3,000 Years of Pollen at the Glen Forney Vernals Natural Area, Michaux State Forest, Pennsylvania

A Paleoecological Study of the South Mountain Landscape from ~850 BC to Present

South Mountain Partnership Science Summit 2024


Nuphar pollen, 2000x

Emily R. Hegedus
MS Geoenvironmental Science & Sustainability,
Shippensburg University, 2023
Paul Marr, PhD
Professor at the Geography-Earth Sciences Department,
Shippensburg University

Acknowledgements

Graduate Student Research Grant Funding by South Mountain Partnership and Shippensburg University Graduate School. Technical expertise, mentoring, and laboratory services provided by Debra Willard, PhD, USGS Palynology Lab and associates.

South Mountain Partnership

Shippensburg University The Graduate School

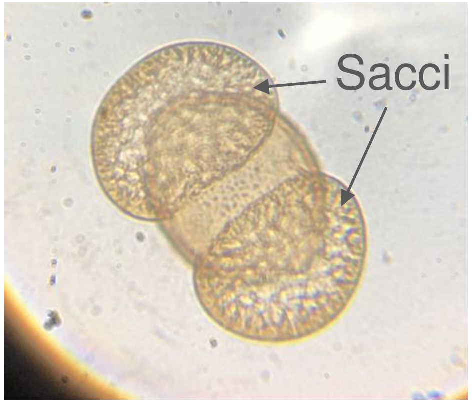
Graduate Research and Travel Grant

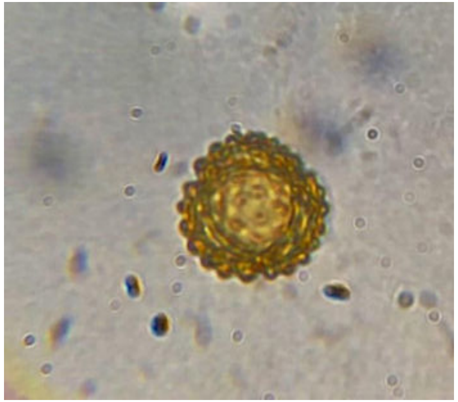
USGS science for a changing world

Introduction

Pollen Analysis

- Provides insights into past ecosystem communities
  - Typically limited to genus level, sometimes only family level, occasionally species is possible
- Wetland sediments preserve pollen due to anoxic nature
- Difference between wind- and insect-pollinated plants
  - Some pine family pollen have air bladders or sacci, may travel up to 3,000 km (Campbell, et al. 1999)
- Ragweed pollen increase linked to arrival of early colonial settlers and landscape disturbance, commonly used as a stratigraphic marker for deforestation (Brush, 1984; McAndrews, 1988)





Ragweed (*Ambrosia*) pollen from sample site

Vernal Pools

- Seasonal wetlands - inundated winter/spring, dry in summer/fall
- Habitat for salamanders and frogs who rely on these pools for reproduction
- Glen Forney Vernals Natural Heritage Area, Michaux State Forest
- Form as local topographic depressions
    - Regionally located at the geologic boundary between the metasedimentary rocks of South Mountain and the carbonate bedrock of the Cumberland Valley
    - Sometimes form in leftover man-made depressions

Study site - vernal pool at Glen Forney Vernals Natural Heritage Area, Michaux State Forest

Research Questions

1. Did the Glen Forney vernal pools in Michaux SF form naturally or are they byproducts of the booming 1800s iron industry (iron ore pits)
2. How did widespread deforestation during 1800s deforestation alter the local ecosystem?

Regional Deforestation in 1800s

- Vast swaths of PA forests cleared - A single ironworks **cleared up to an acre of trees daily** to create charcoal to fuel iron production (Thomas 1985)
  - Accompanying sawmills, forges, settlers increased need for wood
  - Logging practices were reckless: clear-cutting was common, woody debris
  - Timber industry cleared additional acres
- **Sediment accumulation** rate at 4,000 sites in North America **increased 10x** after European colonization and its associated activities, including **deforestation** and **agricultural intensification** (Kemp, et al. 2020)

Photo courtesy of the Pennsylvania Department of Conservation and Natural Resources

A deforested area Big Pocono, in Monroe County, in 1922

Study Area

Pollen Sites

1. Glen Forney Vernals Natural Area, Michaux State Forest
2. Mt. Cydonia Ponds
3. Crider's Pond
4. King's Gap Pond

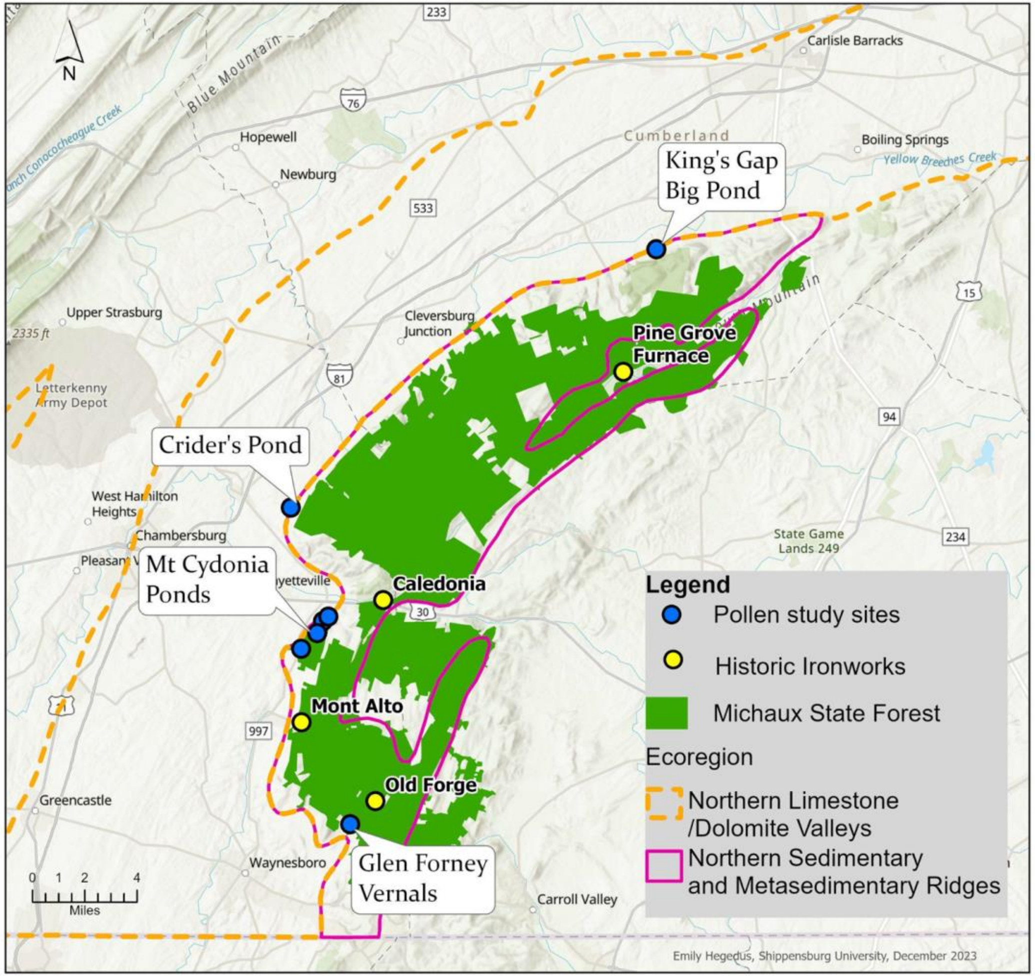
Iron Works

1. Mont Alto Furnace (est. 1807)
2. Old Forge (est. 1811)
3. Pine Grove Furnace (est. 1764)
4. Caledonia Furnace (est. 1837)

Geologic Boundary

1. Carbonate Valley
2. Metasedimentary Mountain

Pollen Study Sites & Historic Ironworks in South Mountain Landscape



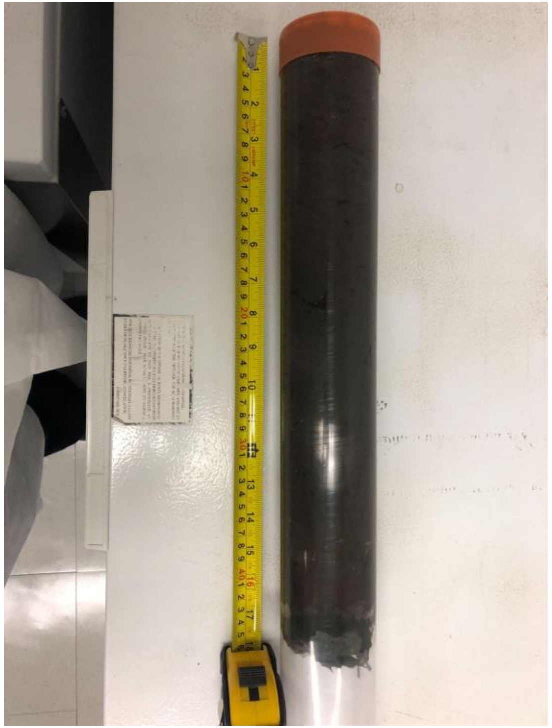
Methods Overview

1. Find a vernal pool that seems likely to be natural in origin - Glen Forney Vernals Natural Area
2. Collect core
3. Process pollen samples @ USGS Lab
4. Send 2 samples for radiocarbon dating
5. Create age-depth model using calibrated radiocarbon dates and other estimated dates
6. Identify pollen with light microscope
7. Plot change % abundance over time

USGS pollen lab technician and pollen vial

Sample Collection

Sediment sampling in August 2023 with Universal Corer; sampled to 0.87 m depth; core compacted to 0.44 m



Sample Processing

- **USGS Pollen Lab**
  - Extrude core into 1cm intervals
  - Pollen samples: 1 cm^3 sample from each layer = 43 samples
    - Apply series of strong acids and bases to remove most organics, carbonates, and silicates, wash w/ distilled water between
    - Centrifuge to concentrate sample
    - Sieve, stain, swirl, mount on slide
  - ID pollen with light microscope based on various pollen keys for N. American pollen
- **Radiocarbon dating** of macrobotanical fraction of bottom and mid-level sample (sent to lab - DirectAMS)

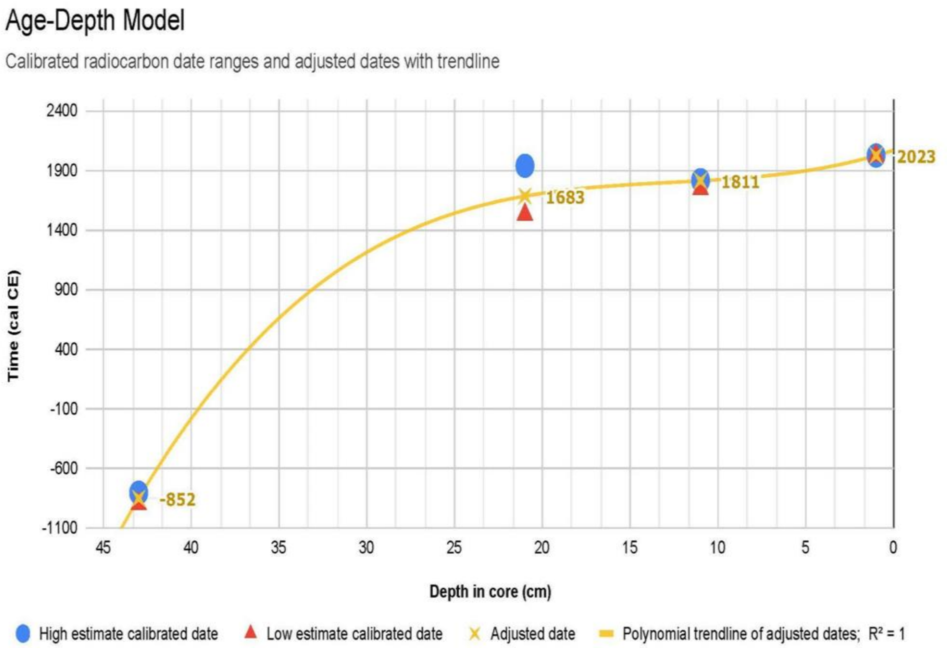
Separating 1 cubic cm pollen sample from extruded 1 cm disc

Calibrate Radiocarbon Results and Make Age Model

Four dates used for age model:

1. Surface sample = 2023
2. “Ag horizon” (ragweed peak) = assumed early 1800s
3. Mid-sample = calibrated radiocarbon date 1635-1802 (92% probability)
4. Bottom sample = calibrated radiocarbon date 805-899 BC (95% probability)

Plot dates in Excel and add trendline



Results (abbreviated)

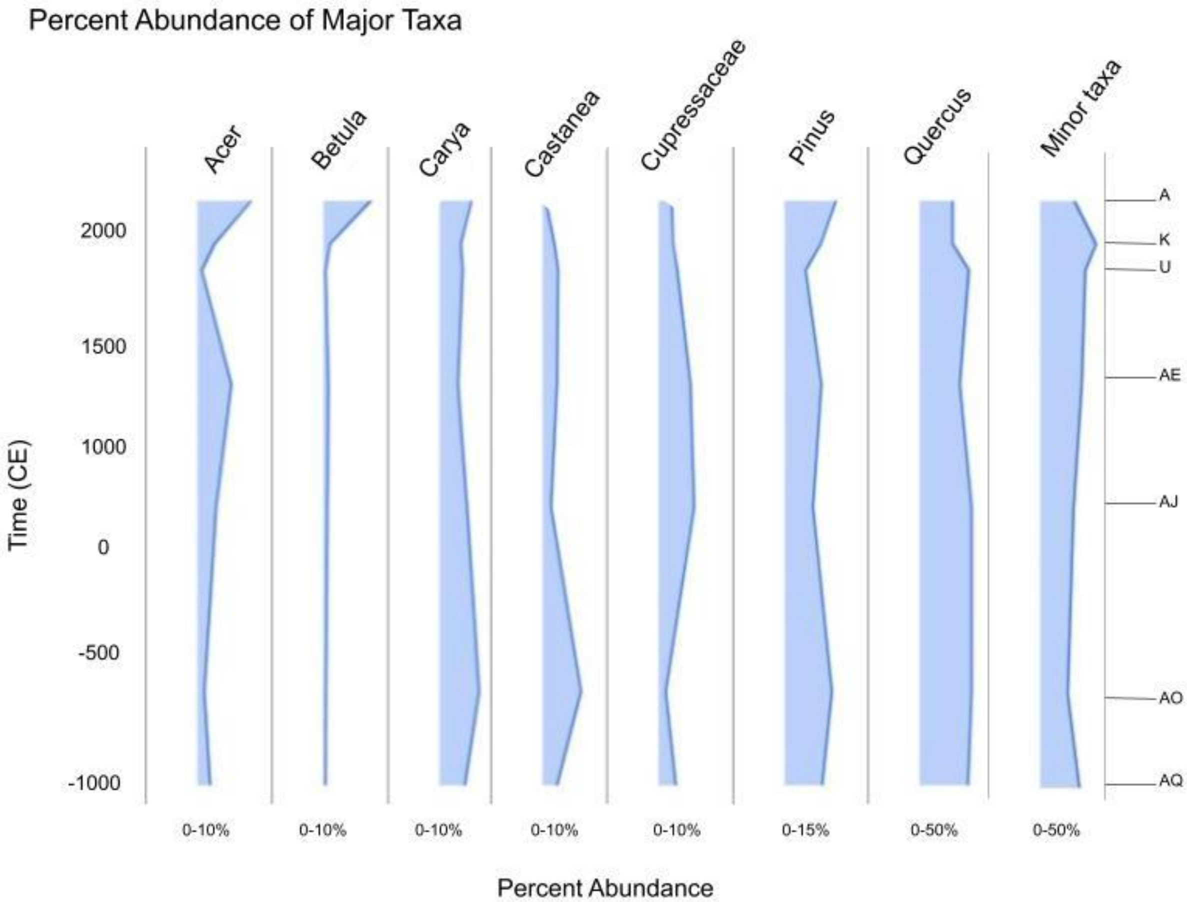
Natural vernal pool formation?

- Yes; bottom sample ~3,000 years old, predating iron ore industry
- Radiocarbon lab stated results have high confidence and the samples seemed undisturbed

Actual age likely older – limited sample depth due to limited funding and scope of study. Probably around the same age as other regional sites, ~15,000 years old

Results: Dominant Taxa Observed

- Oak (30-47%) and pine (6-14%)
  - wind-pollinated taxa tend to dominate, so not a 1:1 representation of plant cover
- Maple, birch, and pine increased since 1800s while oak decreased.
- Fifty minor taxa made up remaining abundance

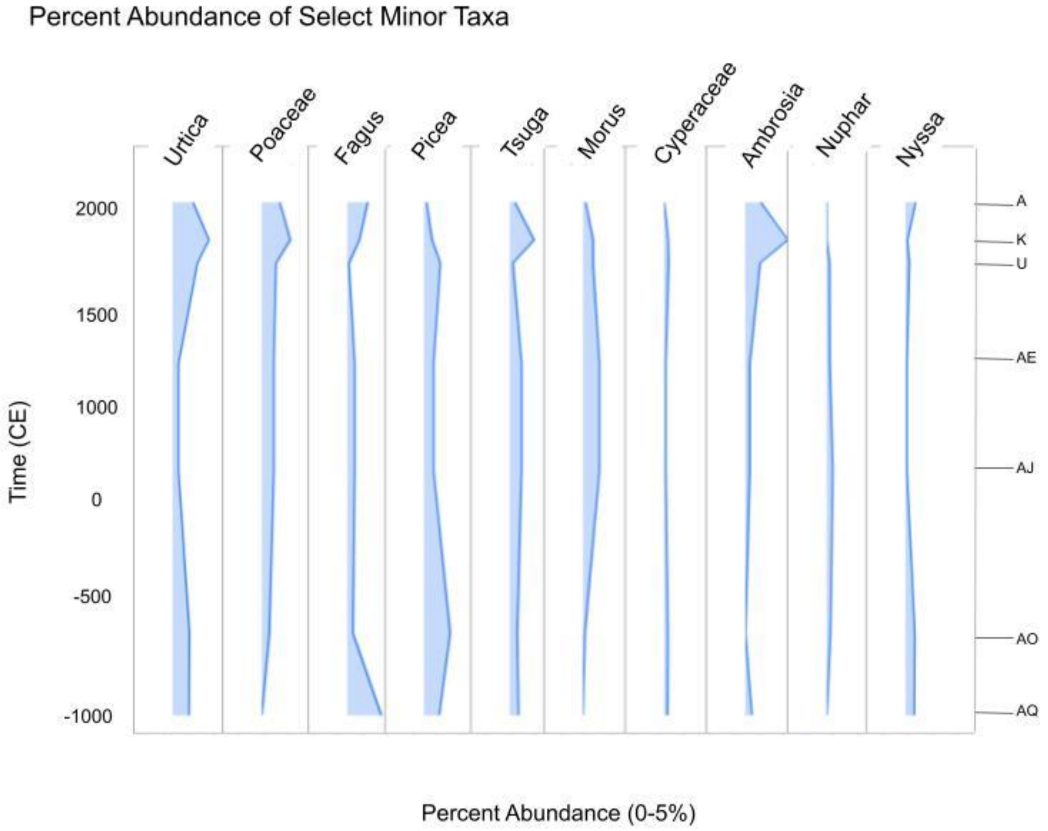


Oak

- By the far the most abundant (30-47%)
  - Average 40%
- Peaked in abundance 400 BC to 500 AD
- Decreased in 1800s and remained at 30% for top two samples
  - Global oak decline: many areas worldwide report decline in oaks in recent years (Moorehead and Douce 2019; Varner, et al. 2016)
  - Potentially linked to modern fire suppression management which selects for shade-tolerant, fire-intolerant species such as maples and beech (Varner, et al. 2016)
- Similar abundance to other regional studies

Results: Select Minor Taxa Observed

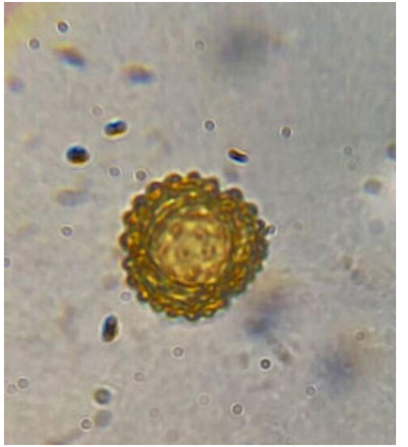
- Also plotted change in abundance of select minor taxa
  - most abundance of minor taxa
  - ecosystem indicators
    - Ragweed
    - Water lily



Ragweed

- Abundance strongly correlated to human disturbance of landscape
- Peaked in 1800s, likely due to deforestation (3x more than average abundance)
- Prior to European settlement, remained below 1%

Time	Ambrosia % abundance
2023	1.8
1811	5.1
1681	1.8
1118	0.5
512	0.5
-397	0.0
-859	0.8
Average	1.5



Water lily

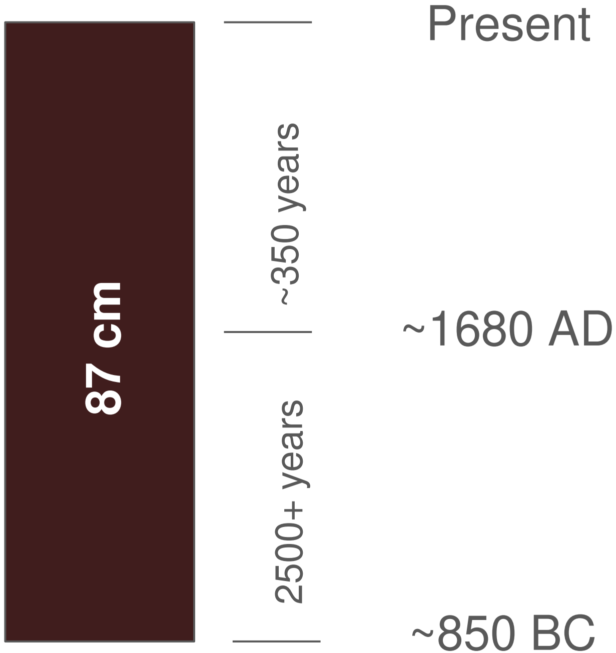
- Water lily (*Nuphar lutea* - yellow pond lily) pollen present from 400 BC to 1800s AD
- Insect-pollinated
- Floating-leaved aquatic plant
- Long-lived, clonal habitat, submerged rhizomes
- Flowers after ~3 years
- Needs water at least 1 ft deep

(Barrat-Segretain 1996)

Time	Nuphar % abundance
2023	0.0
1811	0.2
1681	0.3
1118	0.4
512	0.7
-397	0.4
-859	0.0
Average	0.3

Increase in Sedimentation Rate

- Sample halfway through core was only ~350 years old
  - Average 0.127 cm/yr sedimentation rate in upper half of core
- Bottom sample ~2,850 years old
  - Average 0.017 cm/yr sedimentation rate in lower half of core
- Sevenfold increase in sedimentation rate correlating to deforestation activities



Main Conclusions

- Glen Forney vernal pond is a **natural formation** at least ~3,000 years old
- **Oak, pine, maple, and birch** pollen most abundant
    - Similar abundance to other regional ponds
    - 15% decline in average oak abundance in last 200 years correlates with known global and regional **oak decline**
- Shift from **perennial** to **seasonal** pond
    - **Water lily** pollen key indicator
    - **Change in sedimentation rate** influenced by deforestation rate filled in pond
    - Other modifications to local hydrology during 1800s, including re-routing local streams, installing mills and dams

Nuphar lutea. Image by Christophe Bornand.

Going Forward

Questions raised

- How many other vernal ponds in this landscape may have been perennial before 1800s?
- Are these vernal ponds only providing marginal habitat for native amphibians? Seasonal nature and lack of aquatic vegetation are relatively new occurrences

Eastern Newt. *Photo courtesy of Sue Wetmore/iNaturalist CC BY-NC.*

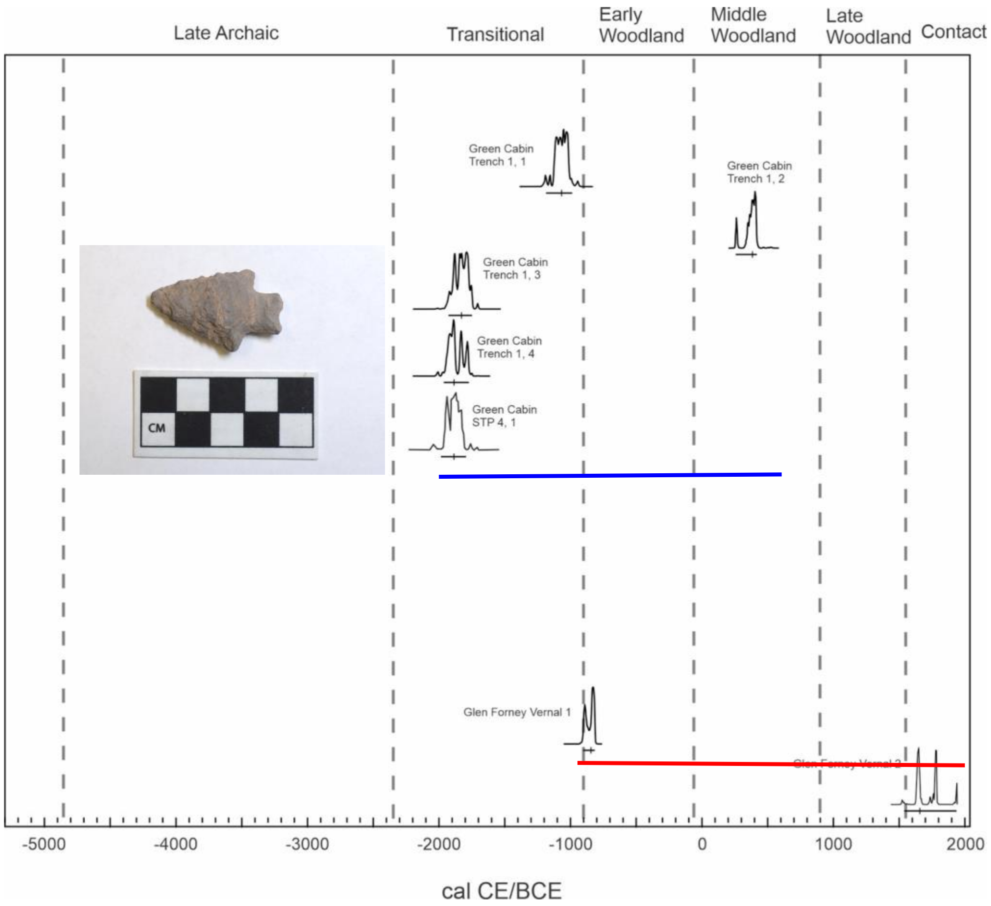
Analysis being further refined with the help of Dr. Willard from USGS Palynology Lab with the hopes of eventually publishing in peer-reviewed journal

Ties to Other Local Research

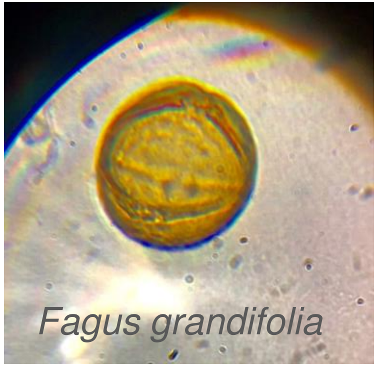
Green Cabin prehistoric quarry site (Kris Montgomery)

Overlapping time scale with Green Cabin Trench 1,1 and Trench 1, 2

When quarry was active, local hydrology may have been different, supported by Glen Forney vernal pool results




Tsuga canadensis

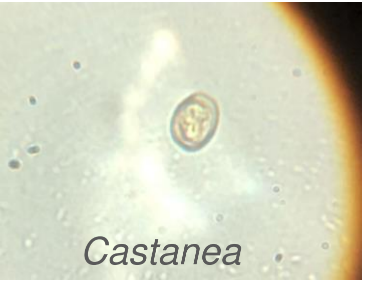

Fagus grandifolia


Cupressaceae


Ilex

Thank you!

Questions???


Castanea


Picea


Carya


Liquidambar styraciflua

References

Bassett, I.J., and J. Terasmae. 1962. Ragweeds, Ambrosia Species In Canada And Their History In Post-Glacial Time. *Canadian Journal of Botany* 40: 141- 150.

Barrat-Segretain, M.H. 1996. Germination And Colonisation Dynamics of *Nuphar lutea* (L.) Sm. In A Former River Channel. *Aquatic Botany* 55(1):31–38. doi: 10.1016/0304-3770(96)01062-5.

Bazzaz, F.A. 1974. Ecophysiology of *Ambrosia artemisiifolia*, a Successional Dominant. *Ecology* 55: 112-119. https://doi.org/10.2307/1934623.

Brugam, R.B. 1978. Pollen Indicators of Land-Use Change in Southern Connecticut. *Quaternary Research* 9: 349–62.

Brush, G.S. 1984. Patterns of Recent Sediment Accumulation in Chesapeake Bay (Virginia-Maryland, U.S.A.) Tributaries. *Chemical Geology* 44: 227-242. https:// doi.org/10.1016/0009-2541(84)90074-3.

Campbell, I. D., K. McDonald, M.D. Flanigan, and J. Kringayark. 1999. Long-distance transport of pollen into the Arctic. *Nature* 399: 29–30.

Kemp, D.B., P.M. Sadler, and V. Vanacker. 2020. The human impact on North American erosion, sediment transfer, and storage in a geologic context. *Nature Communications* 11: 6012. https://doi.org/10.1038/s41467-020-19744-3.

McAndrews, J.H. 1988. Human Disturbance Of North American Forests And Grasslands: The Fossil Pollen Record. In: *Vegetation History*, T. Huntley, and T. Webb (Eds.). Springer, pp. 673-697.

Mitchell, R.J., P.E. Bellamy, C.J. Ellis, R.L. Hewison, N.G. Hodgetts, G.R. Iason, N.A. Littlewood, S. Newey, J.A. Stockan, and A.F.S. Taylor. 2019. Collapsing Foundations: The Ecology of the British Oak, Implications of Its Decline and Mitigation Options. *Biological Conservation* 233: 316-327.

Moorehead, D.J., and G.K. Douce. 2019. Oak Decline. *Climate, Forests and Woodlands*. [https://climate-woodlands.extension.org/oak-decline/]. Accessed January 11, 2024.

Thomas, E.H. 1985. *A History of the Pennsylvania State Forest School, 1903-1929*. Pennsylvania State Forest Academy/School Foundation Society. 213 pages.

Varner, J.M., M.A. Arthur, S.L. Clark, D.C. Dey, J.L. Hart, C.J. Schweitzer. 2016. Fire in Eastern North American Oak Ecosystems: Filling the Gaps. *Fire Ecology* 12(2): 1-6.