DATING THE QUATERNARY OLD CROW TEPHRA VIA ZIRCON U-Th-He GEOCHRONOMETERS

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Background and motivation

Eruption of the Old Crow tephra deposited ~200 km^3 of volcanic ash throughout Alaska and the northwestern Yukon (eastern Beringia), providing an isochronous marker across the region on a scale unique in the Pleistocene. The Old Crow tephra represents a temporal piercing point used to link geographically disparate stratigraphic sections and the paleo-environmental records they contain. Although the canonical age of the Old Crow, determined by the fission-track technique on volcanic glass, suggests eruption during the transition between the glacial and interglacial periods of Marine Isotope Stages (MIS) 5 and 6 at ~125 ka (e.g., Preece et al., 2011), zircon U–Th–Pb and (U–Th)/He dating of the tephra suggests eruption at ~200 ka, within MIS 7 (see Burgess et. al., 2019).

If accurate, this revised eruption age begets significant change to existing models describing the geologic and biotic evolution of Beringia in the Pleistocene. The source-distal loess section near Fairbanks, AK (Fig. 1) from which the Burgess et al. (2019) sample was taken yielded concordant dates from three independent radiometric chronometers but contained a population of detrital zircon from syn- and/or post-depositional admixing. Because an accurate age of the Old Crow tephra is critical to its time-stratigraphic utility, the author group sought to date Old Crow zircon from a more source-proximal locality, where zircon could be isolated from primary Old Crow pyroclasts, ensuring dated crystals are endemic to the tephra.

The source-proximal (<500 km from plausible source) Old Crow sample from near Togiak Bay (Fig. 1) yielded primary pyroclasts from which glass-mantled zircon were isolated. Surfaces of these crystals were dated with the U-Pb and U-Th methods on the Stanford/USGS SHRIMP-RG. This technique is demonstrated to yield as close to independently constrained eruption age as is possible with a mineral (zircon in this case) that crystallizes pre-eruption (Figs. 2, 3). The young population of single-grain dates from this dataset corroborate the eruption age of Burgess et al. (2019), and confirm Old Crow eruption within late MIS 7 at 207 ± 13 ka (Figs. 5, 6, 7). These results indicate that previous estimates of Old Crow eruption timing are young by ~ 80 ka.

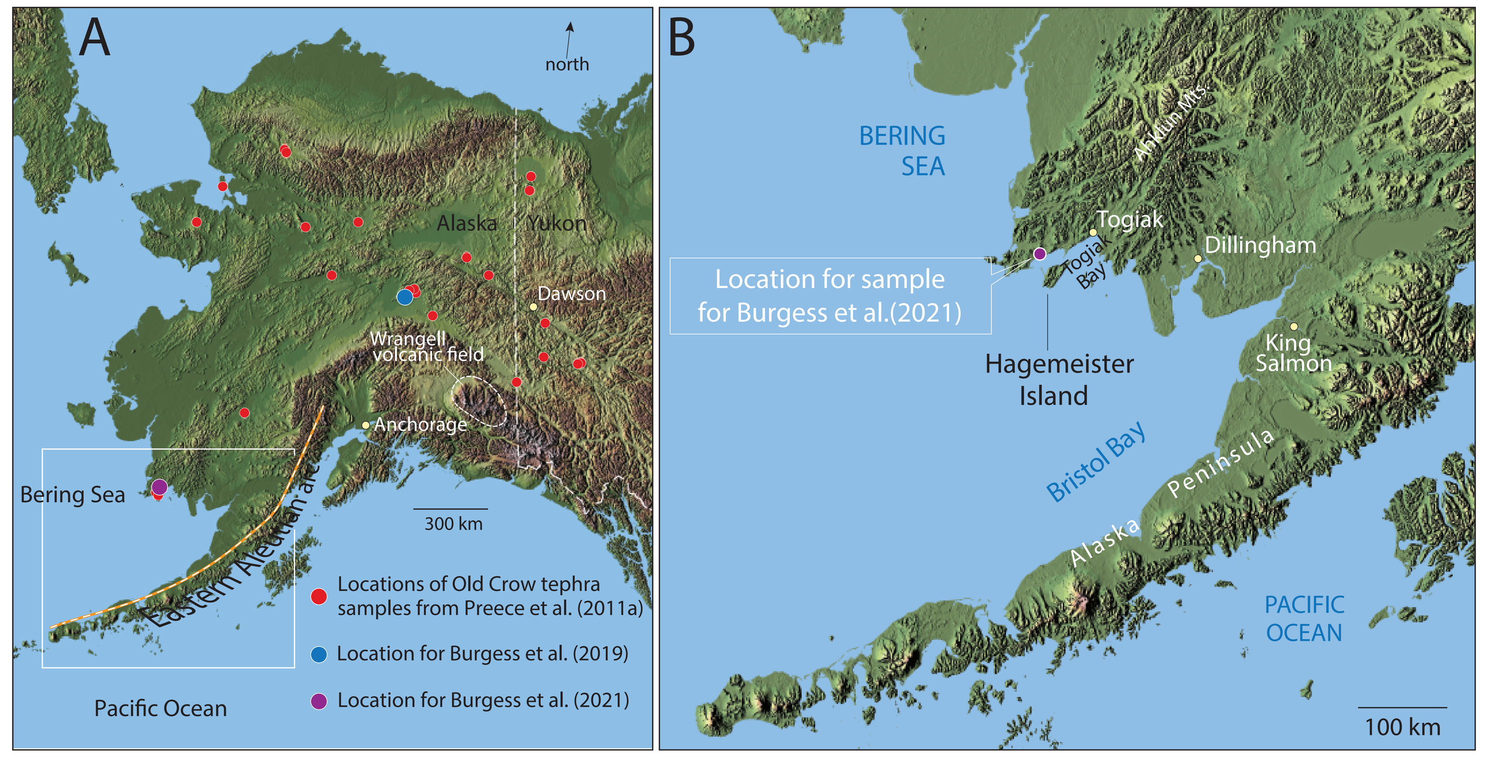


Figure 1. General map of the areal extent of the Old Crow tephra showing the location of sample collection from Burgess et al. (2019; 2021). Red dots in panel A show known outcrops, blue and purple dots in panels A and B show sample locations discussed in this poster.

SHRIMP-RG U-Th-Pb zircon surface analysis

Technique

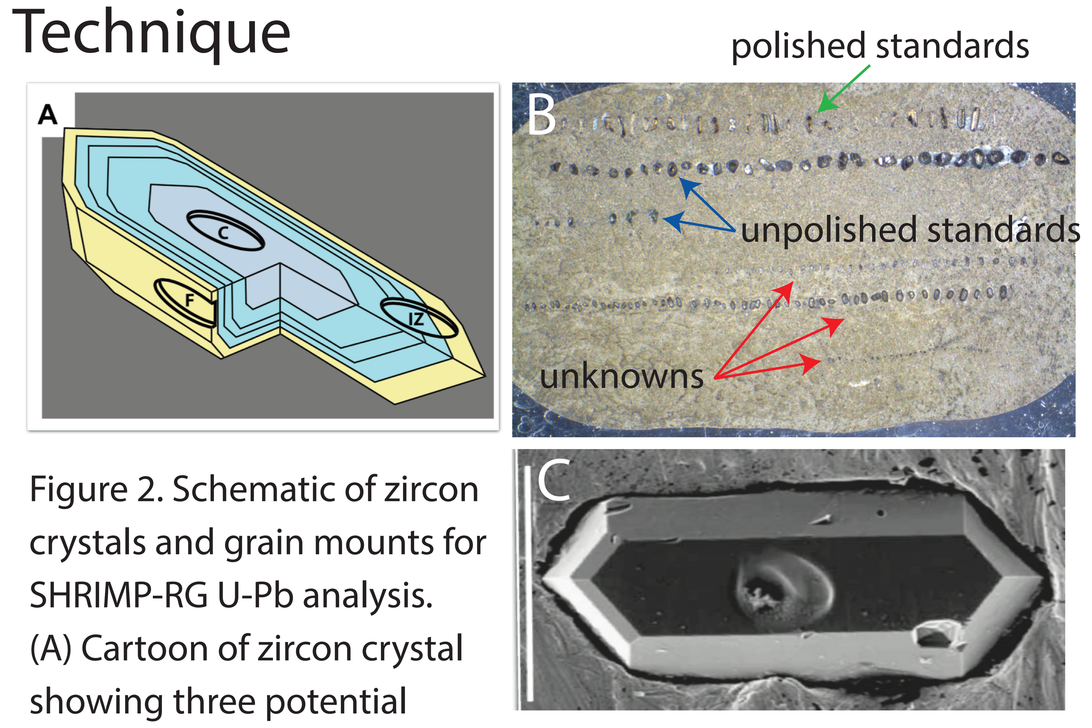
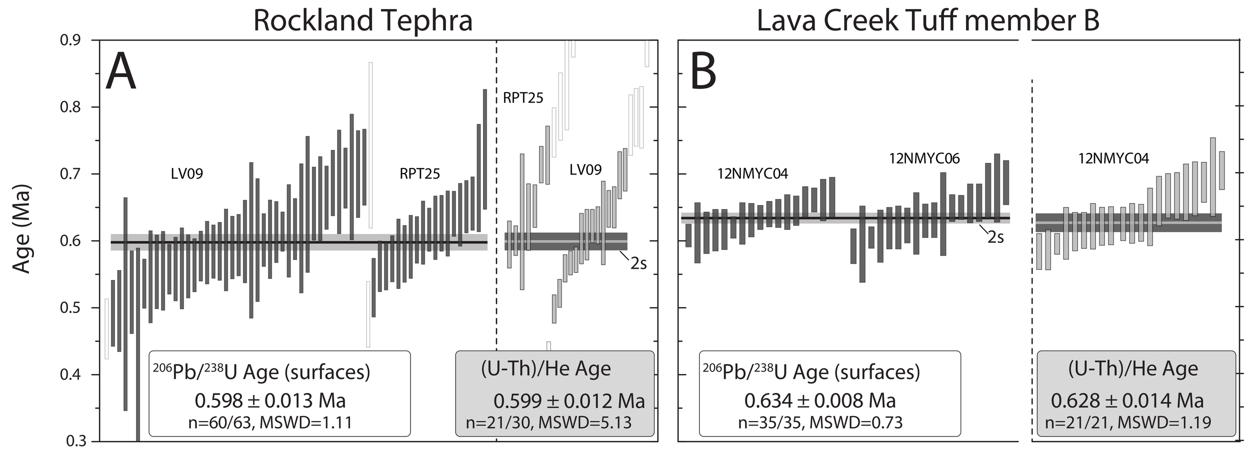


Figure 2. Schematic of zircon crystals and grain mounts for SHRIMP-RG U-Pb analysis. (A) Cartoon of zircon crystal showing three potential SHRIMP-RG sampling sites. Site C and IZ are conventional crystal "core" and "tip" locations, both of which sample at least some (if not all) crystal interior, which may be resolvably older than the grain surface sampled in F. (B) Photo of typical indium mount showing un/polished standards and pressed-in unknowns. Field of view is < 1 inch. (C) BSE image of indium-mounted zircon crystal following surface analysis.

Surface dating yields eruption timing



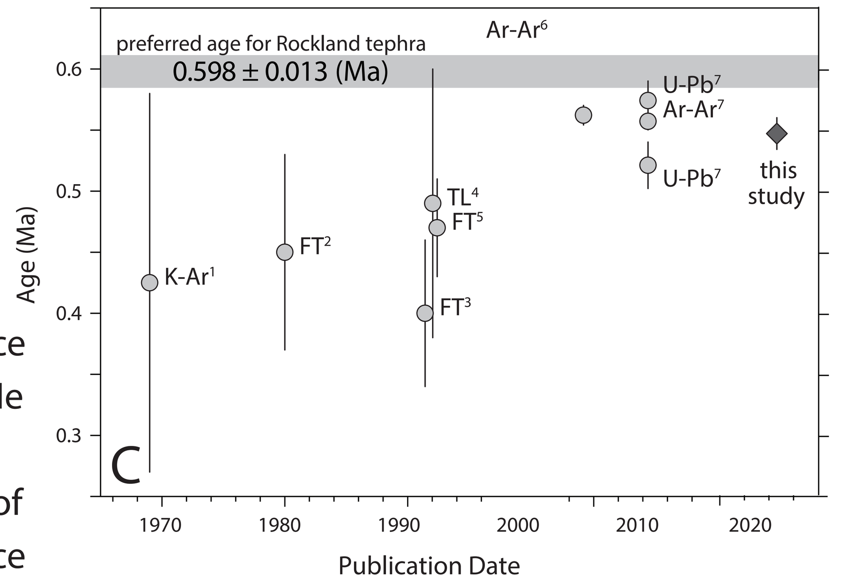


Figure 3. Comparison of SHRIMP-RG U-Pb zircon surface dates with other estimates of eruption age. (A) Comparison of SHRIMP-RG zircon surface date and zircon (U-Th)/He date for the Rockland tephra. (B) Comparison of SHRIMP-RG zircon surface date and zircon (U-Th)/He date for the Lava Creek tephra. (C) Illustration of eruption ages for the Rockland tephra in the literature over time showing accord between recent Ar/Ar and U-Pb surface dates. All panels from Coble et al. (2017).

Outcrop and zircon images

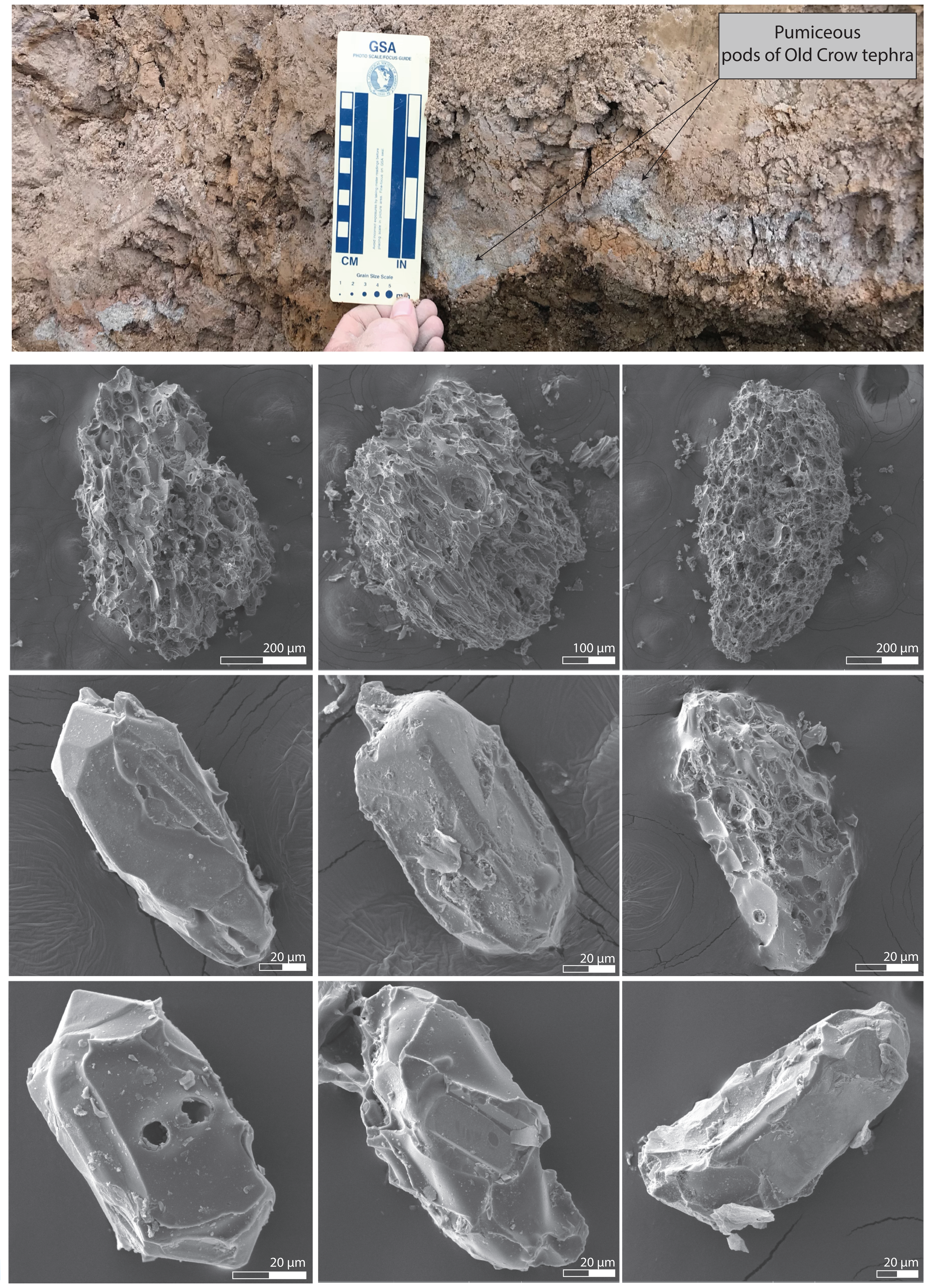


Figure 4. Photo of Burgess et al. (2021) Old Crow sample site and SEM images of zircons from this site. Outcrop photo shows concentrations of pumice-rich Old Crow tephra from which zircon shown in SEM images were exclusively isolated. SEM images below outcrop photo show pumice clasts (upper row) and zircons from these clasts (lower two rows) recovered from Togiak Bay site. Pyroclasts were isolated from bulk sample and crushed. Zircon recovered from this material was mantled in volcanic glass, which can be seen in the bottom two rows of SEM images. Presence of adhering glass indicates that grains are native to the Old Crow source rather than exotic material admixed into the sample post-deposition. Before analysis on the SHRIMP-RG, zircon were bathed in concentrated HF to remove this glass.

References

1. Lisiecki, L.E., Raymo, M.E., 2005. A Pliocene-Pleistocene stack of 57 globally distributed benthic δ18O records. Paleoceanography and Paleoclimatology 20.
2. Preece, S.J., Pearce, N.J.G., Westgate, J.A., Froese, D.G., Jensen, B.J.L., Perkins, W.T., 2011a. Old Crow tephra across eastern Beringia: a single cataclysmic eruption at the close of Marine Isotope Stage 6. Quat. Sci. Rev. 30, 2069–2090.
3. Burgess, S.D., Coble, M.A., Vazquez, J.A., Coombs, M.L., Wallace, K.L., 2019. On the eruption age and provenance of the Old Crow tephra. Quat. Sci. Rev. 207, 64–79.
4. Channell, J.E.T., Singer, B.S., Jicha, B.R., 2020. Timing of quaternary geomagnetic reversals and excursions in volcanic and sedimentary archives. Quat. Sci. Rev. 228, 106–114.
5. Burgess, S.D., Vazquez, J.A., Waythomas, C.F., Wallace, K.L., 2021. U-Pb zircon eruption age of the Old Crow tephra and review ofextant age constraints . Quat. Geochron. 66.

Results:

2019 Fairbanks sample

Weighted mean zircon dates:
(U-Th)/He = **207± 34 ka**
U-Th = **205±25 ka**
U-Pb = **202 ±11 ka**

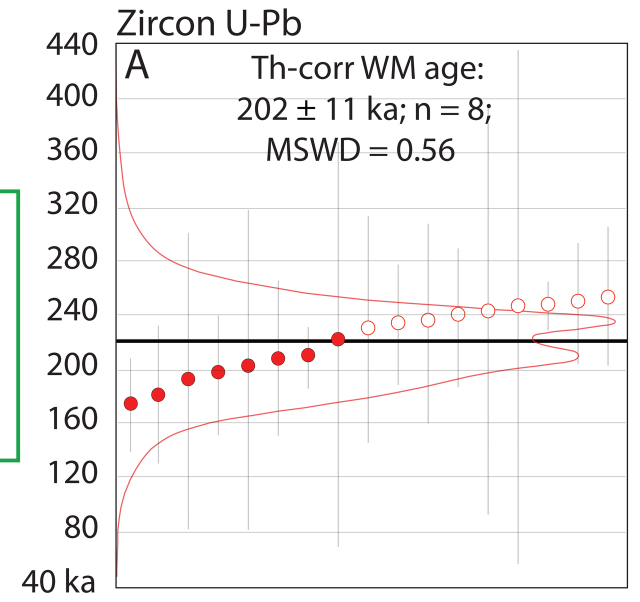


Figure 5. Zircon U-Pb surface dates and Th-corrected weighted mean age from Burgess et al. (2019). Unfilled analysis not included in mean date.

Mean age from Fairbanks sample:
202.9 ± 9.5 ka

2021 Togiak Bay sample

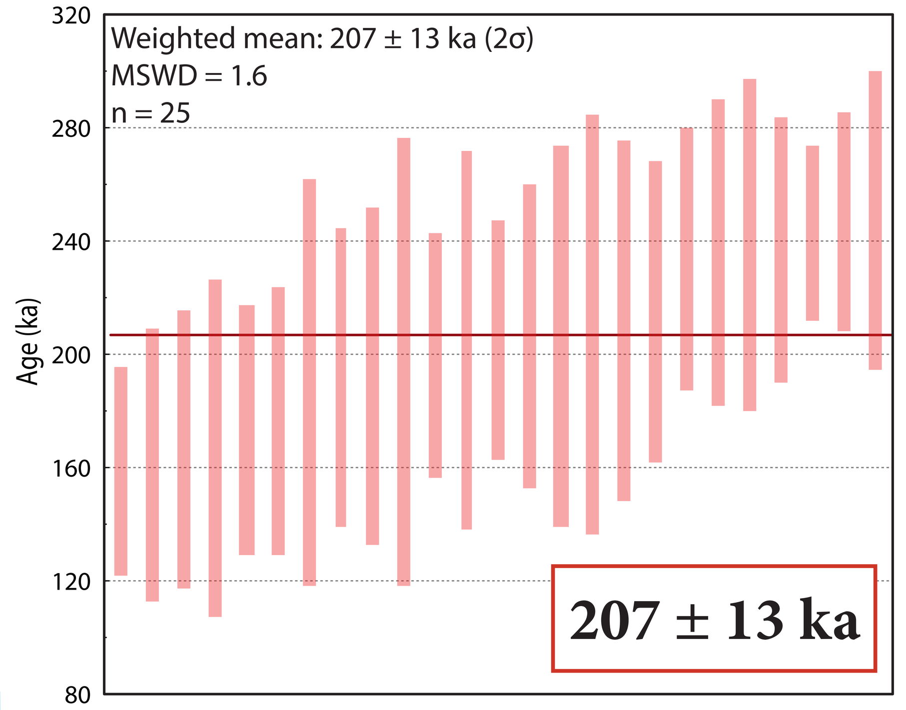


Figure 6. In-situ ion microprobe single-grain U-Pb zircon surface dates corrected for initial Th-disequilibrium. Each box represents a single grain analysis. Box height is proportional to the 2σ uncertainty on that analysis. Weighted mean date in upper left includes all analysis shown on the plot.

Weighted mean U-Pb date from this sample, shown in Figure 4, is concordant with all three dates from Burgess et al. (2019) and their mean date. The U-Pb date from this sample is also identical (within uncertainty) with a SHRIMP-RG U-Th zircon date measured on the same crystals. This data is not shown here but can be found in the supplement to Burgess et al. (2021).

MIS 7 eruption

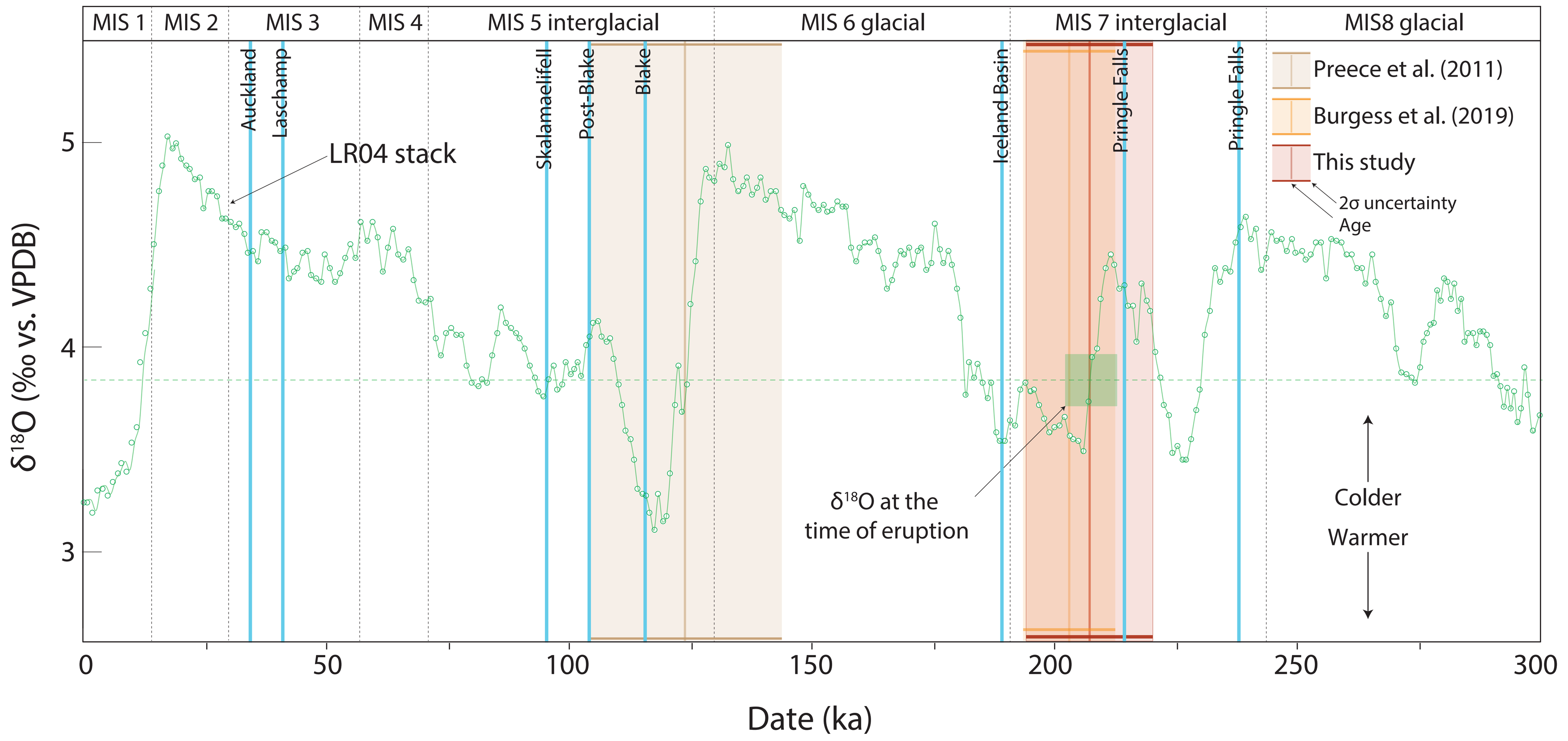


Figure 7. Old Crow eruption ages and geomagnetic excursions superimposed on record of benthic δ^{18}O, and Marine Isotope Stages (Lisceki and Ramo, 2005). Old Crow eruption ages shown as vertical lines with 2σ uncertainty. Ages from Preece et al. (2011), Burgess et al. (2019, 2021). Timing of geomagnetic excursions from Channell et al. (2020). The two excursions labeled Pringle Falls reflect multiple excursions recorded in the 240–210 ka age range that are not yet each named specifically. See Channell et al. (2020) for full explanation.

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