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Assessing climatic and nonclimatic forcing of Pinedale glaciation and deglaciation in the western United States

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ABSTRACT

New ^{10}Be surface exposure ages from adjacent valleys in the upper Arkansas River basin, Colorado (United States), indicate that Pinedale maxima culminated asynchronously at 22.4 ± 1.4, 19.2 ± 0.2, 17.8 ± 0.6, and 15.8 ± 0.4 ka, but that deglaciation initiated synchronously between ca. 16 and 15 ka. These data are combined with published glacial chronologies across the western United States, and indicate that although the ages of Pinedale terminal moraines vary within individual ranges as well as regionally, most western United States glaciers remained near their Pinedale termini until ca. 16 ka, at which time widespread deglaciation commenced. We hypothesize that the near-synchronous demise of glaciers across the western U.S. between ca. 15 and ca. 13 ka was driven by the first major Northern Hemisphere warming following the Last Glacial Maximum, but that some differences in Pinedale culmination ages can be explained by nonclimatic factors intrinsic to individual valleys. These results suggest the need for caution in focusing exclusively on climate forcings to explain apparent asynchrony in Pinedale maxima.

INTRODUCION

Past glacial cycles are recorded in mountain landscapes by moraines that define former glacier maxima. Moraines are thus important targets for dating because accurate and precise moraine chronologies are needed to elucidate spatial and temporal patterns of former glaciation. The recent development of cosmogenic nuclide exposure dating and its application to moraines has led to a substantial increase in the number of moraines dated worldwide (e.g., Gosse and Phillips, 2001; Bierman, 2007). These new moraine chronologies often reveal significant age differences among moraines deposited during a single glacial cycle, differences that commonly are used to infer spatiotemporal patterns of regional climate (e.g., Briner and Kaufman, 2008; Thackray, 2008).

Within the western United States, ages of Pinedale (and Pinedale equivalent; Marine Isotope Stage, MIS 2) terminal moraines of ca. 18 to ca. 16 ka in the northern Rocky Mountains are ~5 k.y. younger than Pinedale terminal moraines in the Wind River Range and at some locations in Colorado (Gosse et al., 1995; Licciardi et al., 2004; Thackray et al., 2004; Benson et al., 2005). This discrepancy has led to the hypothesis that westerly atmospheric flow was altered by the North American ice sheets, affecting the spatial and temporal pattern of moisture delivery to western U.S. glaciers (e.g., Licciardi et al., 2004; Thackray et al., 2004; Thackray, 2008). Another conceptual model invokes moisture provided by Great Basin paleolakes as the driver of asynchronous mountain glaciation in downwind mountain ranges (Laabs et al., 2009). Although some acknowledge that factors intrinsic to the individual glacier systems (e.g., hypsometry, response time) can explain different moraine ages (Licciardi and Pierce, 2008; Ward et al., 2009), most conclusions focus on climatic factors.

To test whether nonclimatic factors can influence Pinedale terminal moraine ages, we obtained cosmogenic ^{10}Be exposure ages from glacial landforms in Clear Creek, Pine Creek, and Lake Creek valleys in the upper Arkansas River basin, Colorado (Fig. 1; Fig. DR1 in the GSA Data Repository[1]). Based on these new

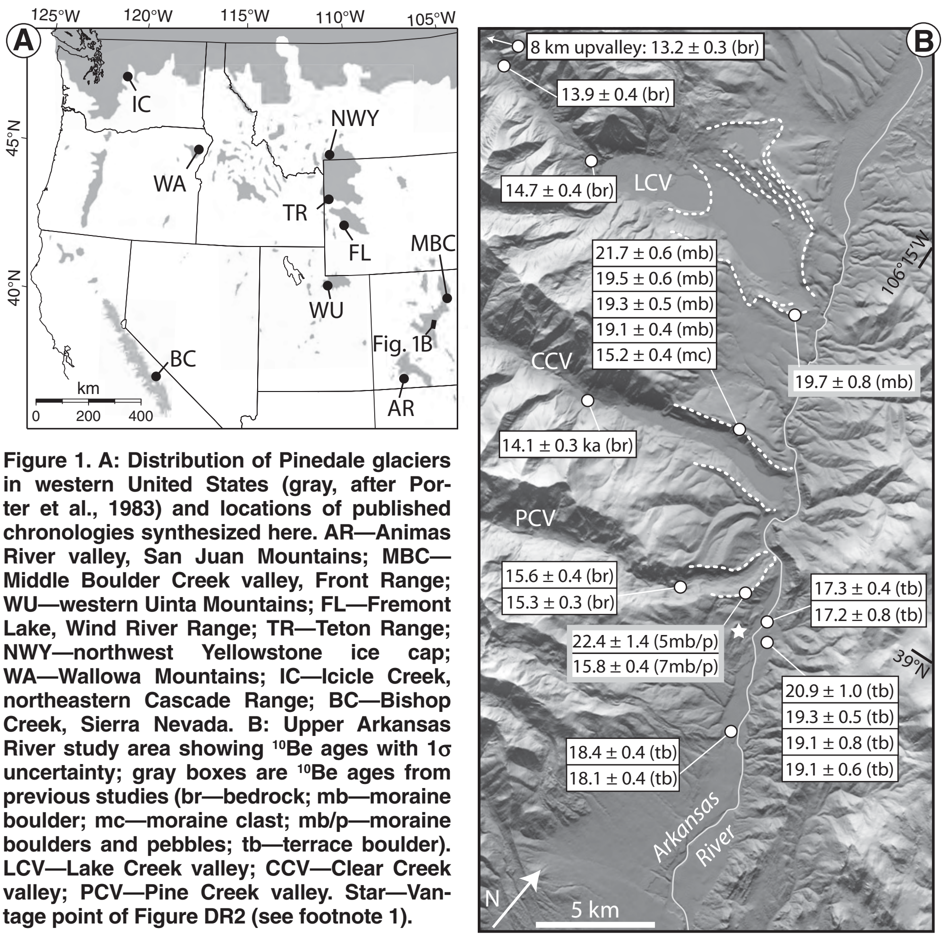

Figure 1. A: Distribution of Pinedale glaciers in western United States (gray, after Porter et al., 1983) and locations of published chronologies synthesized here. AR—Animas River valley, San Juan Mountains; MBC—Middle Boulder Creek valley, Front Range; WU—western Uinta Mountains; FL—Fremont Lake, Wind River Range; TR—Teton Range; NWY—northwest Yellowstone ice cap; WA—Wallowa Mountains; IC—Icicle Creek, northeastern Cascade Range; BC—Bishop Creek, Sierra Nevada. B: Upper Arkansas River study area showing ^{10}Be ages with 1σ uncertainty; gray boxes are ^{10}Be ages from previous studies (br—bedrock; mb—moraine boulder; mc—moraine clast; mb/p—moraine boulders and pebbles; tb—terrace boulder). LCV—Lake Creek valley; CCV—Clear Creek valley; PCV—Pine Creek valley. Star—Vantage point of Figure DR2 (see footnote 1).

[1]GSA Data Repository item 2011072, materials and methods, Figures DR1–DR4, and Tables DR1–DR3, is available online at www.geosociety.org/pubs/ft2011.htm, or on request from editing@geosociety.org or Documents Secretary, GSA, P.O. Box 9140, Boulder, CO 80301, USA.

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ages and a compilation that includes other moraine chronologies throughout the western U.S., we suggest that differences in exposure ages of Pinedale terminal moraines are not solely related to regional climatic controls, but rather may also be due to internal factors such as glacier hypsometry. Furthermore, our compilation of Pinedale recessional moraine ages indicates that deglaciation began ca. 16 ka, and that the most significant change of western U.S. glaciers since the Last Glacial Maximum is their near-synchronous demise between ca. 15 and ca. 13 ka.

UPPER ARKANSAS RIVER VALLEY

The Clear Creek, Pine Creek, and Lake Creek valleys are all east facing, and at their Pinedale maximum extent glaciers emanating from Clear Creek and Pine Creek valleys dammed the Arkansas River (Scott, 1984; Nelson and Shroba, 1998; Lee, 2010). Clear Creek and Pine Creek valleys each host a pair of sharp, single-crested lateral moraines that are >150 m high. These moraines are easily distinguishable from more extensive Bull Lake (MIS 6) moraines that are characterized by a more subdued surface topography and higher degrees of weathering on boulder surfaces (Nelson and Shroba, 1998). Unlike Clear Creek and Pine Creek valleys, where single Pinedale moraines are preserved, the Lake Creek valley contains numerous Pinedale end moraines (Fig. 2; Nelson and Shroba, 1984). Glacier retreat from the terminal moraines in the Clear Creek and Pine Creek valleys likely led to a series of outburst floods that deposited two boulder-rich terraces downstream of Pine Creek, ~15 and 6 m above the modern-day Arkansas River (Scott, 1984; Lee, 2010; Fig. DR2). The geomorphic relationship between Pinedale terminal moraines and flood terraces indicates that moraine abandonment and terrace deposition were synchronous. Our data set includes 19 new ^{10}Be ages from (1) moraine boulders (n = 5), (2) boulders from the two aforementioned flood terraces related to the dated moraines (n = 8), and (3) glacially sculpted bedrock upvalley from Pinedale end moraines (n = 6); we combine these new ^{10}Be ages with 12 previously published moraine clast ^{10}Be ages from the same area (Briner, 2009; Fig. DR1).

The ^{10}Be ages of boulders from the outer Clear Creek lateral moraine range from 21.7 ± 0.6 to 15.2 ± 0.4 ka (n = 5; Tables DR1 and DR2); three of these ages are between 19.5 and 19.1 ka (mean = 19.3 ± 0.2 ka). A sample collected from glacially sculpted bedrock ~9 km upvalley from the terminal moraine is 14.1 ± 0.3 ka. Samples (n = 12) previously collected from the outermost, single-crested right-lateral moraine in the Pine Creek valley range from 24.5 ± 0.7 ka to 13.5 ± 0.4 ka (Briner, 2009). However, these ^{10}Be ages are distributed in two distinct modes that average 22.4 ± 1.4 ka (n = 5) and 15.8 ± 0.4 ka (n = 6; Table DR1), after excluding one younger outlier (13.5 ± 0.4). We suspect that this younger outlier is likely the result of boulder exhumation. Ages of two adjacent samples from glacially sculpted bedrock located ~4 km upvalley from the Pine Creek terminal moraine are 15.6 ± 0.4 ka and 15.3 ± 0.3 ka. The only age control for Pinedale moraines in the Lake Creek valley comes from a single ^{10}Be age of 19.7 ± 0.5 ka on a terminal moraine boulder (Schildgen, 2000). We obtained ^{10}Be ages of 14.7 ± 0.4 ka, 13.9 ± 0.4 ka, and 13.2 ± 0.4 ka from glacially sculpted bedrock at ~10, ~16, and ~25 km upvalley, respectively, of the terminal moraine in Lake Creek valley. Of ^{10}Be ages from boulders on the higher of the two flood terraces, four range between 20.9 ± 1.0 ka and 19.1 ± 0.6 ka; three of these samples cluster at 19.2 ± 0.1 ka. Moreover, four ^{10}Be ages from boulders on the lower terrace range from 18.4 ± 0.4 ka to 17.2 ± 0.8 ka (mean age of 17.8 ± 0.6 ka; Fig. 2).

The ^{10}Be age distribution of the Clear Creek moraine is complex and warrants further discussion. While the oldest ^{10}Be age (21.7 ± 0.6 ka) overlaps the ca. 19.3 ka cluster at 2σ, we suggest that the ca. 19.3 ka mode is most representative of the timing of moraine abandonment because (1) three of four ^{10}Be ages on the upper flood terrace are between 19.3 and 19.1 ka (mean = 19.2 ± 0.1 ka; Fig. 2), and (2) the mouth of Clear Creek valley was likely the main damming point of the Arkansas River (Lee, 2010). These data confirm that moraine abandonment in Clear Creek and deposition of the upper flood terrace were contemporaneous. In addition, two ^{10}Be ages excluded from the Clear Creek age assignment (21.7 ± 0.6 ka and 15.2 ± 0.4 ka) overlap the older and younger modes found in the Pine Creek ^{10}Be age distribution (Fig. 2). It is possible that these ages represent additional Pinedale advances in Clear Creek valley that culminated synchronously with advances in Pine Creek valley; however, the insufficient number of samples from the Clear Creek moraine prevents us from reaching this conclusion with confidence. The ^{10}Be ages on the lower flood terrace (n = 4) have a mean age of 17.8 ± 0.6 ka.

Not all modes of Pinedale maxima are expressed in each valley. The oldest Pinedale ice limit is apparently preserved in the Pine Creek valley (22.4 ± 1.4 ka) and ^{10}Be ages from Clear Creek valley suggest that ice initially retreated from its Pinedale maximum extent at 19.3 ± 0.2 ka. This age correlates with the age of the upper flood terrace (19.2 ± 0.1 ka), implying that the Clear Creek glacier acted as the main ice dam. ^{10}Be ages also indicate that following the Pinedale maximum extent, culminating ca. 22.4 ka in the Pine Creek valley, ice reoccupied the same moraine until 15.8 ± 0.4 ka (Briner, 2009). This is supported by ages of 15.6 ± 0.4 ka and 15.3 ± 0.3 ka from glacially sculpted bedrock upvalley of the moraine, ages that constrain timing of deglaciation in the lower Pine Creek valley. In the Lake Creek valley, the Pindale terminal moraine is dated as 19.7 ± 0.5 ka based on a single ^{10}Be age (Schildgen, 2000); our bedrock age closest to the Pinedale moraines suggests that the Lake Creek glacier was at least ~65% of its Pinedale maximum length until 14.7 ± 0.4 ka (Fig. 2; Table DR3). It is interesting that the age of the lower terrace (17.8 ± 0.6 ka) is not expressed in the moraine records. Nonetheless, deposition of the lower flood terrace requires that glaciers were at or near their Pinedale maxima in order to dam the Arkansas River (Figs. 1 and 2). Based on the close correlation between Clear Creek moraine abandonment and upper flood terrace ages, we hypothesize that the Clear Creek valley glacier

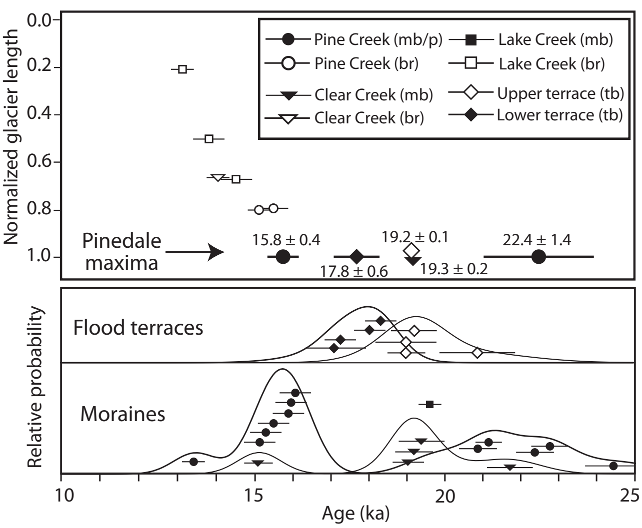

Figure 2. All ^{10}Be ages from upper Arkansas River study area (error bars are 1σ uncertainty); curves show summed probability distribution of all Pine Creek and Clear Creek moraine ages, and of all upper and lower flood terrace ages. Larger symbols at bottom of upper panel are average ages of each terrace and moraine mode, interpreted as four glacier maxima achieved by study glaciers. Positions of ^{10}Be ages from glacially sculpted bedrock from three valleys are normalized with respect to Pinedale or Pinedale-equivalent maximum length of each respective study glacier. Abbreviations as in Figure 1.

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was near its Pinedale maximum ca. 17.8 ka. Following a near Pinedale maximum ca. 17.8 ka, the Clear Creek glacier was at least ~65% of its Pinedale maximum length until 14.1 ± 0.3 ka, based on our bedrock sample located ~9 km upvalley (Fig. 2; Table DR3). Combined, all ^{10}Be ages from the upper Arkansas River valley indicate that Pinedale glacier culminations occurred at 22.4 ± 1.4 (Pine Creek glacier), 19.3 ± 0.2 (Clear and Lake Creek glaciers), 17.8 ± 0.6 ka (Clear Creek glacier), and 15.8 ± 0.4 ka (Pine Creek glacier; Fig. 2).

It is notable that the outermost Pinedale moraines within our neighboring study valleys yield considerably different mean exposure ages. We suggest that these age differences are due to a variety of internal nonclimatic factors unique to each glacier system, as it is difficult to envision substantial differences in climatic forcing across such a small area. Although glacier fluctuations are ultimately driven by climate, the expression of these fluctuations on landscapes is modulated by other factors, including lag time, valley gradient, and glacier hypsometry. In many cases lower-gradient valleys offer better potential to preserve more moraines because small changes in the equilibrium line altitude (ELA) result in larger changes in glacier extent. Thus, a more comprehensive record of glaciation may be found in low-gradient valleys compared to steeper valleys, where only a single moraine might be preserved. In addition, when glaciers of varying character respond to common climate forcing, they may not necessarily deposit moraines at the same time. Consequently, a direct correspondence of moraine ages from valley to valley is not necessarily expected (Gibbons et al., 1984). For example, within the Arkansas River valley the average gradients of Pine Creek, Clear Creek, and Lake Creek valleys are 14.4%, 9.4%, and 7.6%, respectively. Moreover, hypsometric and paleo-ELA data (Fig. DR4) suggest that the Lake Creek paleoglacier, with a large area just above its Pinedale ELA and relatively less area higher in the accumulation zone, would be quite sensitive to small rises in ELA. By contrast, the Pine Creek paleoglacier, with comparatively little area immediately above the paleoELA, might have been less sensitive to initial post-Pinedale ELA rise. This dichotomy may perhaps explain the greater number of Pinedale lateral moraines observed in the Lake Creek drainage, and the persistence of essentially maximum Pinedale ice extent, from ca. 22.5 through 16 ka in the Pine Creek valley. A rigorous test of this hypothesis will require detailed mass balance modeling and is beyond the scope of this paper. In any case, whereas the Pinedale terminal moraine ages differ by as much as ~6 k.y. in the upper Arkansas River basin, indicating an asynchrony of maximum ice stands, ^{10}Be ages from bedrock slightly upvalley of the moraines suggest that significant deglaciation in all valleys most likely initiated relatively synchronously between 16 and 15 ka.

SUPPORT FOR NONCLIMATIC FORCING OF VARIABLE PINEDALE MORAINE AGES IN THE WESTERN U.S.

We compiled available moraine and deglaciation chronologies from elsewhere in the western United States. Only those studies that include age data for both Pinedale moraine sequences and retreat from Pinedale termini are considered, because these records are the most instructive for understanding the timing of both glacial culminations as well as deglaciation. Prior to comparing these chronologies, all ^{10}Be ages were recalculated using the same parameters (Tables DR1 and DR2) and then plotted against the normalized glacier length of each respective glacier system (Fig. 3; Table DR3).

Within the context of available chronologies from across the western United States (U.S.) (Fig. 3), results from the upper Arkansas River basin are not unique. Rather, the variability in outermost Pinedale moraines ages from ca. 22 ka, to ca. 19.3 ka, to ca. 15.8 ka in adjacent valleys is within the range in ages of terminal moraines throughout the western U.S. (ca. 24–15 ka). However, because we expect little variability in climate forcing across the small area of the Arkansas River basin, the asynchrony observed among moraines in this basin suggests that solely invoking climate-related reasoning to explain moraine age variability should be done with caution. In addition, we suggest that nonclimatic factors may be an important source of age differences of Pinedale terminal moraines within and among western U.S. mountain ranges. Although significant age differences between widely spaced Pinedale terminal moraines may plausibly result from spatially variable climate forcing (e.g., Licciardi et al., 2004; Laabs et al., 2009), there remains a local topographic influence that can contribute to asynchrony of glacial maxima within each individual region or range. In valleys where moraines stabilized at terminal positions relatively early (e.g., Wind River Range, ca. 24 ka; Wallowa Mountains, ca. 22 ka), ice remained at or near its maximum extent until after 17 ka, based on the location and age of recessional moraines. Ages of these recessional moraines are consistent with the ages of terminal Pinedale terminal moraines in other western U.S. mountain ranges where Pinedale terminal moraines stabilized much later (e.g., Yellowstone, ca. 16.5 ka; Uinta Mountains, ca. 16 ka). Glacier fluctuations are ultimately driven by climate change, but the exact position of a glacier terminus is filtered by nonclimatic factors intrinsic to each glacier valley system. These factors include glacier hypsometry and how glacier snouts are funneled or otherwise confined by previously deposited moraines. Although we cannot rule out the possibility that the range in Pinedale terminal moraine ages across the western U.S. is largely due to differences in climate forcing, our results in the Arkansas River basin suggest that the individuality of glaciers and their variable response to common climate forcing also can be manifested by moraines of differing age (i.e., Licciardi and Pierce, 2008; Ward et al., 2009).

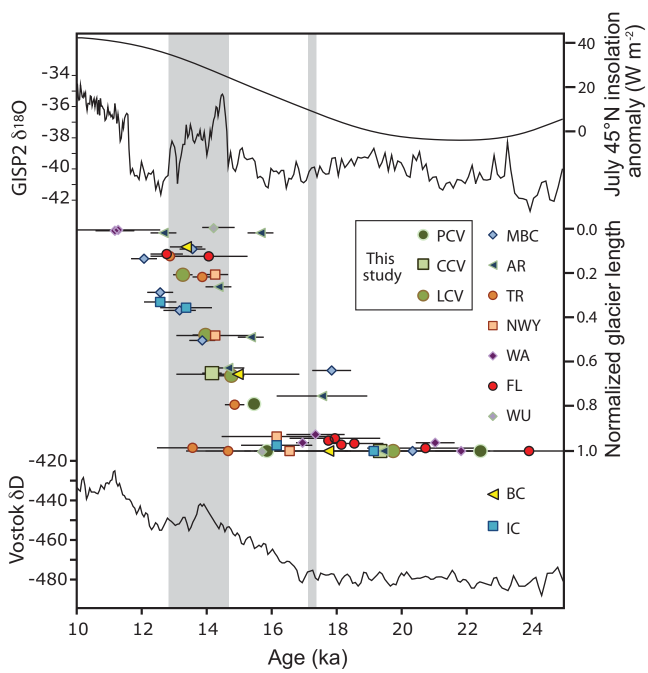

Figure 3. Comparison of chronologies of Pinedale glaciation and deglaciation (see the Data Repository [see footnote 1]) from western United States (error bars are 1σ uncertainty; position normalized as in Fig. 2) with Northern Hemisphere insolation (Berger and Loutre, 1991) and polar ice core records (Stuiver and Grootes, 2000; Petit et al., 1999). Thin gray bar represents onset of deglaciation defined by Schaefer et al. (2006); wide gray bar represents Bølling-Allerød period. Abbreviations as in Figure 1. GISP2—Greenland Ice Sheet Project 2.

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NEAR-SYNCHRONOUS PINEDALE DEGLACIATION IN THE WESTERN U.S.

Chronologies of the last deglaciation in the western U.S. are still relatively sparse, and in many of the data sets used in our compilation, the timing of deglaciation is constrained only by the ages of the innermost dated range-front moraine and a late-glacial moraine in the headwaters. Nonetheless, our synthesis reveals that in most cases glaciers remained at or near their terminal Pinedale positions until ca. 16 ka, and that deglaciation throughout the western U.S. was largely completed within an ~2 k.y. period between ca. 15 and ca. 13 ka. Our results build on the findings of Licciardi et al. (2004), who suggested that western U.S. deglaciation beginning ca. 17 ka may have been part of a global deglaciation trend, and a subsequent analysis by Schaefer et al. (2006), who indicated that the onset of deglaciation from mid-latitude mountain glaciers in both hemispheres was near synchronous ca. 17 ka, driven by warming recorded in Antarctic ice core records. However, we note that in many of the western U.S. chronologies discussed here, glaciers remained at or very close to their Pinedale maximum positions until ca. 16 ka or later (e.g., Applegate, 2005), and when including available chronologies of deglaciation, the majority of glacier retreat occurred significantly later than ca. 17 ka in the western U.S. Furthermore, we wonder if the near-synchronous retreat was driven by the first major warming in the Northern Hemisphere following the Last Glacial Maximum, the Bølling-Allerød period, recorded in Greenland ice cores (Stuiver and Grootes, 2000). Although the Bølling-Allerød period initiated ca. 14.7 ka, slightly later than the widespread onset of deglaciation in the western U.S. between 16 and 15 ka, well-dated speleothem records from the Northern Hemisphere register Bølling-Allerød–like warming between ca. 16 and 15 ka (Genty et al., 2006). Regardless, we hypothesize that near-synchronous deglaciation of western U.S. mountain glaciers was driven by the first significant warming registered in many Northern Hemisphere climate archives that initiated ca. 16–15 ka.

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Pinedale nomenclature

The name 'Pinedale' historically refers to end moraines at the type locality in Pinedale, Wyoming, corresponding to the maximum phase of marine oxygen isotope stage 2 glaciation (Blackwelder, 1915; Gosse et al., 1995a). Initially, moraines across the western US were correlated to the type deposits by relative dating criteria. However, detailed numerical dating has since revealed that many moraines originally referred to as 'Pinedale' are not actually the same age as the terminal moraines at the type locality. Here, we use the name 'Pinedale' in reference to terminal and recessional moraines in the western US that are of marine oxygen isotope stage 2 age.

Upper Arkansas River valley glacial geomorphology

The Upper Arkansas valley in central Colorado encompasses the headwaters for the Arkansas River, which drains the Mosquito Range situated to the east and the Sawatch Range to the west. Bedrock in the region is composed primarily of Precambrian plutonic and metamorphic rocks (granites and gneisses), with exposures of late Cretaceous and Tertiary plutonic rocks (Tweto et al., 1976; 1978; Scott et al., 1978). During the latest Pleistocene glaciation (e.g. Pinedale), Sawatch Range glaciers extended eastward towards the north-south trending upper Arkansas River valley. Notably, glaciers that flowed down Lake Creek, Clear Creek, and Pine Creek valleys extended beyond the range front and onto the Upper Arkansas valley floor, depositing large latero-frontal moraines.

Initial work in the area identified four flood terraces along the Arkansas River south of Pine Creek (Scott, 1975, 1984). Terraces were tentatively correlated to glacier maxima and subsequent outburst floods occurring during the early Pleistocene (uppermost terrace), middle Pleistocene, and late Pleistocene (two lowermost terraces; Scott, 1984). The age of the uppermost terrace is constrained by an outcrop of alluvium containing flood boulders, which is correlated to a surface ~20 km away containing Bishop Ash (~760 ka; Sarna-Wojcicki et al., 2000). Tributary alluvial fans sourced from the Mosquito Range, containing Lava Creek B ash (~640 ka; Lanphere et al., 2002), are correlated with the next highest flood deposit (Scott, 1984). The two lower terraces lie within Pinedale-age outwash and are strewn with large boulders, almost all of which are composed of granodiorite (Scott, 1975); smaller clasts are composed of both granodiorite and metamorphic lithologies. These boulders were likely dislodged from moraines and valley walls during flooding. We only focused on the lowest two terraces of the four (i.e., the late Pleistocene terraces), which we refer to in the text as higher and lower.

Upper Arkansas River valley ^{10}Be ages

Samples from flood terraces (*n* = 8), the Clear Creek Pinedale terminal moraine (*n* =5), and glacial-sculpted bedrock surfaces up-valley from moraines in Pine Creek and Lake Creek valleys (*n* = 6) were collected with hammer and chisel. Sampled boulders on the Clear Creek moraine were all >1 m in height and sampled terrace boulders were at least 1.5 m tall (Fig. DR1). At all locations, samples were collected from horizontal to near-horizontal surfaces and we avoided sampling from boulder edges and corners. Geographic coordinates and sample elevation were collected with a handheld GPS unit and a clinometer was used to measure shielding by the surrounding topography.

All samples were processed at the University at Buffalo Cosmogenic Isotope Laboratory. Quartz was isolated from bulk samples following procedures modified from Kohl and Nishiizumi (1992). Samples were first crushed and sieved to isolate the 425-850 μm size fraction and then pretreated in dilute HCl and HNO_3-HF acid baths. Quartz (~16-35 g) was isolated by heavy-liquid mineral separation and additional HNO_3-HF heated sonification baths. ^9Be carrier (~250- 350 μg; SPEX 1000 μg/g) was added to each sample prior to digestion in concentrated HF. Beryllium was extracted using ion-exchange chromatography, selective precipitation with NH_4OH, and final oxidation to BeO.

$^{10}Be/^9Be$ AMS measurements were completed at the Purdue Rare Isotope Measurement (PRIME) Laboratory and Lawrence Livermore National Laboratory Center for Mass Spectrometry (LLNL-CAMS). Samples measured at both PRIME lab (*n* = 11) and LLNL-CAMS (*n* = 8), were normalized to 07KNSTD standard reference material (Nishiizumi et al., 2007). $^{10}Be/^9Be$ ratios for process blanks (*n* = 3) averaged $1.80 \times 10^{-14} \pm 1.38 \times 10^{-14}$. AMS precision for blank-corrected $^{10}Be/^9Be$ sample ratios ranged from 2.0-4.6%.

^{10}Be exposure ages (Tables DR1 and 2) were calculated using the CRONUS-Earth online exposure age calculator (http://hess.ess.washington.edu/math; Version 2.2; Balco et al., 2008). Ages were calculated using the global reference ^{10}Be production rate (PR) of 4.49 ± 0.39 atoms g^{-1} yr^{-1} and the non-time-dependent production scaling scheme of Lal (1991)/Stone (2000). All ages are presented in ka with 1σ uncertainty. This updated PR reflects a normalization of ^{10}Be calibration material to the 07KNSTD standard (Nishiizumi et al., 2007). We use the global PR and Lal/Stone (St) scaling primarily to be consistent with previously published ^{10}Be ages from the western US. ^{10}Be ages calculated with alternative scaling schemes that incorporate time-dependent production rates based on fluctuations in the Earth's magnetic field are presented in Table DR2. To further ensure consistency with other western US ^{10}Be chronologies, ^{10}Be ages are not corrected for the effects of snow cover or erosion. However, we note that samples were collected at windswept locations and rock surfaces displayed little evidence of surface weathering; we consider the effects of both snow cover and erosion to be minimal.

Arkansas River valley paleoglaciers

Ice-surface contours of paleo-glaciers in the Arkansas River valley were reconstructed by digitizing the areal extent of each paleo-glacier from the cirque headwall to the Pinedale terminal moraine on 1:24,000 scale USGS topographic maps. We follow previously established methods (e.g. Porter, 1975; Leonard, 1984; Brugger and Goldstein, 1999) and make general assumptions regarding ice-surface contour shape in the accumulation and ablation areas (Figure DR3). From the paleoglacier surface reconstructions, we calculated hypsometry, plotted as area-altitude distributions, determined by calculating glacier surface area between successive ice-surface contours (Figure DR4). To estimate paleo-equilibrium-line-altitudes (ELA), we use an accumulation-area ratio of 0.65±0.05, which is a commonly used value and has been used nearby in Colorado (Meir and Post, 1962; Andrews and Miller, 1972; Leonard, 1984, Brugger and Goldstein, 1999). Reconstructed ELAs for Lake Creek, Clear Creek, and Pine Creek valleys are 3350 +64/-183 m (10,990 +210/-600 ft), 3232 + 72/- 149 m (10,605 +235/-490 ft), and 3315+99/-70 m. (10,875 +325/-230 ft), respectively (Figure DR4). Uncertainty values are derived from ELA reconstructions using AAR values of 0.6 (+) and 0.7 (-).

Compilation and recalculation of ^{10}Be ages from Pinedale moraines across the western US

We compiled sample information for 180 surface exposure ages across the western US (Table DR1); all but two (^{26}Al) are ^{10}Be ages. Because PRs and scaling schemes are constantly being updated, all ^{10}Be ages were recalculated using the global PR and St scaling, before comparing our upper Arkansas River basin chronology to other western US chronologies. Recalculated ^{10}Be ages match those for recently published western US ^{10}Be ages that use the global PR and St scaling. In some cases, recalculated ^{10}Be ages were ~2-3% older than originally published values, which is due to a slight reduction of the global PR (i.e. 5.1 to 4.96 atoms $g^{-1}yr^{-1}$) since publication of the original ^{10}Be ages. We also provide western US ^{10}Be ages calculated with different scaling schemes (Table DR2).

We recognize that newly emerging, regionally-calibrated, ^{10}Be production rates are considerably lower (6 to 12%) than the global PR (e.g. Balco et al., 2009; Putnam et al., 2010) and that use of a lower PR would increase ^{10}Be ages. In light of this, ^{10}Be ages using the Northeast North America production rate (e.g. Balco et al., 2009) and the Lifton et al. (2005) scaling scheme (Table DR2; NE Li) are also reported. We present the Li scaling scheme because nuclide production rates in the Li scaling scheme rely strongly on elevation (e.g. Balco et al., 2008) and may be the most suitable to the relatively high elevations of Pinedale sample localities. ^{10}Be ages calculated with these parameters change ^{10}Be ages calculated with the global PR and St scaling by -2 to +9%. Finally, Table DR1 provides all of the necessary input values in which to recalculate western US surface exposure ages on the CRONUS website.

Comparing chronologies of glaciation and deglaciation

Prior to comparing western US chronologies, all ^{10}Be ages were re-calculated using the same parameters (Tables DR1 and DR2) and then plotted against the normalized glacier length of each respective glacier system (Fig. 3; Table DR3). Glacier length at each location, including valleys within the Arkansas River drainage basin, was determined by measuring the distance between the cirque headwall and each dated ice margin position (Table DR3). In valleys with multiple drainages and cirques, we only measured the distance between the dated ice-margin position and the cirque in which the timing of deglaciation is constrained. Below, we briefly summarize the chronological constraints of Pinedale and equivalent moraines and valley deglaciation used in our compilation.

Three studies from Colorado and Utah meet the aforementioned criteria. Guido et al. (2007) dated the Pinedale maximum ice extent in the Animas River valley, southwestern CO, to 19.4±1.5 ka, and Ward et al. (2009) present 4 ages from the Pinedale terminal moraine in the Middle Boulder Creek valley in the Colorado Front Range that average 20.3±2.1 ka. Subsequent retreat of both valley glaciers was constrained by dating a transect of glacially-sculpted bedrock samples. The upper 75% of the Animas River valley deglaciated between 15.1 and 12.3 ka (n=5) and the uppermost 64% of the Middle Boulder Creek valley deglaciated between 13.8 and 12 ka (n=10). In the western Uinta Mountains, Utah, ice remained at its Pinedale maximum limit until 15.8±2.5 ka (mean of 8 moraine boulders), and sculpted bedrock from the ice divide indicate final deglaciation at 14.3±0.4 ka (n=4; Refsnider et al., 2008), indicating complete deglaciation took place between ~15.8 and ~14.3 ka.

Using our criteria, four studies were selected from Wyoming, the Yellowstone region, and northeastern Oregon. In the Wind River Range, WY, Gosse et al. (1995a, b) dated dozens of boulders from a belt of moraines near Fremont Lake, as well as moraine boulders close to the cirque head in the Titcomb Lakes basin. ^{10}Be ages from the terminal moraine average 23.9±1.1 ka; the innermost recessional moraine near Fremont Lake dates to 17.9±1.4 ka (which lies at 94% of the maximum Pinedale glacier length; below, we list glacier-length fractions associated with each dated location). Farther upvalley, the Titcomb Lakes moraine is dated to 12.7±0.5 ka (12%), and boulders just beyond the moraine average 14.0±1.2 ka (13%); combined, these data from the Wind River Range indicate that the valley glacier retreated from 94 to 13% of its Pinedale maximum length between ~17.9 and ~14 ka. At the northwestern margin of the Yellowstone Ice Cap, a terminal moraine and inboard end moraine date to 16.5±1.4 ka (100%) and 16.1±1.7 ka (94%), respectively (Licciardi et al., 2001; Licciardi and Pierce, 2008). Closer to the ice divide in the same sector of the Yellowstone Ice Cap are moraines (Deckard Flats; Junction Butte) dated at 14.2±1.2 ka (48%) and 14.2±0.4 ka (21%; younger mode of a bimodal age distribution), indicating that ice retreated from 94 to 21% of its Pinedale maximum length between ~16.1 and ~14.2 ka. However, once the local ELA rose above the relatively broad ice cap plateau, ice loss may have occurred quickly (Pierce, 1979); this change may be exaggerated in the glacial chronology. In the Teton Range, ^{10}Be ages from Pinedale end moraines at Jenny Lake are 14.6±0.7 ka (100%) and 13.5±1.1 ka (99%), although it is unclear if these moraines represent the maximum Pinedale extent (Licciardi and Pierce, 2008).

Ages for deglaciation upvalley from Jenny Lake are 14.8±0.2 ka (79%), 13.8±0.3 ka (22%) and 12.8±0.6 ka (13%), indicating rapid deglaciation of the valley between ~14.8 and ~12.8 ka. In the Wallowa Mountains, northeastern Oregon, ^{10}Be ages from the Pinedale terminal moraine average 21.8±0.9 ka (Licciardi et al., 2004). End moraines upvalley from the terminal moraine date to 16.9±0.2 ka (96%) and 17.3±0.9 ka (93%), and the glacier was occupying just the cirque by 11.2±1.3 ka (1%), indicating near-complete deglaciation between ~17 and ~11.2 ka.

Outside of the Rocky Mountains, additional studies in the Washington Cascades and the Sierra Nevada meet our criteria. In Icicle Creek, the terminal moraine and adjacent end moraine are 19.1±3.0 ka (100%) and 16.1±1.1 ka (97%), respectively (Porter and Swanson, 2008). Farther up-valley, end moraines date to 13.3±0.8 ka (36%) and 12.5±0.5 ka (33%), indicating that the majority of the Icicle Creek valley was deglaciated between ~16.1 and ~13.3 ka. In the eastern Sierra Nevada, the Tioga glaciation (Pinedale equivalent) is mapped as a four-fold moraine sequence spanning from ~27 to ~15 ka (Clark and Gillespie, 1997; Phillips et al., 2009). Most relevant here is that during the youngest (Tioga-4) phase, glaciers remained at ~65-80% of their Tioga maximum length until 14.9±1.9 ka [average of Tioga-4 ^{36}Cl ages reported by Phillips et al., (1996, 2009)]. Subsequent deglaciation is based on the age of the Recess Peak cirque glacier advance, when glaciers were 5-15% of their Tioga maximum extents just prior to ~13 ka (Clark and Gillespie, 1997), and ^{36}Cl ages from between Recess Peak and Tioga 4 moraines, which average 13.8±1.0 ka (Phillips et al., 2009). Thus, the upper 65-80% of eastern Sierra Nevada valleys rapidly deglaciated between ~14.9 and ~13 ka.

The graphic compilation (Figure 3, main text)

We make several assumptions in order to plot the ages in Figure 3 (main text). (1) We exclude one old outlier (Molas Lake sample) from the Animas River dataset, consistent with original interpretation by Guido et al. (2007). (2) From Middle Boulder Creek, only ages from the main valley are used. Although four ^{10}Be ages from a tributary valley suggest that it may have completely deglaciated ~16.0±0.3 ka (Ward et al., 2009), at least one of the four ^{10}Be ages from the tributary is interpreted to have inheritance. In addition, because there are only a few ages from the tributary, we only plot the transect of ages from the main valley on Figure 3. Furthermore, we average the 6 bedrock ages from the northern tributary cirque and plot as one position (Ward et al., 2009). (3) In the northwest Yellowstone area, the innermost moraine dated (Junction Butte) has two modes, the older of which is older than the Deckard Flats moraine ~30 km down ice-flowline (Licciardi and Pierce, 2008). Thus, we plotted the younger mode of the Junction Butte moraine on Figure 3. (4) The Pinedale terminal moraine in the northwest Yellowstone region was also dated with ^{3}He, which yields an average age of 16.6±1.3 ka (^{10}Be age = 16.5±1.4 ka); we only show the average ^{10}Be age in Figure 3. (5) For the dataset from Fremont Lakes, Wind River Range, we plot the average ages from each individual moraine crest shown in figure 1 in Gosse et al. (1995a). (6) We excluded one old outlier (17.0±0.5 ka) of the four erratics outboard of the Titcomb Lakes moraines (Gosse et al., 1995b). (7) The Icicle Creek (Porter and Swanson,

2008) and Bishop Creek samples (see Phillips et al., 2009) are ^{36}Cl ages; we did no recalculations of these, and report what the authors originally reported. See Phillips et al. (2009) for a discussion of ^{36}Cl production rates. (8). To obtain the average age of the Tioga 4 moraine, we calculated an average of all Tioga 4 moraine boulder ^{36}Cl ages reported by Phillips et al. (1996, 2009), which includes moraines at Bloody Canyon, Little McGee Creek, Chiatovich Creek, and Bishop Creek. (9) Phillips et al. (2009) report several ^{36}Cl ages from glacially-sculpted bedrock between Tioga 4 moraines and Recess Peak moraines; because there is no trend in the ages (Phillips et al., 2009), we plot only the ages of the Tioga 4 and Recess Peak moraines on Figure 3, but note that deglaciation between the two glacier positions at 13.8±1.0 ka falls within the typical range for the age of deglaciation compiled here.

A few other considerations about our data compilation warrant mention. First, there are many additional Pinedale terminal and other end moraines that have been dated in the Rocky Mountains. However, because our goal is to have moraine ages be within the context of information on deglaciation, we did not include them here. Additional Pinedale moraine chronologies from the Rocky Mountains are available from Colorado (Benson et al., 2004, 2005; Brugger, 2007), Wyoming (Phillips et al., 1997), elsewhere in the Uinta Mountains (Laabs et al., 2009 and references therein), and elsewhere around the Yellowstone Ice Cap (Licciardi and Pierce, 2008). Boulder Mountain, located in southern Utah on the Colorado Plateau, hosted a small ice cap that reached its Pinedale maximum sometime between ca. 23 and 20 ka (Marchetti et al., 2005). ^{3}He ages on four moraines ~3 km upvalley and near the plateau accumulation zone either overlap Pinedale terminal moraine ages (2 moraines), or date to ~16.8 and 15.2 ka (2 moraines). However, the timeline of deglaciation after ~16 ka is not known and thus not included in Figure 3 (main text). Fabel et al. (2004) provide additional bedrock ages from the Wind River Range and Sierra Nevada. Our synthesis includes predominantly cosmogenic exposure ages, but we emphasize that although cosmogenic exposure ages provide the bulk of age control on moraines in the Rocky Mountains, these studies necessarily rely on a foundation of decades of mapping and relative dating studies that have taken place across the western US.

Second, there are different approaches regarding how best to interpret a series of individual moraine boulder ages. Mainly, one can either calculate the mean age of all moraine boulder ages, or more weight can be placed on the oldest ages of the distribution. Because moraines degrade, which potentially skews ages in the young direction, and because of the general scarcity of isotopic inheritance (Putkonen and Swanson, 2003), some authors favor the oldest age in a distribution. However, since the majority of the moraines considered here are relatively young (e.g., Pinedale), and generally have age distributions that are normally distributed about their mean, we plot mean ages. Additionally, for this reason, we plot on Figure 3 (main text) the onset of deglaciation (~17.3 ka) that Schaefer et al. (2006) base on average ages, rather than the oldest age (~19.1 ka).

Finally, the onset of deglaciation proposed by Schaefer et al. (2006, ~17.3 ka) is based on a synthesis of primarily ^{10}Be data, along with additional radiocarbon data from northern and southern hemisphere LGM moraine datasets. Therefore the onset of deglaciation age assignment would change if ^{10}Be ages were recalculated using different production rates and scaling schemes. The production rate used in Schaefer et al. (2006) is ~ 2.7% percent higher than the production rate we use for western US chronologies (i.e. 5.1 vs 4.96 atoms g^{-1} yr^{-1}). However, applying the lower production rate to the dataset of Schaefer et al. (2006) would not necessarily result in all ^{10}Be ages becoming 2.7% older. For example, using the St scaling scheme, recalculated ^{10}Be ages from the Wallowa Mountains dataset, which is included in both the Schaefer et al. (2006) and our synthesis, result in ages that are within 2% of those reported in Schaefer et al. (2006). Thus, we consider any potential change to the onset of deglaciation age reported by Schaefer et al. (2006) to be minimal and use the original age of ~17.3 ka in our discussion and figure 3 (main text).

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Table DR1. Sample information for western US cosmogenic surface exposure ages

Sample	Latitude	Longitude	Elevation	Thickness	Density	Shielding correction	^{10}Be concentration (atoms g^{-1})	^{10}Be uncertainty (atoms g^{-1})	^{10}Be standard	^{10}Be age[a]	Sample type	Reference
Lake Creek, CO												
AR09-01	39.065896	-106.407026	2930	1.5	2.65	0.996	513651.9202	12461.80	07KNSTD	14.7 ± 0.4	bedrock	1
AR09-10	39.070594	-106.471824	3048	3.5	2.65	0.989	508739.7905	13867.28	07KNSTD	13.9 ± 0.4	bedrock	1
AR09-11	39.100977	-106.544485	3261	4	2.65	0.983	543494.3132	10770.61	07KNSTD	13.2 ± 0.3	bedrock	1
DC-91-2	39.069676	-106.288887	2850	1	2.7	1	730000	20000	KNSTD	19.7 ± 0.5	moraine boulder	2
Clear Creek, CO												
MF06-01	39.027	-106.269	2938	2	2.65	1	682066.2649	20016.76	07KNSTD	19.5 ± 0.6	moraine boulder	1
MF06-02	39.028	-106.274	2953	1.5	2.65	1	686464.4184	15997.73	07KNSTD	19.3 ± 0.4	moraine boulder	1
MF06-03	39.027	-106.281	2957	2	2.65	1	768307.6912	19615.79	07KNSTD	21.7 ± 0.6	moraine boulder	1
MF06-04	39.026	-106.285	2964	2.5	2.65	1	676327.9371	12545.56	07KNSTD	19.1 ± 0.4	moraine boulder	1
MF06-05	39.026	-106.286	2971	3	2.65	1	540315.0162	14668.53	07KNSTD	15.2 ± 0.4	moraine boulder	1
AR09-03	39.002602	-106.33924	2835	2	2.65	0.992	462709.1138	9308.48	07KNSTD	14.1 ± 0.3	bedrock	1
Pine Creek, CO												
PC1	38.9808	-106.23245	2992	3	2.65	1	828000	19360	KNSTD	20.9 ± 0.5	moraine boulder	3
PC2	38.9807	-106.232369	2992	1	2.65	1	546000	15894	KNSTD	13.5 ± 0.4	moraine boulder	3
PC3	38.9802	-106.23405	2911	1	2.65	1	599000	15943	KNSTD	15.6 ± 0.4	moraine boulder	3
PC4	38.9802	-106.23405	2911	1	2.65	1	859000	20037	KNSTD	22.4 ± 0.5	moraine boulder	3
PC5	38.9818	-106.23165	2845	3	2.65	1	890000	26017	KNSTD	24.5 ± 0.7	moraine boulder	3
PC6	38.9817	-106.231633	2893	1	2.65	1	610000	14423	KNSTD	16.0 ± 0.4	moraine boulder	3
PC7	38.9865	-106.2274	2877	1	2.65	1	858000	20223	KNSTD	22.8 ± 0.5	moraine boulder	3
PC8	38.9889	-106.22725	2851	1	2.65	1	789000	15449	KNSTD	21.3 ± 0.4	moraine boulder	3
PC9	38.9901	-106.22695	2837	1	2.65	1	566000	13421	KNSTD	15.4 ± 0.4	moraine boulder	3
PC11	38.9917	-106.227233	2835	1	2.65	1	564000	13339	KNSTD	15.3 ± 0.4	moraine boulder	3
PC12	38.9980	-106.228633	2739	1.5	2.65	1	560500	13500	KNSTD	16.2 ± 0.4	moraine boulder	3
PC13	38.9979	-106.228528	2739	1	2.65	1	558000	13426	KNSTD	16.1 ± 0.4	moraine boulder	3
AR09-07	38.974371	-106.250598	2931	3	2.65	0.996	536779.4137	14280.09	07KNSTD	15.6 ± 0.4	bedrock	1
AR09-08	38.974371	-106.250598	2931	1	2.65	0.996	537780.799	10675.82	07KNSTD	15.3 ± 0.3	bedrock	1
ARK River valley, CO, Lower flood terrace												
QPOY-01	38.983	-106.212	2616	2	2.65	0.995	495688.5285	12709.90	07KNSTD	17.3 ± 0.4	flood boulder	1
QPOY-02	38.984	-106.212	2616	4	2.65	0.999	486011.3045	23460.67	07KNSTD	17.2 ± 0.8	flood boulder	1
AR09-05	38.942935	-106.189466	2555	3	2.65	0.999	503687.0176	9990.57	07KNSTD	18.4 ± 0.4	flood boulder	1
AR09-06	38.942935	-106.189466	2555	2	2.65	0.999	499121.383	12060.47	07KNSTD	18.1 ± 0.4	flood boulder	1
ARK River valley, CO, Upper flood terrace												
QPOO-2	38.972	-106.204	2620	2.5	2.65	0.996	545831.9166	23470.77	07KNSTD	19.1 ± 0.8	flood boulder	1
QPOO-4	38.975	-106.205	2620	2	2.65	0.998	600223.1971	27610.27	07KNSTD	20.9 ± 1.0	flood boulder	1
QPOO-01	38.975	-106.205	2620	2	2.65	0.996	549660.9314	18527.31	07KNSTD	19.1 ± 0.6	flood boulder	1
QPOO-03	38.965	-106.201	2620	2	2.65	0.999	556144.5244	13713.09	07KNSTD	19.3 ± 0.5	flood boulder	1
Animas Valley, CO												
Baker's Bridge	37.46771	-107.79045	2155	0.7	2.7	0.894	359300	9000	KNSTD	17.5 ± 0.4	bedrock	4
Tacoma	37.56023	-107.77917	2285	2.5	2.7	0.917	330100	11600	KNSTD	14.6 ± 0.5	bedrock	4
Needleton	37.6286	-107.69437	2540	0.6	2.7	0.918	415300	10400	KNSTD	15.3 ± 0.4	bedrock	4
Silverton	37.78546	-107.66853	2835	3.5	2.7	0.482	242900	6400	KNSTD	14.3 ± 0.4	bedrock	4
Highland Mary Lake	37.91239	-107.5807	3704	1.2	2.7	0.948	698384	25421	KNSTD	12.6 ± 0.5	bedrock	4
Elk Creek	37.71465	-107.54033	3871	2.3	2.7	0.947	925981	25464	KNSTD	15.6 ± 0.4	bedrock	4
terminal outwash profile[b]	37.09641	-107.88684	1872	NA	NA	NA	NA	NA	NA	19.4 ± 1.5	depth profile	4

Middle Boulder Creek, CO												
Terminal moraine												
99-t74[c]	40	-105.558	2982	5	2.7	1	4322600 (^{26}Al)	206600 (^{26}Al)	KNSTD	17.8 ± 0.9[c]	moraine boulder	2
99-t76	40	-105.558	2982	5	2.7	1	822400	20300	KNSTD	20.6 ± 0.5	moraine boulder	2
99-t76[c]	40	-105.558	2982	5	2.7	1	4966400 (^{26}Al)	234700 (^{26}Al)	KNSTD	20.5 ± 1.0[c]	moraine boulder	2
MB4J-0	39.9579	-105.5242	2590	5	2.7	1	570029	51815	KNSTD	18.2 ± 1.7	moraine boulder	5
Upvalley bedrock												
33-JB-25	39.9978	-105.6352	3162	3	2.7	0.978	552800	18100	KNSTD	12.5 ± 0.4	bedrock	5
GP4J-1	40.012	-105.6749	3549	3	2.7	0.991	752900	23700	KNSTD	13.5 ± 0.4	bedrock	5
GP4J-2	40.0111	-105.6741	3521	3	2.7	0.979	747700	23100	KNSTD	13.8 ± 0.4	bedrock	5
GP4J-3	40.0097	-105.6752	3520	10	2.7	0.995	704500	25600	KNSTD	13.6 ± 0.5	bedrock	5
GP4J-4	40.0088	-105.6742	3484	3	2.7	0.993	722600	23000	KNSTD	13.4 ± 0.4	bedrock	5
GP4J-5	40.0077	-105.6741	3463	2	2.7	0.988	705200	22700	KNSTD	13.2 ± 0.4	bedrock	5
GP4J-6	40.0103	-105.6681	3451	1	2.7	0.981	704400	27500	KNSTD	13.3 ± 0.5	bedrock	5
GP4J-7	40.0065	-105.6656	3434	1	2.7	0.986	635200	20100	KNSTD	12.0 ± 0.4	bedrock	5
GP4J-10	39.9713	-105.6043	2904	5	2.7	0.976	514200	14400	KNSTD	13.8 ± 0.4	bedrock	5
GP4J-11	39.9872	-105.6242	3051	5	2.7	0.972	528200	19100	KNSTD	13.1 ± 0.5	bedrock	5
GP4J-23	39.9517	-105.5836	2708	5	2.7	0.979	587890	20575	KNSTD	17.8 ± 0.6	bedrock	5
Jenny Lake, WY												
Outer Jenny Lake moraine												
OJEN-1	43.7659	-110.7104	2102	2.25	2.7	1	354000	6000	KNSTD	14.1 ± 0.3	moraine boulder	7
OJEN-2	43.7664	-110.7107	2094	2.5	2.7	1	374000	9000	KNSTD	15.0 ± 0.4	moraine boulder	7
OJEN-3	43.7664	-110.711	2094	1.5	2.7	1	337000	8000	KNSTD	13.4 ± 0.3	moraine boulder	7
OJEN-5	43.7656	-110.7107	2092	1.5	2.7	1	361000	8000	KNSTD	14.4 ± 0.3	moraine boulder	7
OJEN-6	43.7652	-110.7104	2102	1.5	2.7	1	389000	9000	KNSTD	15.4 ± 0.4	moraine boulder	7
OJEN-7	43.765	-110.7103	2099	2	2.7	1	380000	9000	KNSTD	15.1 ± 0.4	moraine boulder	7
OJEN-8	43.7646	-110.7105	2095	1.5	2.7	1	364000	9000	KNSTD	14.4 ± 0.4	moraine boulder	7
OJEN-9	43.7646	-110.7105	2095	2	2.7	1	383000	9000	KNSTD	15.3 ± 0.4	moraine boulder	7
OJEN-10	43.7831	-110.7303	2115	2	2.7	0.992	340000	8000	KNSTD	13.5 ± 0.3	moraine boulder	7
OJEN-11	43.784	-110.7289	2100	2	2.7	0.992	375000	14000	KNSTD	15.0 ± 0.6	moraine boulder	7
Inner Jenny Lake moraine												
IJEN-1	43.7807	-110.7256	2113	1.75	2.7	1	337000	8000	KNSTD	13.2 ± 0.3	moraine boulder	7
IJEN-2	43.7804	-110.7248	2097	1.75	2.7	1	318000	9000	KNSTD	12.6 ± 0.4	moraine boulder	7
IJEN-3	43.7799	-110.7231	2108	2	2.7	1	355000	8000	KNSTD	14.0 ± 0.3	moraine boulder	7
IJEN-5	43.7779	-110.7219	2110	2	2.7	1	296000	7000	KNSTD	11.7 ± 0.3	moraine boulder	7
IJEN-6	43.7751	-110.7186	2103	1.75	2.7	1	359000	9000	KNSTD	14.2 ± 0.2	moraine boulder	7
IJEN-7	43.7669	-110.714	2093	2	2.7	1	324000	8000	KNSTD	12.9 ± 0.3	moraine boulder	7
IJEN-11	43.7581	-110.7158	2084	2	2.7	1	374000	9000	KNSTD	15.0 ± 0.4	moraine boulder	7
IJEN-13	43.7577	-110.7165	2090	1.5	2.7	1	356000	8000	KNSTD	14.2 ± 0.3	moraine boulder	7
Upvalley												
BED-1	43.785	-110.8303	2618	1	2.7	0.955	473000	11000	KNSTD	13.8 ± 0.3	bedrock	7
BED-2	43.767	-110.7491	2214	2.5	2.7	0.973	390000	7000	KNSTD	14.8 ± 0.3	bedrock	7
LS-1	43.7921	-110.8414	2767	1	2.7	0.983	483000	9000	KNSTD	12.5 ± 0.3	boulder	7
LS-7	43.7911	-110.8418	2787	1.5	2.7	0.982	528000	16000	KNSTD	13.5 ± 0.3	boulder	7
LS-8	43.7914	-110.8416	2764	2.25	2.7	0.982	472000	11000	KNSTD	12.3 ± 0.3	boulder	7
NW Yellowstone, MT, WY												
Eightmile terminal moraine												
8-B2	45.429	-110.707	1550	2.5	2.7	1	259000	17000	NIST_Certified*	14.8 ± 1.0	moraine boulder	7,8
8-D1	45.429	-110.705	1545	0.75	2.7	1	283000	16000	NIST_Certified*	16.0 ± 0.9	moraine boulder	7,8
8-F2	45.437	-110.695	1544	1.5	2.7	1	308000	28000	NIST_Certified*	17.6 ± 1.6	moraine boulder	7,8
8-G2	45.436	-110.691	1529	1	2.7	1	334000	28000	NIST_Certified*	19.2 ± 1.6	moraine boulder	7,8
8-I1_I2	45.435	-110.69	1529	1.75	2.7	1	286000	12000	NIST_Certified*	16.5 ± 0.7	moraine boulder	7,8
8-J1_J2	45.365	-110.69	1554	2	2.7	1	298000	25000	NIST_Certified*	17.0 ± 1.4	moraine boulder	7,8

8-K1	45.429	-110.688	1536	2.75	2.7	1	291000	10000	NIST_Certified*	16.9 ± 0.6	moraine boulder	7,8
8-L1_L2	45.365	-110.69	1554	3	2.7	1	271000	12000	NIST_Certified*	15.6 ± 0.7	moraine boulder	7,8
8-M2	45.363	-110.691	1561	2.5	2.7	1	280000	11000	NIST_Certified*	15.9 ± 0.6	moraine boulder	7,8
									KNSTD			
Chico moraines									KNSTD			
CH-1A	45.339	-110.698	1628	2.5	2.7	1	264000	22000	NIST_Certified*	14.3 ± 1.2	moraine boulder	7,8
CH-2A	45.337	-110.697	1634	1.75	2.7	1	290000	18000	NIST_Certified*	15.5 ± 1.0	moraine boulder	7,8
CH-3B	45.334	-110.695	1652	1.75	2.7	1	298000	26000	NIST_Certified*	15.8 ± 1.4	moraine boulder	7,8
CH-6A	45.335	-110.705	1615	1.75	2.7	1	264000	22000	NIST_Certified*	14.3 ± 1.2	moraine boulder	7,8
CH-6B	45.335	-110.705	1615	1.75	2.7	1	248000	27000	NIST_Certified*	13.5 ± 1.5	moraine boulder	7,8
CH-8A	45.336	-110.704	1615	0.75	2.7	1	327000	19000	NIST_Certified*	17.6 ± 1.0	moraine boulder	7,8
CH-9B	45.338	-110.703	1618	1.75	2.7	1	310000	21000	NIST_Certified*	16.8 ± 1.2	moraine boulder	7,8
CH-10B	45.34	-110.703	1612	1.25	2.7	1	347000	20000	NIST_Certified*	18.8 ± 1.1	moraine boulder	7,8
CH-11B	45.342	-110.703	1615	0.75	2.7	1	297000	14000	NIST_Certified*	16.0 ± 0.8	moraine boulder	7,8
									KNSTD			
Deckards Flats moraine									KNSTD			
DF-1A	45.039	-110.685	1811	0.75	2.7	1	299000	13000	NIST_Certified*	14.0 ± 0.6	moraine boulder	7,8
DF-2B	45.039	-110.685	1811	1.75	2.7	1	271000	25000	NIST_Certified*	12.8 ± 1.2	moraine boulder	7,8
DF-3B	45.039	-110.685	1811	1.75	2.7	1	283000	19000	NIST_Certified*	13.4 ± 0.9	moraine boulder	7,8
DF-4A	45.039	-110.685	1811	1.75	2.7	1	267000	23000	NIST_Certified*	12.6 ± 1.1	moraine boulder	7,8
DF-5B	45.039	-110.685	1811	1.5	2.7	1	345000	14000	NIST_Certified*	16.3 ± 0.7	moraine boulder	7,8
DF-6A	45.039	-110.685	1811	1.75	2.7	1	288000	15000	NIST_Certified*	13.7 ± 0.7	moraine boulder	7,8
DF-6B	45.039	-110.685	1811	1.75	2.7	1	319000	24000	NIST_Certified*	15.1 ± 1.1	moraine boulder	7,8
DF-7A	45.039	-110.685	1811	1.5	2.7	1	307000	16000	NIST_Certified*	14.5 ± 0.8	moraine boulder	7,8
DF-8A	45.038	-110.685	1807	1.25	2.7	1	323000	19000	NIST_Certified*	15.3 ± 0.9	moraine boulder	7,8
DF-9B	45.038	-110.684	1804	1.75	2.7	1	281000	11000	NIST_Certified*	13.4 ± 0.5	moraine boulder	7,8
DF-10A	45.038	-110.683	1801	0.75	2.7	1	322000	39000	NIST_Certified*	15.2 ± 1.9	moraine boulder	7,8
Junction Butte moraine												
JB-1	44.9087	-110.3742	1942	0.75	2.7	1	342000	8000	KNSTD	14.7 ± 0.3	moraine boulder	7
JB-2	44.9088	-110.3747	1941	1	2.7	1	333000	8000	KNSTD	14.3 ± 0.3	moraine boulder	7
JB-4	44.9145	-110.3774	1907	1	2.7	1	321000	6000	KNSTD	14.1 ± 0.3	moraine boulder	7
JB-7	44.9169	-110.3776	1897	1	2.7	1	320000	7000	KNSTD	14.2 ± 0.3	moraine boulder	7
JB-8	44.9174	-110.3783	1885	1	2.7	1	290000	8000	KNSTD	13.0 ± 0.4	moraine boulder	7
JB-11	44.9206	-110.3755	1886	1	2.7	1	322000	8000	KNSTD	14.4 ± 0.4	moraine boulder	7
Wallowa, OR												
TTO terminal moraine												
TTO-2B	45.321	-117.196	1530	1.75	2.8	1	363000	16000	NIST_Certified*	21.0 ± 0.9	moraine boulder	9
TTO-3B	45.319	-117.195	1536	1.75	2.8	1	377000	12000	NIST_Certified*	21.7 ± 0.7	moraine boulder	9
TTO-7A	45.326	-117.199	1524	2	2.8	1	373000	27000	NIST_Certified*	21.7 ± 1.6	moraine boulder	9
TTO-9B	45.328	-117.2	1509	1	2.8	1	355000	20000	NIST_Certified*	20.7 ± 1.2	moraine boulder	9
TTO-10B	45.326	-117.199	1524	1.25	2.8	1	399000	24000	NIST_Certified*	23.1 ± 1.4	moraine boulder	9
TTO-11A	45.333	-117.205	1481	1.5	2.8	1	373000	21000	NIST_Certified*	22.3 ± 1.3	moraine boulder	9
TTY end moraine												
TTY-1B	45.312	-117.193	1558	1.75	2.8	1	296000	18000	NIST_Certified*	16.7 ± 1.0	moraine boulder	9
TTY-3B	45.317	-117.195	1542	1.75	2.8	1	298000	24000	NIST_Certified*	17.0 ± 1.4	moraine boulder	9
TTY-6A	45.325	-117.199	1524	2	2.8	1	285000	21000	NIST_Certified*	16.6 ± 1.2	moraine boulder	9
TTY-8A	45.329	-117.202	1498	2	2.8	1	366000	27000	NIST_Certified*	21.7 ± 1.6	moraine boulder	9
TTY-10B	45.331	-117.203	1487	1.5	2.8	1	351000	23000	NIST_Certified*	20.9 ± 1.4	moraine boulder	9
TTY-12B	45.317	-117.221	1509	1.5	2.8	1	351000	19000	NIST_Certified*	20.6 ± 1.1	moraine boulder	9
TTY-13B	45.335	-117.208	1439	1.75	2.8	1	274000	12000	NIST_Certified*	16.9 ± 0.7	moraine boulder	9
WTO end moraine												
WTO-1B	45.324	-117.222	1475	1.75	2.8	1	294000	14000	NIST_Certified*	17.7 ± 0.8	moraine boulder	9
WTO-1C	45.324	-117.222	1475	1.75	2.8	1	313000	14000	NIST_Certified*	18.8 ± 0.8	moraine boulder	9

WTO-3B	45.325	-117.222	1466	1.75	2.8	1	265000	15000	NIST_Certified*	16.0 ± 0.9	moraine boulder	9
WTO-4A	45.326	-117.223	1460	1.75	2.8	1	297000	13000	NIST_Certified*	18.1 ± 0.8	moraine boulder	9
WTO-5A	45.326	-117.223	1454	1.75	2.8	1	282000	10000	NIST_Certified*	17.2 ± 0.6	moraine boulder	9
WTO-9B	45.327	-117.216	1405	2	2.8	1	260000	16000	NIST_Certified*	16.5 ± 1.0	moraine boulder	9
Glacier Lake moraine												
GL-1	45.158	-117.283	2512	1.5	2.8	1	363000	15000	NIST_Certified*	10.5 ± 0.4	moraine boulder	9
GL-3	45.159	-117.284	2509	1.5	2.8	1	301000	12000	NIST_Certified*	8.7 ± 0.3	moraine boulder	9
GL-5	45.16	-117.285	2504	2.5	2.8	1	324000	20000	NIST_Certified*	9.5 ± 0.6	moraine boulder	9
GL-5C	45.16	-117.285	2504	2.5	2.8	1	348000	19000	NIST_Certified*	10.2 ± 0.6	moraine boulder	9
GL-6C	45.16	-117.285	2503	1.5	2.8	1	426000	35000	NIST_Certified*	12.4 ± 1.0	moraine boulder	9
GL-7B	45.16	-117.284	2502	1	2.8	1	351000	19000	NIST_Certified*	10.2 ± 0.6	bedrock	9
Gl-7C	45.16	-117.284	2502	1	2.8	1	344000	32000	NIST_Certified*	10.0 ± 0.9	bedrock	9
Fremont/Titcomb, WRR, Wymoing												
Fremont terminal moraine												
92-108-1	42.90	-109.85	2274	2	2.7	1	676000	20280	KNSTD	24.3 ± 0.7	moraine boulder	10
91-032	42.90	-109.85	2311	5	2.7	1	685000	20550	KNSTD	24.7 ± 0.7	moraine boulder	10
91-35	42.90	-109.85	2262	2	2.7	1	625000	18750	KNSTD	22.7 ± 0.7	moraine boulder	10
Soda Lake moraine												
91-003	42.93	-110	2276	14	2.7	1	518000	15500	KNSTD	20.5 ± 0.6	moraine boulder	10
91-004	42.93	-109.85	2279	5	2.7	1	671000	20130	KNSTD	24.7 ± 0.7	moraine boulder	10
Half Moon moraine												
92-117	42.91	-109.85	2357	3	2.7	1	645000	19350	KNSTD	22.1 ± 0.7	moraine boulder	10
92-119	42.91	-109.85	2319	5	2.7	1	609000	18270	KNSTD	21.8 ± 0.7	moraine boulder	10
Recessional moraines												
92-123	42.91	-109.85	2369	3	2.7	1	534000	16020	KNSTD	18.2 ± 0.5	moraine boulder	10
92-155	42.91	-109.85	2375	2.5	2.7	1	535000	16050	KNSTD	18.1 ± 0.5	moraine boulder	10
92-129	42.91	-109.85	2390	5	2.7	1	561000	16830	KNSTD	19.1 ± 0.6	moraine boulder	10
92-124	42.91	-109.85	2337	5	2.7	1	503000	15090	KNSTD	17.8 ± 0.5	moraine boulder	10
91-020	42.90	-109.85	2352	5	2.7	1	503000	15090	KNSTD	17.6 ± 0.5	moraine boulder	10
92-127	42.91	-109.85	2335	4	2.7	1	504000	15120	KNSTD	17.7 ± 0.5	moraine boulder	10
92-130	42.91	-109.85	2341	5	2.7	1	541000	16230	KNSTD	19.1 ± 0.6	moraine boulder	10
91-024	42.91	-109.85	2323	10	2.7	1	502000	15060	KNSTD	18.7 ± 0.6	moraine boulder	10
92-125	42.91	-109.85	2341	5	2.7	1	528000	15840	KNSTD	18.6 ± 0.6	moraine boulder	10
91-026	42.91	-109.85	2342	4	2.7	1	468000	14040	KNSTD	16.3 ± 0.5	moraine boulder	10
Erratics												
341-O	43.12	-109	3228	8.0	2.7	0.985	813700	24411	KNSTD	17.0 ± 0.5	erratic	10
343-B	43.12	-109	3226	4.0	2.7	0.985	745000	22350	KNSTD	15.1 ± 0.5	erratic	10
344-E	43.11	-109	3247	2.5	2.7	0.985	652000	19560	KNSTD	12.9 ± 0.4	erratic	10
345-B	43.11	-109	3247	4.0	2.7	0.985	728000	21840	KNSTD	14.6 ± 0.4	erratic	10
Titcomb Lakes moraine												
138-I	43.10	-109.6	3230	4	2.7	0.985	627000	18810	KNSTD	12.7 ± 0.4	moraine boulder	11
139-I	43.10	-109.6	3230	4	2.7	0.985	591000	17730	KNSTD	12.0 ± 0.4	moraine boulder	11
333-I	43.10	-109.6	3230	3	2.7	0.985	596600	17898	KNSTD	12.0 ± 0.4	moraine boulder	11
334-I	43.10	-109.6	3230	3	2.7	0.985	669700	20091	KNSTD	13.5 ± 0.4	moraine boulder	11
335-I	43.10	-109.6	3230	8	2.7	0.985	615700	18471	KNSTD	12.9 ± 0.4	moraine boulder	11
336-I	43.10	-109.6	3230	3	2.7	0.985	656600	19698	KNSTD	13.2 ± 0.4	moraine boulder	11
337-I	43.10	-109.6	3230	9	2.7	0.985	624700	18741	KNSTD	13.2 ± 0.4	moraine boulder	11
338-I	43.10	-109.6	3230	5	2.7	0.985	625100	18753	KNSTD	12.8 ± 0.4	moraine boulder	11

339-I	43.10	-109.6	3230	4	2.7	0.985	623900	18717	KNSTD	12.6 ± 0.4	moraine boulder	11
W Unitas, North Fork Provo, Bear, and Bald Mtn, UT												
NF Provo terminal moraine												
NFP-1	40.59	-111.09	2319	5	2.65	0.9997	322000	16000	KNSTD	12.1 ± 0.6	moraine boulder	12,13
NFP-2B	40.70	-111.09	2327	3	2.65	0.9997	435000	15000	KNSTD	15.9 ± 0.6	moraine boulder	12,13
NFP-3A	40.70	-111.09	2321	6	2.65	0.9997	481000	52000	KNSTD	18.1 ± 2.0	moraine boulder	12,13
NFP-4A	40.59	-111.09	2324	5	2.65	0.9990	473000	13000	NIST_Certified*	17.7 ± 0.5	moraine boulder	12,13
NFP-4B	40.59	-111.09	2324	2.5	2.65	0.9995	391000	19000	KNSTD	14.3 ± 0.7	moraine boulder	12,13
NFP-4C	40.59	-111.09	2324	3	2.65	0.9995	375000	19000	KNSTD	13.8 ± 0.7	moraine boulder	12,13
NFP-4D	40.59	-111.09	2324	3	2.65	0.9990	530000	26000	NIST_Certified*	19.5 ± 1.0	moraine boulder	12,13
NFP-5	40.59	-111.08	2346	3.5	2.65	1	446000	17000	KNSTD	16.2 ± 0.6	moraine boulder	12,13
Bald Mountain												
BMP-2	40.69	-110.9	3277	5	2.65	0.997	678000	19000	NIST_Certified*	14.1 ± 0.4	bedrock	12,13
BMP-4	40.69	-110.9	3280	4	2.65	0.997	685000	15000	NIST_Certified*	14.1 ± 0.3	bedrock	12,13
BMP-5	40.69	-110.91	3250	2.5	2.65	0.998	776000	147000	NIST_Certified*	16.0 ± 3.0	bedrock	12,13
BMP-7	40.69	-110.91	3250	3	2.65	0.998	729000	27000	NIST_Certified*	15.2 ± 0.6	bedrock	12,13

[a] Reported ^{10}Be ages using the global production rate (4.49 ± 0.39 atoms g^{-1} yr^{-1}; normalized to 07KNSTD) and the constanct production scaling scheme of Lal (1991)/Stone (2000).

[b] depth profile consistning of multiple ^{10}Be measurements; see source reference for details.

[c] Al-26 age

NIST_Certified* - We report ^{10}Be concentrations provided by the original authors. Before calculating ^{10}Be ages, the original authors applied a 14% correction to $^{10}Be/^{9}Be$ ratios. See source referenes for details.

References: 1-This study; 2- Schlingden, 2000; 3- Briner, 2009; 4- Guido et al., 2007; 5- Ward et al., 2009; 6- Benson et al., 2005; 7- Licciardi and Pierce, 2008; 8- Licciardi et al., 2001; 9- Licciardi et al., 2004; 10- Gosse et al., 1995a; 11- Gosse et al., 1995b; 12- Refsnider et al., 2008; 13- Laabs et al., 2009

Table DR3. Western US cosmogenic exposure ages

Sample	St	De	Du	Li	St (mag)	NE Li	NE St	NE De	NE Du	NE St (mag)
Lake Creek, CO										
AR09-01	14.7 ± 0.4	14.0 ± 0.4	13.9 ± 0.4	13.6 ± 0.4	14.5 ± 0.4	14.7 ± 0.4	16.7 ± 0.4	14.9 ± 0.4	14.8 ± 0.4	16.3 ± 0.4
AR09-10	13.9 ± 0.4	13.1 ± 0.4	13.1 ± 0.4	12.7 ± 0.4	13.7 ± 0.4	13.8 ± 0.4	15.8 ± 0.4	14.0 ± 0.4	13.9 ± 0.4	15.8 ± 0.4
AR09-11	13.2 ± 0.3	12.3 ± 0.3	12.3 ± 0.3	11.9 ± 0.3	13.0 ± 0.3	12.9 ± 0.3	15.1 ± 0.3	15.1 ± 0.3	15.1 ± 0.3	15.4 ± 0.3
DC-91-2	19.7 ± 0.5	18.6 ± 0.5	18.4 ± 0.5	18.0 ± 0.5	19.2 ± 0.5	19.5 ± 0.6	22.4 ± 0.6	19.8 ± 0.6	19.5 ± 0.6	21.6 ± 0.6
Clear Creek, CO										
MF06-01	19.5 ± 0.6	18.3 ± 0.6	18.1 ± 0.6	17.8 ± 0.6	19.0 ± 0.6	19.2 ± 0.7	22.2 ± 0.7	19.5 ± 0.7	19.2 ± 0.7	21.3 ± 0.7
MF06-02	19.3 ± 0.4	18.1 ± 0.4	18.0 ± 0.4	17.6 ± 0.4	18.8 ± 0.4	19.0 ± 0.5	22.0 ± 0.5	19.3 ± 0.5	19.1 ± 0.5	21.2 ± 0.5
MF06-03	21.7 ± 0.6	20.2 ± 0.6	20.0 ± 0.6	19.7 ± 0.6	21.0 ± 0.6	21.2 ± 0.6	24.7 ± 0.6	21.5 ± 0.6	21.2 ± 0.6	23.6 ± 0.6
MF06-04	19.1 ± 0.4	17.9 ± 0.4	17.7 ± 0.4	17.4 ± 0.4	18.6 ± 0.4	18.8 ± 0.4	21.7 ± 0.4	19.1 ± 0.4	18.8 ± 0.4	20.9 ± 0.4
MF06-05	15.2 ± 0.4	14.4 ± 0.4	14.4 ± 0.4	14.0 ± 0.4	15.0 ± 0.4	15.2 ± 0.5	17.4 ± 0.5	15.4 ± 0.5	15.2 ± 0.5	16.9 ± 0.5
AR09-03	14.1 ± 0.3	13.6 ± 0.3	13.5 ± 0.3	13.2 ± 0.3	14.0 ± 0.3	14.3 ± 0.3	16.1 ± 0.3	14.5 ± 0.3	14.4 ± 0.3	15.7 ± 0.3
Pine Creek, CO										
PC1	20.9 ± 0.5	19.5 ± 0.5	19.3 ± 0.5	18.9 ± 0.5	20.3 ± 0.5	20.4 ± 0.6	23.8 ± 0.6	20.7 ± 0.6	20.5 ± 0.6	22.8 ± 0.6
PC2	13.5 ± 0.4	12.8± 0.4	12.8± 0.4	12.5± 0.4	13.3 ± 0.4	13.5 ± 0.5	15.4 ± 0.5	13.7 ± 0.5	13.6 ± 0.5	15.0 ± 0.5
PC3	15.6 ± 0.4	14.8 ± 0.4	14.7 ± 0.4	14.4 ± 0.4	15.3 ± 0.4	15.6 ± 0.5	17.8 ± 0.5	15.8 ± 0.5	15.6 ± 0.5	17.2 ± 0.5
PC4	22.4 ± 0.5	20.9 ± 0.5	20.7 ± 0.5	20.3 ± 0.5	21.7 ± 0.5	21.9 ± 0.6	25.5 ± 0.6	22.3 ± 0.6	21.9 ± 0.6	24.3 ± 0.6
PC5	24.5 ± 0.7	22.9 ± 0.7	22.6 ± 0.7	22.3 ± 0.7	23.6 ± 0.7	24.0 ± 0.8	28.0 ± 0.8	24.4 ± 0.8	24.0 ± 0.8	26.6 ± 0.8
PC6	16.0 ± 0.4	15.3 ± 0.4	15.2 ± 0.4	14.9 ± 0.4	15.8 ± 0.4	16.0 ± 0.4	18.3 ± 0.4	16.2 ± 0.4	16.1 ± 0.4	17.7 ± 0.4
PC7	22.8 ± 0.5	21.4 ± 0.5	21.1 ± 0.5	20.8 ± 0.5	22.1 ± 0.5	22.4 ± 0.6	26.0 ± 0.6	22.7 ± 0.6	22.4 ± 0.6	24.8 ± 0.6
PC8	21.3 ± 0.4	20.1 ± 0.4	19.8 ± 0.4	19.5 ± 0.4	20.7 ± 0.4	21.0 ± 0.5	24.3 ± 0.5	21.3 ± 0.5	21.0 ± 0.5	23.3 ± 0.5
PC9	15.4 ± 0.4	14.7 ± 0.4	14.6 ± 0.4	14.3 ± 0.4	15.1 ± 0.4	15.5 ± 0.4	17.5 ± 0.4	15.7 ± 0.4	15.5 ± 0.4	17.0 ± 0.4
PC11	15.3 ± 0.4	14.7 ± 0.4	14.6 ± 0.4	14.3 ± 0.4	15.1 ± 0.4	15.4 ± 0.4	17.5 ± 0.4	15.6 ± 0.4	15.5 ± 0.4	17.0 ± 0.4
PC12	16.2 ± 0.4	15.6 ± 0.4	15.5 ± 0.4	15.2 ± 0.4	16.0 ± 0.4	16.4 ± 0.4	18.5 ± 0.4	16.6 ± 0.4	16.4 ± 0.4	18.0 ± 0.4
PC13	16.1 ± 0.4	15.5 ± 0.4	15.4 ± 0.4	15.1 ± 0.4	15.8 ± 0.4	16.3 ± 0.4	18.4 ± 0.4	16.5 ± 0.4	16.3 ± 0.4	17.8 ± 0.4
AR09-07	15.6 ± 0.4	14.8 ± 0.4	14.7 ± 0.4	14.4 ± 0.4	15.3 ± 0.4	15.5 ± 0.5	17.7 ± 0.5	15.7 ± 0.5	15.6 ± 0.5	17.2 ± 0.5
AR09-08	15.3 ± 0.3	14.6 ± 0.3	14.5 ± 0.3	14.2 ± 0.3	15.1 ± 0.3	15.3 ± 0.4	17.5 ± 0.4	15.5 ± 0.4	15.4 ± 0.4	17.0 ± 0.4
ARK River valley, CO, Lower flood terrace										
QPOY-01	17.3 ± 0.4	16.7 ± 0.4	16.6 ± 0.4	16.3 ± 0.4	17.0 ± 0.4	17.6 ± 0.5	19.7 ± 0.5	17.8 ± 0.5	17.6 ± 0.5	19.1 ± 0.5
QPOY-02	17.2 ± 0.8	16.6 ± 0.8	16.5 ± 0.8	16.2 ± 0.8	16.9 ± 0.8	17.4 ± 0.1	19.6 ± 0.1	17.7 ± 0.1	17.5 ± 0.1	19.0 ± 0.1
AR09-05	18.4 ± 0.4	17.8 ± 0.4	17.6± 0.4	17.3 ± 0.4	18.0 ± 0.4	18.7 ± 0.4	20.9 ± 0.4	18.9 ± 0.4	18.7 ± 0.4	20.2 ± 0.4
AR09-06	18.1 ± 0.4	17.5 ± 0.4	17.3 ± 0.4	17.0 ± 0.4	17.7 ± 0.4	18.4 ± 0.5	20.6 ± 0.5	18.6 ± 0.5	18.4 ± 0.5	19.9 ± 0.5
ARK River valley, CO, Upper flood terrace										
QPOO-2	19.1 ± 0.8	18.3 ± 0.8	18.2 ± 0.8	17.9 ± 0.8	18.6 ± 0.8	19.3 ± 0.9	21.8 ± 0.9	19.5 ± 0.9	19.3 ± 0.9	20.9 ± 0.9
QPOO-4	20.9 ± 1.0	20.0 ± 1.0	19.8 ± 1.0	19.4 ± 1.0	20.3 ± 1.0	21.0 ± 1.1	23.8 ± 1.1	21.3 ± 1.1	21.0 ± 1.1	22.8 ± 1.1
QPOO-01	19.1 ± 0.6	18.4 ± 0.6	18.2 ± 0.6	17.9 ± 0.6	18.7 ± 0.6	19.3 ± 0.7	21.8 ± 0.7	19.6 ± 0.7	19.3 ± 0.7	21.0 ± 0.7
QPOO-03	19.3 ± 0.5	18.5 ± 0.5	18.4 ± 0.5	18.1 ± 0.5	18.9 ± 0.5	19.5 ± 0.5	22.0 ± 0.5	19.7 ± 0.5	19.5 ± 0.5	21.2 ± 0.5
Animas Valley, CO										
Baker's Ridge	17.5 ± 0.4	17.4 ± 0.4	17.3 ± 0.4	17.0 ± 0.4	17.1 ± 0.4	18.3 ± 0.5	19.9 ± 0.5	18.5 ± 0.5	18.3 ± 0.5	19.3 ± 0.5

Tacoma	14.6 ± 0.5	14.5 ± 0.5	14.4 ± 0.5	14.2 ± 0.5	14.4 ± 0.5	15.3 ± 0.6	16.6 ± 0.6	15.35± 0.6	15.3 ± 0.6	16.2 ± 0.6
Needleton	15.3 ± 0.4	15.0 ± 0.4	14.9 ± 0.4	14.6 ± 0.4	15.0 ± 0.4	15.7 ± 0.4	17.4 ± 0.4	15.9 ± 0.4	15.8 ± 0.4	16.9 ± 0.4
Silverton	14.3 ± 0.4	13.8 ± 0.4	13.7 ± 0.4	13.4 ± 0.4	14.1 ± 0.4	14.5 ± 0.4	16.3 ± 0.4	14.7 ± 0.4	14.6 ± 0.4	15.8 ± 0.4
Highland Mary Lake	12.6 ± 0.5	11.4 ± 0.5	11.4 ± 0.5	11.0 ± 0.5	12.4 ± 0.5	12.0 ± 0.5	14.4 ± 0.5	12.2 ± 0.5	12.1 ± 0.5	14.0 ± 0.5
Elk Crek	15.6 ± 0.4	13.9 ± 0.4	13.8 ± 0.4	13.5 ± 0.4	15.2 ± 0.4	14.5 ± 0.5	17.8 ± 0.5	14.8 ± 0.5	14.7 ± 0.5	17.1 ± 0.5
terminal outwash profile[a]	19.4 ± 1.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
Middle Boulder Creek, CO										
Terminal moraine										
99-t74[b]	17.8 ± 0.9	16.7 ± 0.9	16.6 ± 0.9	16.2 ± 0.9	17.4 ± 0.9	17.5 ± 1.9	20.3 ± 1.9	17.7 ± 1.9	17.6 ± 1.9	19.6 ± 1.9
99-t76	20.6 ± 0.5	19.2 ± 0.5	19.0 ± 0.5	18.7 ± 0.5	20.1 ± 0.5	20.2 ± 0.6	23.5 ± 0.6	20.5 ± 0.6	20.2 ± 0.6	22.6 ± 0.6
99-t76[b]	20.5 ± 1.0	19.1 ± 1.0	18.9 ± 1.0	18.5 ± 1.0	19.9 ± 1.0	20.0 ± 1.1	23.3 ± 1.1	20.3 ± 1.1	20.1 ± 1.1	22.4 ± 1.1
MB4J-0	18.2 ± 1.7	17.5 ± 1.7	17.4 ± 1.7	17.1 ± 1.7	17.9 ± 1.7	18.4 ± 1.9	20.7 ± 1.9	18.6 ± 1.9	18.4 ± 1.9	20.1 ± 1.9
Upvalley bedrock										
33-JB-25	12.5 ± 0.4	11.7 ± 0.4	11.7 ± 0.4	11.3 ± 0.4	12.5 ± 0.4	12.3 ± 0.5	14.3 ± 0.5	12.5 ± 0.5	12.4 ± 0.5	13.9 ± 0.5
GP4J-1	13.5 ± 0.4	12.2 ± 0.4	12.2 ± 0.4	11.8 ± 0.4	13.5 ± 0.4	12.8 ± 0.5	15.4 ± 0.5	13.1 ± 0.5	13.0 ± 0.5	15.0 ± 0.5
GP4J-2	13.8 ± 0.4	12.5 ± 0.4	12.5 ± 0.4	12.1 ± 0.4	13.8 ± 0.4	13.1 ± 0.5	15.7 ± 0.5	13.4 ± 0.5	13.3 ± 0.5	15.3 ± 0.5
GP4J-3	13.6 ± 0.5	12.3 ± 0.5	12.3 ± 0.5	11.9 ± 0.5	13.6 ± 0.5	12.9 ± 0.6	15.4 ± 0.6	13.1 ± 0.6	13.0 ± 0.6	15.1 ± 0.6
GP4J-4	13.4 ± 0.4	12.2 ± 0.4	12.3 ± 0.4	11.8 ± 0.4	13.4 ± 0.4	12.8 ± 0.5	15.3 ± 0.5	13.0 ± 0.5	13.0 ± 0.5	14.9 ± 0.5
GP4J-5	13.2 ± 0.4	12.0 ± 0.4	12.0 ± 0.4	11.6 ± 0.4	13.2 ± 0.4	12.6 ± 0.5	15.1 ± 0.5	12.8 ± 0.5	12.8 ± 0.5	14.7 ± 0.5
GP4J-6	13.3 ± 0.5	12.1 ± 0.5	12.1 ± 0.5	11.7 ± 0.5	13.3 ± 0.5	12.7 ± 0.6	15.1 ± 0.6	12.9 ± 0.6	12.8 ± 0.6	14.8 ± 0.6
GP4J-7	12.0 ± 0.4	11.0 ± 0.4	10.9 ± 0.4	10.6 ± 0.4	12.0 ± 0.4	11.5 ± 0.4	13.7 ± 0.4	11.7 ± 0.4	11.7 ± 0.4	13.4 ± 0.4
GP4J-10	13.8 ± 0.4	13.2 ± 0.4	13.1 ± 0.4	12.8 ± 0.4	13.8 ± 0.4	13.8 ± 0.4	15.8 ± 0.4	14.0 ± 0.4	13.9 ± 0.4	15.4 ± 0.4
GP4J-11	13.1 ± 0.5	12.3 ± 0.5	12.3 ± 0.5	11.9 ± 0.5	13.1 ± 0.5	12.9 ± 0.5	14.9 ± 0.5	13.1 ± 0.5	13.0 ± 0.5	14.6 ± 0.5
GP4J-23	17.8 ± 0.6	17.0 ± 0.6	16.9 ± 0.6	16.6 ± 0.6	17.8 ± 0.6	17.9 ± 0.7	20.3 ± 0.7	18.1 ± 0.7	17.9 ± 0.7	19.7 ± 0.7
Jenny Lake, WY										
Outer Jenny Lake moraine										
OJEN-1	14.1 ± 0.3	14.1 ± 0.3	14.1 ± 0.3	13.7 ± 0.3	14.0 ± 0.3	14.8 ± 0.3	16.0 ± 0.3	15.0 ± 0.3	14.9 ± 0.3	15.8 ± 0.3
OJEN-2	15.0 ± 0.4	15.0 ± 0.4	15.0 ± 0.4	14.6 ± 0.4	14.9 ± 0.4	15.7 ± 0.4	17.1 ± 0.4	15.9 ± 0.4	15.9 ± 0.4	16.8 ± 0.4
OJEN-3	13.4 ± 0.3	13.4 ± 0.3	13.4 ± 0.3	13.1 ± 0.3	13.3 ± 0.3	14.1 ± 0.4	15.2 ± 0.4	14.3 ± 0.4	14.2 ± 0.4	15.1 ± 0.4
OJEN-5	14.4 ± 0.3	14.4 ± 03	14.3 ± 03	14.0 ± 03	14.3 ± 03	15.1 ± 0.4	16.4 ± 0.4	15.3 ± 0.4	15.2 ± 0.4	16.1 ± 0.4
OJEN-6	15.4 ± 0.4	15.3 ± 0.4	15.3 ± 0.4	15.0 ± 0.4	15.3 ± 0.4	16.1 ± 0.4	17.5 ± 0.4	16.3 ± 0.4	16.3 ± 0.4	17.2 ± 0.4
OJEN-7	15.1 ± 0.4	15.1 ± 0.4	15.1 ± 0.4	14.7 ± 0.4	15.0 ± 0.4	15.9 ± 0.4	17.2 ± 0.4	16.1 ± 0.4	16.0 ± 0.4	16.9 ± 0.4
OJEN-8	14.4 ± 0.4	14.5 ± 0.4	14.4 ± 0.4	14.1 ± 0.4	14.4 ± 0.4	15.2 ± 0.4	16.5 ± 0.4	15.4 ± 0.4	15.3 ± 0.4	16.2 ± 0.4
OJEN-9	15.3 ± 0.4	15.2 ± 0.4	15.2 ± 0.4	14.9 ± 0.4	15.2 ± 0.4	16.0 ± 0.4	17.4 ± 0.4	16.2 ± 0.4	16.2 ± 0.4	17.1 ± 0.4
OJEN-10	13.5 ± 0.3	13.5 ± 0.3	13.5 ± 0.3	13.1 ± 0.3	13.4 ± 0.3	14.2 ± 0.4	15.3 ± 0.4	14.4 ± 0.4	14.3 ± 0.4	15.1 ± 0.4
OJEN-11	15.0 ± 0.6	15.0 ± 0.6	15.0 ± 0.6	14.6 ± 0.6	14.9 ± 0.6	15.8 ± 0.6	17.1 ± 0.6	16.0 ± 0.6	15.9 ± 0.6	16.8 ± 0.6
Inner Jenny Lake moraine										
IJEN-1	13.2 ± 0.3	13.3 ± 0.3	13.2 ± 0.3	12.9 ± 0.3	13.2 ± 0.3	14.0 ± 0.4	15.0 ± 0.4	14.1 ± 0.4	14.1 ± 0.4	14.9 ± 0.4
IJEN-2	12.6 ± 0.4	12.7 ± 0.4	12.7 ± 0.4	12.3 ± 0.4	12.6 ± 0.4	13.3 ± 0.4	14.4 ± 0.4	13.5 ± 0.4	13.5 ± 0.4	14.2 ± 0.4
IJEN-3	14.0 ± 0.3	14.0 ± 0.3	14.0 ± 0.3	13.7 ± 0.3	14.0 ± 0.3	14.8 ± 0.4	16.0 ± 0.4	14.9 ± 0.4	14.9 ± 0.4	15.7 ± 0.4
IJEN-5	11.7 ± 0.3	11.7 ± 0.3	11.7 ± 0.3	11.4 ± 0.3	11.6 ± 0.3	12.3 ± 0.4	13.3 ± 0.4	12.5 ± 0.4	12.4 ± 0.4	13.1 ± 0.4
IJEN-6	14.2 ± 0.2	14.2 ± 0.2	14.2 ± 0.2	13.8 ± 0.2	14.1 ± 0.2	15.0 ± 0.4	16.2 ± 0.4	15.1 ± 0.4	15.1 ± 0.4	15.9 ± 0.4
IJEN-7	12.9 ± 0.3	13.0 ± 0.3	13.0 ± 0.3	12.6 ± 0.6	12.9 ± 0.3	13.7 ± 0.4	14.7 ± 0.4	13.8 ± 0.4	13.8 ± 0.4	14.6 ± 0.4

IJEN-11	15.0 ± 0.4	15.0 ± 0.4	15.0 ± 0.4	14.6 ± 0.4	15.0 ± 0.4	15.8 ± 0.4	17.1 ± 0.4	16.0 ± 0.4	15.9 ± 0.4	16.8 ± 0.4
IJEN-13	14.2 ± 0.3	14.2 ± 0.3	14.2 ± 0.3	13.8 ± 0.3	14.2 ± 0.3	14.9 ± 0.4	16.2 ± 0.4	15.1 ± 0.4	15.1 ± 0.4	15.9 ± 0.4
Upvalley										
BED-1	13.8 ± 0.3	13.4 ± 0.3	13.4 ± 0.3	13.0 ± 0.3	13.7 ± 0.3	14.1 ± 0.4	15.7 ± 0.4	14.3 ± 0.4	14.2 ± 0.4	15.5 ± 0.4
BED-2	14.8 ± 0.3	14.7 ± 0.3	14.7 ± 0.3	14.3 ± 0.3	14.7 ± 0.3	15.4 ± 0.3	16.8 ± 0.3	15.6 ± 0.3	15.6 ± 0.3	16.6 ± 0.3
LS-1	12.5 ± 0.3	12.0 ± 0.3	12.0 ± 0.3	11.6 ± 0.3	12.4 ± 0.3	12.6 ± 0.3	14.2 ± 0.3	12.8 ± 0.3	12.7 ± 0.3	14.0 ± 0.3
LS-7	13.5 ± 0.3	13.0 ± 0.3	13.0 ± 0.3	12.6 ± 0.3	13.4 ± 0.3	13.6 ± 0.5	15.4 ± 0.5	13.8 ± 0.5	13.8 ± 0.5	15.2 ± 0.5
LS-8	12.3 ± 0.3	11.9 ± 0.3	11.9 ± 0.3	11.5 ± 0.3	12.3 ± 0.3	12.5 ± 0.3	14.1 ± 0.3	12.7 ± 0.3	12.6 ± 0.3	13.9 ± 0.3
NW Yellowstone, MT, WY										
Eightmile terminal moraine										
8-B2	14.8 ± 1.0	15.2 ± 1.0	15.3 ± 1.0	14.8 ± 1.0	14.9 ± 1.0	16.0 ± 1.1	16.9 ± 1.1	16.2 ± 1.1	16.2 ± 1.1	16.7 ± 1.1
8-D1	16.0 ± 0.9	16.5 ± 0.9	16.5 ± 0.9	16.0 ± 0.9	16.0 ± 0.9	17.3 ± 1.0	18.3 ± 1.0	17.5 ± 1.0	17.5 ± 1.0	18.1 ± 1.0
8-F2	17.6 ± 1.6	18.0 ± 1.6	18.0 ± 1.6	17.5 ± 1.6	17.5 ± 1.6	18.9 ± 1.8	20.0 ± 1.8	19.1 ± 1.8	19.1 ± 1.8	19.8 ± 1.8
8-G2	19.2 ± 1.6	19.6 ± 1.6	19.6 ± 1.6	19.1 ± 1.6	19.1 ± 1.6	20.6 ± 1.8	21.9 ± 1.8	20.9 ± 1.8	20.9 ± 1.8	21.5 ± 1.8
8-I1&I2	16.5 ± 0.7	17.0 ± 0.7	17.0 ± 0.7	16.5 ± 0.7	16.5 ± 0.7	17.8 ± 0.8	18.8 ± 0.8	18.1 ± 0.8	18.0 ± 0.8	18.6 ± 0.8
8-J1&J2	17.0 ± 1.4	17.4 ± 1.4	17.4 ± 1.4	17.9 ± 1.4	16.9 ± 1.4	18.3 ± 1.6	19.3 ± 1.6	18.5 ± 1.6	18.5 ± 1.6	19.1 ± 1.6
8-K1	16.9 ± 0.6	17.3 ± 0.6	17.3 ± 0.6	16.9 ± 0.6	16.9 ± 0.6	18.2 ± 0.7	19.2 ± 0.7	18.4 ± 0.7	18.4 ± 0.7	19.0 ± 0.7
8-L1&L2	15.6 ± 0.7	16.0 ± 0.7	16.0 ± 0.7	15.6 ± 0.7	15.6 ± 0.7	16.8 ± 0.8	17.7 ± 0.8	17.0 ± 0.8	17.0 ± 0.8	17.5 ± 0.8
8-M2	15.9 ± 0.6	16.3 ± 0.6	16.4 ± 0.6	15.9 ± 0.6	15.9 ± 0.6	17.2 ± 0.7	18.1 ± 0.7	17.4 ± 0.7	17.4 ± 0.7	17.9 ± 0.7
Chico moraines										
CH-1A	14.3 ± 1.2	14.7 ± 1.2	14.7 ± 1.2	14.3 ± 1.2	14.3 ± 1.2	15.4 ± 1.4	16.3 ± 1.1	15.6 ± 1.1	15.6 ± 1.1	16.1 ± 1.1
CH-2A	15.5 ± 1.0	15.9 ± 1.0	15.9 ± 1.0	15.5 ± 1.0	15.5 ± 1.0	16.7 ± 1.1	17.7 ± 1.0	16.9 ± 1.0	16.9 ± 1.0	17.5 ± 1.0
CH-3B	15.8 ± 1.4	16.1 ± 1.4	16.1 ± 1.4	15.7 ± 1.4	15.7 ± 1.4	16.9 ± 1.6	18.0 ± 1.8	17.1 ± 1.8	17.1 ± 1.8	17.7 ± 1.8
CH-6A	14.3 ± 1.2	14.7 ± 1.2	14.7 ± 1.2	14.4 ± 1.2	14.4 ± 1.2	15.5 ± 1.4	16.3 ± 1.8	15.7 ± 1.8	15.7 ± 1.8	16.2 ± 1.8
CH-6B	13.5 ± 1.5	13.8 ± 1.5	13.9 ± 1.5	13.5 ± 1.5	13.5 ± 1.5	14.6 ± 1.7	15.3 ± 0.8	14.7 ± 0.8	14.7 ± 0.8	15.2 ± 0.8
CH-8A	17.6 ± 1.0	18.0 ± 1.0	18.0 ± 1.0	17.5 ± 1.0	17.6 ± 1.0	18.9 ± 1.2	20.1 ± 1.6	19.1 ± 1.6	19.1 ± 1.6	19.8 ± 1.6
CH-9B	16.8 ± 1.2	17.2 ± 1.2	17.2 ± 1.2	16.7 ± 1.2	16.78± 1.2	18.0 ± 1.3	19.1 ± 0.7	18.3 ± 0.7	18.3 ± 0.7	18.3 ± 0.7
CH-10B	18.8 ± 1.1	19.2 ± 1.1	19.2 ± 1.1	18.7 ± 1.1	18.7 ± 1.1	20.1 ± 1.2	21.4 ± 0.8	20.4 ± 0.8	20.4 ± 0.8	21.1 ± 0.8
CH-11B	16.0 ± 0.8	16.4 ± 0.8	16.4 ± 0.8	16.0 ± 0.8	16.0 ± 0.8	17.2 ± 0.9	18.2 ± 0.7	17.4 ± 0.7	17.4 ± 0.7	18.0 ± 0.7
Deckards Flats moraine										
DF-1A	14.0 ± 0.6	14.3 ± 0.6	14.3 ± 0.6	13.9 ± 0.6	14.1 ± 0.6	15.0 ± 0.7	16.0 ± 0.7	15.2 ± 0.7	15.2 ± 0.7	15.8 ± 0.7
DF-2B	12.8 ± 1.2	13.0 ± 1.2	13.0 ± 1.2	12.7 ± 1.2	12.8 ± 1.2	13.8 ± 1.4	14.6 ± 1.4	13.9 ± 1.4	13.9 ± 1.4	14.5 ± 1.4
DF-3B	13.4 ± 0.9	13.6 ± 0.9	13.7 ± 0.9	13.3 ± 0.9	13.4 ± 0.9	14.4 ± 1.0	15.3 ± 1.0	14.5 ± 1.0	14.5 ± 1.0	15.1 ± 1.0
DF-4A	12.6 ± 1.1	12.9 ± 1.1	12.9 ± 1.1	12.6 ± 1.1	12.7 ± 1.1	13.6 ± 1.2	14.4 ± 1.2	13.7 ± 1.2	13.7 ± 1.2	14.3 ± 1.2
DF-5B	16.3 ± 0.7	16.5 ± 0.7	16.5 ± 0.7	16.1 ± 0.7	16.3 ± 0.7	17.4 ± 0.8	18.6 ± 0.8	17.6 ± 0.8	17.6 ± 0.8	18.3 ± 0.8
DF-6A	13.7 ± 0.7	13.9 ± 0.7	13.9 ± 0.7	13.5 ± 0.7	13.7 ± 0.7	14.6 ± 0.8	15.5 ± 0.8	14.8 ± 0.8	14.8 ± 0.8	15.4 ± 0.8
DF-6B	15.1 ± 1.1	15.3 ± 1.1	15.3 ± 1.1	15.0 ± 1.1	15.1 ± 1.1	16.1 ± 1.3	17.2 ± 1.3	16.3 ± 1.3	16.3 ± 1.3	17.0 ± 1.3
DF-7A	14.5 ± 0.8	14.8 ± 0.8	14.8 ± 0.8	14.4 ± 0.8	14.5 ± 0.8	15.5 ± 0.9	16.5 ± 0.9	15.7 ± 0.9	15.7 ± 0.9	16.4 ± 0.9
DF-8A	15.3 ± 0.9	15.5 ± 0.9	15.5 ± 0.9	15.1 ± 0.9	15.3 ± 0.9	16.3 ± 1.0	17.4 ± 1.0	16.5 ± 1.0	16.5 ± 1.0	17.2 ± 1.0
DF-9B	13.4 ± 0.5	13.6 ± 0.5	13.6 ± 0.5	13.3 ± 0.5	13.4 ± 0.5	14.3 ± 0.6	15.2 ± 0.6	14.5 ± 0.6	14.5 ± 0.6	15.1 ± 0.6
DF-10A	15.2 ± 1.9	15.5 ± 1.9	15.5 ± 1.9	15.1 ± 1.9	15.2 ± 1.9	16.3 ± 2.1	17.4 ± 2.1	16.5 ± 2.1	16.4 ± 2.1	17.2 ± 2.1
Junction Butte moraine										

JB-1	14.7 ± 0.3	14.8 ± 0.3	14.7 ± 0.3	14.7 ± 0.3	14.7 ± 0.3	15.5 ± 0.4	16.7 ± 0.4	15.7 ± 0.4	15.7 ± 0.4	16.5 ± 0.4
JB-2	14.3 ± 0.3	14.5 ± 0.3	14.3 ± 0.3	14.3 ± 0.3	14.3 ± 0.3	15.2 ± 0.4	16.3 ± 0.4	15.4 ± 0.4	15.4 ± 0.4	16.1 ± 0.4
JB-4	14.1 ± 0.3	14.3 ± 0.3	14.1 ± 0.3	14.1 ± 0.3	14.1 ± 0.3	15.0 ± 0.3	16.1 ± 0.3	15.2 ± 0.3	15.2 ± 0.3	15.9 ± 0.3
JB-7	14.2 ± 0.3	14.4 ± 0.3	14.2 ± 0.3	14.2 ± 0.3	14.2 ± 0.3	15.1 ± 0.4	16.2 ± 0.4	15.3 ± 0.4	15.3 ± 0.4	16.0 ± 0.4
JB-8	13.0 ± 0.4	13.2 ± 0.4	13.0 ± 0.4	13.0 ± 0.4	13.0 ± 0.4	13.8 ± 0.4	14.8 ± 0.4	14.0 ± 0.4	14.0 ± 0.4	14.7 ± 0.4
JB-11	14.4 ± 0.4	14.5 ± 0.4	14.4 ± 0.4	14.4 ± 0.4	14.4 ± 0.4	15.3 ± 0.4	16.4 ± 0.4	15.5 ± 0.4	15.5 ± 0.4	16.2 ± 0.4
Wallowa, OR										
TTO terminal moraine										
TTO-2B	21.0 ± 0.9	21.4 ± 0.9	21.4 ± 0.9	20.8 ± 0.9	20.8 ± 0.9	22.5 ± 1.1	23.9 ± 1.1	22.8 ± 1.1	22.8 ± 1.1	23.5 ± 1.1
TTO-3B	21.7 ± 0.7	22.1 ± 0.7	22.1 ± 0.7	21.5 ± 0.7	21.5 ± 0.7	23.2 ± 0.8	24.7 ± 0.8	23.5 ± 0.8	23.5 ± 0.8	24.2 ± 0.8
TTO-7A	21.7 ± 1.6	22.1 ± 1.6	22.1 ± 1.6	21.5 ± 1.6	21.5 ± 1.6	23.2 ± 1.8	24.7 ± 1.8	23.5 ± 1.8	23.5 ± 1.8	24.3 ± 1.8
TTO-9B	20.7 ± 1.2	21.1 ± 1.2	21.2 ± 1.2	20.6 ± 1.2	20.6 ± 1.2	22.2 ± 1.3	23.6 ± 1.3	22.5 ± 1.3	22.5 ± 1.3	23.2 ± 1.3
TTO-10B	23.1 ± 1.4	23.5 ± 1.4	23.5 ± 1.4	22.8 ± 1.4	23.9 ± 1.4	24.6 ± 1.6	26.3 ± 1.6	25.0 ± 1.6	25.0 ± 1.6	25.7 ± 1.6
TTO-11A	22.3 ± 1.3	22.8 ± 1.3	22.8 ± 1.3	22.2 ± 1.3	22.1 ± 1.3	23.9 ± 1.4	25.4 ± 1.4	24.2 ± 1.4	24.2 ± 1.4	24.9 ± 1.4
TTY end moraine										
TTY-1B	16.7 ± 1.0	17.2 ± 1.0	17.2 ± 1.0	16.7 ± 1.0	16.7 ± 1.0	18.0 ± 1.2	19.1 ± 1.2	18.3 ± 1.2	18.3 ± 1.2	18.8 ± 1.2
TTY-3B	17.0 ± 1.4	17.5 ± 1.4	17.5 ± 1.4	17.0 ± 1.4	17.0 ± 1.4	18.4 ± 1.6	19.4 ± 1.6	18.6 ± 1.6	18.6 ± 1.6	19.2 ± 1.6
TTY-6A	16.6 ± 1.2	17.0 ± 1.2	17.0 ± 1.2	16.6 ± 1.2	16.5 ± 1.2	17.9 ± 1.4	18.9 ± 1.4	18.1 ± 1.4	18.1 ± 1.4	18.6 ± 1.4
TTY-8A	21.7 ± 1.6	22.1 ± 1.6	22.2 ± 1.6	21.6 ± 1.6	21.6 ± 1.6	23.2 ± 1.8	24.7 ± 1.8	23.6 ± 1.8	23.6 ± 1.8	24.3 ± 1.8
TTY-10B	20.9 ± 1.4	21.4 ± 1.4	21.4 ± 1.4	20.8 ± 1.4	20.8 ± 1.4	22.4 ± 1.6	23.8 ± 1.8	22.7 ± 1.6	22.7 ± 1.6	23.4 ± 1.8
TTY-12B	20.6 ± 1.1	21.0 ± 1.1	21.0 ± 1.1	20.4 ± 1.1	20.4 ± 1.1	22.1 ± 1.3	23.4 ± 1.3	22.3 ± 1.3	22.3 ± 1.3	23.0 ± 1.3
TTY-13B	16.9 ± 0.7	17.4 ± 0.7	17.5 ± 0.7	17.0 ± 0.7	16.9 ± 0.7	18.4 ± 0.8	19.3 ± 0.8	18.6 ± 0.8	18.6 ± 0.8	19.1 ± 0.8
WTO end moraine										
WTO-1B	17.7 ± 0.8	18.2 ± 0.8	18.2 ± 0.8	17.7 ± 0.8	17.7 ± 0.8	19.1 ± 1.0	20.1 ± 1.0	19.3 ± 1.0	19.3 ± 1.0	19.9 ± 1.0
WTO-1C	18.8 ± 0.8	19.3 ± 0.8	19.4 ± 0.8	18.8 ± 0.8	18.8 ± 0.8	20.3 ± 1.0	21.5 ± 1.0	20.6 ± 1.0	20.6 ± 1.0	21.2 ± 1.0
WTO-3B	16.0 ± 0.9	16.5 ± 0.9	16.6 ± 0.9	16.1 ± 0.9	16.1 ± 0.9	17.4 ± 1.0	18.3 ± 1.0	17.6 ± 1.0	17.6 ± 1.0	18.1 ± 1.0
WTO-4A	18.1 ± 0.8	18.6 ± 0.8	18.6 ± 0.8	18.1 ± 0.8	18.1 ± 0.8	19.5 ± 0.9	20.6 ± 0.9	19.8 ± 0.9	19.8 ± 0.9	20.3 ± 0.9
WTO-5A	17.2 ± 0.6	17.7 ± 0.6	17.8 ± 0.6	17.3 ± 0.6	17.2 ± 0.6	18.7 ± 0.7	19.6 ± 0.7	18.9 ± 0.7	18.9 ± 0.7	19.4 ± 0.7
WTO-9B	16.5 ± 1.0	17.1 ± 1.0	17.1 ± 1.0	16.7 ± 1.0	16.5 ± 1.0	18.0 ± 1.2	18.8 ± 1.2	18.2 ± 1.2	18.2 ± 1.2	18.6 ± 1.2
Glacier Lake moraine										
GL-1	10.5 ± 0.4	10.3 ± 0.4	10.4 ± 0.4	10.0 ± 0.4	10.5 ± 0.4	10.8 ± 0.5	12.0 ± 0.5	11.0 ± 0.5	11.0 ± 0.5	11.9 ± 0.5
GL-3	8.7 ± 0.3	8.6 ± 0.3	8.6 ± 0.3	8.3 ± 0.3	8.7 ± 0.3	9.0 ± 0.4	9.9 ± 0.4	9.2 ± 0.4	9.2 ± 0.4	9.8 ± 0.4
GL-5	9.5 ± 0.6	9.4 ± 0.6	9.4 ± 0.6	9.0 ± 0.6	9.5 ± 0.6	9.8 ± 0.7	10.8 ± 0.7	10.0 ± 0.7	10.0 ± 0.7	10.7 ± 0.7
GL-5C	10.2 ± 0.6	10.1 ± 0.6	10.1 ± 0.6	9.7 ± 0.6	10.2 ± 0.6	10.5 ± 0.6	11.6 ± 0.6	10.7 ± 0.6	10.7 ± 0.6	11.5 ± 0.6
GL-6C	12.4 ± 1.0	12.2 ± 1.0	12.2 ± 1.0	11.8 ± 1.0	12.4 ± 1.0	12.8 ± 1.2	14.1 ± 1.2	13.0 ± 1.2	13.0 ± 1.2	14.0 ± 1.2
GL-7B	10.2 ± 0.6	10.0 ± 0.6	10.1 ± 0.6	9.7 ± 0.6	10.2 ± 0.6	10.5 ± 0.6	11.6 ± 0.6	10.7 ± 0.6	10.7 ± 0.6	11.5 ± 0.6
Gl-7C	10.0 ± 0.9	9.8 ± 0.9	9.9 ± 0.9	9.5 ± 0.9	10.0 ± 0.9	10.3 ± 1.1	11.4 ± 1.1	10.5 ± 1.1	10.5 ± 1.1	11.3 ± 1.1
Fremont/Titcomb, WRR, Wymoing										
Fremont terminal moraine										
92-108-1	24.3 ± 0.7	23.6 ± 0.7	23.5 ± 0.7	23.0 ± 0.7	23.8 ± 0.7	24.7 ± 0.8	27.8 ± 0.8	25.1 ± 0.8	24.9 ± 0.8	26.8 ± 0.8
91-032	24.7 ± 0.7	23.9 ± 0.7	23.7 ± 0.7	23.2 ± 0.7	24.1 ± 0.7	25.0 ± 0.9	28.1 ± 0.9	25.4 ± 0.9	25.2 ± 0.9	27.1 ± 0.9

91-35	22.7 ± 0.7	22.1 ± 0.7	22.0 ± 0.7	21.5 ± 0.7	22.2 ± 0.7	23.2 ± 0.8	25.9 ± 0.8	23.5 ± 0.8	23.3 ± 0.8	25.0 ± 0.8
Soda Lake moraine										
91-003	20.5 ± 0.6	20.1 ± 0.6	20.0 ± 0.6	19.5 ± 0.6	20.2 ± 0.6	21.1 ± 0.7	23.4 ± 0.7	21.3 ± 0.7	21.2 ± 0.7	22.7 ± 0.7
91-004	24.7 ± 0.7	23.9 ± 0.7	23.8 ± 0.7	23.3 ± 0.7	24.1 ± 0.7	25.1 ± 0.9	28.1 ± 0.9	25.4 ± 0.9	25.3 ± 0.9	27.1 ± 0.9
Half Moon moraine										
92-117	22.1 ± 0.7	21.5 ± 0.7	21.4 ± 0.7	20.9 ± 0.7	21.7 ± 0.7	22.5 ± 0.8	25.2 ± 0.8	22.8 ± 0.8	22.7 ± 0.8	24.4 ± 0.8
92-119	21.8 ± 0.7	21.2 ± 0.7	21.1 ± 0.7	20.6 ± 0.7	21.4 ± 0.7	22.3 ± 0.8	24.9 ± 0.8	22.6 ± 0.8	22.4 ± 0.8	24.1 ± 0.8
Recessional moraines										
92-123	18.2 ± 0.5	17.7 ± 0.5	17.7 ± 0.5	17.3 ± 0.5	17.9 ± 0.5	18.6 ± 0.6	20.7 ± 0.6	18.9 ± 0.6	18.8 ± 0.6	20.2 ± 0.6
92-155	18.1 ± 0.5	17.6 ± 0.5	17.5 ± 0.5	17.2 ± 0.5	17.8 ± 0.5	18.5 ± 0.6	20.6 ± 0.6	18.8 ± 0.6	18.6 ± 0.6	20.1 ± 0.6
92-129	19.1 ± 0.6	18.6 ± 0.6	18.5 ± 0.6	18.1 ± 0.6	18.9 ± 0.6	19.6 ± 0.7	21.8 ± 0.7	19.8 ± 0.7	19.7 ± 0.7	21.3 ± 0.7
92-124	17.8 ± 0.5	17.4 ± 0.5	17.3 ± 0.5	16.9 ± 0.5	17.5 ± 0.5	18.3 ± 0.6	20.3 ± 0.6	18.5 ± 0.6	18.4 ± 0.6	19.8 ± 0.6
91-020	17.6 ± 0.5	17.2 ± 0.5	17.1 ± 0.5	16.8 ± 0.5	17.4 ± 0.5	18.1 ± 0.6	20.1 ± 0.6	18.3 ± 0.6	18.2 ± 0.6	19.6 ± 0.6
92-127	17.7 ± 0.5	17.3 ± 0.5	17.2 ± 0.5	16.9 ± 0.5	17.5 ± 0.5	18.2 ± 0.6	20.2 ± 0.6	18.4 ± 0.6	18.3 ± 0.6	19.7 ± 0.6
92-130	19.1 ± 0.6	18.6 ± 0.6	18.5 ± 0.6	18.1 ± 0.6	18.8 ± 0.6	19.6 ± 0.7	21.7 ± 0.7	19.8 ± 0.7	19.7 ± 0.7	21.2 ± 0.7
91-024	18.7 ± 0.6	18.2 ± 0.6	18.2 ± 0.6	17.8 ± 0.6	18.4 ± 0.6	19.2 ± 0.6	21.3 ± 0.6	19.4 ± 0.6	19.3 ± 0.6	20.7 ± 0.6
92-125	18.6 ± 0.6	18.2 ± 0.6	18.1 ± 0.6	17.7 ± 0.6	18.3 ± 0.6	19.1 ± 0.6	21.2 ± 0.6	19.4 ± 0.6	19.2 ± 0.6	20.7 ± 0.6
91-026	16.3 ± 0.5	16.0 ± 0.5	16.0 ± 0.5	15.6 ± 0.5	16.2 ± 0.5	16.9 ± 0.6	18.6 ± 0.6	17.1 ± 0.6	17.0 ± 0.6	18.2 ± 0.6
Erratics										
341-O	17.0 ± 0.5	15.7 ± 0.5	15.6 ± 0.5	15.3 ± 0.5	16.8 ± 0.5	16.5 ± 0.6	19.4 ± 0.6	16.7 ± 0.6	16.6 ± 0.6	18.9 ± 0.6
343-B	15.1 ± 0.5	14.0 ± 0.5	13.9 ± 0.5	13.6 ± 0.5	14.9 ± 0.5	14.7 ± 0.5	17.2 ± 0.5	14.9 ± 0.5	14.8 ± 0.5	16.8 ± 0.5
344-E	12.9 ± 0.4	12.0 ± 0.4	11.9 ± 0.4	11.6 ± 0.4	12.8 ± 0.4	12.5 ± 0.4	14.7 ± 0.4	12.8 ± 0.4	12.7 ± 0.4	14.4 ± 0.4
345-B	14.6 ± 0.4	13.5 ± 0.4	13.4 ± 0.4	13.1 ± 0.4	14.4 ± 0.4	14.2 ± 0.5	16.6 ± 0.5	14.4 ± 0.5	14.3 ± 0.5	16.3 ± 0.5
Titcomb Lakes moraine										
138-I	12.7 ± 0.4	12.7 ± 0.4	12.7 ± 0.4	12.7 ± 0.4	12.7 ± 0.4	12.4 ± 0.4	14.5 ± 0.4	12.6 ± 0.4	12.5 ± 0.4	14.2 ± 0.4
139-I	12.0 ± 0.4	12.0 ± 0.4	12.0 ± 0.4	12.0 ± 0.4	12.0 ± 0.4	11.7 ± 0.4	13.6 ± 0.4	11.9 ± 0.4	11.8 ± 0.4	13.4 ± 0.4
333-I	12.0 ± 0.4	12.0 ± 0.4	12.0 ± 0.4	12.0 ± 0.4	12.0 ± 0.4	11.7 ± 0.4	13.7 ± 0.4	11.9 ± 0.4	11.8 ± 0.4	13.4 ± 0.4
334-I	13.5 ± 0.4	13.5 ± 0.4	13.5 ± 0.4	13.5 ± 0.4	13.5 ± 0.4	13.1 ± 0.5	15.3 ± 0.5	13.3 ± 0.5	13.8 ± 0.5	15.1 ± 0.5
335-I	12.9 ± 0.4	12.9 ± 0.4	12.9 ± 0.4	12.9 ± 0.4	12.9 ± 0.4	12.6 ± 0.4	14.7 ± 0.4	12.8 ± 0.4	12.7 ± 0.4	14.4 ± 0.4
336-I	13.2 ± 0.4	13.2 ± 0.4	13.2 ± 0.4	13.2 ± 0.4	13.2 ± 0.4	12.8 ± 0.5	15.0 ± 0.5	13.1 ± 0.5	13.0 ± 0.5	14.8 ± 0.5
337-I	13.2 ± 0.4	13.2 ± 0.4	13.2 ± 0.4	13.2 ± 0.4	13.2 ± 0.4	12.8 ± 0.5	15.0 ± 0.5	13.1 ± 0.5	13.0 ± 0.5	14.8 ± 0.5
338-I	12.8 ± 0.4	12.8 ± 0.4	12.8 ± 0.4	12.8 ± 0.4	12.8 ± 0.4	12.4 ± 0.4	14.6 ± 0.4	12.7 ± 0.4	12.6 ± 0.4	14.3 ± 0.4
339-I	12.6 ± 0.4	12.6 ± 0.4	12.6 ± 0.4	12.6 ± 0.4	12.6 ± 0.4	12.3 ± 0.4	14.4 ± 0.4	12.5 ± 0.4	12.5 ± 0.4	14.2 ± 0.4
W Unitas, North Fork Provo, Bear, and Bald Mtn, UT										
NF Provo terminal moraine										
NFP-1	12.1 ± 0.6	12.0 ± 0.6	12.0 ± 0.6	11.7 ± 0.6	12.0 ± 0.6	12.6 ± 0.7	13.7 ± 0.7	12.8 ± 0.7	12.7 ± 0.7	13.7 ± 0.7
NFP-2B	15.9 ± 0.6	15.7 ± 0.6	15.6 ± 0.6	15.3 ± 0.6	15.8 ± 0.6	16.5 ± 0.6	18.2 ± 0.6	16.7 ± 0.6	16.6 ± 0.6	17.7 ± 0.6
NFP-3A	18.1 ± 2.0	17.8 ± 2.0	17.7 ± 2.0	17.4 ± 2.0	17.8 ± 2.0	18.7 ± 2.2	20.7 ± 2.2	18.9 ± 2.2	18.8 ± 2.2	20.1 ± 2.2
NFP-4A	17.7 ± 0.5	17.4 ± 0.5	17.3 ± 0.5	17.0 ± 0.5	17.4 ± 0.5	18.3 ± 0.6	20.2 ± 0.6	18.5 ± 0.6	18.3 ± 0.6	19.6 ± 0.6
NFP-4B	14.3 ± 0.7	14.2 ± 0.7	14.1 ± 0.7	13.9 ± 0.7	14.2 ± 0.7	15.0 ± 0.8	16.3 ± 0.8	15.1 ± 0.8	15.0 ± 0.8	16.0 ± 0.8
NFP-4C	13.8 ± 0.7	13.7 ± 0.7	13.6 ± 0.7	13.4 ± 0.7	13.7 ± 0.7	14.4 ± 0.8	15.7 ± 0.8	14.6 ± 0.8	14.5 ± 0.8	15.4 ± 0.8
NFP-4D	19.5 ± 1.0	19.1 ± 1.0	19.0 ± 1.0	18.6 ± 1.0	19.2 ± 1.0	20.1 ± 1.1	22.3 ± 1.1	20.3 ± 1.1	20.1 ± 1.1	21.6 ± 1.1

NFP-5	16.2 ± 0.6	16.0 ± 0.6	15.9 ± 0.6	15.6 ± 0.6	16.0 ± 0.6	16.8 ± 0.7	18.5 ± 0.7	17.0 ± 0.7	16.9 ± 0.7	18.1 ± 0.7
Bald Mountain										
BMP-2	14.1 ± 0.4	13.1 ± 0.4	13.1 ± 0.4	12.7 ± 0.4	13.9 ± 0.4	13.8 ± 0.5	16.1 ± 0.5	14.0 ± 0.5	13.9 ± 0.5	15.7 ± 0.5
BMP-4	14.1 ± 0.3	13.1 ± 0.3	13.1 ± 0.3	12.7 ± 0.3	14.0 ± 0.3	13.8 ± 0.4	16.1 ± 0.4	14.0 ± 0.4	13.9 ± 0.4	15.7 ± 0.4
BMP-5	16.0 ± 3.0	14.9 ± 3.0	14.8 ± 3.0	14.5 ± 3.0	15.8 ± 3.0	15.6 ± 3.3	18.3 ± 3.3	15.8 ± 3.3	15.7 ± 3.3	17.8 ± 3.3
BMP-7	15.2 ± 0.6	14.1 ± 0.6	14.0 ± 0.6	13.7 ± 0.6	15.0 ± 0.6	14.8 ± 0.6	17.3 ± 0.6	15.0 ± 0.6	14.9 ± 0.6	16.8 ± 0.6

[a] Be-10 depth profile consisting of multiple measurements; see source referece for details

[b] Al-26 age

Scaling schemes: St - Lal (199)/Stone (2000); De - Desilets and others (2003, 2006); Du - Dunai (2001); Li - Lifton et al., (2005); St (mag) - Lal (1991)/ Stone (2000) time dependent; NE Li - uses the Northeast North America ^{10}Be calibration of Balco et al., (2009) and scaling scheme of Lifton et al., (2005; Li), resulting in a North America ^{10}Be production rate of 4.50 ± 0.22 atoms g^{-1} yr^{-1}

Table DR3. Cosmogenic exposure ages and normalized distance calculations

Location and feature (#=number of ages)	Age (ka)	Uncertainty (ka)	distance from cirque headwall (km)	normalized distance
Pine Creek, CO (Briner, 2009; this study)				
terminal moraine old mode (5)	22.4	1.4	17.1	1.00
terminal moraine young mode (7)	15.8	0.4	17.1	1.00
bedrock (2)	15.4	0.2	13.5	0.79
Clear Creek, CO (this study)				
terminal moraine (3)	19.3	0.2	26.7	1.00
bedrock (1)	14.1	0.3	17.4	0.65
Lake Creek, CO (Schilgden, 2000; this study)				
Terminal moraine (1)	19.7	0.5	31.2	1.00
bedrock (1)	14.7	0.4	20.7	0.66
bedrock (1)	13.9	0.4	15	0.48
bedrock (1)	13.2	0.3	6.6	0.21
Animas River valley, CO (Guido et al., 2007; Ward et al., 2009)				
terminal outwash profile	19.4	1.5	82.1	1.00
bedrock (1)	17.5	1.4	61.9	0.75
bedrock (1)	14.6	0.5	51.6	0.63
bedrock (1)	15.3	0.4	40.3	0.49
bedrock (1)	15.6	0.4	2	0.02
bedrock (1)	14.3	0.4	21.8	0.27
bedrock (1)	12.6	0.4	2	0.02
Middle Boulder Creek, CO (Ward et al., 2009)				
terminarl moraine (4)	20.3	2.1	18.6	1.00
bedrock (1)	17.8	0.6	11.9	0.64
bedrock (1)	13.8	0.4	9.4	0.51
bedrock (1)	13.1	0.5	6.9	0.37
bedrock (1)	12.5	0.4	5.4	0.29
bedrock (1)	12.0	0.4	2.6	0.14
cirque bedrock (6)	13.5	0.4	1.8	0.10
Jenny Lake, WY (Licciardi and Pierce, 2008)				
outer terminal moraine (10)	14.6	0.7	14	1.00
inner end moraine (8)	13.5	1.1	13.8	0.99
bedrock (1)	14.8	0.3	11.1	0.79
bedrock (1)	13.8	0.3	3.1	0.22
inner solitude cirque lip boulders (3)	12.8	0.6	1.8	0.13
*NW Yellowstone, MT, WY (Licciardi and Pierce, 2008)**				
Eightmile terminal moraine (9) (be ages)	16.5	1.4	111.1	1.00
Chico end moraine (8)	16.1	1.7	103.9	0.94
Deckard Flats moraine (10)	14.2	1.2	53.7	0.48
Junction Butte moraine, young mode (6)	14.2	0.4	23.4	0.21
Wallowa Mountains, OR (Licciardi et al., 2004)				
TTO terminal moraine (6)	21.8	0.9	27.1	1.00
TTY end moraine old mode (3)	21.0	0.6	26.1	0.96
TTY end moraine young mode (4)	16.9	0.2	26.1	0.96
WTO end moraine (5)	17.3	0.9	25.1	0.93
bedrock (1)	11.1	0.6	0.4	0.01
Glacier Lakes moraine (4)	11.2	1.3	0.3	0.01
Freemont/Titcomb, Wind River Range, WY (Gosse et al., 1995a, b)				
terminal moraine #1, outermost (3)	23.9	1.1	38.7	1.00
all other terminal moraine #1 (15)	20.7	1.8	38.2	0.99
end moraine #2 (2)	18.1	0.1	37.6	0.97
end moraine #3 (2)	18.5	0.9	37.4	0.97
end moraine #4 (2?)	17.7	0.1	36.9	0.95
end moraine #5 (3)	17.9	1.4	36.5	0.94
outboard titcomb lakes boulders (4)	14.0	1.2	5	0.13
titcomb lakes moraine (9)	12.7	0.5	4.6	0.12
*Western Unita Mountains, UT (Refsnider et al., 2008; Laabs et al., 2009)***				
terminal moraine - North Fork Provo River (8)	15.8	2.5		1
Bald Mtn bedrock (4)	14.3	0.5		0
Eastern Cascades, WA (36Cl ages; Porter and Swanson, 2008)				
Leavenworth I (17)	19.1	3	19.5	1.00
Leavenworth II (11)	16.1	1.1	19	0.97
Rat Creek I (6)	13.3	0.8	7	0.36
Rat Creek II (9)	12.5	0.5	6.5	0.33
Sierra Nevada, CA (36Cl ages; Phillips et al., 1996, 2009)				
Tioga 3 - Bishop (11)	17.7	0.7	23	1.00
Tioga 4 - all ages (24)	14.9	1.9	15.1	0.66
Recess Peak - Bishop (summary)	13.3	0.5	2	0.09

*Distances are from ice divide shown in Figure 1 from Licciardi and Pierce (2008).
**Measuring absolute distancse in the western Uinta Mountains are not appropriate because the ice divide and terminal moraine are in adjacent valleys.

Figure DR1. Representative samples used for ^{10}Be dating in the upper Arkansas River valley.

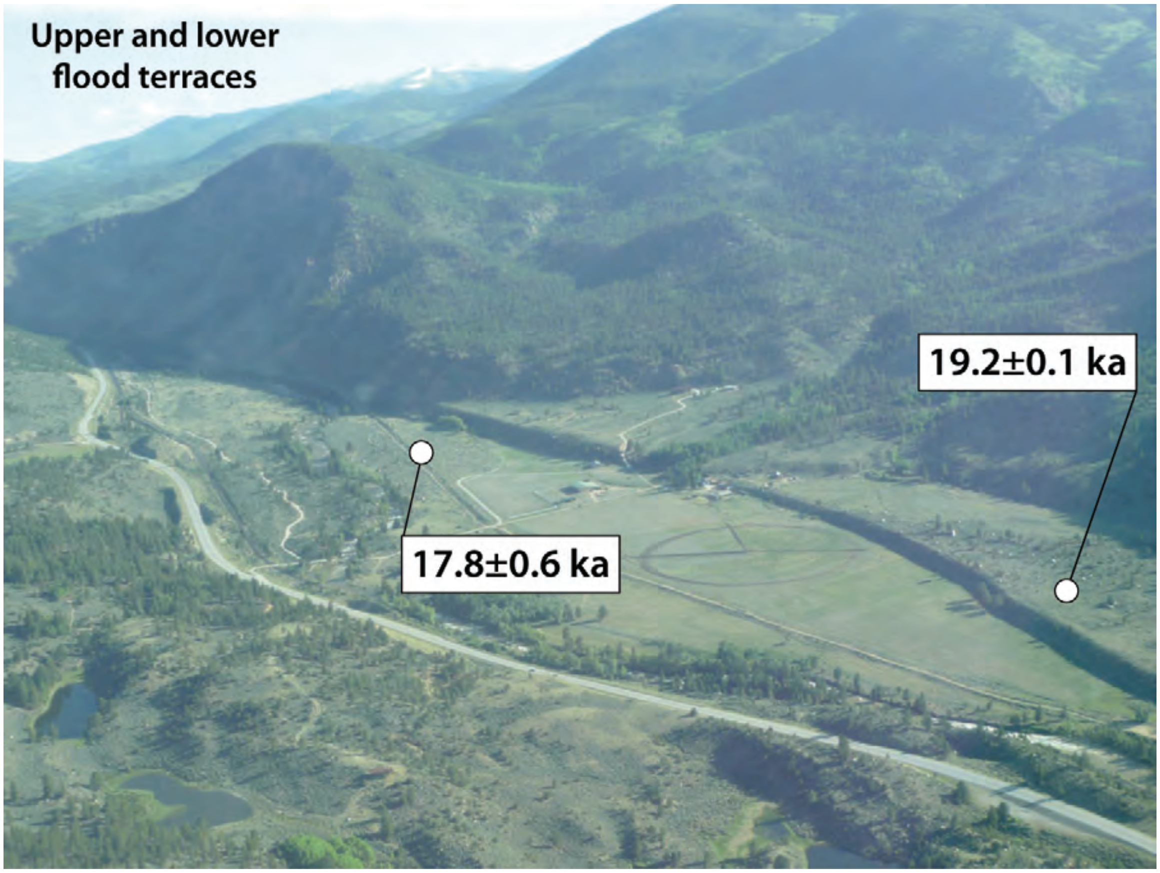

Figure DR2. Aerial view to the northeast showing both the upper and lower flood terraces deposited at 19.2±0.1 ka and 17.8±0.6 ka. The valley wall in the top-left portion of the photo likely served as the source region for terrace flood boulders. Flow of the Arkansas River is from left to right in photo.

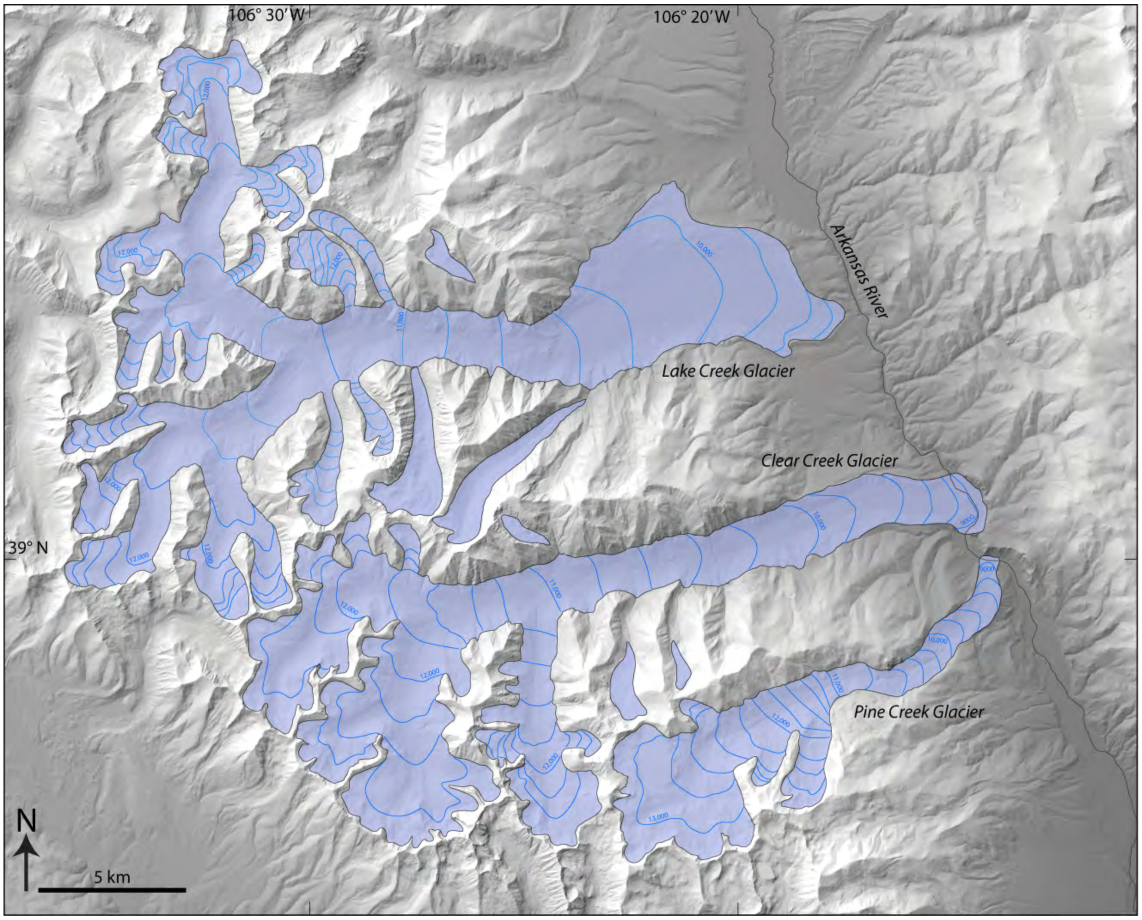

Figure DR3. Reconstructed Pinedale paleoglaciers for Lake Creek, Clear Creek, and Pine Creek valleys. Ice surface contour interval is 200-ft (~61-m).

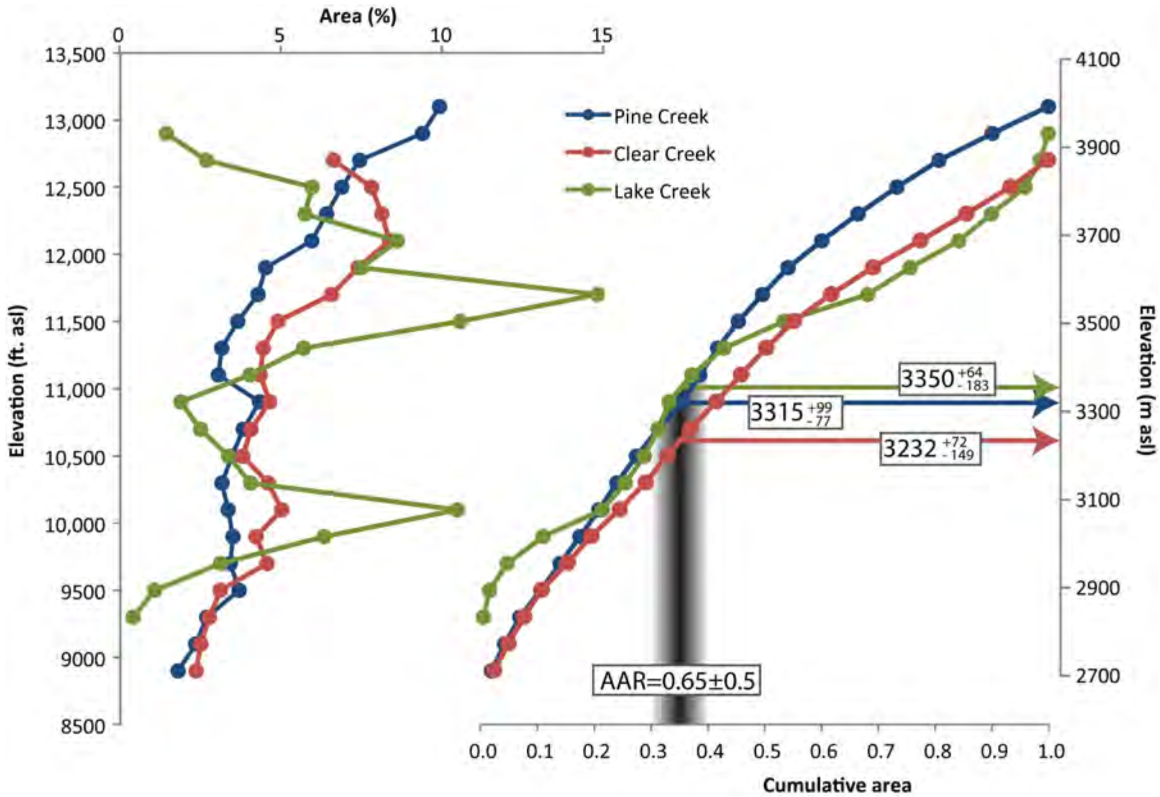

Figure DR4. Hypsometry data for Lake Creek, Clear Creek, and Pine Creek paleoglaciers. Left graph shows elevation distribution by area percent; right graph by cumulative area. Data points represent 200 ft. (~61 m) bins. See supplemental text (above) for ELA reconstruction methods.