# Vegetation Changes Associated with the Younger Dryas from the Sediments of Silver Lake, Summit County, Ohio, USA

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**ABSTRACT.** As the climate was warming during the last deglaciation, a millennium-long return to near-glacial conditions—called the Younger Dryas (YD) stadial—occurred about 12.9 to 11.7 ka ago. Prior studies have characterized the vegetation and climatic impacts of the YD stadial in the US upper Midwest from a network of fossil pollen records. The goal of this study was to locate the pronounced rise in organic matter and *Pinus* (pine) pollen—associated with the latter part of the YD event—in a sediment core from Silver Lake, a kettle lake in Summit County, Ohio. Based upon radiocarbon dating of the Silver Lake sediment core, an increase in sediment organic matter at 1,070 cm (35.1 ft) core depth dates to 12,130 calibrated years (cal yr) BP within the latter part of the YD stadial. A pollen study spanning the change in organic matter displays a gradual decline in *Picea* (spruce) pollen as well as a pronounced increase in *Pinus* pollen, similar to published records of the latter part of the YD event. Thus, the Silver Lake pollen record adds a new site to the network of fossil pollen sites, and further refines the vegetation changes within the Allegheny Plateau of Ohio that occurred during the latter part of the YD event. Furthermore, identifying the pronounced rise in *Pinus* pollen allows for biostratigraphic correlation between the Silver Lake record and another local dated pollen record. This biocorrelation adds further support to the Silver Lake radiometric age model.

## INTRODUCTION

Pollen preserved in lake sediments can be used to characterize past climates, because the plants reflect specific temperature and moisture conditions present at the time of their growth (Webb et al. 1993; Bennett and Willis 2001). There are, however, limitations to pollen as a recorder of past climatic change; for example, wind-dispersed pollen producing large, often overrepresented, amounts of pollen within sediment records compared to insect-dispersed pollen (Bennett and Willis 2001). Despite these limitations, pollen records have been successfully used to reconstruct climate change and provide insight into the underlying forcing mechanisms (Shane and Anderson 1993; Webb et al. 1993; Shuman et al. 2002; Gonzales and Grimm 2009; Gill et al. 2012).

Superimposed on the overall Laurentide deglaciation were climate oscillations to colder stadial periods. The Younger Dryas (YD) stadial was an abrupt return to near-glacial conditions that persisted from about 12,900 to 11,700 calibrated years (cal yr) ago (Alley 2000; Carlson 2013). The YD cooling is thought to result, in part, from glacial

meltwater entering the North Atlantic Ocean and decreasing the Atlantic Meridional Overturning Circulation—thereby inducing hemisphere-wide changes, including the YD cooling (Alley et al. 1999; Carlson 2013; Renssen et al. 2018). Pollen records from the higher-elevation Allegheny Plateau of northeastern Ohio and the lower elevation Till Plains of western Ohio reveal varying vegetative response to the YD stadial (Shane 1987; Shane and Anderson 1993). For example, 5 pollen records from the Allegheny Plateau do not have a distinct recurrence of *Picea* (spruce) during the YD, but rather a general decline in *Picea* (Shane 1987; Shane and Anderson 1993). In contrast, to the west, 9 pollen records from the Till Plains of Ohio, Indiana, and Michigan show a recurrence of *Picea* during the YD (Shane 1987; Shane 1989; Shane and Anderson 1993; Gill et al. 2012; Watson et al. 2018). From a network of pollen records, Shane and Anderson (1993) were able to quantitatively reconstruct the cooler conditions of the YD, revealing a greater reduction in precipitation in the Allegheny Plateau than in the Till Plains of Ohio. Because past climatic

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change is best characterized from a network of pollen records, a new lake site in northeastern Ohio was chosen to produce a pollen record of the YD.

The current report presents a new pollen profile from Silver Lake, in Summit County, within the Allegheny Plateau of northeastern Ohio (Fig. 1). Both Silver Lake—and East Twin Lake, located 11.3 km (7 miles) to the northeast—originated as glacial kettle lakes following the final retreat of Hiram glacial ice approximately 14,500 radiocarbon (approximately 17,600 cal) years ago (Szabo et al. 2003, 2013). Silver Lake sits atop glacial outwash and ice contact deposits and is groundwater-controlled, with slope wash and minor surface drainage culverts entering the lake and no outflowing stream (Szabo et al. 2013). The lake has a surface area of 36.4 hectares (90 acres) and contains 2 deep basins, a 7 m (23 ft) deep northern basin and an 11 m (36.1 ft) deep southern basin (Shaw 2013). A lake-wide study of surficial sediment bulk density and water content determined wave base, and the limit of wave-induced sediment reworking, to be at about 2 m (6.6 ft) water depth (Shaw 2013). The Silver Lake in Summit County should not be confused with the Silver Lake located in Logan County, within the Till Plains of west-central Ohio (Fig. 1). The Logan County Silver Lake has long been the subject of paleoenvironmental studies (Ogden 1966; Gill et al. 2012; Watson et al. 2018) and displays the

recurrence of *Picea* during the YD stadial (Ogden 1966; Gill et al. 2012).

This new Summit County Silver Lake pollen record, presented in the current study, is consistent with other studies documenting the vegetation response on the Allegheny Plateau during the YD stadial. Furthermore, this pollen record allows biostratigraphic correlation to nearby dated records which support the radiocarbon chronology of the Silver Lake sediment core.

## METHODS AND MATERIALS

In 2015, three companion Livingstone piston cores, with offset drives, were obtained from the northern basin (lat 41°09'25.6"N, long 81°27'28.8"W) of Silver Lake. Loss-on-ignition profiles, measured at a 1 cm interval, were used to correlate these companion cores to create a complete composition sediment sequence to 1,046 cm (34.3 ft) below lakefloor (Lally 2016). Only 1 of the piston cores extended beyond 1,046 cm (34.3 ft) and reached 1,353 cm (44.4 ft) below lakefloor. Thus, there are gaps in the sediment record at 1,046 to 1,053; 1,142 to 1,153; and 1,246 to 1,253 cm (34.3 to 34.5; 37.5 to 37.8; and 40.9 to 41.1 ft) marking the boundaries between individual core drives. Although the 7 cm (0.2 ft) gap at 1,046 to 1,053 cm (34.3 to 34.5 ft) lies within the interval for pollen analyses, the gap does not negatively
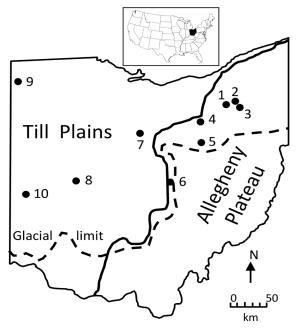


FIGURE 1. Map of Ohio showing the extent of Late Wisconsinan glaciation (dashed line) and physiographic sections (solid line) (modified from Szabo et al. 2006). (1) Silver Lake, Summit County, current study; (2) East Twin Lake; (3) Battaglia Bog; (4) Quillin Site; (5) Brown's Lake; (6) Smoot Lake Bog; (7) Bucyrus Bog; (8) Silver Lake, Logan County; (9) Ladd Lake; and (10) Stotzel-Leis Site.

impact this study because the pronounced changes in lithology, organic matter, and pollen occur deeper down at 1,070 cm (35.1 ft). Lally (2016) measured loss-on-ignition (LOI), elemental analysis, magnetic susceptibility, radiocarbon dating, and X-ray diffraction to characterize lake-watershed changes since deglaciation. Lally (2016) identified a pronounced increase in sediment organic content at 1,070 cm (35.1 ft) core depth and suggested that sediment having low organic content between 1,103 to 1,070 cm (36.2 to 35.1 ft) corresponded with the YD stadial. However, Shane (1987) and Shane and Anderson (1993) characterized the latter part of the YD stadial by a pronounced increase in both *Pinus* (pine) pollen and organic matter at 5 sites within the Allegheny Plateau of Ohio. Therefore, the current pollen study sampled Lally's (2016) inferred YD interval and extended upward into sediment having high organic content where the pronounced *Pinus* pollen rise was suspected to be located.

The core from 1,109 to 1,008 cm (36.4 to 33.1 ft) core depth was subsampled with a 1 cm³ volumetric sampler at a spacing of about 10 cm (0.33 ft). Pollen was extracted from 10 Silver Lake sediment samples using the method of Bennett and Willis (2001). The addition of exotic pollen was not used; therefore, quantitative abundance could not be calculated. A minimum of 288 pollen grains per sample were identified to the family or genera level and counted under a light microscope at 400× magnification. Palynologist David M. Jarzen, Research Associate at the Cleveland Museum of Natural History, visited The University of Akron to confirm the pollen identifications. The relative abundance (percentages) of each pollen type were calculated from the sum of the total pollen grains, excluding those that were unknown.

## RESULTS

The Silver Lake sediment core had previously been radiometrically dated (Lally 2016) (Table 1), and that age model provided the basis for targeting a specific core interval for pollen analysis (Fig. 2). The Silver Lake age model indicated that the rise in organic matter content, located deepest in the core at 1,070 cm (35.1 ft) core depth, dates to about 12,130 cal yr BP. This age estimate was obtained by linear interpolation between an old-carbon corrected, calibrated radiocarbon age of 7,150 cal yr BP at 812 cm (26.6 ft) core depth (Lally 2016) and the Summit County Morainic Complex deglaciation age estimate of 17,600 cal yr BP at 1,353 cm (44.4 ft) core depth (Szabo et al. 2003, 2013) (Fig. 2). An age of 12,130 cal yr BP for core depth 1,070 cm (35.1 ft) places it within the latter part of the YD event. Five other sediment core studies from elsewhere in the Allegheny Plateau of Ohio all show an increase in sediment organic content during the latter part of the YD event (Shane 1987; Shane and Anderson 1993). The results of the pollen analysis are presented next, starting from the deeper (thus older) samples.

Within the Silver Lake core, a deeper *Picea*-dominated zone (Zone I) is overlain by a *Pinus*-dominated zone (Zone II) (Table 2, Fig. 3). *Pinus* pollen increases from 4% at 1,077 cm (35.3 ft) to 34% at 1,069 cm (35.1 ft). Because organic content increases at 1,070 cm (35.1 ft), the boundary between the 2 pollen zones was also placed at 1,070 cm (35.1 ft) and not at the midpoint between analyzed pollen samples.

Pollen Zone I spans 1,109 to 1,070 cm (36.4 to 35.1 ft) core depth and is comprised of light brown mud having 6 to 11% organic content (Table 2, Fig. 3). Zone I is dominated by *Picea* pollen, which decreases from 33% at the base of the zone to 19%

## Table 1
### Radiocarbon dates from Silver Lake, Summit County, core and calibrated ages
### (modified from Table 15 in Lally 2016)

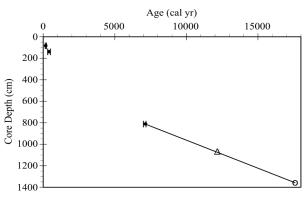| Core - drive - depth in drive (cm) | Composite core depth (cm) | Material dated | Sample ID | ¹⁴C age (yr) | 1 σ error (yr) | Corrected ¹⁴C age (yr) | Calibrated age (cal yr BP) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Max. | Median | Min. |
| C2-D1-53 | 84.5 | Unidentified plant fragments | Beta 428155 | 1500 | 30 | 200 | 222 | 181 | 140 |
| C2-D2-104 | 140 | Bulk sediment | Beta 424795 | 1660 | 30 | 360 | 500 | 408 | 315 |
| C3-D7-44 | 812 | Bulk sediment | Beta 424794 | 7500 | 30 | 6200 | 7179 | 7150 | 7000 |

**FIGURE 2. Age control for Silver Lake, Summit County, Ohio. Calibrated radiocarbon dates (dots) from Lally (2016), deglacial age estimate (circle) from Szabo et al. (2003, 2013), Silver Lake linear interpolation age estimate (line), and biocorrelated calibrated radiocarbon age from East Twin Lake (triangle) from Neotoma Explorer (2018).**

## Table 2
## Pollen abundance counts from the sediments of Silver Lake, Summit County, Ohio

| Core data | Pollen zone II | | | | | | Pollen zone I | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Core - drive - depth in drive (cm) | C3-D9-55.5 | C3-D9-63.5 | C3-D9-74.5 | C3-D9-91.5 | C3-D10-10.5 | C3-D10-16.5 | C3-D10-24.5 | C3-D10-36.5 | C3-D10-44.5 | C3-D10-56.5 |
| *Composite core depth (cm) | 1008 | 1016 | 1027 | 1044 | 1063 | 1069 | 1077 | 1089 | 1097 | 1109 |
| *Organic content (%) | 17.4 | 20.3 | 34.0 | 30.9 | 19.1 | 13.5 | 8.0 | 8.9 | 6.4 | 10.8 |
| **Pollen type** | #Pollen zone II counts | | | | | | #Pollen zone I counts | | | |
| *Picea* | 37 | 43 | 17 | 56 | 28 | 70 | 127 | 101 | 96 | 112 |
| *Abies* | 10 | 19 | 12 | 40 | 53 | 103 | 83 | 64 | 37 | 77 |
| *Pinus* | 296 | 280 | 162 | 323 | 159 | 193 | 29 | 15 | 9 | 13 |
| *Quercus* | 24 | 25 | 24 | 19 | 10 | 31 | 110 | 64 | 73 | 66 |
| *Fraxinus* | 4 | 2 | 3 | 7 | 2 | 4 | 26 | 19 | 13 | 4 |
| *Ostrya / Carpinus* | 2 | 1 | 4 | 2 | 0 | 8 | 31 | 3 | 13 | 1 |
| *Betula* | 11 | 11 | 7 | 7 | 2 | 9 | 40 | 6 | 11 | 19 |
| *Larix* | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| *Carya* | 3 | 4 | 4 | 3 | 3 | 8 | 23 | 5 | 12 | 8 |
| *Acer* | 6 | 6 | 6 | 7 | 3 | 4 | 7 | 6 | 15 | 2 |
| *Tsuga* | 7 | 4 | 2 | 5 | 3 | 3 | 2 | 5 | 4 | 0 |
| *Populus* | 9 | 5 | 2 | 4 | 1 | 4 | 4 | 1 | 3 | 1 |
| *Alnus* | 6 | 6 | 13 | 1 | 2 | 5 | 16 | 0 | 0 | 7 |
| *Salix* | 0 | 4 | 2 | 3 | 1 | 5 | 9 | 0 | 0 | 2 |
| *Ambrosia* | 2 | 2 | 1 | 4 | 2 | 10 | 14 | 7 | 5 | 2 |
| Other NAP[†] | 22 | 9 | 22 | 63 | 25 | 84 | 113 | 105 | 41 | 15 |
| Unknown angiosperm | 6 | 5 | 5 | 3 | 7 | 20 | 38 | 52 | 55 | 10 |
| Unknown | 13 | 11 | 8 | 3 | 6 | 2 | 20 | 11 | 25 | 6 |
| **Number counted | 445 | 426 | 288 | 547 | 301 | 561 | 672 | 453 | 390 | 339 |

\* Indicates data from Lally (2016).        [†] Non-arboreal pollen.        ** Excludes the category "Unknown."
[#] Each individual pollen count was obtained from the core sample and depth shown in the column vertically above.
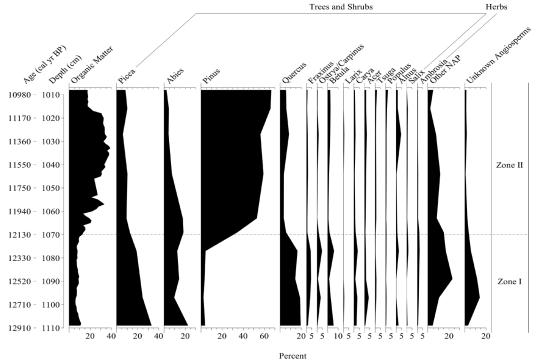
**FIGURE 3. Pollen diagram for Silver Lake, Summit County, Ohio, with the 2 pollen zones delineated. Pollen analysis by S.E. Swisher and organic matter data from Lally (2016).**

in the topmost Zone 1 sample (Table 2, Fig. 3). *Abies* (fir) pollen percent is highest (23%) at the base of the zone and then varies from 9 to 14% for the remainder of the zone. *Pinus* pollen is low within Zone I, varying from 2 to 4%, whereas *Quercus* (oak) pollen is relatively abundant (14 to 19%). Zone I also has slightly more (1 to 2%) *Fraxinus* (ash), *Ostrya/Carpinus* (hornbeam), *Betula* (birch), *Carya* (hickory), and possibly *Ambrosia* (ragweed) pollen than the overlying Zone II (Table 2, Fig. 3). The category unknown angiosperm pollen contains less than 2% of the pollen counted in each sample, with the exception of several samples from Zone I, where these unknown angiosperms comprised up to 14% of the sample. The category other non-arboreal pollen (NAP), includes Cyperaceae (sedges), Gramineae (grasses), *Artemisia* (wormwood), ferns, and other herbs.

Pollen Zone II spans 1,070 to 1,008 cm (35.1 to 33.1 ft) core depth and is comprised of dark brown mud having 9 to 39% organic content (Fig. 3). Zone II is characterized by abundant *Pinus* pollen (34 to 66%), however, wind-dispersed *Pinus* pollen may be overrepresented in lacustrine sediment (Bennett and Willis 2001). Within Zone II, both *Picea* and *Quercus* pollen percentages are substantially reduced compared to Zone I (Fig. 3). However, the decline in *Abies* pollen occurs higher up in Zone II, as the 2 deepest Zone II samples still contain high concentrations of *Abies* (18%) pollen (Fig. 3).

## DISCUSSION
### Establishing the Younger Dryas Interval within the Silver Lake Core

The YD impact on woody vegetation is readily identified within the Silver Lake sediment record. This interpretation is supported by both radiocarbon dating of the Silver Lake core and the correlation of the pronounced rise in organic content and *Pinus* pollen between Silver Lake and other published records in the Allegheny Plateau of Ohio. The Silver Lake age model—based on linear interpolation between a radiocarbon age at 812 cm (26.6 ft) core depth (Lally 2016) and the local deglaciation age estimate at 1,353 cm (44.4 ft) core depth (Szabo et al. 2003, 2013)—dates 1,070 cm (35.1 ft) core depth to 12,130 cal yr BP (Fig. 2). Based upon this age, the core segment studied lies within the timing of the YD event.

Blois et al. (2011) shows how pollen biostratigraphic correlation can be used to constrain the age of records with limited dating control. Thus, a direct biostratigraphic correlation of the Silver Lake and nearby East Twin Lake pollen records was performed (Fig. 4). A distinguishing feature of the latter part of the YD event in the Allegheny Plateau of Ohio is the gradual decline in *Picea* pollen and pronounced rise (about 50%) in *Pinus* pollen (Shane 1987; Shane and Anderson 1993; Shuman et al. 2002). In the Silver Lake record at 1,070 cm (35.1 ft) core depth, *Pinus*
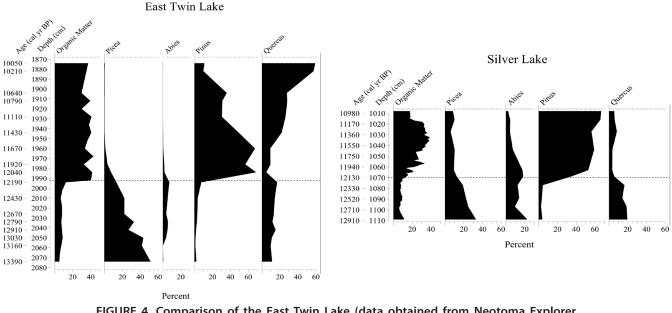
**FIGURE 4. Comparison of the East Twin Lake (data obtained from Neotoma Explorer 2018) and Silver Lake pollen records. Silver Lake organic content data from Lally (2016). Horizontal lines mark the increase in organic content and *Pinus* pollen in each lake.**

pollen increases from less than 10% to between 50 and 70% (Fig. 4). In East Twin Lake, located only 11.3 km (7 miles) to the northeast of Silver Lake, there is a rise in *Pinus* pollen of similar magnitude (Fig. 4). The detailed East Twin Lake pollen study identified a rise first in *Pinus banksiana/resinous* followed by *Pinus strobus* (Shane and Anderson 1993) pollen, whereas the current study considers total *Pinus* pollen. Furthermore, both lake records show similar declines in *Picea*, *Abies*, and *Quercus* pollen and increases in sediment organic content associated with the *Pinus* pollen rise (Fig. 4).

East Twin Lake has more age control points located closer to the decline in *Picea* pollen and the pronounced rise in *Pinus* pollen than Silver Lake. Data for East Twin Lake, obtained from Neotoma Explorer (2018), reveals that the *Pinus* pollen rise lies between samples from 1,984 and 1,994 cm (65.1 and 65.4 ft) total depth and organic content changes at 1,993 cm (65.4 ft). The Neotoma 1 chronology model yields an old-carbon corrected, calibrated radiocarbon age of 12,170 cal yr BP for 1,993 cm (65.4 ft) total depth (Neotoma Explorer 2018). A similar age of 12,210 cal yr BP is obtained for East Twin Lake using the Blois 2011 age model in Neotoma Explorer (2018). Thus, the age model for each lake yields a similar date for the pronounced rise in *Pinus* pollen: 12,130 and 12,170 cal yr BP for Silver Lake and East Twin Lake, respectively (Fig. 2, Fig. 4). On a regional scale the *Pinus* expansion is time-transgressive, and Shuman et al. (2002) estimated a rapid [>300 km (>186 miles) in 100 yr]

westward expansion of *Pinus* during the YD. Silver and East Twin Lakes, however, are only 11.3 km (7 miles) apart, so the timing of the *Pinus* pollen rise is expected to be synchronous—and that was found to be the case.

The Silver Lake pollen record correlates to the East Twin Lake record. The Silver Lake pollen record is also similar to the pollen records of the latter part of the YD from Battaglia Bog, Quillin Site, Brown's Lake, and Smoot Lake Bog, all in the Allegheny Plateau of Ohio (Shane 1987; Shane and Anderson 1993). The similarity between Silver Lake and these other records includes increases in *Pinus* pollen and organic matter, and decreases in *Picea*, *Abies*, and *Quercus* pollen, all at the same time (Fig. 4). However, in sediment younger than 12,130 cal yr BP, the Silver Lake record has higher abundances of *Picea* and *Abies* pollen than the East Twin Lake record (Fig. 4). Furthermore, *Quercus* pollen remains low to the top of the interval studied from Silver Lake, whereas in East Twin Lake *Quercus* pollen increases back to 20% and *Picea* pollen disappears at about 11,600 cal yr BP—marking the end of the YD interval (Fig. 4). These differences suggest that in Silver Lake the sedimentation rate was higher than the linear age model after 12,130 cal yr BP. If the sedimentation did increase, then the current pollen study did not extend high enough up the core to locate the rise in *Quercus* pollen that marks the end of the YD event at other Allegheny Plateau sites. In spite of this uncertainty, the identification of the pronounced rise in *Pinus* pollen provides a

key biostratigraphic correlation marker that agrees with the Silver Lake radiometric age model (Fig. 2) and confirms that Lally (2016) correctly identified the early part of the YD event as sediment having low organic content and high concentrations of Al, K, and Ti.

## Vegetation and Climate Impacts

Pollen records of vegetation changes have long been studied to better understand past temperature and precipitation changes in response to the YD (Shane and Anderson 1993; Shuman et al. 2002; Watson et al. 2018). Within the East Twin Lake pollen record, 2 intervals (i.e., phases in the original study)—each having different pollen assemblages—span the time of the YD event (Shane and Anderson 1993; Neotoma Explorer 2018). The older phase, IIa, begins at 13,160 cal yr BP [2,058 cm depth (67.5 ft)] and ends abruptly at 12,170 cal yr BP [1,993 cm (65.4 ft)] (Fig. 4) (Shane and Anderson 1993; Neotoma Explorer 2018). Phase IIa is characterized by declining *Picea* pollen, low *Pinus* pollen, and abundant (approximately 13%) *Quercus* pollen (Fig. 4). The younger phase IIb spans 12,170 cal yr BP [1,993 cm (65.4 ft)] to 11,600 cal yr BP [1,955 cm depth (64.1 ft)] and is characterized by a pronounced increase in *Pinus* pollen and organic matter, and low amounts of *Quercus* pollen (Fig. 4) (Shane and Anderson 1993; Neotoma Explorer 2018). The end of phase IIb is marked by the disappearance of *Picea* pollen and the return of abundant *Quercus* pollen (Fig. 4) (Shane and Anderson 1993; Neotoma Explorer 2018). The Zone I to II boundary in the Silver Lake pollen record displays similar changes in pollen and organic matter, at nearly the same time as the East Twin Lake phase IIa to IIb boundary (Fig. 4).

Based on the relationship between modern pollen and climate data sets, response surfaces and transfer functions were applied to Allegheny Plateau pollen records, including East Twin Lake, to estimate past July and January temperatures and annual precipitation (Shane and Anderson 1993). Within phase IIa on the Allegheny Plateau, Shane and Anderson (1993) estimate a July and January warming of about 1 °C and 5 °C, respectively, and a minor annual precipitation increase of about 3 to 5 cm, all compared to conditions prior to 13,160 cal yr BP. During approximately the first quarter of Phase IIb, Shane and Anderson (1993) estimate a brief

cooling in July and January of about 1 °C and 5 °C, respectively. For the latter three-fourths of phase IIb, July temperatures rebound to the earlier phase IIa temperatures, whereas January temperatures increase 3 to 6 °C above phase IIa temperatures (Shane and Anderson 1993). The net effect of these temperature changes is that seasonality declined during phase IIb. Shane and Anderson (1993) also estimate major drying during phase IIb with a 10 to 20 cm/yr (3.94 to 7.87 in/yr) decrease in annual precipitation between about 12,170 and 11,600 cal yr BP. This drying estimate is supported by a change from limnic to peat sedimentation at several Allegheny Plateau sites (Shane and Anderson 1993) and lower lake levels elsewhere in the southern Great Lakes region (Shuman et al. 2002). The increase in *Pinus* pollen in the latter part of the YD may be a result of cool, open, or drier conditions (Shane and Anderson 1993; Shuman et al. 2002; Gill et al. 2012). Accompanying the pronounced increase in *Pinus* pollen there is an increase in sedimentary organic content in both East Twin Lake and Silver Lake (Fig. 4). There is also an increase in *Pinus* pollen and organic content in other Allegheny Plateau records from Battaglia Bog, Brown's Lake, and the Quillin Site (Shane 1987). To the west, the Till Plain sites of Bucyrus Bog, Pyle Site, Stotzel-Leis Site, and Silver Lake (Logan County) show increases in *Picea* and *Pinus* pollen, as well as organic content, during the YD (Shane 1987; Gill et al. 2012; Watson et al. 2018). A well-dated Till Plain lake record shows increased organic content beginning at 13,000 cal yr BP and remaining high throughout the YD interval (Watson et al. 2018), whereas the organic matter increase in East Twin Lake and Silver Lake begins later at about 12,130 cal yr BP (Fig. 4). Interestingly, Gill et al. (2012) documents an increase in both organic content and in the Zr/Al ratio—a measure of wind-blown sedimentation—at Silver Lake, Logan County, during the YD. Increased lake sediment organic content, during the cooler and drier YD interval, reflects a variety of factors including changes in lake level, lake productivity, watershed stability, organic matter oxidation, and basin infilling (Shane 1987; Gill et al. 2012; Watson et al. 2018). To the west in the Till Plains, Shane and Anderson (1993) estimate that the YD drying was about half the magnitude of the Allegheny Plateau; however, some Till Plain sites do not show drying. Other sites from the Till Plains indicate that the

YD was wet and cool (Gonzales and Grimm 2009; Voelker et al. 2015). A computer model simulation of a YD freshwater meltwater pulse to the ocean was performed to assess the global hydroclimate response (Renssen et al. 2018). The study by Renssen et al. (2018) included a detailed analysis of the central contiguous US, labeled as southeastern North America, where model results indicate mean annual temperature cooled by about 1 °C and soil moisture increased by about 15%. In their model, atmospheric pressure anomalies over North America resulted in southerly winds, increasing the advection of moisture from the Gulf of Mexico to the central contiguous US. Although hemispheric in scope, their April to August precipitation anomaly map reveals increased precipitation to the west of Ohio and decreased precipitation to the east toward the Allegheny Plateau (Fig. 8 in Renssen et al. 2018). The aforementioned east-to-west precipitation gradient model is in general agreement with the interpretation that drier conditions favored the *Pinus* expansion in the Allegheny Plateau; conditions being less favorable farther westward (Shuman et al. 2002). Spatial variations in past climatic conditions are best assessed through networks of individual pollen records (Shuman et al. 2002).

Regional pollen stacks can also be used to minimize complications associated with local proxy records, and thus better assess past climatic changes (Watson et al. 2018). Although of limited temporal duration, this new Silver Lake, Summit County, pollen record provides an additional site in support of vegetation changes occurring during the YD event in the Allegheny Plateau of Ohio. Furthermore, well-dated records are required to assess past climate change and forcing mechanisms. For example, Crystal Lake, Illinois, has a robust radiocarbon chronology that indicates the vegetation and climate lagged the Greenland ice core record of the YD onset by 300 to 400 years (Gonzales and Grimm 2009). A well-dated temperature record, based on pollen and soil biomarkers from Silver Lake, Logan County, Ohio, indicates that the YD onset recorded at Silver Lake lags a northern mid-latitude synthesis temperature record by about 300 to 500 years (Watson et al. 2018). The delay in cooling in the southern Great Lakes region, compared to the North Atlantic, is likely the result of the influence of the Laurentide ice sheet on both the region and atmospheric circulation—not a dating resolution problem (Gonzales and Grimm 2009; Watson et al. 2018). The Silver Lake pollen record agrees well with other YD pollen records from the Allegheny Plateau of Ohio, and thus contributes a new site to the regional pollen network. Future work on the Silver Lake core could include pollen analysis spanning the entire YD event, the full approximately 17,600 cal yr sediment record, and detailed radiocarbon dating of terrestrial plant remains.

## CONCLUSIONS

A pollen record was produced from the sediment of Silver Lake, Summit County, Ohio, that had been radiometrically dated to the YD stadial. This new pollen record agrees with existing records that document a climate reversal to cool and dry conditions. In addition, this record shows that pronounced increases in *Pinus* pollen and organic content are distinguishing features of the latter part of the YD stadia in the Allegheny Plateau of Ohio. Because the *Pinus* increase is so pronounced, it allows for biostratigraphic correlation between the Silver Lake record and a nearby radiocarbon dated pollen record. This biocorrelation provides additional support to the Silver Lake radiometric age model.

## ACKNOWLEDGEMENTS

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