Title: The impact of Pleistocene-Holocene climate shifts on vegetation and fire dynamics and its implications for Prearchaic humans in the central Great Basin, USA

Short title: Central Great Basin vegetation & fire history

Authors: Sandra Olivia Brugger[1,2,*], David Rhode[2,*]

[1] Division of Hydrologic Sciences, Desert Research Institute, 2215 Raggio Parkway, Reno NV 89512

[2] Division of Earth and Ecosystem Sciences, Desert Research Institute, 2215 Raggio Parkway, Reno NV 89512

[*] both authors contributed equally to this study

Corresponding author: Sandra Olivia Brugger (Sandra.Brugger@dri.edu)

Abstract

The effects of climate change during the Terminal Pleistocene-Early Holocene transition on ecosystems and early Prearchaic hunter-gatherers in the central Great Basin of North America are currently not well understood. We present a palynological reconstruction of regional vegetation and fire history in Grass Valley, central Nevada, from ~14 to ~7.5k cal a BP showing that *Pinus*-dominated woodlands were replaced by dry-adapted steppe and desert vegetation accompanied by an increase in regional fire activity at the beginning of the Holocene, in response to summer warming and drying climate. Following a severe drought period peaking ~10.2 to 9.3k cal a BP, *Pinus* woodlands partially recovered contemporaneous with the 8.2k cal a BP climate anomaly. Local wetlands provided important resource patches for human foraging societies, and periodic declines of wetlands in response to changing local hydrological conditions may have necessitated adjustments in subsistence and settlement practices and technology.

Introduction

North America's Great Basin, like much of the globe (Denton et al., 2010; Clark et al., 2012), underwent dramatic environmental changes during the Terminal Pleistocene-Early Holocene (TP-EH) transition. Warming and drying trends associated with the TP-EH varied spatially across the Great Basin, affecting regional vegetation and fire activity (Thompson et al., 1993; Madsen et al., 2001; Wigand and Rhode, 2002; Meltzer and Holliday, 2010; Rhode, 2016a; 2016b; Hudson et al., 2019). Vast lakes shrank or dried up, valley marshlands expanded and then contracted, desert shrubland replaced former conifer parkland, cold-adapted plant communities retreated northwards or upslope to mountain peaks, and a remarkable array of species went locally extinct (Grayson, 2011; Lyle 2012; Hudson et a., 2019). From this period we also find the earliest substantial evidence of human populations in western North America (Goebel et al., 2011; Jenkins et al., 2012, 2013; Jones et al., 2012; Elston and Zeanah, 2002; Madsen et al., 2015; Davis et al., 2019).

Information on TP-EH environmental dynamics is essential for understanding how these early hunter-gatherer societies adapted to different landscapes in the Great Basin (Duke and King, 2014; Elston et al., 2014; Madsen, 2016; Smith et al., 2020). Though TP-EH environmental history is reasonably well understood in some parts of the Great Basin (e.g., the Bonneville Basin; Oviatt and Shroder, 2016), past conditions are poorly constrained in the central Great Basin. Here, we aim at (1) reconstructing vegetation and fire history in the central Great Basin during the TP-EH climate transition with pollen, spores, and microcharcoal, (2) investigating how these ecosystem changes relate to patterns elsewhere in the Great Basin, and (3) discussing local wetlands in Grass Valley as potential habitat resources for Prearchaic groups in the central Great Basin.

Study area

Grass Valley is a small closed basin with an area of 1500 km^2 located ~30 km northeast of Austin, Nevada in the central Great Basin. It is ~60 km long and ~20 km wide, with a minimum elevation of ~1713 m a.s.l. enclosed by the Toiyabe Range, Simpson Park Mountains, and Cortez Mountains. Much of the valley floor contains the remnant playa of pluvial Lake Gilbert (Hubbs and Miller 1948), which reached a late glacial high-stand of 1750 m a.s.l. (Mifflin and Wheat 1979), and subsequently formed a significant recessional shoreline at 1724 m a.s.l. before 14k cal a BP. The regional climate is arid with annual summer temperatures reaching 30 °C and winter temperatures below freezing. The average annual wet precipitation is 330 mm a^{-1} with significant snowfall in the winter season of up to 1700 mm (U.S. Climate Data, 2020). Currently, Grass Valley is the focus of archaeological research on TP-EH human foraging adaptations in the central Great Basin (Elston et al., 2014; Codding et al. 2016).

The Gund Ranch sediment core (39.904° N, 116.590° W, 1731 m a.s.l.) was taken in a small wetland east of the playa that is fed by the Walti Hot Springs geothermal complex (Fig. 1). Native vegetation in the wetland consists of *Juncus*, *Carex*, *Eleocharis*, *Fimbristylis*, and various forbs. Surrounding shrublands are dominated by *Artemisia tridentata*, *Ericameria nauseosa*, *Chrysothamnus viscidiflorus*, *Atriplex confertifolia*, and *Sarcobatus vermiculatus* on drier alluvial fans and remnant lakebed deposits (Young and Evans, 1980; Young et al., 1986). *Artemisia* steppe typically occurs on upper fans and piedmonts, while salt desert shrub communities dominated by *Atriplex* and *Sarcobatus* are found at lower elevations on low lake terraces and ridges (Young and Evans, 1980:22-23). *Pinus monophylla* woodlands presently occur ~1.25 km away in the Simpson Park Range, mixed with *Juniperus osteosperma* and *Artemisia tridentata*. Small scattered stands

71 of *Pinus flexilis* occur on nearby mountaintops >2500-2750 m a.s.l. (750-1000 m above the coring

72 location; Little 1971; Charlet 1996, 2020).

Methods

74   We collected a 6.22 m long sediment core using a 5 cm manual square-rod piston coring device

75 (Wright et al., 1983). We analyzed the TP-EH section (338-556 cm sediment depth) of organic-

76 rich sediments deposited above sands and marls associated with the ~1724 m recessional shoreline

77 of pluvial Lake Gilbert at the bottom, and capped by thick tephra (most likely associated to the

78 Mazama eruption) at the top. The depth-age model is based on nine accelerator mass spectrometry

79 (AMS) radiocarbon dates from macrofossils and extracted humates calibrated with the INTCAL13

80 curve (Suppl. table S1; Reimer et al., 2013). One radiocarbon date was rejected as discordantly

81 young (Fig. 2). Additionally, we included the age of the tephra layer, presumably associated with

82 the Mazama eruption at ~7.633 ka (Egan et al., 2015). For the depth-age model we fit a smooth-

83 spline interpolation between the dates with uncertainties derived from Bayesian modelling routine

84 (Blaauw, 2010; Blaauw and Christen, 2011). We analyzed loss-on-ignition every 5 cm along the

85 core using standard protocols (Heiri et al., 2001). Magnetic susceptibility was measured using a

86 Geotek MSCL core logging system (Lascu, 2009).

87   We processed 24 pollen samples of 1.25 cm^3 volume using standard chemical treatments after

88 adding *Lycopodium* spores tablets (Faegri et al., 1989; Brugger et al., 2018a). Pollen and spores

89 were counted at 400x magnification under a light microscope and identified using palynological

90 keys (Moore et al., 1991; Kapp et al., 2000; Beug, 2004). All pollen and spore percentages are

91 based on the terrestrial pollen sum including trees, shrubs, and herbs, excluding wetland taxa (e.g.

92 Cyperaceae) and spores. Zonation of the pollen record was derived from constrained hierarchical

93 cluster analysis (Grimm, 1987) based on Euclidean distances of square root-transformed terrestrial

94   pollen percentages and tested for statistical significance ($p < 0.05$) with the broken stick model

95   (Bennett, 1996). Microcharcoal fragments were counted following established protocols

96   (Finsinger and Tinner, 2005; Tinner and Hu, 2003).

Results and interpretation

98   The depth-age model reflects varying accumulation rates among major sediment units (Fig. 2)

99   Organic gyttja sediments start to accumulate after ~14.1k cal a BP, on top of silty clays and sands

100   associated with lacustral/playa landforms (Figure 3). Between ~10.2-9.3k cal a BP, gyttja was

101   replaced by gray sandy silt with increased carbonates and thin organic stringers. After ~9.3k cal a

102   BP, the organic content increased again until Mazama tephra deposition.

103   Cluster analysis revealed one statistically significant zone boundary between Gund-1 and

104   Gund-2 (Fig. 4). Gund-1 (~14.1-11.2k cal a BP) is dominated by *Pinus* fluctuating around ~50%,

105   with moderately high *Artemisia* (~25%), low Chenopodiaceae (<10%) pollen (probably deriving

106   from *Atriplex*), and herbs dominated by Poaceae accounting for ~20% of the pollen assemblage.

107   The pollen composition suggests that before 11.2k cal a BP, regional vegetation was composed of

108   *Pinus*-dominated woodlands while *Artemisia*-Poaceae steppe likely covered surrounding alluvial

109   fans and upland slopes, consistent with both modern vegetation patterns (Young and Evans, 1980)

110   and northern intermontane TP-EH paleovegetation records (Mehringer 1985; Rhode 2016a). A

111   single Poaceae peak of ~40% and contemporaneous *Pinus* decline (20%) at ~12.6 k cal a BP could

112   indicate a short-term expansion of herbaceous steppe at the cost of *Pinus* woodlands. After ~11.7k

113   cal a BP *Pinus* pollen rapidly declines to 20% while Chenopodiaceae rises to 20% suggesting a

114   shift toward drier shrubland vegetation (Fig. 4).

115   At the beginning of Gund-2 (~11.2-7.6k cal a BP), *Pinus* pollen remains at low values (20%)

116   deriving from distant or scattered stands as *Pinus* pollen is extremely well dispersed over long

distances (e.g., Thompson, 1992; Brugger et al., 2019). Chenopodiaceae increases to ~50%, reaching greater than modern values, *Artemisia* decreases slightly to ~10%, while herbs, predominantly Poaceae and Asterioideae, contribute 20%. The pollen composition suggests that the regional vegetation was composed of open dry-adapted shrubby steppe and widespread xeric-desert vegetation until ~8.3k cal a BP possibly responding to culminating drought conditions for vegetation at ~10.2-9.3k cal a BP. After ~8.3k cal a BP the pollen assemblages become similar to the modern reference sample with *Pinus* pollen increasing to ~35% and Chenopodiaceae declining to 20%, suggesting that the regional vegetation reached modern composition already prior to the Mazama eruption ~7.633k cal a BP (Egan et al., 2015).

The entire pollen record is dominated by Cyperaceae with values >50% suggesting that the pollen derives predominantly from local wetland taxa such as *Carex* sp. currently growing at the coring site. Major Cyperaceae pollen peaks occur at ~13.7k, ~11.7-10.2k, and ~9.3-8.2k cal a BP, when values reach >200% suggesting short-term expansion of wetlands (Fig. 4). These peaks are accompanied by *Typha* peaks indicating expansion of shallow ponds or open water. Simultaneous traces of fern spores also imply wetter climatic phases or improved local hydrologic conditions. Single finds of *Sporormiella*, a coprophilous dung spore indicative of herbivore grazing (e.g. Rey et al., 2017), occur at ~13.4k and ~11.0-10.5k cal a BP, during maximum wetland expansions.

Microcharcoal concentrations and influx values show similar trends along the record, suggesting that the reconstructed fire history is robust (Fig. 4, S1). Microcharcoal influx remains low between ~14.0k cal a BP and 12.7k cal a BP suggesting minimal fire activity when *Pinus* woodlands are most widespread. Increasing microcharcoal influx (>3000 fragments cm^{-2} a^{-1}) after ~12.7k cal a BP suggests an increase of fire activity contemporaneous with the decline of *Pinus* woodlands and the spread of dry adapted salt desert shrubs.

Discussion

The impact of climate on regional vegetation and fire in the central Great basin

At the beginning of the pollen record ~14k cal a BP, *Pinus* woodlands (presumably *P. flexilis*) occurred in nearby upland slopes with *Artemisia*-Poaceae steppe covering alluvial fans and pied-monts, which is in agreement with other regional vegetation reconstructions (e.g., Thompson, 1992). A brief decline ~12.7-12.0k cal a BP and subsequent recovery of *Pinus* woodlands likely corresponds to climatic transitions at the beginning and end of the Younger Dryas (Rasmussen et al., 2006). The dieback of *Pinus* woodlands and subsequent replacement by open steppe vegetation possibly provided herbaceous fuel for fire during the dry summer season (Betancourt 2015), resulting in an increase of fire activity. Subsequent increases of fire activity after forest diebacks at the forest steppe ecotone is an ecological phenomenon observed in paleoecological reconstructions in other geographic areas where forests grow at their drought limit (e.g. Eichler et al., 2011; Marlon et al., 2012; Schwörer et al., 2017; Brugger et al., 2018b).

After ~11.7k cal a BP, *Pinus* woodlands retreated upslope while xeric-desert vegetation with abundant Chenopodiaceae expanded and suggested maximum drought conditions at ~10.2-9.3k cal a BP. This shift to dry-adapted vegetation is in agreement with regional vegetation records from Ruby Valley and the western Bonneville Basin (225 km east of Grass Valley) where conifer woodlands declined at the expense of xeric-desert steppe vegetation after ~9.5k cal a BP, and ~11.7k cal a BP, respectively (Thompson, 1992; Louderback and Rhode, 2009). Other records from the northern Great Basin and Snake River Plain indicate early Holocene drying with decreasing conifers and expanding steppe (Thompson, 1984; Thompson et al. 2016; Rhode, 2016a, 2016b). These pollen records unfortunately do not extend deep enough in time to determine when this warming and drying trend began.

163   Regional vegetation-independent climate reconstructions, such as decreasing lake levels in the

164   Great Basin and a speleothem record from Lehman Cave, suggest that the moisture retractions may

165   have varied regionally in timing but that overall the Great Basin experienced a drying trend cul-

166   minating in the mid-Holocene (e.g. McGee et al., 2012; Steponaitis et al., 2015).

167   *Pinus* woodlands expanded in Grass Valley again after ~8.3k cal a BP, possibly in response to

168   moister conditions coincident with the 8.2 ka Northern Hemisphere climatic anomaly (Alley et al.

169   1997). This increase in *Pinus* pollen may signal the approach of *Pinus monophylla* in its mid-

170   Holocene northwards expansion (Madsen, 1985, 1986; Madsen and Rhode, 1990; Thompson,

171   1990; Rhode and Madsen 1998).

172   **Climate-driven wetland dynamics as a changing resource for Prearchaic groups**

173   In contrast to upland vegetation, local wetlands in Grass Valley responded dynamically to

174   changing local hydrological conditions. The pollen record indicates that wetland vegetation dom-

175   inated by Cyperaceae became established at ~14.1k cal a BP at the coring site, near the end of the

176   warm and dry Bølling interstadial (Rasmussen et al., 2006) that caused dropping lake levels across

177   the Great Basin. The wetland was established on remnant playa and lacustral sediments of the

178   formerly larger Lake Gilbert, indicated by a paleo-shoreline at ~1724 m a.s.l. dating older than the

179   beginning of the pollen record (Young and Evans, 1980; Madsen, 1985). Wetland and aquatic taxa

180   in the record indicate maximum expansions of wetlands at ~13.7k, ~11.7-10.2k, and ~9.3-8.2k cal

181   a BP possibly in response to changing local hydrologic conditions. The expanding wetlands in

182   response to periods of increased moisture possibly served as attractive habitats for large herbi-

183   vores. The microfossil record tentatively indicates presence of such herbivores by finds of dung

184   fungal spores at ~13.4k and ~11.0-10.5k cal a BP commonly associated with herbivore presence

185   (Gill et al., 2012; Rey et al., 2017, 2020). Elston et al. (2014) have argued that productive wetlands

9

186 attractive to large herbivores would also have been highly appealing primary resource areas for

187 Prearchaic human foraging societies. Under their model, foraging family groups practicing a gen-

188 der-based division of labor would have preferentially occupied wetlands, where males focused

189 subsistence efforts on high-value but possibly infrequently obtained wild game, and female forag-

190 ers focused on lower-value but more reliable resources such as smaller game, bird eggs, and *Typha*

191 rhizomes (Elston et al. 2014). As regional drying continued through the early to mid-Holocene,

192 declining wetland productivity in Grass Valley may have ultimately necessitated the abandonment

193 of a wetland subsistence focus and adoption of new food procurement strategies such as intensive

194 small-seed processing more typical of later Archaic foraging groups in the region (Rhode et al.,

195 2006; Beck and Jones, 2008, 2014; McGuire et al., 2016).

Conclusions

197   Our paleoecological reconstruction from Grass Valley provides new information about the re-

198 sponse of ecosystems to regional climate change during the TP-EH and fills an important gap in

199 understanding these highly sensitive vegetation communities in the central Great Basin. The *Pinus*

200 woodland expansions were mainly driven by effective moisture availability from 14k cal a BP

201 onwards and reached modern conditions by the mid-Holocene after 8.2k cal a BP. We infer that

202 fire dynamics were largely influenced by a combination of herbaceous biomass availability and

203 flammability in response to drying climate. This finding has important implications for ongoing

204 and future climate change and related fire risks in the central Great Basin. While regional upland

205 vegetation responded to large-scale climate change, the local wetlands in Grass Valley reacted

206 more strongly to shorter periods of locally changing hydrological conditions and probably served

207 as important resource habitats for foraging Prearchaic groups. Further paleoecological and

208 archeological investigations are needed to gain a better understanding of the relationships between

209 TP-EH climate change, ecosystem dynamics, and human activities in the central Great Basin.

Acknowledgements

Data availability

222 The data will be accessible on the NEOTOMA data base (https://www.neotomadb.org/).

References

224 Alley RB, Mayewski PA, Sowers T. et al. 1997. Holocene climatic instability: A prominent, wide-
225   spread event 8200 yr ago. *Geology*, *25*(6), 483-486.

226 Beck C, Jones GT. 2008. *Archaic times*. In: Fowler CS, Fowler DD (Eds.). The Great Basin: People
227   and Place in Ancient Times. School for Advanced Research Press, Santa Fe, pp. 45-54.

228 Beck C, Jones GT. 2014. *Moving into the mid-Holocene: The Paleoarchaic/Archaic transition in*
229   *the intermountain west*. In: Parezo NJ, Janetski JC (Eds.). Archaeology in the Great Basin and
230   Southwest: Papers in Honor of Don D. Fowler. University of Utah Press, Salt Lake City, pp.
231   61-84.

232 Bennett KD. 1996. Determination of the number of zones in a biostratigraphical sequence *New*
233 *Phytologist* 132(1), 155-170.

234 Betancourt JL. 2015. Energy flow and the "grassification" of desert shrublands. *Proceedings of*
235 *the National Academy of Sciences*, 112(31), 9504-9505.

236 Beug H-J. 2004. 2004: *Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Ge-*
237 *biete*. Friedrich Pfeil, Munich.

238 Blaauw M, Christen JA. 2011. Flexible paleoclimate age-depth models using an autoregressive
239 gamma process. *Bayesian Analysis* 6(3), 457-474.

240 Blaauw M. 2010. Methods and code for 'classical' age-modelling of radiocarbon sequences. *Qua-*
241 *ternary Geochronology* 5(5), 512-518.

242 Brugger SO, Gobet E, Schanz FR et al. 2018a. A quantitative comparison of microfossil extraction
243 methods from ice cores. *Journal of Glaciology*, 64(245), 432-442.

244 Brugger SO, Gobet E, Blunier T et al. 2019. Palynological insights into global change impacts on
245 Arctic vegetation, fire, and pollution recorded in Central Greenland ice. *The Holocene*, 29(7),
246 1189-1197.

247 Brugger SO, Gobet E, Sigl M. 2018b. Ice records provide new insights into climatic vulnerability
248 of Central Asian forest and steppe communities. *Global and Planetary Change*, 169, 188-201.

249 Charlet DA. 1996. *Atlas of Nevada Conifers – A Phytogeographic Reference*. University of Ne-
250 vada Press, Reno.

251 Charlet DA. 2020. *Nevada Mountains – Landforms, Trees, and Vegetation*. University of Utah
252 Press, Salt Lake City.

253 Clark P, Shakun JD, Baker PA et al. 2012. Global climate evolution during the last deglaciation.
254 *Proceedings of the National Academy of Sciences*, 109(19), E1134-E1142.

255 Codding BF, Zeanah DW, Yung DC et al. 2016. *Prearchaic Adaptations in the Central Great*
256 *Basin: Preliminary Findings from a Stratified Open-Air Site in Grass Valley, Nevada*. Presen-
257 tation, Great Basin Anthropological Conference, Reno NV.

258 Davis LG, Madsen DB, Becerra-Valdivia L et al. 2019. Late upper Paleolithic occupation at
259 Cooper's Ferry, Idaho, USA, ~16,000 years ago. *Science,* 365(6456), 891-897.

260 Denton GH, Anderson RF, Toggweiler JR et al. 2010. The last glacial termination. *Science,*
261 328(5986), 1652-1656.

262 Duke DG, King J. 2014. A GIS model for predicting wetland habitat in the Great Basin at the
263 Pleistocene-Holocene transition and implications for Paleoindian archaeology. *Journal of Ar-*
264 *chaeological Science,* 49, 276-291.

265 Egan J, Staff R, Blackford J. 2015. A high-precision age estimate of the Holocene Plinian eruption
266   of Mount Mazama, Oregon, USA. *The Holocene*, 25(7), 1054-1067.

267 Eichler A, Tinner W, Brütsch S et al. 2011. An ice-core based history of Siberian forest fires since
268   AD 1250. *Quaternary Science Reviews*, 30(9-10), 1027-1034.

269 Elston RG, Zeanah DW, Codding BF. 2014. Living outside the box: An updated perspective on
270   diet breadth and sexual division of labor in the Prearchaic Great Basin. *Quaternary Interna-*
271   *tional*, 352, 200-211.

272 Elston RG, Zeanah DW. 2002. Thinking outside the box: A new perspective on diet breadth and
273   sexual division of labor in the Prearchaic Great Basin. *World Archaeology*, 34(1), 103-130.

274 Faegri K, Kaland PE, Kzywinski K. 1989. *Textbook of Pollen Analysis*. John Wiley, New York.

275 Finsinger W, Tinner W. 2005. Minimum count sums for charcoal concentration estimates in pollen
276   slides: accuracy and potential errors. *The Holocene*, 15(2), 293-297.

277 Gill JL, Williams JW, Jackson ST et al. 2012. Climatic and megaherbivory controls on late-glacial
278   vegetation dynamics: a new, high-resolution, multi-proxy record from Silver Lake, Ohio. *Qua-*
279   *ternary Science Reviews*, 34, 66-80.

280 Goebel T, Hockett B, Adams KD et al. 2011. Climate, environment, and humans in North Amer-
281   ica's Great Basin during the Younger Dryas, 12,900-11,600 calendar years ago. *Quaternary*
282   *International*, 242, 479-501.

283 Grayson DK. 2011. *The Great Basin: A Natural Prehistory*. University of California Press, Berke-
284   ley.

285 Grimm EC. 1987. CONISS: a FORTRAN 77 program for stratigraphically constrained cluster
286   analysis by the method of incremental sum of squares. *Computers and Geosciences*, 13(1), 13-
287   35.

288 Heiri O, Lotter AF, Lemcke G. 2001. Loss on ignition as a method for estimating organic and
289   carbonate content. *Journal of Paleolimnology,* 25, 101-110.

290 Hubbs CL, Miller RR. 1948. The zoological evidence: Correlation between fish distribution and
291   hydrographic history in the desert basins of western United States. In: The Great Basin, with
292   emphasis on glacial and post-glacial times. *Bulletin of the University of Utah, Biological Series*,
293   38(20), 18-166.

294 Hudson AM, Hatchett BJ, Quade J et al. 2019. North-south dipole in winter hydroclimate in the
295   western United States during the last deglaciation. *Scientific Reports*, 9(1), 4826.

296 Jenkins DL, Davis LG, Stafford TW. et al. 2012. Clovis age Western Stemmed projectile points
297   and human coprolites at the Paisley Caves. *Science*, 337(6091), 223–228.

298   Jenkins DL, Davis LG, Stafford TW et al. 2013. *Geochronology, archaeological context, and DNA*
299   *at the Paisley Caves*. In: Graf KE, Ketron CE, Waters ME (Eds.). Paleoamerican Odyssey.
300   College Station: Texas A&M Press.

301   Jones GT, Fontes LM, Horowitz RA et al. 2012. Reconsidering Paleoarchaic mobility in the central
302   Great Basin. *American Antiquity*, 77, 351-367.

303   Kapp RO, Davis OK, King JE. 2000. Ronald O. *Kapp's Pollen and Spores*. American Association
304   of Stratigraphic Palynologists, College Station TX. 2nd ed.

305   Lascu, I. 2009. Magnetic susceptibility logging for cores. Limnological Research Center Core Fa-
306   cility (LacCore) SOP series, susceptibility.pdf. University of Minnesota, Minneapolis.

307   Little EL Jr. 1971. *Atlas of United States trees, volume 1. Conifers and important hardwoods*. US
308   Department of Agriculture, Forest Service, Miscellaneous Publication 1146. Washington, DC.

309   Louderback LA, Rhode D. 2009. 15,000 years of vegetation change in the Bonneville basin: The
310   Blue Lake pollen record. *Quaternary Science Reviews*, 28, 308-326.

311   Lyle M, Heusser L, Ravelo C et al. 2012. Out of the tropics: the Pacific, Great Basin Lakes, and
312   Late Pleistocene water cycle in the western United States. *Science*, 337(6102), 1629-1633.

313   Madsen DB, Rhode D. 1990. Early Holocene pinyon (*Pinus monophylla*) in the northeastern Great
314   Basin. *Quaternary Research*, 33, 94-101.

315   Madsen DB. 1985. *Two Holocene pollen records from the central Great Basin*. In: Fall PL, Davis
316   OK (Eds.). Late Quaternary Vegetation and Climates of the American Southwest. American
317   Association of Stratigraphic Palynologists Contribution Series, 16, 113-126.

318   Madsen DB, 1986. *Great Basin nuts: A short treatise on the distribution, productivity, and prehis-*
319   *toric use of pinyon*. In: Condie CJ, Fowler DD (Eds.). Anthropology of the Desert West: Essays
320   in Honor of Jesse D. Jennings, pp. 21-42. University of Utah Press, Salt Lake City.

321   Madsen DB. 2016. The early human occupation of the Bonneville basin. In: Oviatt CG, Shroder J
322   Jr (Eds.). 2016. Lake Bonneville: A scientific update. Developments in Earth Surface Processes,
323   volume 20, pp. 504-525. Elsevier, Amsterdam.

324   Madsen DB, Rhode D, Grayson DK et al. 2001. Late Quaternary environmental change in the
325   Bonneville basin, western USA. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 167(3-
326   4), 243-271.

327   Madsen DB, Schmitt DN, Page D. 2015. *The Paleoarchaic Occupation of the Old River Bed Delta*.
328   University of Utah Anthropological Papers 128, Salt Lake City.

329   Marlon JR, Bartlein PJ, Gavin DG. 2012. Long-term perspective on wildfires in the western USA.
330   *Proceedings of the National Academy of Sciences*, 109(9), E535-E543.

331   McGee D, Quade J, Edwards RL et al. 2012. Lacustrine cave carbonates: Novel archives of paleo-
332   hydrologic change in the Bonneville Basin (Utah, USA). *Earth and Planetary Science Letters*,
333   351, 182-194.

334   McGuire K, Ugan A, Carpenter K, Brinz L. 2016. *Trans-Holocene subsistence-settlement change*
335   *in northern Nevada*. In: Hildebrandt W, McGuire K, King J et al. (Eds.). Prehistory of Nevada's
336   Northern Tier: Archaeological Investigations along the Ruby Pipeline. Anthropological Papers
337   101. American Museum of Natural History, New York, pp. 261-278.

338   Mehringer PJ Jr. 1985. *Late-Quaternary pollen records from the interior Pacific Northwest and*
339   *Northern Great Basin of the United States*. In: Bryant VM Jr, Holloway RG (Eds.). Pollen
340   Records of Late-Quaternary North American Sediments. American Association of Stratigraphic
341   Palynologists, Dallas TX, pp. 167-189.

342   Meltzer DJ, Holliday VT. 2010. Would North American Paleoindians have noticed younger Dryas
343   age climate changes?. *Journal of World Prehistory*, *23*(1), 1-41.

344   Mifflin MD, Wheat MM. 1979. *Pluvial lakes and estimated pluvial climates of Nevada*. Nevada
345   Bureau of Mines and Geology Bulletin 94. Mackay School of Mines, University of Nevada,
346   Reno.

347   Moore PD, Webb JA, Collison ME. 1991. *Pollen analysis.* Blackwell scientific publications, Ox-
348   ford.

349   Oviatt CG, Shroder J Jr. 2016. *Lake Bonneville: A scientific update.* Developments in Earth Sur-
350   face Processes, volume 20. Elsevier, Amsterdam.

351   Rasmussen SO, Andersen KK, Svensson AM et al. 2006. A new Greenland ice core chronology
352   for the last glacial termination. *Journal of Geophysical Research: Atmospheres*, 111(D6).

353   Reimer PJ, Bard E, Bayliss A et al. 2013. IntCal13 and Marine13 radiocarbon age calibration
354   curves 0-50,000 yr cal BP. *Radiocarbon*, 55(4), 1869-1887.

355   Rey F, Gobet E, van Leeuwen JF et al. 2017. Vegetational and agricultural dynamics at Burgäschi-
356   see (Swiss Plateau) recorded for 18,700 years by multi-proxy evidence from partly varved sed-
357   iments. *Vegetation History and Archaeobotany*, 26(6), 571-586.

358   Rey F, Gobet E, Schwörer C et al. 2020. Climate impacts on vegetation and fire dynamics since
359   the last deglaciation at Moossee (Switzerland). *Climate of the Past*, 16(4), 1347-1367.

360   Rhode D, Madsen DB. 1998. Pine nut use in the early Holocene and beyond: The Danger Cave
361   archaeobotanical record. *Journal of Archaeological Science*, 25(12), 1199-1210.

362   Rhode D, Madsen DB, Jones KT. 2006. Antiquity of early Holocene small-seed consumption and
363   processing at Danger Cave. *Antiquity,* 80(308), 328-339.

364   Rhode D. 2016a. *Paleoenvironments of the northern tier*. In: Hildebrandt W, McGuire K, King J
365   et al. (Eds.). Prehistory of Nevada's Northern Tier: Archaeological Investigations along the

366 Ruby Pipeline. Anthropological Papers 101. American Museum of Natural History, New York,
367 pp. 57-70.

368 Rhode D. 2016b. *Quaternary vegetation changes in the Bonneville basin.* In: Oviatt CG, Shroder
369 J Jr. (Eds.). Lake Bonneville: A scientific update. Developments in Earth Surface Processes,
370 volume 20. Elsevier, Amsterdam, pp. 420-441.

371 Schwörer C, Gavin DG, Walker IR. 2017. Holocene tree line changes in the Canadian Cordillera
372 are controlled by climate and topography. *Journal of Biogeography*, 44(5), 1148-1159.

373 Smith GM, Duke D, Jenkins DL et al. 2020. The Western Stemmed Tradition: Problems and pro-
374 spects in Paleoindian archaeology in the intermountain west. *Paleoamerica*, 6(1), 23-42.

375 Steponaitis E, Andrews A, McGee D et al. 2015. Mid-Holocene drying of the U.S. Great Basin
376 recorded in Nevada speleothems. *Quaternary Science Reviews*, 127, 174-185.

377 Stuiver M, Reimer PJ, Reimer RW. 2020. CALIB 7.1. WWW program] Retrieved from:
378 http://calib.org, accessed 2020-7-20.

379 Thompson RS. 1984. *Late Pleistocene and Holocene environments in the Great Basin.* PhD thesis,
380 University of Arizona, Tucson.

381 Thompson RS. 1990. *Late Quaternary vegetation and climate in the Great Basin.* In: Betancourt
382 JB, Van Devender TR, Martin PS (Eds.). Packrat Middens—The Last 40,000 Years of Biotic
383 Change. University of Arizona Press, Tucson, pp. 200-239.

384 Thompson RS. 1992. Late Quaternary environments in Ruby Valley, Nevada. *Quaternary Re-
385 search*, 37(1), 1-15.

386 Thompson RS, Oviatt CG, Honke JS et al. 2016. Late Quaternary changes in lakes, vegetation,
387 and climate in the Bonneville basin reconstructed from sediment cores from Great Salt Lake.
388 In: Oviatt CG, Shroder JF Jr (Eds.). Lake Bonneville: A scientific update. Developments in
389 Earth Surface Processes, vol. 20. Elsevier, Amsterdam, pp. 221-291.

390 Thompson RS, Whitlock C, Bartlein PJ et al. 1993. Climatic changes in the western United States
391 since 18,000 yr B.P. In: Wright HE Jr, Kutzbach JE, Webb T III et al. (Eds.). Global Climates
392 Since the Last Glacial maximum, pp. 468-513. University of Minnesota Press, Minneapolis.

393 Tinner W, Hu FS. 2003. Size parameters, size-class distribution and area-number relationship of
394 microscopic charcoal: relevance for fire reconstruction. *The Holocene*, 13(4), 499-505.

395 U.S. Climate Data. 2020. version 3.0. https://www.usclimatedata.com/website-info, accessed on
396 Aug 31, 2020.

397 Wigand PE, Rhode D. 2002. *Great Basin vegetation history and aquatic systems: the last 150,000
398 years.* In: Hershler R, Madsen DB, Currey DR (Eds.). Great Basin Aquatic Systems History.
399 Smithsonian Contributions to the Earth Sciences, 33, pp. 309-368. Washington DC.

400 Wright HE Jr, Mann DH, Glaser PH. 1983. Piston corers for peat and lake sediments. *Ecology*, 65,
401   657-659.

402 Young JA, Evans RA. 1980. *Physical, Biological, and Cultural Resources of the Gund Research
403   and Demonstration Ranch, Nevada*. Agricultural Reviews and Manuals ARM-W-11. Agricul-
404   tural Research (Western Region), Science and Education Administration, U.S. Department of
405   Agriculture, Oakland CA.

406 Young JA, Evans RA, Roundy BA et al. 1986. Dynamic landforms and plant communities in a
407   pluvial lake basin. *Great Basin Naturalist*, 46(1), 1-21.

408 **Figures and tables**
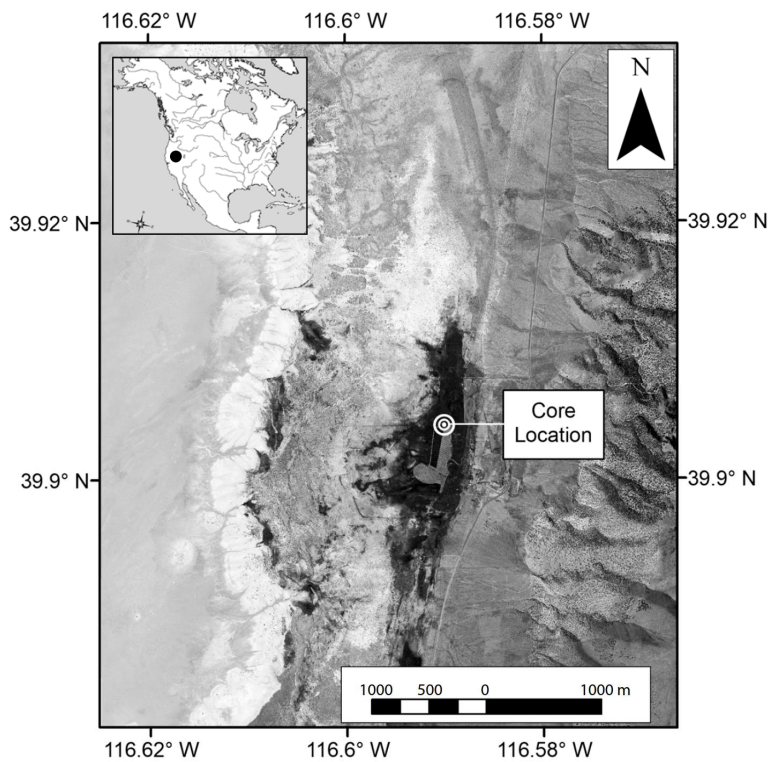
409

410 **Figure 1.** Map showing Grass Valley in the central Great Basin in Nevada with indication of the coring location at

411 Gund Ranch. The playa of Pleistocene Lake Gilbert is located west of the core location, and the Simpson Park Moun-

412 tains lie to the east.
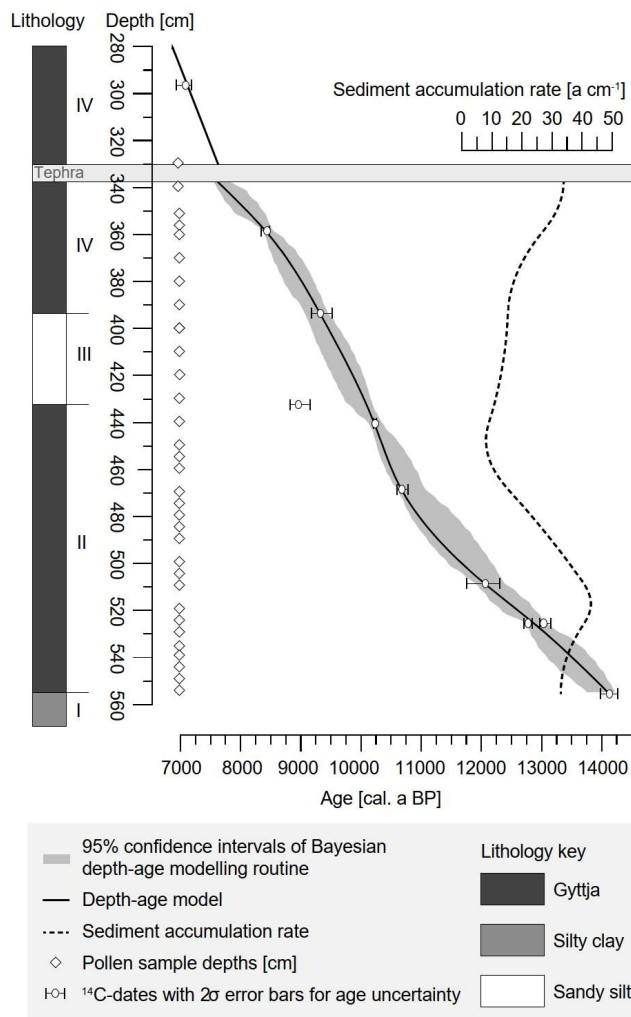
Figure 2. The depth–age model of Gund Ranch sediment core (pre-Mazama: smooth spline with smoothing level =0.1 fitted with Clam 2.2; post-Mazama: linear interpolation Blaauw 2010) is shown as solid black line with a gray envelope delimiting the 95% confidence interval of the estimated ages pre-Mazama obtained with the Bayesian depth–age modeling routine Bacon (Blaauw and Christen 2011). Nine radiocarbon dates (white dots with 95% confidence intervals of the calibrated ages, Reimer et al. 2013) and the Mazama tephra layer (7633 ± 49 cal a BP, Egan et al., 2015) were used to fit the age-depth model. One additional radiocarbon date was considered an outlier based on the Bayesian depth-age modeling routine. Age is shown in calibrated years before present (cal a BP with 1950=0). Sediment accumulation rate is calculated based on the depth-age model (dashed line) and left column shows lithology of the sediment core including major units (I-IV).

18
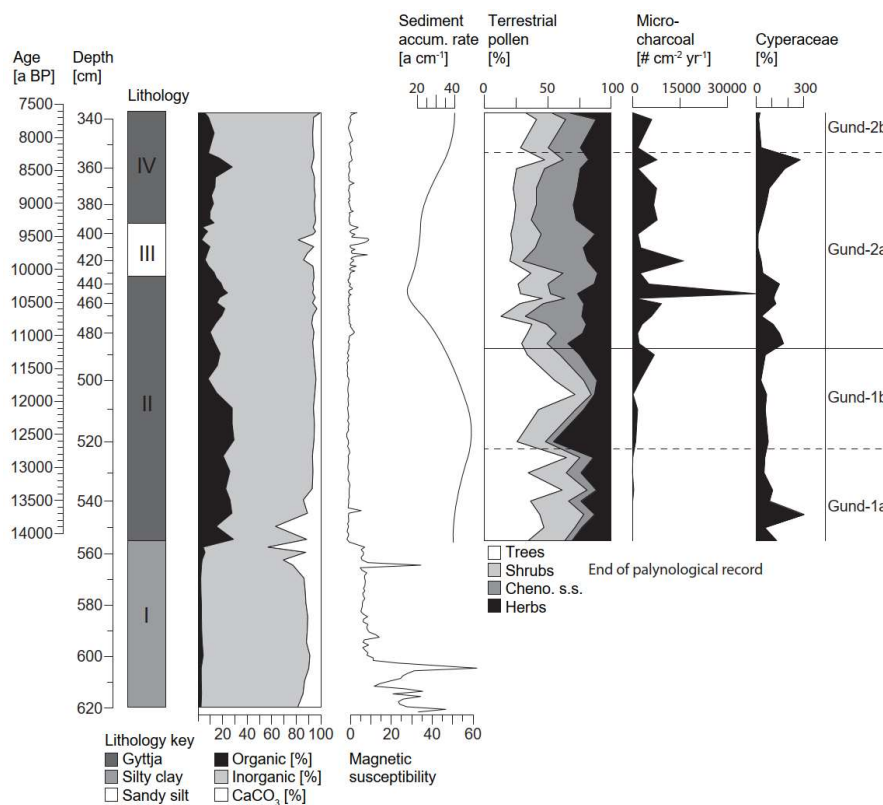
Figure 3. Sedimentology of Gund Ranch core before 7500 cal a BP showing from left: major depositional units, loss-on-ignition, magnetic susceptibility (SI units), sediment accumulation rate derived from the depth-age model (Fig. 2), summary of tree, shrub, Chenopodiaceae, and herb pollen as percentages, microcharcoal influx, and Cyperaceae percentages based on the terrestrial pollen sum. Note that record below 550 cm is presented on a depth-scale and undated.

19
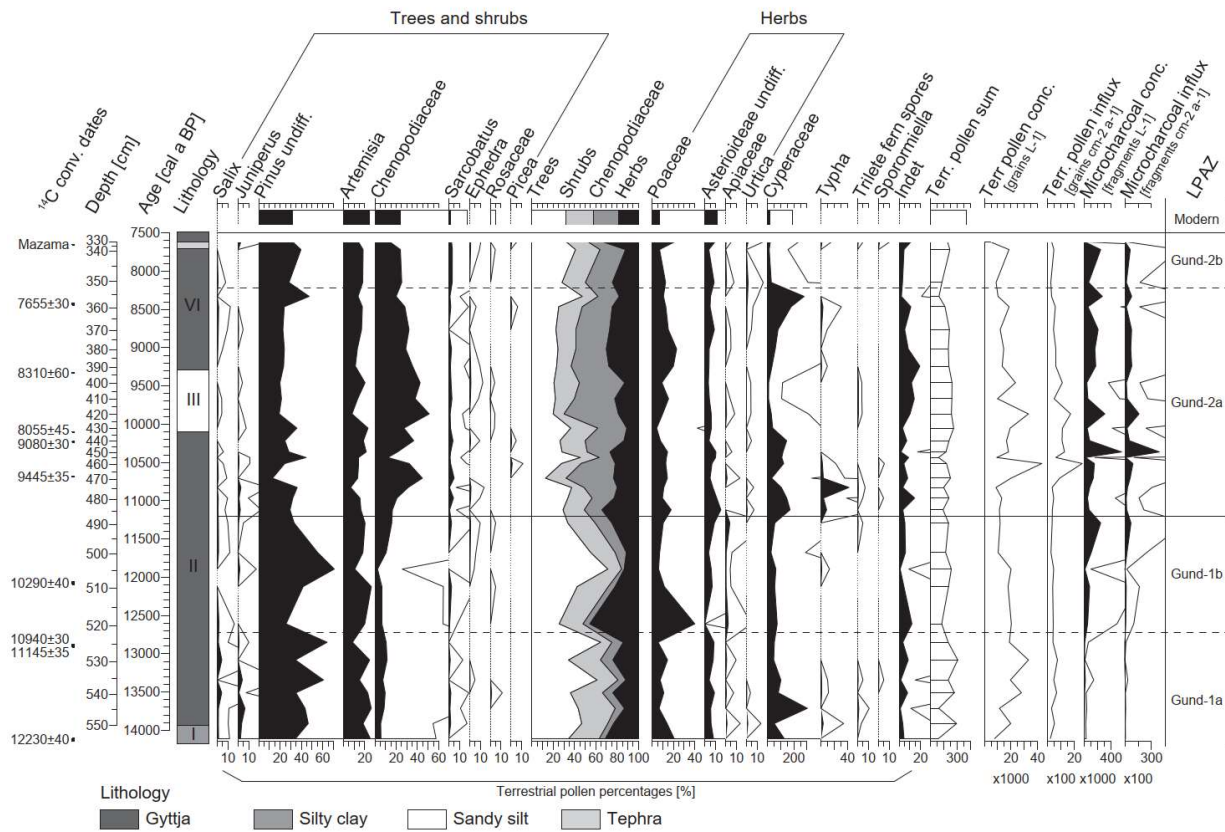
Figure 4. Pollen diagram of Gund Ranch core spanning 14.0-7.5k cal a BP showing selected terrestrial pollen types, marshland taxa, trilete fern spores, *Sporormiella* and damaged pollen grains (indet) as percentages based on the terrestrial pollen sum, the counted terrestrial pollen sum and terrestrial pollen influx, microcharcoal concentrations and influx. Note that we included the sediment surface pollen sample as modern reference. Hollow curves = 10x exaggeration, indet = indeterminable pollen grains, LPAZ = Local pollen assemblage zones.

436 **Supplementary material**
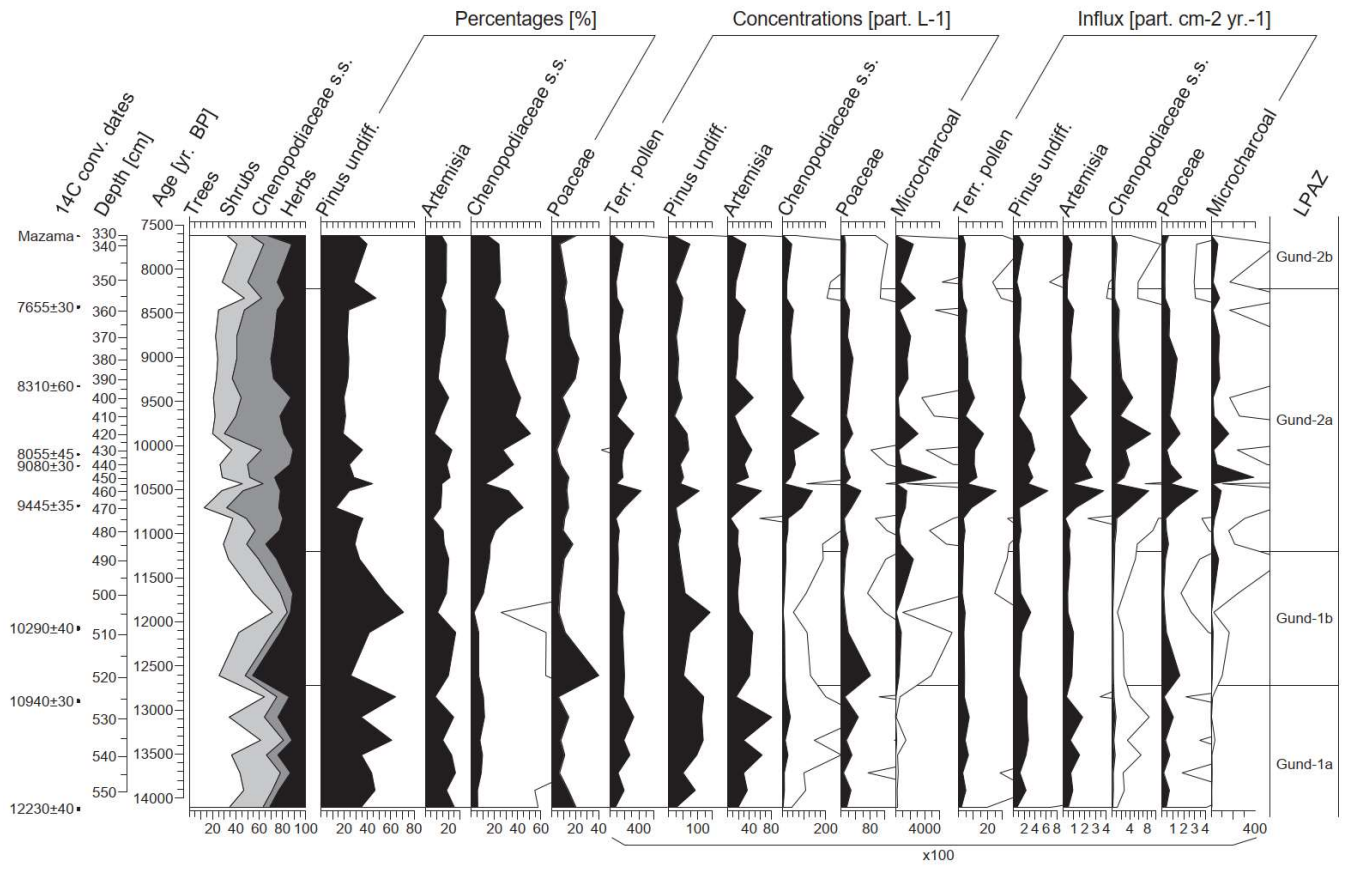
437

438　**Supplementary figure S1.** Percentages, concentrations, and influx of major pollen taxa of Gund Ranch core.

439 **Supplementary table S1.** Radiocarbon dates used for the depth-age model of Gund Ranch core. Radiocarbon dates

440 were calibrated based on the Intcal13 curve (Reimer et al. 2013) in Calib 7.1. (Stuiver et al. 2020). Modelled ages are

441 based on a smooth spline curve before the tephra layer (smooth factor =0.1) and a linear interpolation for uppermost

442 part post-tephra generated with Clam 2.2 (Blaauw 2010). Radiocarbon dates were measured at the Pennsylvania State

443 University's Accelerator Mass Spectrometry Lab (PSU) and Beta Analytic, Inc (B).

Lab code	Depth (cm)	Dated material	14C age ± 1σ (a BP conv.)	Median calibrated age, 2σ range (cal a BP)	Modelled age (cal a BP)
PSU-3306	296.5	Charcoal + terr. macrofossils indet	6195±35	7087 (6991-7238)	7115
PSU-7078	358.5	Extracted humates	7655 ± 30	8438 (8393-8536)	8432
PSU-3307	393.5	Charcoal + terr. macrofossils indet	8310 ± 60	9324 (9132-9465)	9338
PSU-3308	432.5	Charcoal + terr. macrofossils indet	8055 ± 45	Outlier 8959 (8766-9091)	10103
PSU-7079	440.5	Extracted humates	9080 ± 30	10234 (10197-10258)	10232
PSU-7080	468.5	Extracted humates	9445 ± 35	10678 (10580-10758)	10684
PSU-7081	508.5	Extracted humates	10290 ± 40	12067 (11835-12377)	12075
PSU-7082	525.5	Terrestrial macrofossils indet	10940 ± 30	12776 (12710-12848)	12897
PSU-7143	525.5	Extracted humates	11145 ± 35	13034 (12918-13099)	12897
B-490318	555	Peat fragments in gyttja	12230 ± 40	14126 (13991-14274)	14128

444