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Research paper

Using correlated tephras to refine radiocarbon-based age models, upper and lower Whitshed Lakes, south-central Alaska

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ABSTRACT

Tephra deposits correlated between nearby lakes provide the opportunity to improve age estimates of the sediment sequences, even if the ages of the tephras are previously unknown. We explore this potential using cryptotephras and visible tephra deposits in sediment cores from Upper and Lower Whitshed Lakes near Cordova, Alaska. Each tephra was described in terms of visual stratigraphy and shard morphology, and the major-oxide glass geochemistry was analyzed. Independent age models were developed for the cores using radiocarbon ages and profiles of short-lived radioisotopes for the near-surface sediments. Four tephras were correlated between the two lakes based on the magnitude and spacing of magnetic susceptibility peaks and glass major-oxide geochemistry. These correlations confirm agreement of the age models because the independently modeled confidence intervals overlap for each correlated tephra. The stratigraphic correlations were subsequently used to improve the age models by extracting the subset of possible age-model iterations that produce similar ages for each of the four correlated tephras at the two lakes. The iterations that agree within 25 years for each correlated tephra were used to create tephra-matched age models for both lakes, which narrowed the width of the 95% confidence intervals of the age models by 3% overall and reduced the uncertainty in age estimates of the correlated tephras by 34% on average. This synchronization technique may be useful in other studies that have multiple independently dated records with confident stratigraphic correlations.

1. Introduction

Radiocarbon-based age models are the most common method used to date sediment cores that are less than 50,000 years old. The accuracy of these age models depends on the extent to which the constraining ages reliably represent the true timing of sedimentation. The precision of the analyses (the laboratory-reported counting error) accounts for only a small part of the overall uncertainty. More important is the extent to which the material dated actually represents the age of the down core property of interest (Howarth et al., 2013), which is difficult to evaluate without independent evidence. One indicator of the robustness of radiocarbon-based age models is whether the modeled ages of simultaneous events overlap among different cores. Previous studies have used tephra deposits as a test of age-model reliability by correlating tephras in nearby lakes and comparing their modeled ages (e.g., Krawiec et al., 2013). Even if the age of a tephra is unknown, the marker bed still provides a valuable time-line (Lowe, 2011). Dating a tephra deposit in multiple locations also improves the confidence in the age estimate of that deposit, which can then be used as a chronostratigraphic marker in future studies (Lowe, 2011; Kaufman et al., 2012).

In studies of multiple sedimentary sequences within a region, it is often desirable to synchronize the records or combine the geochronological information of multiple records. Most commonly, this is achieved through 'wiggle-matching', whereby downcore properties are aligned visually (e.g., Hoek and Bohncke, 2001; Burns et al., 2003) or quantitatively (e.g., Marwan et al., 2002; Fohlmeister, 2012). In this study, we present a novel approach that uses tephra deposits correlated between two lakes to not only check the agreement of the age models, but also to further constrain the age-depth relationship. We produced independent age models for the sedimentary sequences of Upper and Lower Whitshed Lakes located near Cordova, Alaska, using radiocarbon and short-lived isotopes. Four tephra deposits were correlated between the two lakes based on their relative stratigraphic position, magnetic

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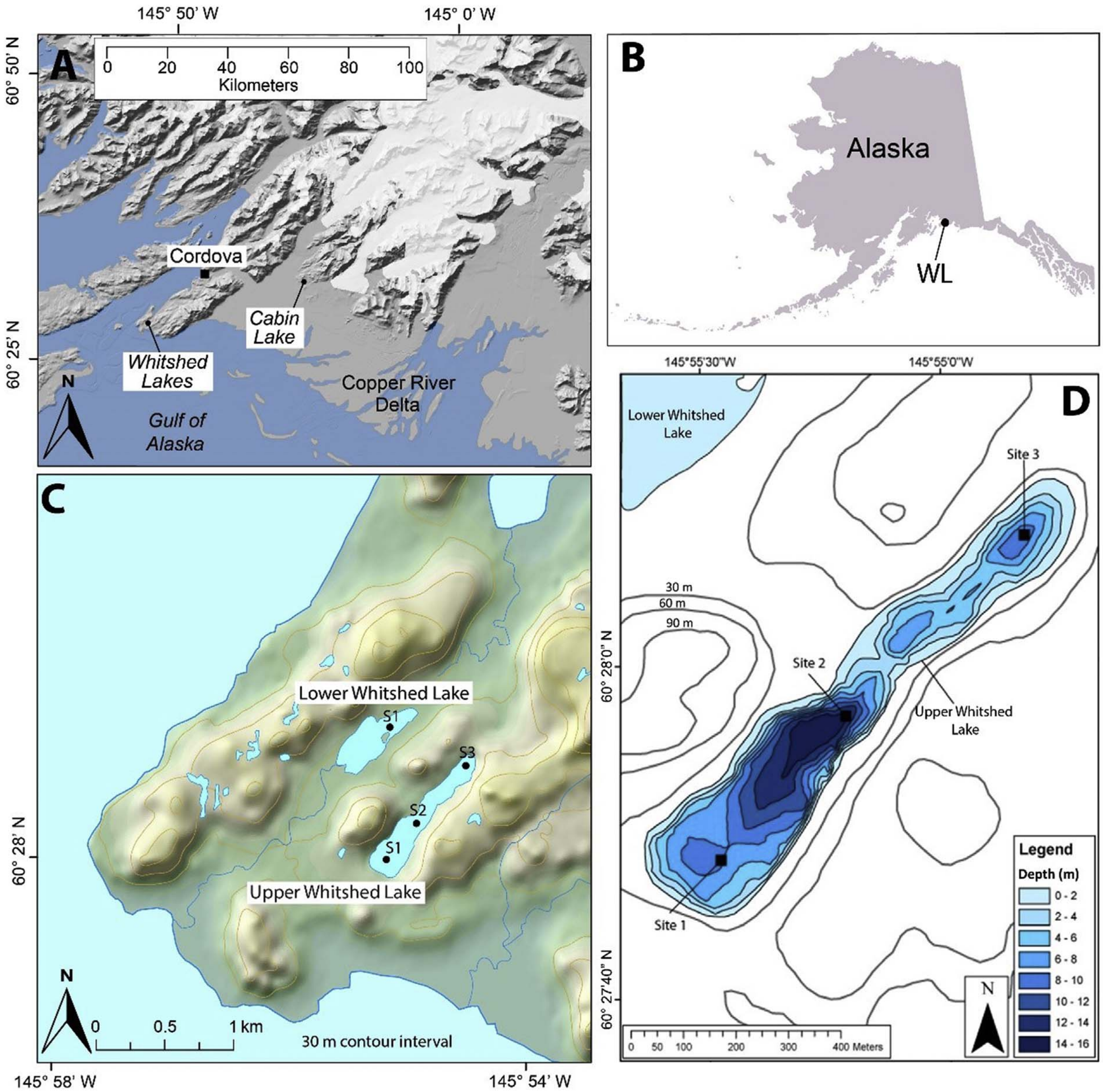

Fig. 1. Location maps. (A) Copper River Delta region, showing Whitshed Lakes and other sites mentioned in text. (B) Alaska state map for reference, WL = Whitshed Lakes. (C) Whitshed Peninsula showing the two lakes with location of core sites. Topographic base from U.S. Geological Survey. (D) Bathymetry of Upper Whitshed Lake with core sites shown. Site 2 (S2) is the focus of this study from Upper Whitshed Lake.

susceptibility (MS) profiles, glass geochemistry, and physical characteristics. The correlated tephras were subsequently used to select the age model runs with the closest agreement in predicting the ages of the correlated tephras. This approach allowed for a single best age estimate for each tephra to be calculated using age information from both lakes, and reduced the uncertainty range of the age-model for both sites. In addition to presenting a new approach to age modeling, we report descriptions and geochemical data from 11 tephra samples, thereby contributing to the tephrostratigraphy for the Copper River Delta region.

1.1. Study area

Upper Whitshed (60.466° N, 145.918° W) and Lower Whitshed (60.473° N, 145.923° W) Lakes are located in the foothills of the Heney Range about 12 km southwest of Cordova, Alaska, at elevations of about 30 and 3 m asl, respectively (Fig. 1). The lakes are both approximately 1 km inland from Prince William Sound on the Gulf of Alaska near Point Whitshed, from which we derive their informal names. Upper Whitshed Lake is slightly larger (1.1 × 0.2 km) than Lower Whitshed Lake (0.7 × 0.3 km). The bathymetry of Upper Whitshed Lake includes several sub-basins divided by ridges, and a maximum depth of about 15 m (Fig. 1). No bathymetric data were obtained from Lower Whitshed Lake.

The lakes are located near the active Alaska-Aleutian megathrust where changes in land elevation occur on multiple time scales (Garrett et al., 2015), including approximately 1.9 m of uplift during the great Alaska earthquake of 1964 AD (Plafker, 1969). Lower Whitshed Lake received marine sediments during the Little Ice Age, and became isolated as a lacustrine basin during the 1964 event (Garrett et al., 2015). The nearest likely source volcanoes for tephras deposited in these lakes are the Aleutian Arc/Alaska Peninsula (AAAP located more than 350 km to the west and southwest) and the Wrangell Volcanic field (located more than 200 km to the northeast). Modern prevailing winds are from the southwest, making deposits from the Wrangell Volcanic field less likely. Glass compositions often distinguish AAAP (Type 1)