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RESOLVING A ONE-YEAR ECESIS INTERVAL FOR ALASKA PAPER BIRCH: DATING A ROCKFALL EVENT, WISHBONE HILL, SOUTHCENTRAL ALASKA

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ABSTRACT

Numerous large boulders at the base of Wishbone Hill, northeast of Anchorage, Alaska, suggest a historic rockfall event and potential for future surface instability, putting lives and property at risk. The source of the rockfall-boulders is an exposed syncline with a cliff face composed of conglomerate. The age of trees growing atop boulders provides a minimum exposure-age of those boulders and, thus, the rockfall event. To determine when the rockfall occurred, we dated trees growing atop the boulders using tree-ring samples collected from 30 Alaska paper birch trees. After mounting and polishing, each tree-ring sample was dot-counted, and tree-ring widths were measured using Measure J2X software to generate a master chronology (1938-2017). To estimate the youngest age for the rockfall event, we recorded pith-year for each sample. For samples lacking a pith (n=21), we used pith indicators to match existing rings to diagrams of corresponding ring widths, projecting approximate pith for each sample. All samples we corrected for sampling height (mean=0.8m) using a low estimate growth rate (0.6m/yr). The oldest birch tree sampled included pith and, with height correction, we estimate a germination year of 1936. When using first-year growth as an event's temporal marker, accounting for the ecesis interval, the time between the availability of a new surface (i.e., boulders) and germination provides a more representative date of the event than using the pith/germination date alone. Considering birch ecesis and primary observations recorded in 1935, we propose that the rockfall event most likely occurred in 1934-1935. This finding suggests an ecesis interval as low as one year for Alaska paper birch in fresh rockfall areas. The risk of another destabilizing event may prompt those utilizing this area for recreational and residential purposes to reconsider future use.

KEY WORDS: Wishbone Hill, Dendrochronology, Rockfall

INTRODUCTION

Wishbone Hill, located in southcentral, Alaska, approximately 100km northeast of Anchorage (figure 1), is a tree-covered hillside consisting of an exposed syncline with a cliff face of conglomerate. Historically, the Wishbone Hill area was the site of several coal mining operations, the largest of which remained active until 1968 (ADNR, 2009). Currently, the area includes residential neighborhoods, and it is a popular destination for outdoor recreation activities, including off-highway vehicle (OHV) use. Several forest fires have occurred in the area, most recently, the "Eska" and "Buffalo" fires of 1942 (FRAMES, 2019).

Boulders sourced from the cliff litter the slope base, support the growth of Alaska paper birch trees (Betula papyrifera var. neoalaskana (Sarg.) Raup) and are evidence of a rockfall event. The potential for future mass movement puts residents and those who recreate in the area at risk. Understanding the frequency and process of mass movements at Wishbone Hill may allow us to better understand potential impacts to new residential construction and infrastructure and recreation activities. With additional information, land managers can understand landscape change concerning human needs and make more informed decisions.

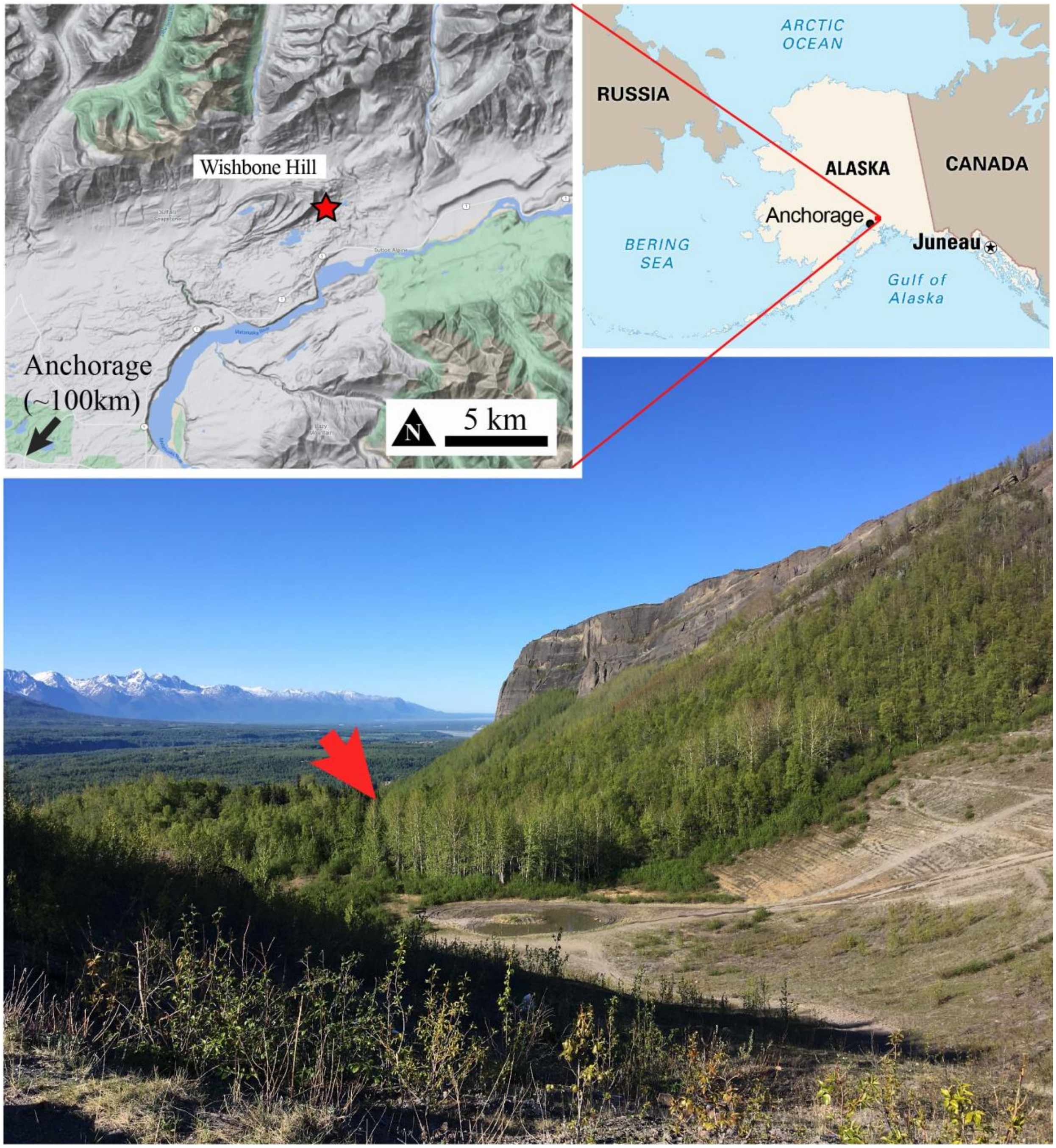

Figure 1. Overview map of the state of Alaska (modified from Britannica, 2020), regional map (modified from Google, 2020), and a perspective photograph of sampling site taken facing the southwest; red star and arrow are sampling site. The area of study, known as Wishbone Hill, is located approximately 100 km northeast of Anchorage.

According to Hults et al. (2019), "Alaska is the most geologically active part of North America" (p. 1), so land management agencies must take geohazards, like rockfalls, into consideration when opening areas for recreation or considering them for development. For example, the U.S. Department of Transportation's Federal Highway Administration established the Unstable Slope Management System for Federal Land Management Agencies (Beckstrand et al., 2019); however, this manual primarily deals with slope management related to infrastructure (i.e., roads and trails). Many rockfall, risk-assessment rating systems have been developed, assessing risks presented by slopes altered for infrastructure development. For example, the Rockfall Hazard Rating System (Pierson et al., 1990), Rock Slope Hazard Index (McMillan and Matheson, 1997) and the Colorado Rockfall Hazard Rating System (Andrew, 1994; Santi et al., 2009). While these systems apply primarily to slopes altered for infrastructure development, they highlight the importance of slope stability in planning and development, especially in areas under state or federal control for recreational purposes.

To further understand the impact of rockfall events on recreation and development, we looked at data from Yosemite National Park. The park receives over 4 million visitors annually and has welcomed a total of over 200 million visitors since the National Park Service began collecting visitor use data in 1906 (NPS, 2020). The United States Geological Survey (USGS) maintains a detailed inventory of rockfall history in the Yosemite Valley, suggesting rockfalls pose a threat to visitors and the park's infrastructure (Stock et al., 2013). By recording historic events, the park management hopes to better understand rockfall events, and reduce visitor-risk (Stock et al., 2013). From 1857 to 2011, 925 rockfalls observed in the Yosemite Valley resulted in 15 fatalities and 85 injuries (Stock et al., 2013). In 2017, 10,324 m3 of rock fell from El Capitan (NPS, 2020), killing one recreator and injuring another at one of the park's most famed destinations (NPS, 2017).

Wishbone Hill does not draw near the number of visitors as the Yosemite Valley, but the measures taken by the National Park Service to understand the history and damage of rockfalls underscore both their danger and their cost. Understanding historic rockfalls, such as the one at Wishbone Hill, will provide data to make more informed decisions that protect both recreators and the integrity of any existing or planned developments, including roads and trails. To better understand landscape change at Wishbone Hill, we utilized tree-ring dating to approximate the youngest possible rockfall event age. Research (e.g., Borella et al., 2019) suggests that past rockfalls do not necessarily predict the magnitude, or effect of future events but indicate a need for caution in areas that have undergone development since the last known rockfall event. Data show that development leads to vegetation removal and increased potential for more catastrophic outcomes from future rockfalls (Borella et al., 2019).

Our research also helps better understand the sensitive growth of Alaska paper birch atop boulders in this region. We used ring-width and climate data to help understand the driving factor of birch growth in this area of Alaska. In doing so, we can understand how these unique growing conditions might remain consistent with, or differ from, known conditions for best growth.

PAPER BIRCH

There are five major varieties of paper birch (Betula papyrifera), named for their geographic distribution. They share many of the same basic characteristics but with some unique to each variety. Alaska paper birch (B. papyrifera var. neoalaskana (Sarg.) Raup), evaluated as part of this study, is one of five major varieties. All paper birch has a relatively short lifespan, typically less than 140 years, and reaches maturity after 60 to 70 years, with seed production occurring after about 15 years (Safford et al., 1990). Birch trees often colonize as pioneer species after a disturbance that instigates succession, such as a wildfire or mass movement event. Still, they can endure wildfires if sprouts remain post-fire (Safford et al., 1990).

Germination

Paper birch germination follows one of two scenarios depending on the environmental conditions: a) with proper growing conditions, germination is initiated and continues until complete, or b) germination may taper off when growing conditions become undesirable, continuing later in the growing season under more favorable conditions (Safford et al., 1990). Shaded areas produce twice the germinants of full-sun areas (Safford et al., 1990), highlighting the north- and east-facing slope aspects' advantageous conditions.

Figure 2. Portion of the boulder field from the rockfall event with birch trees. Note the large boulder and person for scale.

Ecesis

Ecesis is the lapse in time between the establishment of available surface for tree growth (i.e., landform formation or stabilization) and seed germination on that surface (Pierson, 2007; Van Der Burght et al., 2012). Ecesis intervals vary with climate and tree species (Van Der Burght et al., 2012). One study reveals birch ececis in areas subjected to secondary succession by rockslide events to be five years (Van Der Burght et al., 2012).

Figure 3. Sample extraction from Alaska paper birch (Betula neoalaskana) growing atop a boulder.

METHODS

We sampled 30 Alaska paper birch trees growing atop 30 individual boulders in a rockfall zone at the base of Wishbone Hill (figures 2 and 3). Trees were selected and sampled to maximize tree age, with two samples collected from opposing sides (n=60 samples) (figure 4). For each tree, we recorded the location, elevation, sampling height, crown density, tree height, diameter at breast height, a description of the tree's lean characteristics, and the boulder characteristics (e.g., height and circumference to estimate volume).

Samples were stored and transported back to the St. Lawrence University tree-ring lab, where they were dried, mounted, and polished in preparation for observation under a microscope. We dot counted each sample (i.e., providing a year value to each ring) and measured the ring widths using Measure J2X software to generate a master chronology (1938-2017, Whitney and Stewart, 2019) evaluated with COFECHA (Grissino-Mayer, 2000). For trees that did not include pith (i.e., center growth of the tree), we matched our samples to pith-indices diagrams (see Speer, 2012, p. 283) with corresponding ring sizes to project an approximate pith year and better constrain tree ages. Additionally, we corrected for sampling height using a low estimate growth rate (0.6m/yr) to better constrain tree ages. In all, samples were dated, projected to the pith (if the pith was missing), and corrected for growth based on sampling height. The volume of each boulder was also estimated using boulder height and circumference.

Figure 4. Increment borer in an Alaska paper birch with spoon and sample extracted.

RESULTS/INTERPRETATIONS

Based on ring count, pith projection, and corrections for sampling height, the mean germination year was 1948±6yr. (Table 1). With no correction needed for pith, and adjusting for sampling height, the oldest tree dates to 1936. From 1936-1941, the tree population remained low, with one tree germinated in 1936 and one germinated in 1939. Less than 7% of the trees within our sample population germinated within a range of three years (figure 5). In 1942, tree germination increased to two trees and again, two trees, in 1945 (figure 5). In 1946, the tree population increased to four trees germinated/yr from our sample population. That rate remained steady at four trees/yr through 1949 (figure 5).

Germination tapers off and becomes less consistent (i.e., germination is intermittent and demonstrates no pattern) from 1950 on; new tree germination within the sample population essentially ceased in 1956, with 97% of sampled trees germinated (figure 5). Our sample population included one outlier germinated in 1969 (figure 5). The calculated mean boulder volume was 62.0m3 (SD=119.6m3) (Table 1). We observed no correlations between tree metadata (e.g., DBH, height) and boulder metadata (e.g., volume, height).

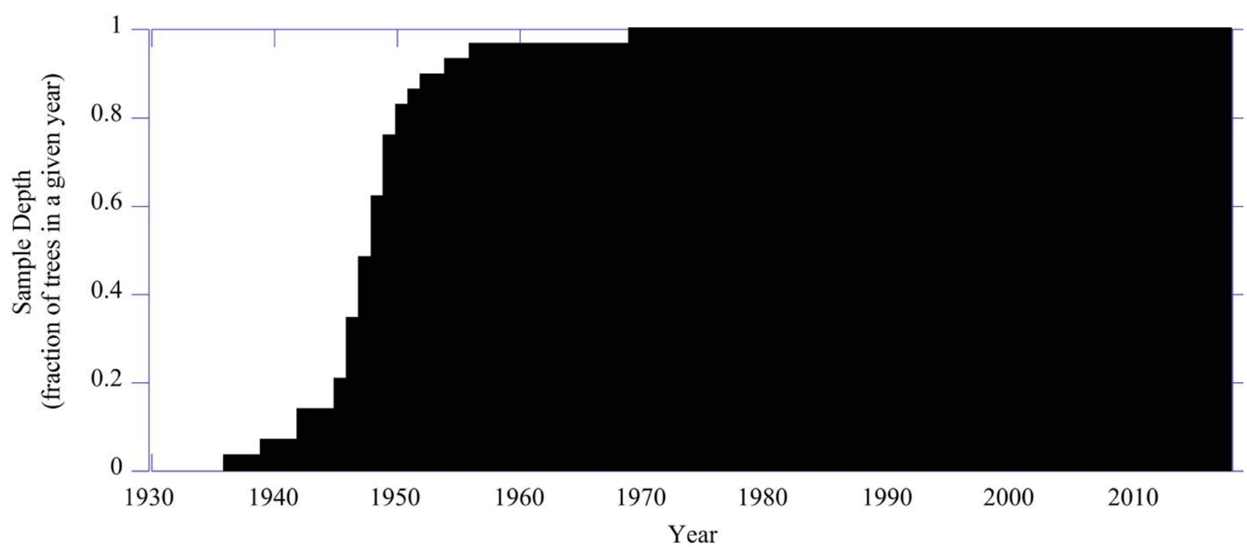

Figure 5. Sample depth (i.e., fraction of samples expressed per growth year) within our sample population (n=30).

Sample Number	Dot Count	Projected Pith	Sampling Height Adjustment	Boulder Volume (m3)
WBH51	1949	1945	1944	13.9
WBH52	1949	1946	1945	48.7
WBH53	1948	1948	1947	31
WBH54	1949	1947	1946	39
WBH55	1949	1949	1949	31
WBH56	1950	1949	1948	26.4
WBH57	1953	1950	1950	295
WBH58	1949	1949	1948	28.2
WBH59	1948	1947	1946	34.3
WBH60	1974	1970	1969	1.2
WBH61	1952	1952	1952	10.1
WBH62	1952	1950	1949	20.2
WBH63	1950	1948	1947	7.6
WBH64	1937	1937	1936	13.2
WBH65	1962	1956	1956	18
WBH66	1949	1947	1946	7.3
WBH67	1951	1949	1949	25.3
WBH68	1941	1940	1939	12.2
WBH69	1947	1946	1945	9
WBH70	1953	1951	1950	599.6
WBH71	1955	1955	1954	229.4
WBH72	1949	1949	1948	11.4
WBH73	1948	1948	1946	65.6
WBH74	1943	1943	1942	55.7
WBH75	1946	1944	1942	13.2
WBH76	1954	1950	1948	59
WBH77	1950	1949	1947	84.9
WBH78	1947	1947	1946	25.4
WBH79	1954	1953	1951	42.2
WBH80	1952	1950	1948	3.1
		Mean	**1948**	**62 m3**
		StDev	**6 years**	**120 m3**

Table 1. 30 birch trees were sampled, and rings were dot counted for germination year (Mean = 1948) (SD = 6 years). Two corrections were made where we 1) projected germination year for samples where pith was not present and 2) corrected for sampling height to determine the final germination year. Oldest sample is annotated in green. Estimated boulder volume for the corresponding sample is also shown.

DISCUSSION

Based on our analysis, we estimate the oldest tree within our sample population germinated in 1936. Birch ecesis estimates on boulder fields (Van der Burght el al., 2012) suggest it takes five years between the substrate (i.e., the boulder) becoming available for growth (e.g., a rockfall event) and seed deposition and gemination. These boulder-top birches are growing atop a rough-surfaced conglomerate that likely facilitated a) dust accumulation, during and shortly after the rockfall and b) deposition of wind-blown seeds into the interstices between grains. As a result, roots could grow and set in the spaces between grains without an extended ecesis interval (Van der Burght et al., 2012). Because paper birch is a shallow-rooted species (Safford et al., 1990), it’s reasonable to assume that given proper nutrients from the boulder, the inability to establish deep roots atop a boulder should not have hindered growth.

Based on a known ecesis interval of five years for birch trees in areas with recent mass-movement deposits, we estimated a rockfall date of no younger than 1931. A 1937 USGS report based on field observations in the summer and fall of 1935 recognized slide rock on the south side of Wishbone Hill, near the Evan Jones Mine and our sampling area. They described the material as "irregular shaped blocks of Eska conglomerate" some of which was "so recent that it [was] not covered with vegetation" (Tuck, 1937, p. 195). A later USGS Bulletin also recognizes large, soil-covered conglomeratic blocks just west of the Evan Jones Mine—the area of our sampling —as the "largest landslide mass" in the area (Barnes and Payne, 1956). Based on the 1935 observation recorded USGS (1937) publication, the boulders were not vegetated. Considering the observed recency and freshness of the surface (Tuck, 1937), we know that the rockfall occurred before the summer/fall of 1935. Incorporating this observation with our tree-ring data and the five-year ecesis interval by Van der Burght et al. (2012) suggests that the rockfall likely occurred between 1931 and 1935. Because our oldest sample germinated less than a year after the USGS observations of the rockfall in mid-1935, our study suggests an ecesis interval for Alaska paper birch atop rockfall debris could be as short as one year.

In suggesting 1931 to 1935 as the youngest possible time frame for the rockfall event, we assume the boulders accumulated from one large event rather than several smaller events over time. Most samples germinated between 1936-1956, except for one tree that germinated in 1969. The possibility of smaller scale rockfall events sourced from the same cliff face could justify the presence of trees germinated outside of our sample population's general distribution.

While the earliest sample in our population germinated in 1936, only sparse, intermittent germination occurred from 1936-1945, after which germination became more consistent (2+ germinants/yr) until 1951 (figure 5). Forest fires in the area could explain this germination pattern. In 1942, the "Buffalo" fire burned over 5,000 acres surrounding Wishbone Hill, and the "Eska" fire burned over 13,000 acres to the east of Wishbone Hill (FRAMES, 2019). If the years leading up to these fires were dominated by warm and dry conditions (no climate data is available before 1952), then seed viability could have been hindered, explaining inconsistent germination from 1936-1945 (figures 5 and 6). Similarly, dry conditions might have prompted some seeds to lie dormant, preventing germination in the period leading up to the fires, as birch seeds can remain dormant for more than a year in dry conditions (Safford et al., 1991).

Paper birch is a pioneer species, one of the first species to populate a burned area post-disturbance (i.e., fire) (Safford et al., 1990). Post-fire conditions can positively affect tree germination, and seedling germination is typically the greatest two to five years post-fire (Uchytil, 1991). In our sample population, the "Buffalo" and "Eska" fires could explain the increased number and consistency of germinants beginning in 1945, three years post-fire (figure 6). After 1949, germination tapers off again, perhaps as the post-fire effect on germination ends (figure 5).

Birch trees are typically resilient to the effects of coal mining and are often used to revegetate mined areas (Safford et al., 1990); therefore, mining probably did not have a direct negative impact on tree growth. Mines in the area, however, could indirectly affect tree growth. The Eska Mine operated from 1917 to 1946 (Barnes and Payne, 1956), less than 2 kilometers northeast of the sampling site (figure 7). The Evan Jones Mine operated from 1920 to 1968 (Barnes and Payne, 1956; ANDR, 2009), less than 0.5 km from the sampling site (figure 7). According to the Office of Surface Mining and Reclamation Development (2016), coal spoils have ignited forest fires at the site of the Evan Jones Mine in the past, and it's possible that the "Eska" and "Buffalo" forest fires ignited this way.

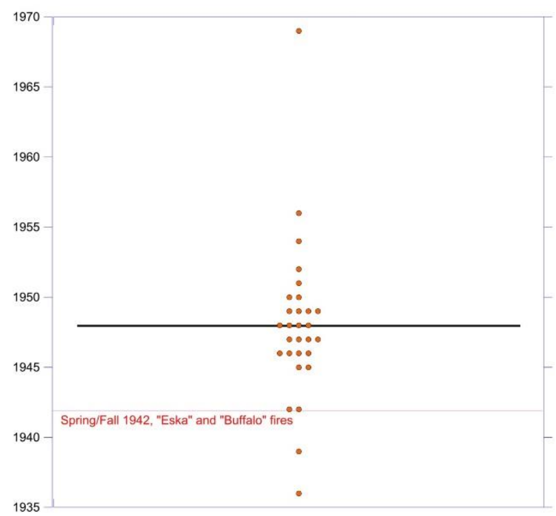

Figure 6. Dot plot showing tree germination over time within the sample population, noting major events in the area such as "Eska" and "Buffalo" wildfires. Black line represents median.

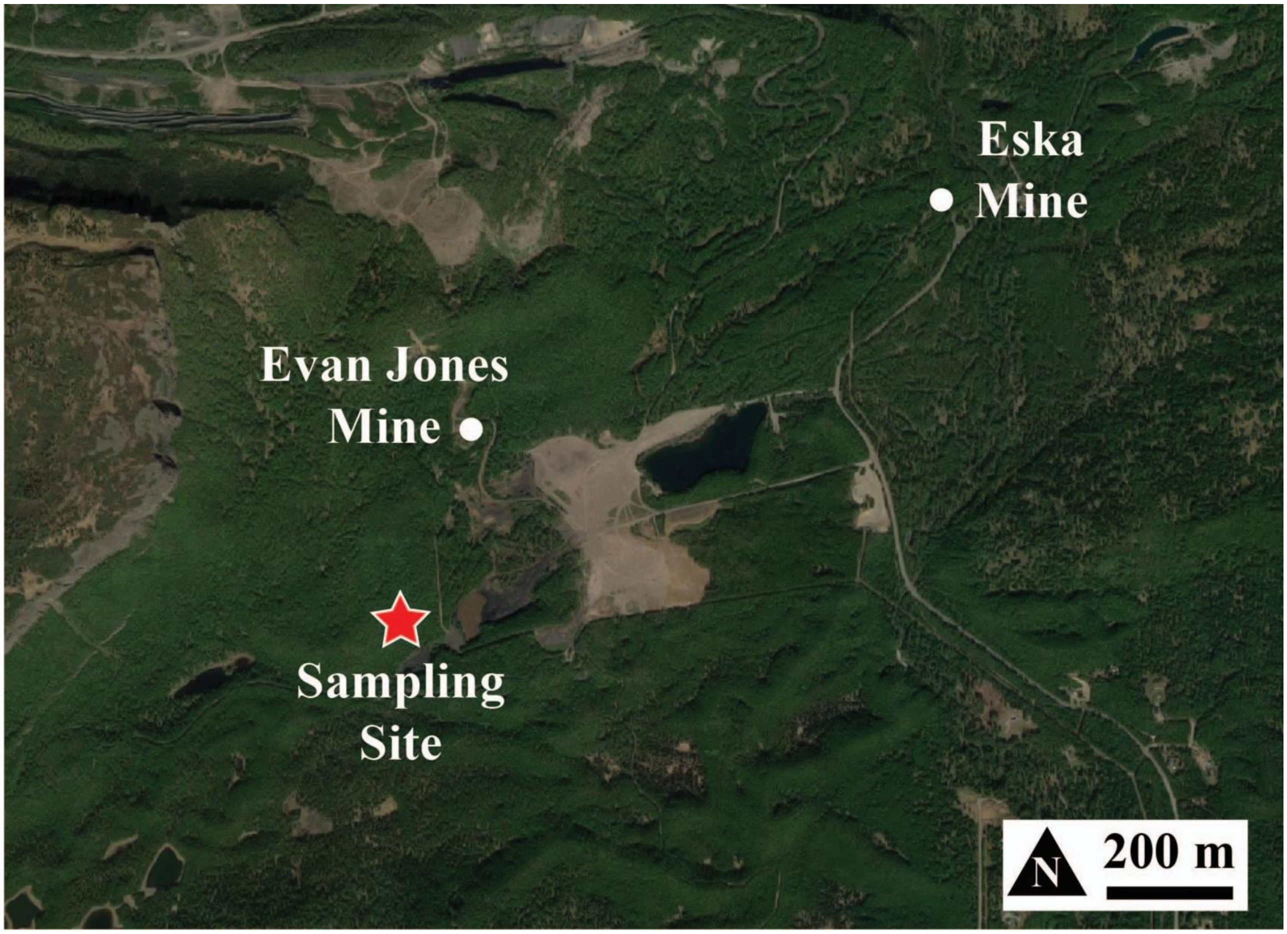

Figure 7. The sampling site and the approximate locations of the Evan Jones and Eska mines.

Climate

To better understand the climate controls on the growth of paper birch in southcentral Alaska, we used our detrended master chronology weather data from the station at Ted Stevens International Airport in Anchorage, accessed via CLIMOD 2 (NRCC, 2020), and Seascorr, a program that allows the identification of the annual climate control on growth using weather data and tree-ring widths (Meko et al., 2011). After correlating monthly climate data from 1952 to 2017 (mean temperature, maximum temperature, minimum temperature, and precipitation) with our master chronology in Seascorr, we found that a warmer prior summer (i.e., June, July, August) is the primary climate driver, negatively impacting ring widths (r=-0.433) the following year.

Though these birch trees grow atop boulders, presumably particularly sensitive to environmental change, these data support our general understanding of birch tree growth. As discussed by Safford et al. (1990), paper birches are sensitive to extreme temperatures and remain less affected by fluctuations in precipitation, thriving in cooler environments.

CONCLUSION

Boulders deposited at the base of a steep slope indicate a rockfall event occurred at Wishbone Hill. Tree-ring dating of Alaska paper birch trees growing atop these boulders, along with historical observation of the area of study, dates the event as occurring between 1931 and 1935. Forest fires, potentially initiated by mining, could have impacted tree germination over time, but there is no direct evidence to support this. While past literature suggests birch ecesis in rockfall areas is five years, dating the rockfall at 1931 based on our oldest sample, historical accounts of the site recognize unvegetated boulders present as late as 1935. This finding suggests Alaska paper birch ecesis could be as short as one-year when growing atop conglomeratic material in southcentral Alaska. This new, shorter ecesis interval for birches growing in rockfall zones, 80% less than previously reported, is an important finding of our work.

In considering the area for future residential development, planners should understand that, as demonstrated in Borella et al. (2019), de-forestation/removal of vegetation in areas prone to rockfall events can lead to broader dispersal of boulders, creating the potential for catastrophic impacts of subsequent rockfalls. Evidence of rockfall during a time when the area was populated and mining was actively occurring implies dangerous conditions for living and working. Mining also presents a possible link to forest fires in the area. Understanding the potential impacts of mining and development should inform those wishing to utilize the area for recreational, commercial (e.g., mining), or residential purposes of the risk and the potential for damage should future destabilization occur.

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