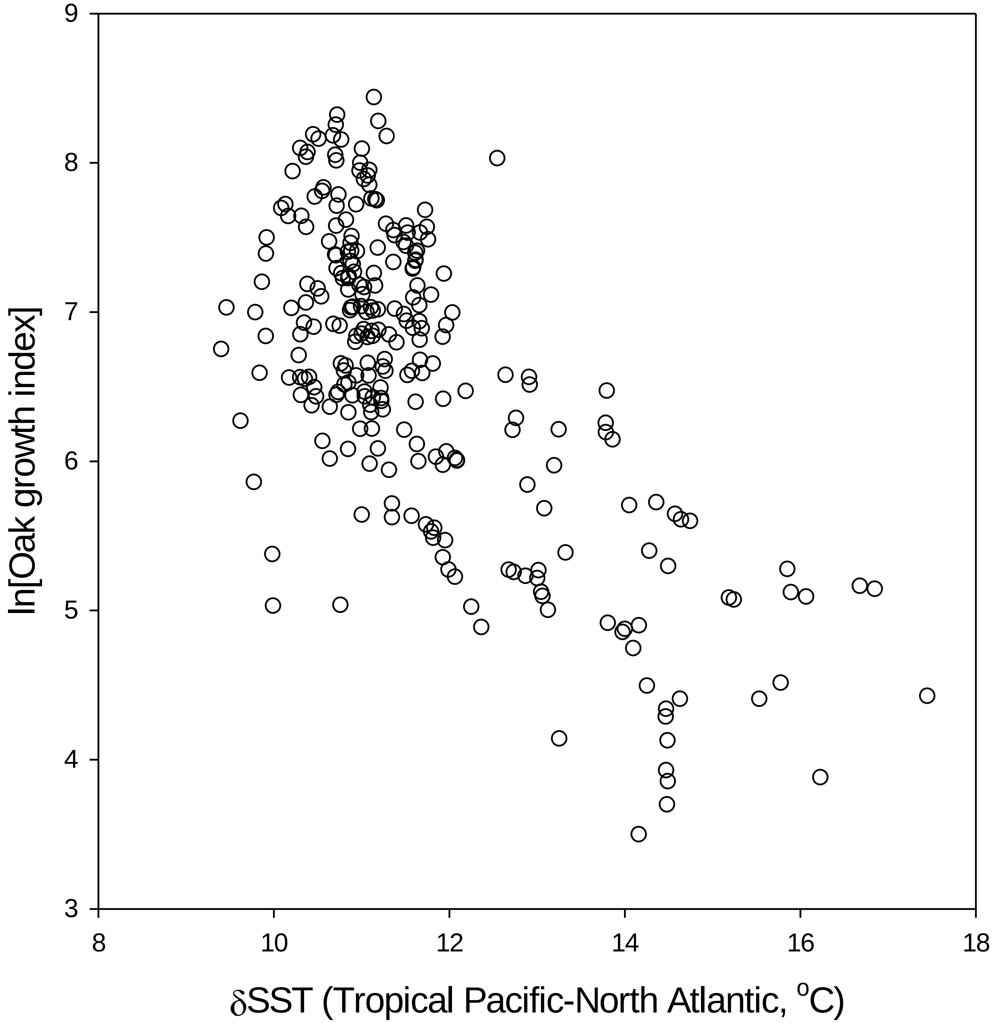
Data: 371 single year maximum ring widths from 371 trees with 49,714 rings

Improvements to max ring width as a predictor include:

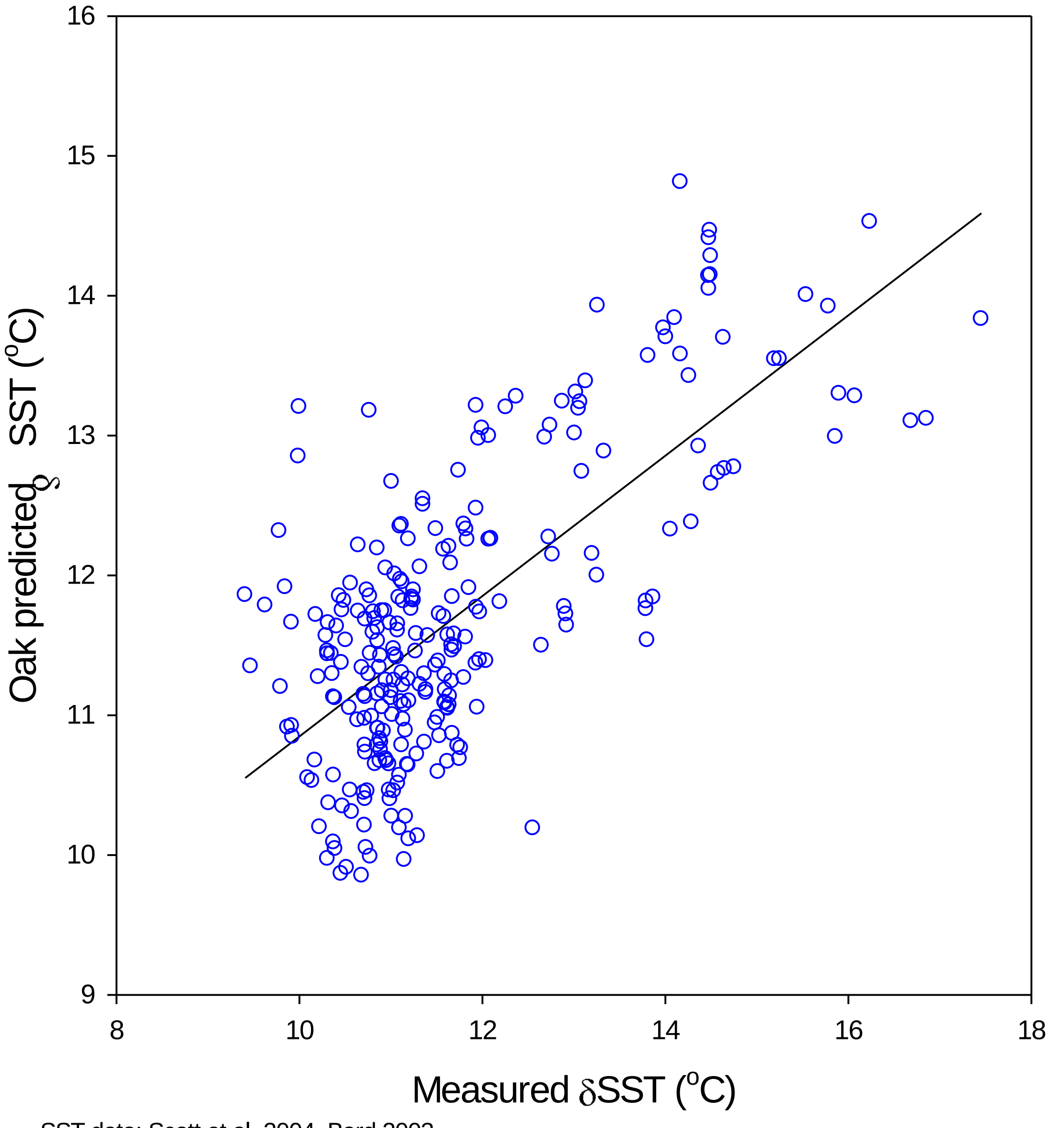
1. using ring averages of groups of maximum rings

2. using mature tree data only

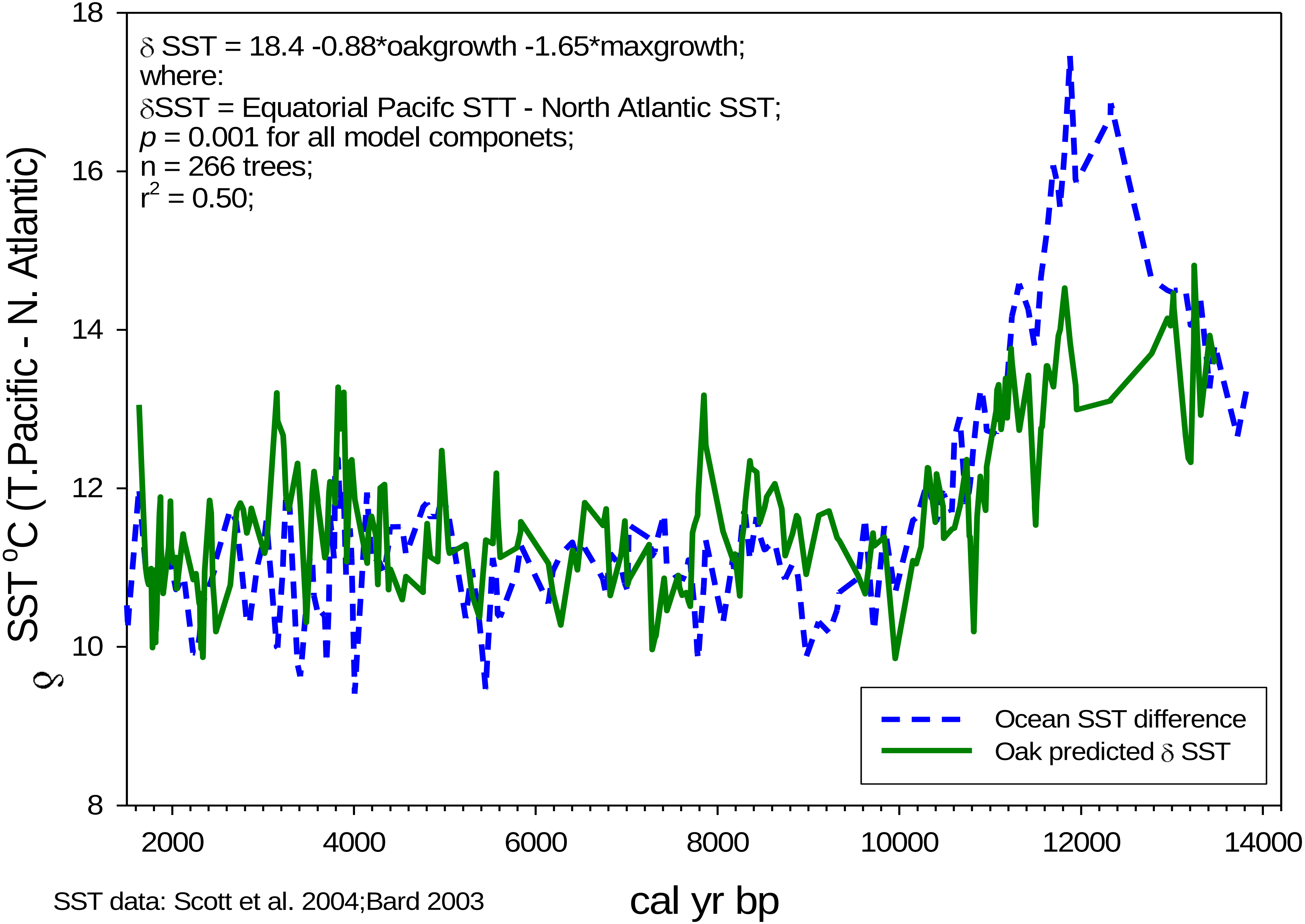
The combined effects of Tropical Pacific and North Atlantic sea surface temperature on mid continental climate and oak growth

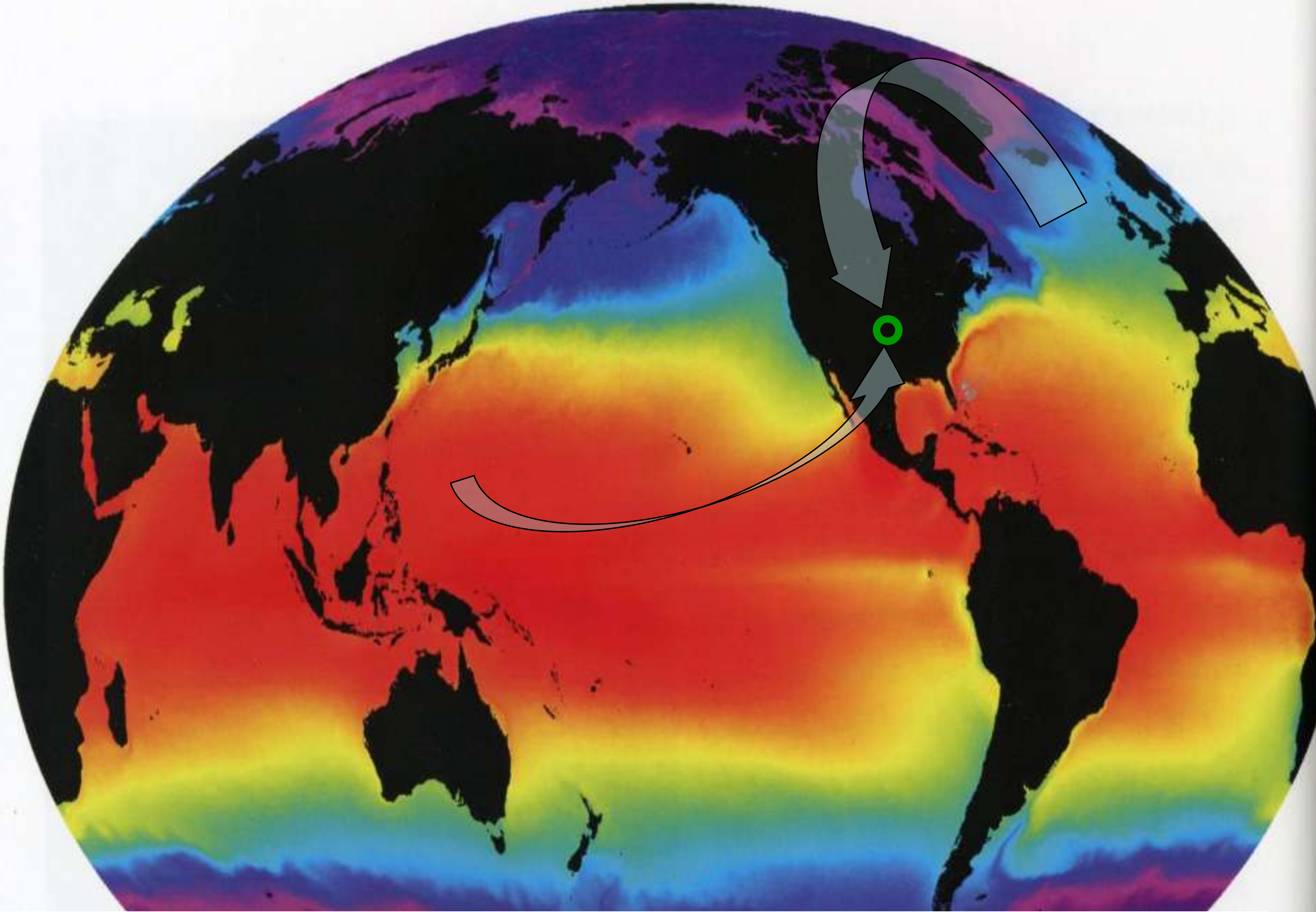


SST data: Scott et al. 2004, Bard 2003.



SST data: Scott et al. 2004, Bard 2003.


δ SST = 18.4 -0.88*oakgrowth -1.65*maxgrowth;
where:
δSST = Equatorial Pacifc STT - North Atlantic SST;
p = 0.001 for all model componets;
n = 266 trees;
r2 = 0.50;
Ocean SST difference
Oak predicted δ SST
δ SST °C (T.Pacific - N. Atlantic)
18
16
14
12
10
8
2000
4000
6000
8000
10000
12000
14000
cal yr bp
SST data: Scott et al. 2004;Bard 2003



How do the equatorial Pacific and North Atlantic effect or climate and

Conclusions

Sea surface temperatures of the tropical Pacific and North Atlantic are important long-term variables influencing Midwestern climate and ecosystems

The growth oaks connects agriculture and Midwestern climate to global changes over millennia and distant locations

The northern North Atlantic and the thermohaline were central to Midwestern climate between 6500 and 14000 cal yrs BP

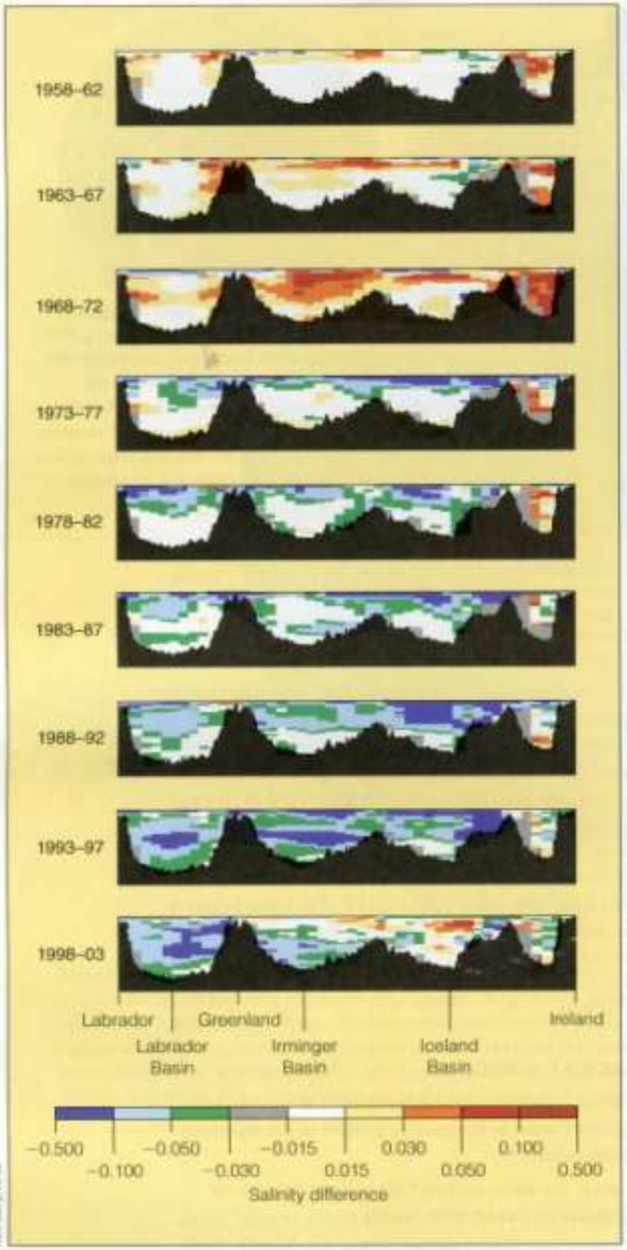
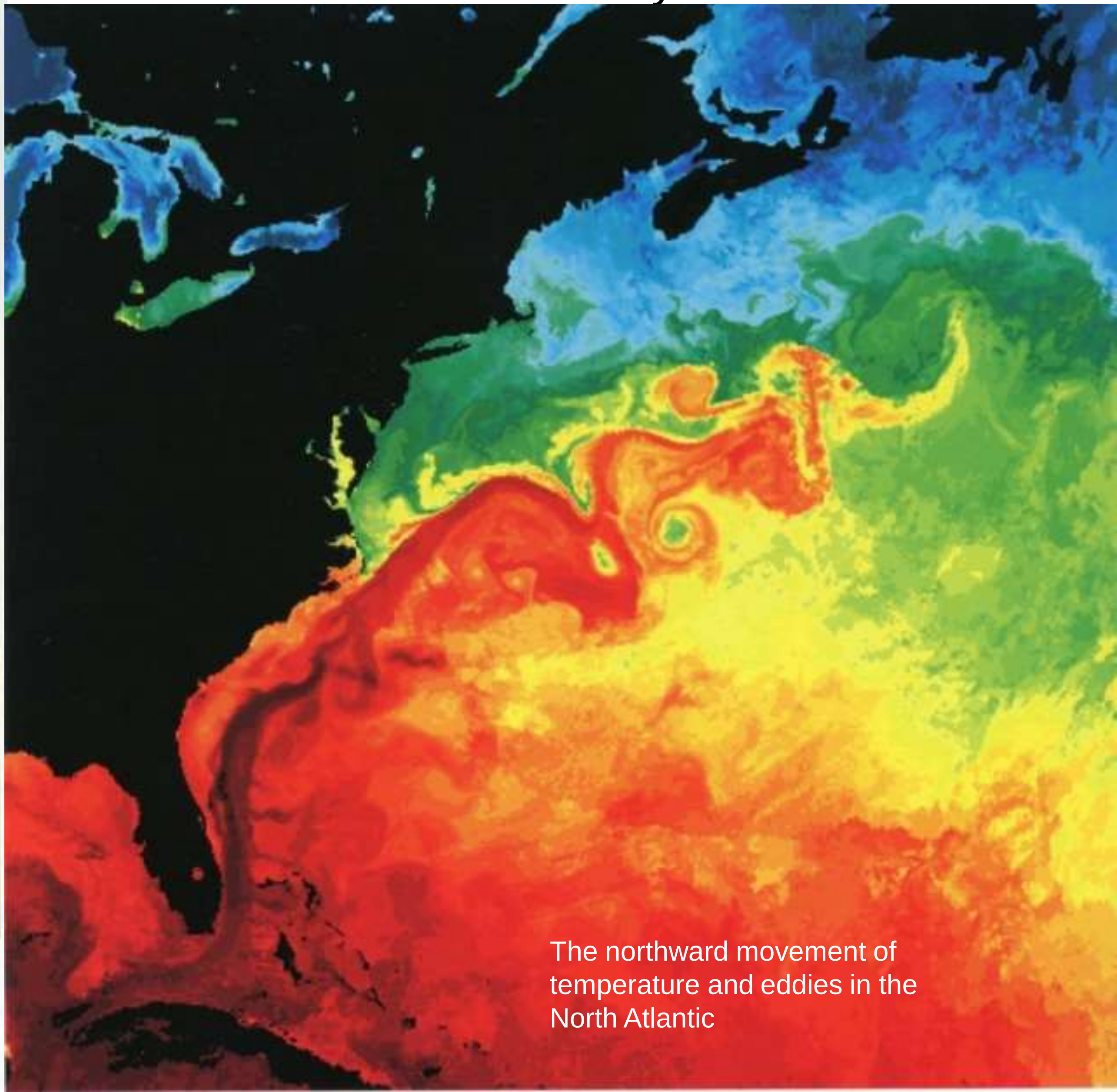
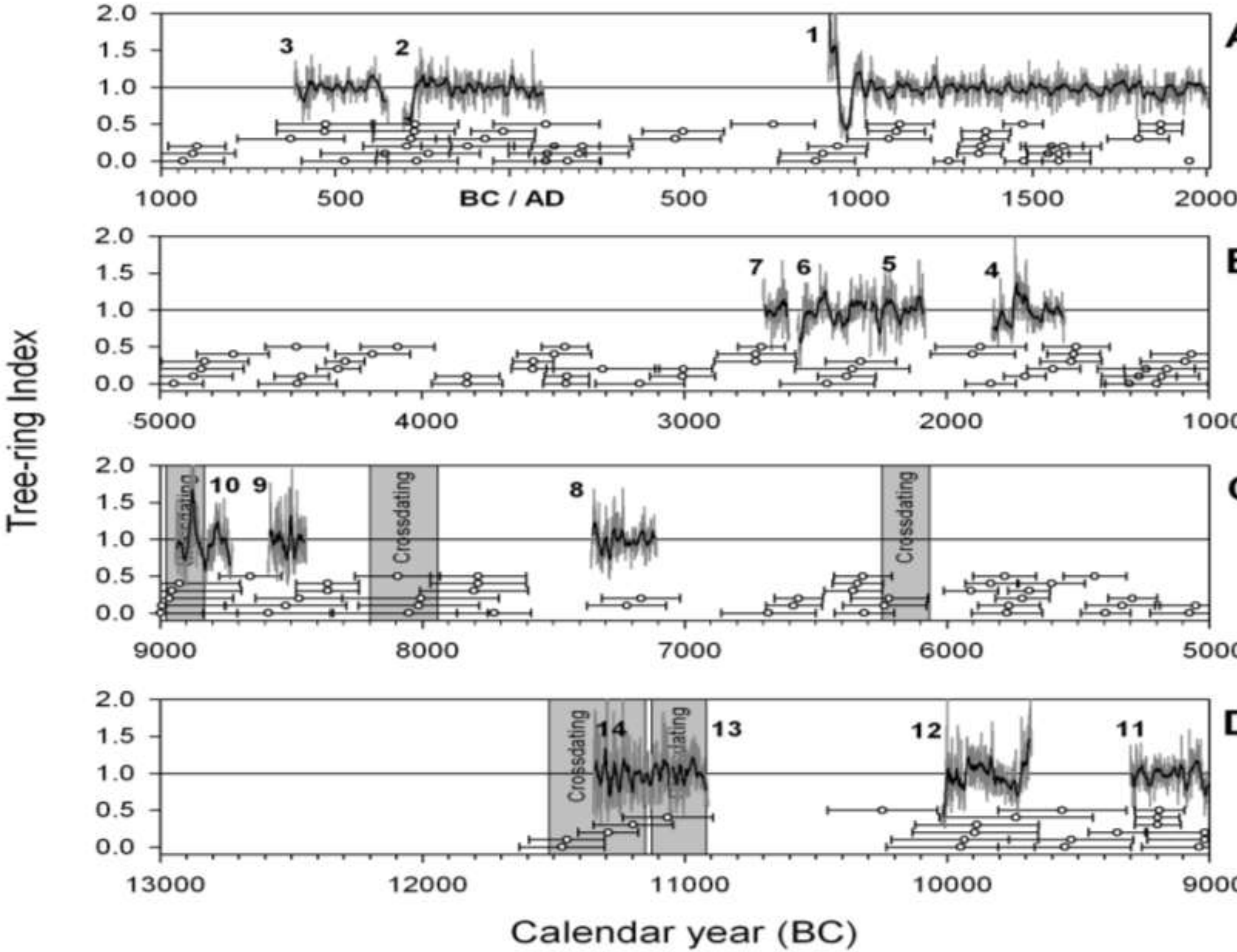


Figure 9.30 An analysis of salinity over the past 55 years shows a progressive "freshening" of the North Atlantic Ocean between Canada and Ireland. The fresh water comes from melting glaciers and Arctic sea ice, and increased precipitation at high northern latitudes. Saltier waters are red, orange, and yellow; fresher waters are blue and green.

Garrison 2007



The present record of the American Long Oak Chronology



Conclusions

- Growth and isotopic data from the long oak chronology show that changing ocean temperatures will effect the continental climate of the Midwest

- The circulation of the North Atlantic has played a large role in the past and could effect future climates of Midwest despite its distance from marine climates

- Periods of cooling in the Midwest are strongly associated with abrupt changes in the North Atlantic thremolhaline circulation

- Although warming has prevailed for thousands of years the record is not continuous and has had many abrupt changes.

5.0kV 8.0mm x2.00k SE(M) 20.0um


Bur oak sample
spanning 1158 to
1351 AD