

# A Complete Database of AMS Radiocarbon Estimates from Lake Baikal Sediment Cores with a Lake-Wide Assessment of TOC Age Offsets

Samuel R. S. Newall<sup>1</sup>, Anson W. Mackay<sup>2</sup>, Natalia Piotrowska<sup>3</sup>, Maarten Blaauw<sup>4</sup>

<sup>1</sup>Earth Sciences, UC Santa Barbara, Santa Barbara, 93106, USA

<sup>2</sup>Department of Geography, Environmental Change Research Centre, UCL, London, WC1E 6BT, England, UK

<sup>3</sup>Division of Geochronology and Environmental Isotopes, Institute of Physics – CSE, Silesian University of Technology, Konarskiego 22B, 44-100 Gliwice, Poland

<sup>4</sup>School of Natural and Built Environment, Queen’s University Belfast, Belfast, BT7 1NN, Northern Ireland, UK

*Correspondence to:* Samuel R. S. Newall (newall@ucsb.edu)

**Abstract.** We present a database of AMS radiocarbon dates from Lake Baikal sediment cores, encompassing 51 cores and 518 dates, providing a complete record from literature spanning 1992 to 2025 (with transcription errors corrected) and including 22 previously unpublished dates from cores CON01-603-5 and CON01-605-5. The most common material used for radiocarbon dating in our dataset is total organic carbon (TOC). Unfortunately, the interpretation of TOC ages in lake sediments is hindered by issues such as the reservoir effect, in situ contamination by old organic carbon, and/or the hardwater effect. These issues may culminate in age estimates thousands of years older than the true depositional age of that sediment, which we term the “age offset”. Linear regression of uncalibrated radiocarbon dates has been used to estimate the age offset in Lake Baikal, with results ranging from 0 to 1.5 <sup>14</sup>C kyr in different cores. Estimates from other methods have returned estimates of approximately 2 <sup>14</sup>C kyr BP. Despite this, most previous studies have not incorporated age offset uncertainty in their age depth modeling, or have included uncertainty of, at most,  $\pm 0.09$  <sup>14</sup>C kyr. Furthermore, the varying age offset estimates have been interpreted by some as evidence that different regions of Lake Baikal have different age offsets, with implications as to the cause of the age offsets. We use the database to review the use of linear regression on uncalibrated radiocarbon ages as a method for estimating age offsets of TOC. We apply the linear regression age offset method to all suitable cores in our database, returning 21 estimates of age offset from throughout the lake. Our results provide no statistically significant evidence for a systematic difference in age offset in different regions of Lake Baikal (specifically Academician Ridge and Buguldeika Saddle). Our results return a lake-wide TOC radiocarbon age offset of  $1.62 \pm 0.76$  <sup>14</sup>C kyr, suggesting previous studies in Lake Baikal have significantly underestimated the temporal uncertainty of radiocarbon ages from TOC. Finally, our results are a caution that linear regression-based age offset estimates in lake sediments have a large uncertainty that might only be observable with multiple datasets.

## 1 Introduction

Lake sediments are natural archives that contain information on environmental histories, spanning every continent, at timescales from the past few decades to tens of millions of years. Spatially, therefore, lakes contain palaeoenvironmental information allowing space-time reconstructions of, for example, human (Dubois et al., 2018) and climate change impacts on the environment (Fritz, 2008). Reconstructing past environments from lake

37 sediments requires appropriate dating techniques and chronology construction. Radiocarbon dating is one of the  
38 most common dating techniques, with an ~50,000-year range of applicability that includes the transition from the  
39 Last Glacial Maximum to the Holocene, one of the most studied periods of paleoclimate. The process of using  
40 radiocarbon dates includes age offset correction (if applicable), calibration, and age-depth modelling – all aspects  
41 that introduce temporal uncertainty, a significant but often ignored limitation to paleoclimate research (Snyder,  
42 2010). Radiocarbon calibration and age-depth modelling techniques are regularly improved and updated (Reimer,  
43 2022), facilitating better understanding of radiocarbon analyses and the opportunity to reduce temporal  
44 uncertainty. However, this can be challenging if the radiocarbon data are not easily findable or accessible. We  
45 present a database of accelerator mass spectrometry (AMS) radiocarbon dates from Lake Baikal sediment cores  
46 to promote ‘FAIR’ principles (Wilkinson et al., 2016) and facilitate improvement of Lake Baikal paleoclimate  
47 reconstructions. Whilst a number of studies have curated regional radiocarbon datasets to facilitate better age-  
48 depth modelling (Giesecke et al., 2014; Goring et al., 2012; Wang et al., 2019; Zimmerman and Wahl, 2020) to  
49 our knowledge no systematic study has applied such an approach to a single lake before.

50

51 One challenge to reusing Lake Baikal radiocarbon dates is the presence of a significant age offset, which we  
52 define as a difference between the depositional age of a sample and the analysed age, typically making a  
53 radiocarbon date older than expected. The term “reservoir effect” has been used to describe this phenomenon  
54 (Karabanov et al. 2004) and may be more familiar to readers but we prefer not to use this term as the reservoir  
55 effect is conceptually linked to a specific process, namely the disequilibrium of radiocarbon concentrations  
56 between the atmosphere and the water in which the organic carbon is produced. In the marine setting this is  
57 typically referred to as a result of a slow rate of exchange between deep water and the atmosphere, which may  
58 also occur in lake systems: However, in lacustrine settings it is more common that this disequilibrium is due to  
59 the presence of carbonate bedrock within the watershed which supplies the water with old, radiocarbon-free  
60 dissolved inorganic carbon (DIC), known as the hardwater effect (Phillipsen, 2013). Another potential contributor  
61 to the age offset, which we consider to be different to the reservoir effect, is contamination by both young and old  
62 organic material, due to: deposition and reworking of older sediments (known as the old carbon effect);  
63 bioturbation; root penetration; and infiltration of humic acids (Björck and Wohlfarth, 2002). Contamination that  
64 occurs post-coring, such as in core storage or transport, we do not consider a contributor to age offsets. To  
65 reiterate, the difference between the depositional age and radiocarbon age of a sample (the age offset) may be the  
66 result of a number of processes, potentially including but not limited to the reservoir effect (Colman et al., 1996;  
67 Watanabe et al., 2009a). The use of these terms in the literature is, unfortunately, inconsistent.

68

69 The majority of the radiocarbon dates from Lake Baikal are of total organic carbon (TOC), also known as bulk  
70 sediment (Strunk et al., 2020). The presence of a significant age offset of TOC radiocarbon dates in Lake Baikal  
71 was highlighted by Colman et al. (1996), who wrote: “One [problem] is the mixture of carbon sources in TOC,  
72 not all of which are syndepositional in age. This problem manifests itself in apparent ages for the surface sediment  
73 that are greater than zero.” By applying a linear regression to uncalibrated radiocarbon dates they calculated age  
74 offsets of approximately  $0.47 \pm 0.37$   $^{14}\text{C}$  kyr in Academician Ridge and approximately  $1.22 \pm 0.18$   $^{14}\text{C}$  kyr in  
75 Buguldeika Saddle. The greater age offsets in Buguldeika Saddle were interpreted to be due to reworked sediment  
76 from the Selenga River (which outflows near the Buguldeika Saddle). Subsequent papers have used a similar

77 linear regression method (Demske et al., 2005; Karabanov et al., 2004), or different methods such as: directly  
78 dating the surface sediment (Murakami et al., 2012); using the Younger Dryas radiocarbon plateau as a tie-point  
79 (Watanabe et al., 2009a); comparing TOC ages to pollen concentrate ages (Nara et al., 2010); using wood  
80 radiocarbon ages (Prokopenko et al., 2007); or equating it to the residence time of the lake (Nara et al., 2023).  
81 The results range from 0.38  $^{14}\text{C}$  kyr (Nara et al., 2023) to  $2.1 \pm 0.090$   $^{14}\text{C}$  kyr (Watanabe et al., 2009a).

82  
83 Despite the evident uncertainty in estimating the radiocarbon age offset of Lake Baikal, many papers do not use  
84 uncertain estimates of age offset when constructing their age models (e.g. Murakami et al., 2012; Nara et al., 2010,  
85 2023; Prokopenko et al., 2007) and those that do have very small uncertainty ranges (e.g.  $\pm 0.09$   $^{14}\text{C}$  kyr; Watanabe  
86 et al., 2009a). One potential reason for this in older papers is that statistical packages to incorporate such offsets  
87 were not available or were not user friendly. This is no longer the case (Sweeney et al., 2018). Bayesian age-depth  
88 modelling software are now more user-friendly and sophisticated (Blaauw and Christen, 2011; Haslett and Parnell,  
89 2008; Bronk Ramsey, 2008 ) and the development of techniques to analyse the resulting temporally uncertain  
90 records has been prolific (i.e. Anchukaitis and Tierney, 2013; Franke and Donner, 2019; Hu et al., 2017;  
91 McClelland et al., 2021; McKay et al., 2021; Rehfeld and Kurths, 2014).

92  
93 Whilst many papers have estimated the age offset, there remains a very poor understanding of the causes of the  
94 age offset in Lake Baikal. Despite Lake Baikal's immense volume, deep-water renewal or ventilation (the process  
95 whereby surface waters in contact with the atmosphere are exchanged with deep waters) is surprisingly rapid,  
96 ranging between 10-18 years (Hohmann et al., 1998; Weiss et al., 1991). This rapid deep-water ventilation in Lake  
97 Baikal rules out the possibility of aged water masses contributing to the lake's radiocarbon age offset (i.e. ruling  
98 out the reservoir effect). Very few carbonate rocks are present in the Baikal catchment providing no possibility of  
99 a hardwater effect (Prokopenko et al., 2007). Modern  $^{14}\text{C}$  concentrations of dissolved inorganic carbon (DIC) in  
100 both surface and deep waters in the lake corroborate that neither the reservoir or hardwater effect are significant  
101 in the lake (Watanabe et al., 2009a). Contamination by rootlets of subsurface sediments is not expected to be an  
102 issue at the depths from which nearly all the cores that have been dated come from. Although bioturbation does  
103 occur on the surface sediments of the lake, it has little impact on multidecadal trends (e.g. Mackay et al., 2017;  
104 Swann et al., 2020), so also cannot explain a kiloyear-order age offset. Colman et al. (1996) suggested that  
105 reworked carbon from the Selenga Delta may be responsible for the older age offsets at Buguldeika Saddle  
106 however more recent estimates of equally large age offsets at Academician Ridge (Watanabe et al., 2009a) suggest  
107 other mechanisms must also be at play. Furthermore, over 90% of organic carbon in post-glacial Lake Baikal  
108 sediments is autochthonous (mainly from diatoms and picoplankton), and less than 10% is allochthonous (from  
109 catchment sources - Colman et al., 1996; Nagata et al., 1994; Votintsev et al., 1975), so even infinitely old  
110 allochthonous carbon could not, solely, account for the scale of the observed age offsets (see Figure 5 from  
111 Colman et al., 1996).

112  
113 Using our database, we generate multiple estimates of the radiocarbon age offset of TOC in the lake's sediments  
114 with a linear regression method to better quantify the TOC age offset and its uncertainty in Lake Baikal. We use  
115 a linear regression age offset estimation method because it is the most commonly used in Lake Baikal (Colman et  
116 al., 1996; Demske et al., 2005; Karabanov et al., 2004) and is well-suited to our database. The method has also

117 been used in other locations such as the Tibetan Plateau (see discussions in: Hou et al., 2012; Mischke et al.,  
118 2013). By making multiple estimates on different cores, we can deliver an estimate of age offset with a robustly  
119 calculated uncertainty and evaluate spatial variability of age offset estimates throughout the lake.

## 120 **2 Methods**

### 121 **2.1 Dataset Collection**

122 Collation of studies which have published and/or used radiocarbon dates from Lake Baikal sediments was  
123 undertaken initially using Google Scholar with search terms such as "Lake Baikal" and "radiocarbon" alongside  
124 "Palaeoclimate", "Paleoclimate", "Age Depth Modelling", "Holocene", "LGIT". Grey literature, especially reports  
125 published pre-1995 were also consulted, including those in Russian, English and Japanese. Research leads  
126 (identified from corresponding author status in publications) were also contacted. Articles were read and their  
127 citations and references interrogated, leading to ~80 relevant papers being identified. Although our approach did  
128 not set out to be a systematic review, the five basic steps required for a review were followed including (i) careful  
129 framing of the question, (ii) identification of relevant work, (iii) assessment of the quality of identified work, (iv)  
130 summarising the evidence and (v) interpretation of the findings (Khan et al., 2003).

131

132 Metadata and radiocarbon data were recorded for all cores with radiocarbon data identified from the literature.  
133 Each core was assigned to a region of the lake - as is common in Lake Baikal literature due to the lake's size.  
134 Cores reported with differing names in the literature are reported under a single name.

### 135 **2.2 New Radiocarbon Dates**

136 The dataset includes 22 previously unpublished TOC radiocarbon dates from cores CON01-603-5 and CON01-  
137 605-5. The samples were pretreated to remove any carbonates by submersion in 0.5M hydrochloric acid at 75 °C  
138 for 1 hr and then rinsed to neutral pH with demineralised water. After drying, the samples were combusted to CO<sub>2</sub>  
139 in quartz tubes and converted to graphite for AMS radiocarbon dating following the protocol described by  
140 Piotrowska (2013). The graphite targets were analysed at Poznan Radiocarbon Laboratory (Goslar et al., 2004).

### 141 **2.3 Data Organisation**

142 All radiocarbon data are reported as conventional <sup>14</sup>C age alongside its 1σ uncertainty (Stuiver and Polach, 1977).  
143 Following the convention suggested by Millard (2014), we also provide the laboratory codes, δ<sup>13</sup>C values,  
144 indication of how δ<sup>13</sup>C was measured, and carbon content (%), where available. AMS-derived δ<sup>13</sup>C values may  
145 have undergone fractionation during the AMS process hence may not be representative of the true sample value.  
146 We also include the section label and δ<sup>13</sup>C 1σ uncertainty where available.

147

148 We provide sample depth as a combination of the top, middle, bottom depth and thickness of the sample based on  
149 how the information was presented in the original paper or in our communication with the original author. All  
150 these depths are presented with the core top as the datum. Where cores had depth corrections for estimated loss  
151 of sediment at the top of the core (e.g. Colman et al., 1996; Morley et al., 2005) we provide a corrected middle  
152 depth for each sample. Corrected depths have the lake bottom as their datum. The method for depth correction in

153 any core is explained in the metadata text file attached to the dataset. The original references for each date are  
154 provided. Any differences between the original data and the provided data, for example corrected typos, are  
155 explained as a comment. Any data that did not have age uncertainty values and are therefore unsuitable for re-use  
156 were not included in the dataset but are detailed in a text file for completeness.

157

158 The metadata text file attached to the dataset also provides metadata for each core, including: the core name; the  
159 general region of the core within the lake (i.e. Buguldeika Saddle or Academician Ridge); latitude and longitude  
160 in degrees; water depth of drilling site; coring method used; length of the core; references for original data; and  
161 comments describing any corrections to the data made by us or providing explanation for depth correction.

162

163 The selection of what data to provide was driven by our focus on TOC, hence we do not provide information  
164 relevant only to pollen concentrate or lipid fraction dates, such as purity as reported in Piotrowska et al. (2004).  
165 We do not perform calibration on any of the dates, so we do not provide any calibrated date ranges or calibration  
166 information. Furthermore, we do not include an indication of whether an age was rejected by previous authors or  
167 by us in our analysis as rejection can vary across publications. We highlight that all data should be carefully  
168 considered before any reuse.

#### 169 **2.4 Age Offset Estimation**

170 The most common approach to estimating age offset in Lake Baikal is using linear regression. A linear regression  
171 of the mean of each (uncalibrated) radiocarbon age on sample midpoint depths for each sediment core is made,  
172 with the y-intercept value, which we term the “apparent surface age” (ASA), taken to be the age offset. This  
173 approach assumes the age offset and sedimentation rate are essentially constant over the period included in the  
174 linear regression. Studies using this technique have differed in how many ages they use in the calculation. For  
175 example, Colman et al. (1996) sometimes only used the top two dates of a core and sometimes used all dates  
176 younger than 13 <sup>14</sup>C kyr BP. Karabanov et al. (2004) and Demske et al. (2005) also apply a linear regression  
177 method to calculate age offset in their study but do not describe what subset of ages they used for each regression.

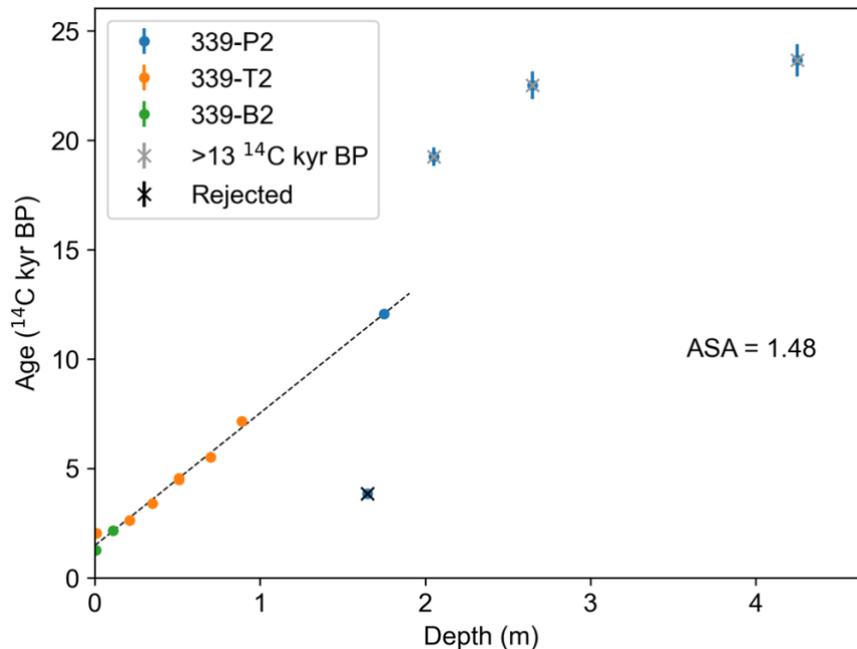
178

179 We follow Colman et al. (1996) in performing regressions using all dates younger than 13 <sup>14</sup>C kyr BP. The  
180 exclusion of ages older than 13 <sup>14</sup>C kyr BP follows from the change in sediment type at approximately this age,  
181 from organic-poor glacial sediments to organic-rich post-glacial sediments (Carter and Colman, 1994). These  
182 organic-rich sediments have carbon primarily from algae (such as diatoms and picoplankton) whereas the organic-  
183 poor glacial sediments are more heavily influenced by catchment sources of carbon (Vologina and Sturm, 2009).  
184 We also follow Colman et al. (1996) in their creation of composite cores for cores they report from the same  
185 drilling site.

186

187 For each (composite) core, we perform a simple ordinary least-squares linear regression of mean radiocarbon age  
188 on midpoint depth and use the fitted line to estimate the age at depth = 0, i.e. the ASA (Figure 1). The radiocarbon  
189 profile of each (composite) core was examined beforehand to remove outliers and to check that the ages are  
190 generally ageing with increasing depth and are approximately linear - cores that do not follow this description are  
191 excluded from this analysis. Obvious outliers are also removed, and where the selection of outliers is not clear we

192 evaluated multiple options and chose one. Analyses were carried out using a reproducible Jupyter Notebook  
193 workflow; the full notebook and supporting files are publicly archived on Zenodo (Newall, 2025).  
194



195  
196 **Figure 1: An example of the creation of composite cores using cores from the same drilling site, following Colman et**  
197 **al. (1996). The radiocarbon ages (all from TOC) from cores 339-B2, 339-T2 and 339-P2 are plotted against depth**  
198 **forming a composite core from Site 339. Circles show the mean radiocarbon age and bars show the analytical  $1\sigma$**   
199 **uncertainty. Ages that are rejected or not used in the linear regression are overlain with a black or grey cross**  
200 **respectively. The rejected ages shown here follow the interpretation of Colman et al. (1996), and those older than 13**  
201  **$^{14}\text{C}$  kyr BP are not used in the linear regression. The black dotted line shows the linear regression (only shown up to**  
202 **13  $^{14}\text{C}$  kyr BP). The y-intercept, or ASA, is 1.48  $^{14}\text{C}$  kyr BP. In our interpretation of this core, we additionally rejected**  
203 **the 2<sup>nd</sup> deepest date from 339-P2 (the single blue dot in this figure), because all other ages from this core seem**  
204 **problematic. Both interpretations return an ASA of 1.48  $^{14}\text{C}$  kyr BP.**

### 205 3 Results

#### 206 3.1 Core Data Overview

207 Our review identified 51 cores that contained AMS  $^{14}\text{C}$  dates (Table 1; Figure 2; Figure 3), encompassing 518  
208 radiocarbon datapoints (Figure 4). The cores are mainly taken from two underwater ridges: the Academician  
209 Ridge, separating the Northern Basin and Central Basin, and the Buguldeika Saddle, separating the Central Basin  
210 and the Southern Basin. Bathymetric highs such as these are often chosen as coring sites because they often  
211 provide continuous and uninterrupted sediment records free from turbidites (Vologina and Sturm, 2009), unlike  
212 slopes, deep-water basins, or delta fan sites near the mouths of large rivers (Colman et al., 2003).

213



214  
 215 **Figure 2: Map of Lake Baikal showing location of all cores (black crosses). Relevant lake locations and major**  
 216 **tributaries are labeled.**

217

Region	Core Name	Latitude (°)	Longitude (°)	Depth (m)	References
<b>Academician Ridge</b>	18-B1	53.56	108.01	345	Colman et al. (1996)
	18-P2	53.56	108.01	345	Colman et al. (1996); Nakamura et al. (2003)
	307-A3	53.59	108.07	335	Colman et al. (1996)
	331-P1	53.47	107.79	360	Colman et al. (1996)
	331-T1	53.47	107.79	360	Colman et al. (1996)
	333-P2	53.65	108.16	390	Colman et al. (1996)
	333-T2	53.65	108.16	390	Colman et al. (1996)
	340-B1	53.67	108.36	280	Colman et al. (1996)
	340-P1	53.67	108.36	280	Colman et al. (1996)

	340-T1	53.67	108.36	280	Colman et al. (1996)
	BDP96-1	53.70	108.35	335	Nakamura et al. (2003)
	BDP96-2	53.70	108.35	335	Nakamura et al. (2003)
	BDP98-1	53.74	108.41	325	Nakamura et al. (2003)
	VER98-1 St.5GC	53.74	108.41	325	Watanabe et al. (2009a); Watanabe et al. (2009b)
	VER98-1 St.5PC	53.74	108.41	325	Watanabe et al. (2009a)
	VER98-1 St.6GC	53.69	108.35	335	Watanabe et al. (2009a)
	Ver93-2 St.4-PC	53.56	108.02	356	Nakamura et al. (2003)
	Ver94-5 St.16-PC	53.71	108.38	310	Nakamura et al. (2003)
	Ver94-5 St.16-Pilot	53.71	108.38	310	Nakamura et al. (2003)
	Ver94-5 St.19-PC	53.56	108.01	350	Nakamura et al. (2003)
	Ver96-2 St.3-GC	53.7	108.35	320	Nakamura et al. (2003)
	Ver96-2 St.7-PC	53.56	108.1	*	Nakamura et al. (2003)
	Ver96-2 St.7-Pilot	53.56	108.1	*	Nakamura et al. (2003)
	Ver97-1 St.6	53.68	108.33	335	Nakamura et al. (2003); Sakai (2006)
<b>Buguldeika Saddle</b>	305-A5	52.4	106.12	290	Colman et al. (1996)
	316-P3	52.44	106.15	300	Colman et al. (1996)
	316-T3	52.44	106.15	300	Colman et al. (1996)
	339-B2	52.51	106.17	375	Colman et al. (1996)
	339-P2	52.52	106.17	375	Colman et al. (1996)
	339-T2	52.52	106.17	375	Colman et al. (1996)
	BDP93-1	52.52	106.15	354	Colman et al. (1996); Nakamura et al. (2003)
	BDP93-2	52.52	106.15	354	Colman et al. (1996); Nakamura et al. (2003)
	BSS06-G2	52.46	106.13	360	Murakami et al. (2012)

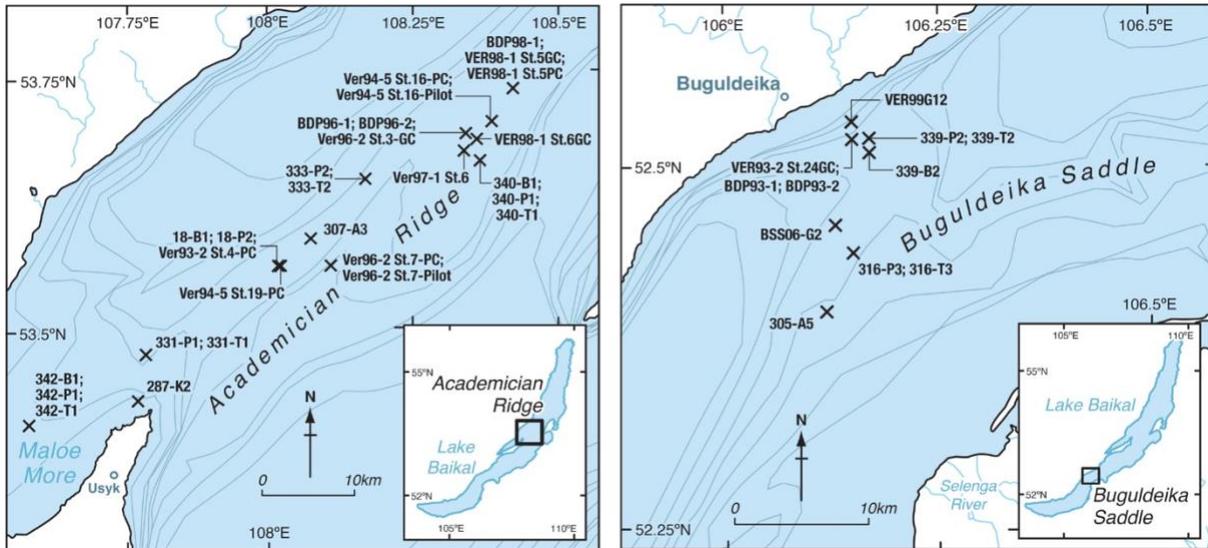
	VER93-2 St.24GC	52.52	106.15	355	Karabanov et al. (2004); Tarasov et al. (2007)
	VER99G12	52.53	106.15	350	Watanabe et al. (2007); Watanabe et al. (2009b); Nara et al. (2010)
<b>Barguzin Bay</b>	BarguzinBa y18	53.42	108.82	41	Fedotov et al. (2023)
<b>Central Basin</b>	308-A3	53.42	108.32	1700	Colman et al. (1996)
<b>Continent Ridge</b>	CON01- 603-5	53.95	108.91	386	Piotrowska et al. (2004);
<b>Maloe More</b>	287-K2	53.42	107.78	300	Colman et al. (1996)
	342-B1	53.4	107.59	240	Colman et al. (1996)
	342-P1	53.4	107.59	240	Colman et al. (1996)
	342-T1	53.4	107.59	240	Colman et al. (1996)
<b>Northern Basin</b>	323-PC1	55.54	109.52	710	Ogura (1992); Nakamura et al. (2003);
	Ver94-5 St.22-GC	55.32	109.54	825	Nakamura et al. (2003)
<b>Posolskoe Bank</b>	CON01- 606-3	52.08	105.87	130	Piotrowska et al. (2004)
	Ver.99 G-6	52.09	105.84	200	Tani et al. (2002)
<b>Southern Basin</b>	BAIK13-1C	51.77	104.42	1360	Swann et al. (2020)
	BAIK13-4F	51.69	104.3	1360	Swann et al. (2020)
	BDP97-1	51.85	105.55	1450	Nakamura et al. (2003)
<b>Vydrino Shoulder</b>	CON01- 605-3	51.59	104.85	675	Demske et al. (2005)
	CON01- 605-5	51.58	104.85	665	Piotrowska et al. (2004); Demske et al. (2005)

218 **Table 1: A list of all cores for which radiocarbon data were found. Each core was categorized by its general location,**  
219 **and the longitude, latitude and depth are provided. The references for the original radiocarbon data (or important**  
220 **metadata) are provided. Boxes with asterisks denote information that was not found.**

221 The location data provided for core CON01-603-5 by Piotrowska et al. (2004) and for core 287-K2 by Colman et  
222 al. (1996) placed the cores outside the boundaries of the lake. The location of 287-K2 was corrected by sight to  
223 match the locations provided on the map figures of Colman et al. (1996) and the location of CON01-603-5 was  
224 revised to fit that of Demske et al. (2005). Numerous slightly differing location data for BDP96-1 and BDP96-2  
225 were found (Kashiwaya et al., 2001; Nakamura et al., 2003; Sakai et al., 2000), being 20 km apart at most. We  
226 use the value from Nakamura et al. (2003). Note, latitude/longitude data for core Ver97-1 St.6 was only found to  
227 the precision of degree minutes, not degree seconds (Sakai, 2006).

228

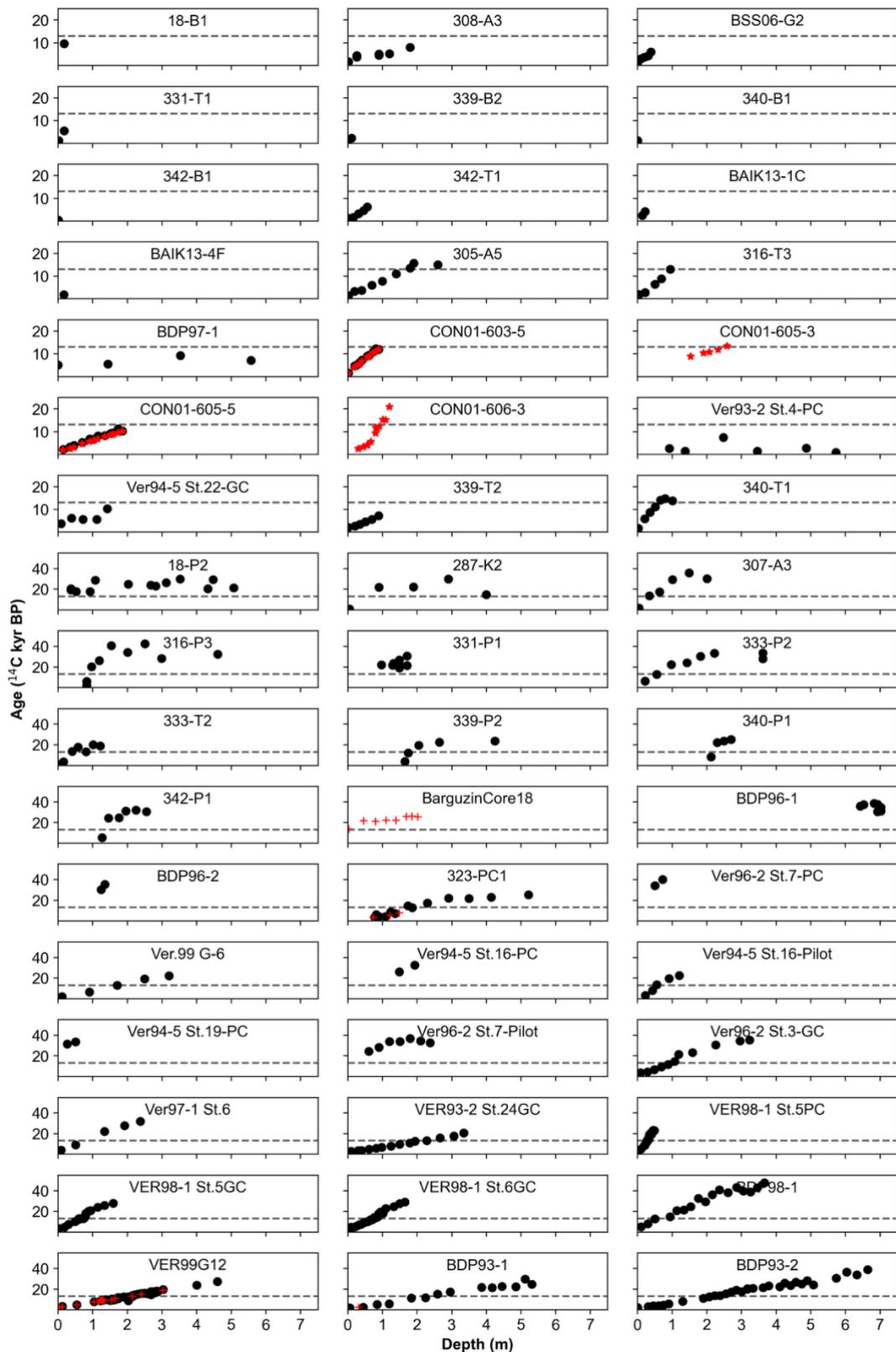
229 To aid the reader in finding the locations of cores in the densely cored regions, we provide higher resolution maps  
230 of Academician Ridge and Buguldeika Saddle (Figure 3).



231  
232 **Figure 3: Detailed maps of the core locations in Academician Ridge (left) and Buguldeika Saddle (right). Black crosses**  
233 **denote core locations, some crosses represent multiple cores.**

### 234 3.2 Radiocarbon Ages Overview

235 The cores in the database have between 1 and 71 radiocarbon dates (Figure 4). The vast majority of radiocarbon  
236 dates (438 dates) in the dataset are from TOC (a.k.a. decalcified bulk sediment). The dates from core  
237 BarguzinCore18 (8 dates) were described as being from “bulk silty clay” - no acidification/decalcification step is  
238 mentioned, hence we are unable to confirm that they are TOC dates (they may contain inorganic carbon). Pollen  
239 concentrates have also been dated (42 dates). However, they are not nearly as widely exploited due to their more  
240 intensive preparatory workload. It is notable that the pollen concentrate dates still seem to suffer from age offsets,  
241 as they show non-zero surface ages after regression (Demske et al., 2005). A few other materials have been dated  
242 but only in very low numbers. These include total lipids (9 dates), picked organic matter (POM; 7 dates), fine  
243 organic matter (FOM; 5 dates); lipid fraction (2 dates); and wood (2 dates). Note that POM and FOM relate to  
244 two different forms of organic matter, described by Colman et al. (1996). It was concluded that they were not  
245 statistically different to the TOC ages they reported.



246

247

248

249

250

251

Figure 4: Radiocarbon data from all 51 cores in this database, with mean uncalibrated radiocarbon age in  $^{14}\text{C}$  kyr BP on y axis and depth in m plotted on x axis. TOC ages are shown as black dots, pollen ages as red stars, and all other materials (lipids, diatom/pelitic silt, wood) are shown as red crosses. The top seven rows have smaller y axis limits to better show shorter cores. All x axes are the same. Horizontal dashed lines are plotted at 13  $^{14}\text{C}$  kyr BP to highlight the cut-off for our linear regression method.

252 Several errors were found in Table 2 of Colman et al. (1996) providing depth values off by a factor of 10. These  
 253 were cross-checked by contacting S. M. Colman and are reported correctly here. These errors were simply  
 254 transcription errors, so no results are affected. Lab IDs and sample top/bottom depths for core BSS06 G-2 were  
 255 added to this dataset by personal communication with Murakami. Finally, some lab codes that were wrongly  
 256 transcribed in Nara et al. (2023) are corrected. Four dates were reported with negative radiocarbon ages, all from  
 257 core Ver93-2 St.4-PC, including one with an age of  $-13.365 \pm 80$   $^{14}\text{C}$  kyr BP (i.e. a fraction modern value of  $5.237$   
 258  $\pm 0.049$ ) at a core depth of 653cm. We include them in the database for completeness. Nine dates were reported  
 259 with ‘lower-bound’ radiocarbon ages (i.e. ‘>43240’), all from cores BDP96-1 and BDP96-2: These are reported  
 260 in Newall et al. (2025) in a separate file (non\_numeric\_data.tab) for completeness, but we suggest not using them.

### 261 3.3 Age Offset Estimates from Linear Regression

262 Of the 51 cores with radiocarbon data reported in this compilation, 26 are used to calculate age offsets. In total,  
 263 21 ASA estimates are made, using 140 TOC ages. To recap, the ASA is the y-intercept of the linear regression on  
 264 TOC ages younger than 13  $^{14}\text{C}$  kyr BP and represents an estimate of the age offset. The results for each core,  
 265 grouped and summarised by their location are provided below.

#### 266 3.3.1 Academician Ridge

267	Core/Site	# of ages	ASA ( $^{14}\text{C}$ kyr BP)
268	Ver94-5 St.16	2	-2.49*
269	333 (2)	4	0.08
270	331 (1)	2	0.55
271	340 (2)	5	1.28
272	Ver96-2 St.3-GC	5	1.94
273	VER98-1 St.6GC	16	2.17
274	VER98-1 St.5 (1)	9	2.54
275	Ver97-1 St.6	2	2.77
	BDP98-1	3	2.86
	Mean		1.77
	Range		2.78

276 **Table 2: The ASAs ( $^{14}\text{C}$  kyr BP) for each core/site at Academician Ridge. Where cores were analysed as a composite,**  
 277 **the number of cores from which data was used in the linear regression is denoted in parentheses. Cores with anomalous**  
 278 **ASAs are marked with \*.**

279 The ASA of 9 sites, using 11 cores, were returned from Academician Ridge (Table 2). Core Ver94-5 St.16 returned  
 280 a negative age offset estimate and we consider it an outlier, leaving 8 accepted ASAs. Cores 18-P2 and 18-B1  
 281 were left out as the former was non-linear and the latter only had one age. Core 340-P1 was left out because its  
 282 only age younger than 13  $^{14}\text{C}$  kyr BP was a large reversal from the older ages of 340-T1 and was clearly erroneous.  
 283 Core 307-A3 was left out because it only had one age younger than 13  $^{14}\text{C}$  kyr BP. Cores 331-P1, Ver94-5 St.19-  
 284 PC, Ver96-2 St.7-Pilot, Ver96-2 St.7PC, BDP96-1, and BDP96-2 were left out because they had no ages younger

285 than 13 <sup>14</sup>C kyr BP. Core Ver98-1 St.5PC seems to have suffered from partial compression (clear from comparison  
 286 to Ver98-1 St.5GC; Watanabe et al., 2009a) so was left out.

### 287 3.3.2 Buguldeika Saddle

288	Core/Site	# of ages	ASA ( <sup>14</sup> C kyr BP)
289	316 (1)	6	0.92
290	BDP93 (1)	9	1.26
291	305-A5	6	1.34
292	339 (2)	8	1.48
293	BSS06-G2	5	1.50
294	VER93-2 St.24GC	11	1.75
295	VER99G12	11	1.99
	Mean		1.46
	Standard Deviation		0.32

296 **Table 3: The ASAs (<sup>14</sup>C kyr BP) for each core/site at Buguldeika Saddle. Where cores were analysed as a composite,**  
 297 **the number of cores from which data was used in the linear regression is denoted in parentheses.**

298 The ASA of 7 sites, using 8 cores, were returned from Buguldeika Saddle (Table 3). Core 339-P2 was left out due  
 299 to its non-linearity (Figure 1). Core 316-P3 was also left out due to its non-linearity. BDP93-1 was also left out,  
 300 due to its suspected contamination by modern carbon (Colman et al., 1996). Including data from BDP93-1 would  
 301 have changed the BDP93 ASA to 1.15 <sup>14</sup>C kyr BP.

### 302 3.3.3 Other Locations

Location	Core/Site	# of ages	ASA ( <sup>14</sup> C kyr BP)
Maloe More	342 (3)	7	0.50
Posolskoe Bank	Ver.99 G-6	2	1.19
Central Basin	308-A3	4	1.42
Vydrino Shoulder	CON01-605-5	12	1.62
Continent Ridge	CON01-603-5	10	1.89
Northern Basin	VER94-5	3	2.80
	St.22-GC		
	323-PC1	7	-2.20*
Southern Basin	BDP97-1	4	5.06*
	BAIK13-1C	2	-0.45*
Mean			1.61
Standard Deviation			0.76

303 **Table 4: The ASAs (<sup>14</sup>C kyr BP) for each core/site in other regions. Where cores were analysed as a composite, the**  
 304 **number of cores from which data was used in the linear regression is denoted in parentheses. Cores with anomalous**  
 305 **ASAs are marked with \*.**

306 The ASA of 8 sites, using 10 cores, was returned from other locations in the lake (i.e. not Academician Ridge or  
 307 Buguldeika Saddle). The ASA of 1 site, using 3 cores, was returned from Maloe More. Core Ver.99 G-6 has a  
 308 10cm depth correction applied (Tani et al., 2002) after comparison with a corresponding multiple core M-6. Both  
 309 CON01-603-5 and CON01-605-5 were suggested by Demske et al. (2005) to have had sediment missing from the  
 310 core tops. Morley et al. (2005) calculated a depth correction for CON01-605-5 of 12.5cm based on correlation of  
 311 diatom species profiles, which we apply to this data. However, no such depth correction for CON01-603-5 has  
 312 been provided, so its ASA may be an overestimate. We did not calculate an ASA for core BarguzinBay18 for two  
 313 reasons. First, we could not confirm that dates from core BarguzinBay18 were TOC dates, and second, it has no  
 314 ages younger than 13 <sup>14</sup>C kyr BP. The top 3cm of core sediment returned a radiocarbon age > 13 <sup>14</sup>C kyr BP,  
 315 suggesting there has been erosion at this location, likely due to its shallow setting or proximity to the mouth of  
 316 the Barguzin river, further rendering the core unsuitable for the linear regression method.

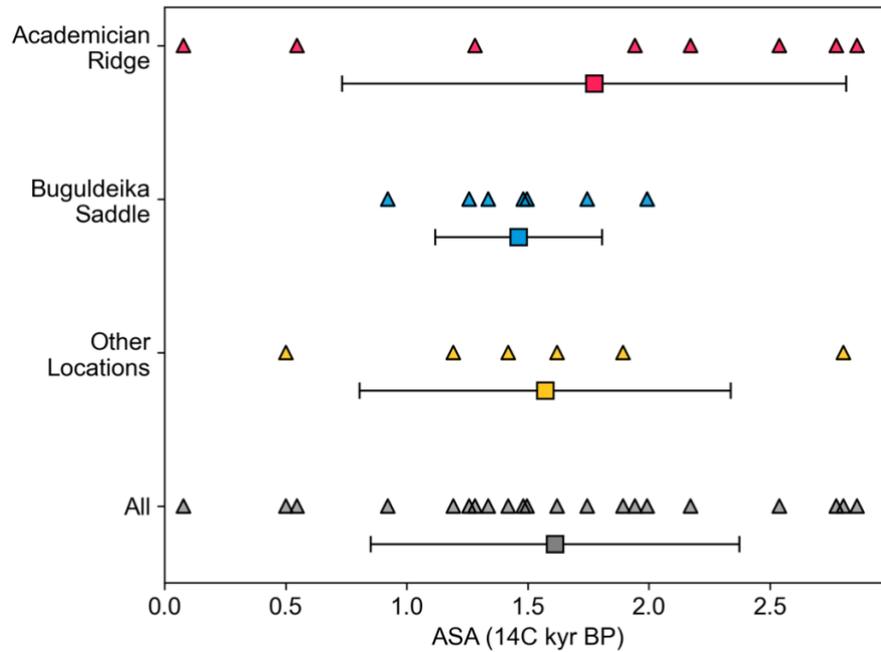
317 **3.3.4 Synthesis**

318

	No. of ASAs	No. of ages	Mean	Standard Deviation	Min	Max
<b>Academician Ridge</b>	8	46	1.77	1.04	0.08	2.86
<b>Buguldeika Saddle</b>	7	56	1.47	0.37	0.92	2.34
<b>Other Locations</b>	6	38	1.57	0.77	0.5	2.80
<b>All</b>	21	140	1.62	0.76	0.08	2.86

319 **Table 5: Summary statistics of all ASA (<sup>14</sup>C kyr BP) estimates, when looking at different subsets, one of which being**  
 320 **the entire lake.**

321 Our results have a mean and standard deviation of  $1.62 \pm 0.76$  <sup>14</sup>C kyr BP (Table 5; Figure 5). The median  
 322 estimate is similar to the mean, at 1.48 <sup>14</sup>C kyr BP and a Shapiro-Wilk test returns a p-value of 0.70, suggesting  
 323 it would be reasonable to consider the results normally distributed. The means for Buguldeika Saddle,  
 324 Academician Ridge, and for all other locations are similar to the mean of the entire lake (Figure 5). The  
 325 minimum and maximum ASA estimates are 0.08 and 2.86 <sup>14</sup>C kyr BP respectively, both from Academician  
 326 Ridge, providing a very large range. The Buguldeika Saddle region provides a much less variable set of ASA  
 327 estimates than Academician Ridge.



328

329 **Figure 5: Individual ASA estimates (triangles) grouped as being either from Academician Ridge,**  
 330 **Buguldeika Saddle, or other locations. The mean of each location is denoted as a square and the standard**  
 331 **deviation is illustrated with symmetrical error bars. Estimates from all locations are then considered as a**  
 332 **single group (“All”, in grey), showing the mean and standard deviation.**

333 **4 Discussion**

334 **4.1 Data Compilation**

335 Whilst radiocarbon specific data compilation papers have been published for Lake Baikal before (Colman et al.,  
 336 1996; Nakamura et al., 2003) this paper represents the first complete collection of all AMS radiocarbon data from  
 337 sediment cores published before 2025 for Lake Baikal. Whilst most of the data we present is not of our own  
 338 analysis, the paper represents a large step towards making all the data more accessible for future reuse. Having  
 339 all data in one compilation, with transcription errors fixed, extra metadata, and some data made accessible for the  
 340 first time will reduce the time needed to find/verify data of interest. We hope it may encourage those interested to  
 341 utilise more data than they would have previously or to work on compiling databases of other proxies from the  
 342 lake. Within the radiocarbon realm there is still room for growth, as radiocarbon dates from surface sediment  
 343 samplers, sediment traps, suspended sediment and DIC are not included here but are present in the literature and  
 344 regularly invoked when discussing the age offset (discussed in detail below; Colman et al. 1996; Prokopenko et  
 345 al. 2007; Watanabe et al. 2009a). We stuck to data from sediment cores as opposed to from other sources in this  
 346 paper due to the significantly better reporting of sediment core data.

347 **4.1.1 Poor Representation in Data Repositories**

348 Archiving of radiocarbon data (and proxy data in general) from Lake Baikal into international data repositories  
 349 has been poor; compiling data using typical data repositories (Neotoma, Pangaea, NOAA) provided data from  
 350 only three cores (searches done as of 1<sup>st</sup> July 2025): Neotoma contained 1 dataset for core CON01-603-5, but

351 under a slightly different core name (CON16035); Pangaea contained datasets for CON01-603-5, CON01-605-5  
352 and CON01-606-3, although data for core CON01-606-3 was reported twice with differing reporting standards;  
353 NOAA held no radiocarbon datasets from Lake Baikal. Furthermore, interrogating the case of CON01-605-5 from  
354 Pangaea, this dataset is actually a composite core consisting of dates taken from neighbouring cores CON01-605-  
355 5 and CON01-605-3. Whilst composite cores are certainly useful when presenting and analysing data for study,  
356 we only report datasets that are delineated by core (and we deconstruct composite cores into their original cores),  
357 as this helps highlight the origin of the data.

358

359 The lack of this representation in recognised data repositories means these data are not contributing to influential  
360 large scale data compilation or assimilation projects (Erb et al., 2022; Kaufman et al., 2020). Whilst reporting  
361 their radiocarbon data alone will not allow their inclusion in such studies, this study may act to spur proxy  
362 compilation work for Lake Baikal or the Baikal region.

#### 363 **4.1.2 Naming/Data Inconsistencies**

364 Horiuchi et al. (2000) report radiocarbon data from a gravity core ‘VER94/st.16’ which were identical to data  
365 reported by Nakamura et al. (2003) from core Ver94-5 St.16-Pilot and a sediment sampler - we report the data  
366 under Ver94-5 St.16-Pilot and do not report the date from the sediment sampler (which has laboratory code  
367 NUTA-4152). This inconsistency in core naming, and the reporting of a date from a sediment sampler as if it was  
368 from a core, makes proper reuse of data more difficult. Inconsistency in the spellings of different locations within  
369 the lake, such as five different spellings for Posolskoe Bank, may also make searching for relevant literature  
370 difficult. However, different spellings are to be expected across such a broad range of research, perhaps for cultural  
371 or linguistic reasons. We chose the more common spellings in the radiocarbon literature (such as “Northern Basin”  
372 instead of “North Basin” and “Posolskoe Bank” instead of “Posolsky Bank”). There were also inconsistencies in  
373 the data reported for a single core between different papers: For example, subsequent papers describing  
374 radiocarbon data for cores Ver93-2 St.24GC and VER99G12 sometimes left out some radiocarbon dates from  
375 previous papers without explanation. Lastly, there were some radiocarbon data with identical laboratory codes  
376 (which are supposed to be unique) but different data.

377

#### 378 **4.1.3 Data Reporting Conventions**

379 Despite longstanding published conventions for reporting radiocarbon ages (Stuiver and Polach, 1977) and recent  
380 calls for better adherence to these conventions (Millard, 2014) many of the papers that have reported radiocarbon  
381 in Lake Baikal do not follow the conventions. All followed the most important convention of reporting  
382 conventional radiocarbon ages. However, two papers did not provide the laboratory codes (Murakami et al., 2012;  
383 Swann et al., 2020) and 7 papers did not provide any quality control measurements such as  $\delta^{13}\text{C}$  in their  
384 radiocarbon data tables (Fedotov et al., 2023; Murakami et al., 2012; Nara et al., 2023; Swann et al., 2020;  
385 Watanabe et al., 2007, 2009a, b). We were able to gather much missing information by contacting the authors,  
386 but not all authors were within contact. We reaffirm the need for better adherence to radiocarbon age reporting  
387 conventions.

388

389 Another proposal by Millard (2014) is that the pretreatment method should be described or referenced. Description  
390 regarding preparation of samples for dating TOC was generally very concise. All papers, with the exception of  
391 Fedotov et al. (2023), describe an acidification step similar to the steps we describe in section 2.2. Only Colman  
392 et al. (1996) describes any sieving procedure, but this is likely because they analysed samples of both picked  
393 organic matter (POM) and fine organic matter (FOM) to evaluate whether these fractions of organic matter may  
394 have provided better results than TOC. They found no consistent relationship between the POM, FOM, and TOC  
395 ages, which may be why future studies did not mention (and therefore, we assume, did not perform) any sieving  
396 or filtering. No papers reported any treatment with alkaline solution to remove base-soluble organic carbon (humic  
397 acids).

398

399 No convention has been agreed upon regarding how to report sample depth information from sediment cores. In  
400 the papers reporting radiocarbon data in Lake Baikal, sample depth information was reported in the following  
401 three ways: (1) reporting the top and bottom depth of the core sample; (2) reporting the middle depth and thickness  
402 of the core sample; (3) reporting just the middle depth of the sample. Khider et al. (2019) record a community  
403 belief that sample thickness should be an essential property to report and note a community preference for top and  
404 bottom depth to be reported. Lacourse and Gajewski (2020) stress the importance of this metric after analysing a  
405 set of publications from 2018 and 2019 in *Quaternary Research* and *Journal of Quaternary Science*, finding that  
406 75% of 34 papers they analysed failed to report sample thickness. Only 56% of radiocarbon dates in this  
407 compilation contain thickness data. We reaffirm the need for better reporting of sample thickness, either by  
408 reporting top and bottom depth of the core sample or reporting the middle depth and thickness.

## 409 **4.2 Age Offset Estimates**

410 The application of a single age offset estimation method to a number of cores within a single lake, or a single  
411 region of a lake has been done before by Colman et al. (1996; n=10 age offset estimates) and Watanabe et al.  
412 (2009a; n=3 age offset estimates) however this study represents the largest number of cores analysed with the  
413 same method (n= 21 age offset estimates). The method used in this paper is similar to that of Colman et al. (1996).  
414 The method of Watanabe et al. (2009a), by contrast, aligns positive anomalies in linear sedimentation rate to the  
415 radiocarbon plateau of the Younger Dryas. We first discuss other results on the age offset for Lake Baikal, then  
416 compare them to our own. The papers discussed below are not an exhaustive list of papers that utilise an age offset  
417 estimate but focus on those that make some justification for their choice.

### 418 **4.2.1 Previous Age Offset Estimates**

419 Colman et al. (1996) use linear regression methods to estimate the age offset for cores in Lake Baikal, using either  
420 the topmost two ages in a core or all ages younger than 13 <sup>14</sup>C kyr BP. The cores they analyse come from either  
421 the Academician Ridge or Buguldeika Saddle regions. They report that the age offsets from these two regions are  
422 distinct from each other ( $0.47 \pm 0.37$  <sup>14</sup>C kyr BP at Academician Ridge and  $1.22 \pm 0.18$  <sup>14</sup>C kyr BP at Buguldeika  
423 Saddle). They hypothesise that the older age offset in Buguldeika Saddle may be due to an influx of older  
424 terrigenous sediment from the Selenga River, with its outflow very near the Buguldeika Saddle, supported by a  
425 radiocarbon age of  $2.68 \pm 0.03$  <sup>14</sup>C kyr BP from suspended sediment of the Selenga River. However, they

426 recognise that where allochthonous carbon is ~10%, as in Academician Ridge, even infinitely old terrigenous  
427 sediment could not cause some of the age offsets they observe.

428

429 Karabanov et al. (2004), use a regression methodology to estimate an age offset of 1588 years from core VER93-  
430 2 st.24GC in the Buguldeika Saddle, however, they do not describe whether all their dates are used for regression.  
431 This result was not reproducible by us using any subset of their ages. Tarasov et al. (2007), examining the same  
432 core, chose instead to use an age offset estimate from Colman et al. (1996). However, instead of using the average  
433 Buguldeika Saddle estimate of  $1.22 \pm 0.18$   $^{14}\text{C}$  kyr, they use  $1.16$   $^{14}\text{C}$  kyr based on the linear regression of the  
434 BDP93 cores' radiocarbon data.

435

436 Demske et al. (2005) estimate the age offset of pollen concentrate ages (not the TOC age offset) by performing  
437 linear regressions on three cores, however the number of ages used for each regression is not described. For core  
438 CON01-603-5 (Continent Ridge) they use a value of  $0.930$   $^{14}\text{C}$  kyr, which we could reproduce using the shallowest  
439 three ages in the core. For core CON01-606-3 (Posolskoe Bank) they report a value of  $0.675$   $^{14}\text{C}$  kyr and for the  
440 composite core consisting of cores CON01-605-3 and CON01-605-5 (Vydrino Shoulder) they report a value of  
441  $0.96$   $^{14}\text{C}$  kyr. We could not reproduce either of those values using any combination of their data with a simple  
442 ordinary least squares linear regression. Note these results are from pollen concentrates, which likely have a  
443 different age offset to TOC. The non-zero nature of these offsets however highlights that pollen concentrate ages  
444 in Lake Baikal still suffer from an age offset, similar to what has been determined by other studies (Kilian et al.,  
445 2002; Neulieb et al., 2013; Schiller et al., 2021), possibly through contamination or redeposition.

446

447 Prokopenko et al. (2007) argue that a “true reservoir effect for a lake cannot be core- or site-specific” and reject  
448 age offset estimates determined from linear regression-based approaches due to their resulting in “core-specific  
449 reservoir corrections... from the same site”. However, the different estimates from nearby cores can be simply  
450 reconciled by recognising that the estimation method used has uncertainty, like all estimation methods. Further,  
451 they propose that Lake Baikal TOC age corrections “should not exceed 500yr”. However, this proposal is based  
452 on 3 ages from surface sediments or modern sediment traps, which may underestimate the age estimates due to  
453 bomb carbon (Colman et al. 1996) and their justifications show misunderstandings that both wood samples and  
454 pollen concentrates are free themselves from age offsets (which they are not). For example, Prokopenko et al.  
455 (2007) suggest a “critical cross-check” for the TOC age offset is available in the radiocarbon ages of the twin  
456 BDP-93 cores, referencing a wood and a TOC age that are from similar depths in different cores. The wood age  
457 is approximately 500 years younger than the slightly deeper TOC age, so imposing an offset of over 500y on the  
458 TOC age creates a stratigraphic reversal, the deeper age now being younger. This supposed contradiction,  
459 however, doesn't account for the fact that wood ages are also known to have age offsets (Hatté and Jull, 2013).  
460 For example, Oswald et al. (2005) compare the ages of different macrofossil types in Arctic lakes and find that  
461 “wood and charcoal are generally older than other macrofossils of the same sample depth with age differences  
462 ranging from tens to thousands of years”, which they attribute to the decay-resistance and/or the in-built age of  
463 woody macrofossils. Similarly, Prokopenko et al. (2007) discuss a lamina enriched in the diatom *Synedra acus*  
464 and compare the age of this lamina in CON01-603-5, interpolated from pollen concentrate ages, to the TOC ages  
465 of similar lamina in three other cores. They suggest the difference in radiocarbon age of only  $\sim 0.3$   $^{14}\text{C}$  kyr is

466 consistent with a 500-yr adjustment to bulk TOC ages. Again, this doesn't account for the fact that pollen  
467 concentrate ages can exhibit age offsets (Kilian et al., 2002; Neulieb et al., 2013; Schiller et al., 2021). These two  
468 instances of mistaking dates of terrestrial material as being free of age offsets highlight here the utility in using  
469 the term age offset, instead of reservoir age: The fact that terrestrial material is free of a reservoir age does not  
470 mean it is free of an age offset.

471

472 Watanabe et al. (2009a) present radiocarbon dates from three cores in Academician Ridge each showing a region  
473 of paired positive and negative linear sedimentation rate (LSR) anomalies. These events all show anomalously  
474 low apparent sedimentation rate and then anomalously high apparent sedimentation rate before returning to  
475 'normal' sedimentation rates at 12.1 <sup>14</sup>C kyr BP or 12.2 kyr BP. Several explanations for these LSR anomalies  
476 are ruled out before settling on the possibility that they represent the radiocarbon plateau of the Younger Dryas  
477 (YD). Using a calendar age of 11.6 cal kyr BP for the end of the YD, they de-calibrate this to 10.1 <sup>14</sup>C ka BP and  
478 calculate a  $2.1 \pm 0.09$  <sup>14</sup>C kyr correction to match their LSR anomaly dates to the end of the YD. The uncertainty  
479 of their estimate does not include the uncertainty of the de-calibration, however.

480

481 Nara et al. (2010) apply an age offset of 0.5 <sup>14</sup>C kyr to both TOC dates and pollen concentrate dates from core  
482 VER99G12. They mention the modern sediment trap radiocarbon age of  $0.61 \pm 0.04$  reported by Colman et al.  
483 (1996) and that Boës et al. (2005) found a lag of ~500 yr between the GISP2  $\delta^{18}\text{O}$  and a record of grayscale  
484 fluctuation from core CON01-603-5 attached to a pollen concentrate radiocarbon chronology (no age offset  
485 correction is mentioned for the pollen concentrate radiocarbon chronology). Recognising the offset predicted by  
486 Watanabe et al. (2009a) of  $2.1 \pm 0.09$  <sup>14</sup>C yr at Academician Ridge, they suggest that this lower offset at  
487 Buguldeika Saddle may be due to a large input of modern organic material from the Selenga River. Coincidentally,  
488 this is the mirror image of the reasoning Colman et al. (1996) who suggested the Selenga may have provided older  
489 carbon material.

490

491 Murakami et al. (2012) use an age offset value of 1.418 <sup>14</sup>C kyr. This is inferred from a radiocarbon date from  
492 depth 0-1cm in their core BSS06-G2, reported with an age  $1.418 \pm 0.036$  <sup>14</sup>C yr BP, assuming that this sediment  
493 should be approximately modern.

494

495 Nara et al. (2023) correct for a reservoir effect of 0.38 <sup>14</sup>C kyr in core VER99G12, due to the 380 yr water  
496 residence time of the lake measured by Shimaraev et al. (1993). There is no reason the residence time of water  
497 should impact the reservoir age, however, especially given the lake's rapid ventilation rates (Weiss et al., 1991).

#### 498 **4.2.2 Our Age Offset Results**

499 We return 21 age offset estimates from cores across the whole lake (Figure 5; Table 5). The range of accepted  
500 estimates (0.08 – 2.86) is greater than the range of estimates in the previous literature. The range and standard  
501 deviation of estimates from Buguldeika Saddle (n=7), are much lower than the Academician Ridge (n=8). The  
502 lower spread of estimates in Buguldeika Saddle is likely related to higher sedimentation rates, approximately 5  
503 times that of the Academician Ridge (Colman et al., 2003), for two reasons: Regarding the estimation method,  
504 the y-intercept of a linear regression is more susceptible to error in the y-direction when the slope is lower;

505 Regarding sediment processes, in slower accumulating sediments dates may be affected by post-depositional  
506 processes, such as bioturbation of the surface sediments, for longer.

507

508 The mean and standard deviation of the estimates from each site are  $1.77 \pm 1.04$   $^{14}\text{C}$  kyr for Academician Ridge  
509 and  $1.47 \pm 0.37$   $^{14}\text{C}$  kyr for Buguldeika Saddle. To test whether we can argue the Academician Ridge or Buguldeika  
510 Saddle have different age offsets we use a Welch's T-Test. This returns a p-value of 0.44, so we cannot reject the  
511 null-hypothesis that these regions have statistically indistinguishable age offsets. Estimates from other regions of  
512 the lake are all within the range of estimates from Academician Ridge providing no clear evidence that the age  
513 offset of the lake differs between different regions of the lake.

514

515 However, the absence of statistically significant spatial variation in age offset does not imply that spatial  
516 variability does not exist. This may contribute to the spread in ASA estimates, alongside other sources of  
517 variability such as: temporal variability of sedimentation rate; temporal variability of age offset; and variable loss  
518 of top sediment during coring. Temporal variability of sedimentation rate or age offset will increase scatter in the  
519 results but are not expected to introduce a systematic bias. In contrast, variable loss of top sediment during coring  
520 would introduce scatter and impart a bias towards older ASAs. This bias would be greater where sedimentation  
521 rates are lower, which may partially explain why the Academician Ridge ASAs have a greater mean than the  
522 Buguldeika Saddle estimates. Additionally, while all samples in our analysis appear to have undergone broadly  
523 comparable pretreatment (i.e., an acidification/decalcification step applied to bulk sediment), we cannot rule out  
524 the possibility that differences in laboratory pretreatment protocols contributed to some of the observed variability  
525 in age offset estimates.

526

527 Grouping the cores by location helps control for spatial variability in age offset, however even within our regional  
528 groupings the Academician Ridge cores are spread over ~35km and the Buguldeika Saddle cores over ~15km  
529 (Figure 3). We highlight a cluster of cores/sites within the Buguldeika Saddle area (BDP93, 339, VER93-2  
530 St.24GC, and VER99G12) that are within 2km of each other (Figure 3) and can, with high confidence, be expected  
531 to have experienced the same sediment input. These returned ASA estimates of 1.26, 1.48, 1.75 and 1.99  $^{14}\text{C}$  kyr  
532 BP respectively, with a mean and standard deviation of  $1.62 \pm 0.28$   $^{14}\text{C}$  kyr BP. This demonstrates that factors  
533 other than spatial variability account for a standard deviation of at least 0.28  $^{14}\text{C}$  kyr in Buguldeika Saddle.

534

535 Other methods of estimating age offset, such as taking a surface sample or comparing to some perceived known  
536 date (i.e. Watanabe et al., 2009a), may seem to have lower uncertainty, however this uncertainty is likely less well  
537 constrained and may be just as large. We argue, therefore, that any estimate of age offset should, for Lake Baikal,  
538 incorporate a 1sigma uncertainty of at least 0.28  $^{14}\text{C}$  kyr - a more conservative approach would be to use the  
539 standard deviation of all estimates in the lake, leading to a 1sigma uncertainty of 0.76  $^{14}\text{C}$  kyr. Considering that  
540 most previous studies incorporated no uncertainty in their age offset estimates, or at the most an uncertainty of  
541 0.09  $^{14}\text{C}$  kyr, it is clear that previous work using radiocarbon will have significantly underestimated their temporal  
542 uncertainty. Temporal changes in carbon dynamics may lead to temporal changes in the age offset. For example,  
543 given the change in carbon content in Lake Baikal sediments at 13  $^{14}\text{C}$  kyr BP, it is reasonable that the age offset

544 of TOC may be significantly different when comparing post-glacial and glacial sediments, imparting further  
545 uncertainty on the age offset for older ages.

546

547 The indistinguishable mean age offsets at Academician Ridge and Buguldeika Saddle have interesting  
548 implications regarding the sources of the age offsets. A region-specific age offset may be explained by some  
549 source of older terrestrial carbon entering the system and having a local effect, for example through the Selenga  
550 River as was proposed by Colman et al. (1996). However, it is not obvious that this mechanism could explain the  
551 lake-wide age offsets that our results suggest.

552

553 More generally, our results highlight that the method of using a linear regression to estimate the age offset can  
554 have uncertainties of multiple hundreds of years. Linear regression is likely to provide a more accurate answer  
555 where sedimentation rates are high, but it should not be used where turbidites or variable sedimentation break the  
556 assumption of constant sedimentation that is required for the technique. Ideally, when used in previously unstudied  
557 lake systems, multiple cores should be taken/used to evaluate the uncertainty in the estimate. A further implication  
558 of our result is that many previous studies are likely to have significantly underestimated the uncertainty in their  
559 estimates of age offset.

560

#### 561 **4.3 Future Directions**

562 Future work to improve the linear regression method would be welcome. For example, we followed Colman et  
563 al. (1996) in using simple ordinary least squares linear regression, however given the provided uncertainties in  
564 radiocarbon ages, a weighted least squares linear regression technique may be more appropriate. Furthermore,  
565 when multiple subsets of ages could be used in the regression for each core, we made a subjective choice regarding  
566 which subset to use (see choices for site 339, site BDP93, core VER99G12, core CON01-603-5, core CON01-  
567 605-5, core VER94-5 St.22-GC in the ICE) - protocol as to how to propagate the uncertainty related to making  
568 those subjective choices would be valuable. Most significantly, however, would be an update to incorporate  
569 calibration of the radiocarbon ages into the linear regression method. Without calibration the uncertainty of the  
570 ages is understated, and the assumption of constant sedimentation rates is not truly held, because the calibration  
571 curve is not quite straight. One difficulty would be that calibrated ages are often bimodal, non-parametric, and  
572 cannot be well-represented by a single point estimate (Michczyński, 2007) but a Monte-Carlo approach could  
573 solve this.

574

575 The linear regression method, regardless of any aforementioned improvements, assumes the age offset over the  
576 period of the regression is constant, so cannot resolve changes in the age offset. Understanding temporal changes  
577 in TOC age offset would not only improve geochronological pursuits but could be used to evaluate carbon cycle  
578 dynamics (e.g. Gaglioti et al., 2014; Lindberg et al., 2025) and would help uncover the cause of the TOC age  
579 offsets. Such studies typically use pairs of TOC and plant macrofossil radiocarbon dates, but plant macrofossils  
580 are not sufficiently found in Lake Baikal sediments to do this. However the promise of reliable radiocarbon dating  
581 free of age offsets through a new technique preparing pollen concentrates by Omori et al. (2023) may now make  
582 this possible.

583 **5 Data Availability**

584 The data can be accessed at <https://doi.org/10.1594/PANGAEA.973799> (Newall et al., 2025).

585 **6 Interactive Coding Environment**

586 A fully interactive computing environment (ICE) accompanying this study is archived in Zenodo and can be  
587 accessed at <https://doi.org/10.5281/zenodo.18090849> (Newall, 2025). The ICE provides a Jupyter Notebook  
588 (notebooks/ASAanalysis.ipynb) containing age offset analyses and creation on non-map figures used in this paper.  
589 This allows readers to reproduce all scientific results presented here and to interact directly with figures, plots,  
590 and analytical steps. The ICE is containerized using Binder web services, enabling the notebook to be executed  
591 online in a browser without local installation. The environment can be accessed via its DOI on Zenodo, and  
592 executed through the Binder launch link provided in both the Zenodo record and the associated GitHub repository  
593 ([https://github.com/samrsnewall/baikal\\_essd\\_ice](https://github.com/samrsnewall/baikal_essd_ice)). To access the analyses within the ICE navigate to  
594 notebooks/ASAanalysis.ipynb.  
595

596 **7 Conclusions**

597 In this study, we have (i) created a complete database of all AMS radiocarbon dates from Lake Baikal sediment  
598 cores published up to 2025, standardising the reporting, updating missing or incorrect metadata, and adding some  
599 previously unpublished dates, (ii) produced a new estimate of age offset for TOC in Lake Baikal sediments of  
600  $1.62 \pm 0.76$  <sup>14</sup>C kyr BP, and (iii) did not find evidence to suggest that different regions of Lake Baikal have a  
601 statistically different age offset, as previous studies have suggested. The primary implication of our results is that  
602 previous Lake Baikal studies have significantly underestimated the temporal uncertainty from radiocarbon results.  
603 More generally, our study has shown that a linear regression method for estimating age offsets has a large inherent  
604 uncertainty that has likely been underestimated when used in other lakes/previous studies. Other techniques for  
605 estimating age offset should be examined in a similar manner to evaluate their uncertainties. We hope that this  
606 study facilitates further research in Lake Baikal by improving access to, and understanding of, previous  
607 radiocarbon work that has taken place, and spurs on further work to understand the uncertainties in estimating  
608 radiocarbon age offsets.

609 **8 Author Contribution**

610 Conceptualisation: SN and AM

611 Data Curation: SN

612 Formal Analysis: SN

613 Investigation: SN and NP

614 Methodology: SN

615 Project Administration: SN and AM

616 Software: SN

617 Supervision: AM

618 Visualisation: SN  
619 Writing: original draft preparation: SN  
620 Writing: Review and Editing: SN, AM, NP, and MB

## 621 **9 Competing Interests**

622 The authors declare that they have no conflict of interest.

## 623 **10 Acknowledgements**

624 Many thanks to Miles Irving for creating the map figures. We are very grateful for feedback from Darrell Kaufman  
625 and one anonymous reviewer that made the manuscript much tighter and more thorough. We would also like to  
626 acknowledge the great help we received from Daniela Ransby and the PANGAEA team.

## 627 **11 References**

- 628 Anchukaitis, K. J. and Tierney, J. E.: Identifying coherent spatiotemporal modes in time-uncertain proxy  
629 paleoclimate records, *Clim Dyn*, 41, 1291–1306, <https://doi.org/10.1007/s00382-012-1483-0>, 2013.
- 630 Björck, S. and Wohlfarth, B.: 14C Chronostratigraphic Techniques in Paleolimnology, in: *Tracking*  
631 *Environmental Change Using Lake Sediments*, vol. 1, edited by: Last, W. M. and Smol, J. P., Kluwer Academic  
632 Publishers, Dordrecht, 205–245, [https://doi.org/10.1007/0-306-47669-X\\_10](https://doi.org/10.1007/0-306-47669-X_10), 2002.
- 633 Blaauw, M. and Christen, J. A.: Flexible paleoclimate age-depth models using an autoregressive gamma process,  
634 *Bayesian Anal.*, 6, 457–474, <https://doi.org/10.1214/11-BA618>, 2011.
- 635 Boës, X., Piotrowska, N., and Fagel, N.: High-resolution diatom/clay record in Lake Baikal from grey scale, and  
636 magnetic susceptibility over Holocene and Termination I, *Global and Planetary Change*, 46, 299–313,  
637 <https://doi.org/10.1016/j.gloplacha.2004.09.025>, 2005.
- 638 Bronk Ramsey, C.: Deposition models for chronological records, *Quaternary Science Reviews*, 27, 42–60,  
639 <https://doi.org/10.1016/j.quascirev.2007.01.019>, 2008.
- 640 Carter, S. J. and Colman, S. M.: Biogenic Silica in Lake Baikal Sediments: Results From 1990–1992 American  
641 Cores, *Journal of Great Lakes Research*, 20, 751–760, [https://doi.org/10.1016/S0380-1330\(94\)71192-8](https://doi.org/10.1016/S0380-1330(94)71192-8), 1994.
- 642 Colman, S. M., Jones, G. A., Rubin, M., King, J. W., Peck, J. A., and Orem, W. H.: AMS radiocarbon analyses  
643 from Lake Baikal, Siberia: Challenges of dating sediments from a large, oligotrophic lake, *Quaternary Science*  
644 *Reviews*, 15, 669–684, [https://doi.org/10.1016/0277-3791\(96\)00027-3](https://doi.org/10.1016/0277-3791(96)00027-3), 1996.
- 645 Colman, S. M., Karabanov, E. B., and Nelson, C. H.: Quaternary Sedimentation and Subsidence History of Lake  
646 Baikal, Siberia, Based on Seismic Stratigraphy and Coring, *Journal of Sedimentary Research*, 73, 941–956,  
647 <https://doi.org/10.1306/041703730941>, 2003.
- 648 Demske, D., Heumann, G., Granoszewski, W., Nita, M., Mamakowa, K., Tarasov, P. E., and Oberhänsli, H.: Late  
649 glacial and Holocene vegetation and regional climate variability evidenced in high-resolution pollen records from  
650 Lake Baikal, *Global and Planetary Change*, 46, 255–279, <https://doi.org/10.1016/j.gloplacha.2004.09.020>, 2005.
- 651 Dubois, N., Saulnier-Talbot, É., Mills, K., Gell, P., Battarbee, R., Bennion, H., Chawchai, S., Dong, X., Francus,  
652 P., Flower, R., Gomes, D. F., Gregory-Eaves, I., Humane, S., Kattel, G., Jenny, J., Langdon, P., Massaferrro, J.,  
653 McGowan, S., Mikomägi, A., Ngoc, N. T. M., Ratnayake, A. S., Reid, M., Rose, N., Saros, J., Schillereff, D.,  
654 Tolotti, M., and Valero-Garcés, B.: First human impacts and responses of aquatic systems: A review of

- 655 palaeolimnological records from around the world, *The Anthropocene Review*, 5, 28–68,  
656 <https://doi.org/10.1177/2053019617740365>, 2018.
- 657 Erb, M. P., McKay, N. P., Steiger, N., Dee, S., Hancock, C., Ivanovic, R. F., Gregoire, L. J., and Valdes, P.:  
658 Reconstructing Holocene temperatures in time and space using paleoclimate data assimilation, *Clim. Past*, 18,  
659 2599–2629, <https://doi.org/10.5194/cp-18-2599-2022>, 2022.
- 660 Fedotov, A. P., Trunova, V. A., Stepanova, O. G., Vorobyeva, S. S., Parkhomchuk, E. V., Krapivina, S. M.,  
661 Zheleznyakova, T. O., and Legkodymov, A. A.: Changes in patterns of mineral and chemical elements in bottom  
662 sediments of Lake Baikal (Russia) as high-resolution records of moisture for the past 31–16 ka BP, *Quaternary*  
663 *International*, 644–645, 51–60, <https://doi.org/10.1016/j.quaint.2021.05.026>, 2023.
- 664 Franke, J. G. and Donner, R. V.: Correlating paleoclimate time series: Sources of uncertainty and potential pitfalls,  
665 *Quaternary Science Reviews*, 212, 69–79, <https://doi.org/10.1016/j.quascirev.2019.03.017>, 2019.
- 666 Fritz, S. C.: Deciphering climatic history from lake sediments, *J Paleolimnol*, 39, 5–16,  
667 <https://doi.org/10.1007/s10933-007-9134-x>, 2008.
- 668 Gaglioti, B. V., Mann, D. H., Jones, B. M., Pohlman, J. W., Kunz, M. L., and Wooller, M. J.: Radiocarbon age-  
669 offsets in an arctic lake reveal the long-term response of permafrost carbon to climate change: Radiocarbon age-  
670 offsets, *J. Geophys. Res. Biogeosci.*, 119, 1630–1651, <https://doi.org/10.1002/2014JG002688>, 2014.
- 671 Giesecke, T., Davis, B., Brewer, S., Finsinger, W., Wolters, S., Blaauw, M., De Beaulieu, J.-L., Binney, H., Fyfe,  
672 R. M., Gaillard, M.-J., Gil-Romera, G., Van Der Knaap, W. O., Kuneš, P., Kühl, N., Van Leeuwen, J. F. N.,  
673 Leydet, M., Lotter, A. F., Ortu, E., Semmler, M., and Bradshaw, R. H. W.: Towards mapping the late Quaternary  
674 vegetation change of Europe, *Veget Hist Archaeobot*, 23, 75–86, <https://doi.org/10.1007/s00334-012-0390-y>,  
675 2014.
- 676 Goring, S., Williams, J. W., Blois, J. L., Jackson, S. T., Paciorek, C. J., Booth, R. K., Marlon, J. R., Blaauw, M.,  
677 and Christen, J. A.: Deposition times in the northeastern United States during the Holocene: establishing valid  
678 priors for Bayesian age models, *Quaternary Science Reviews*, 48, 54–60,  
679 <https://doi.org/10.1016/j.quascirev.2012.05.019>, 2012.
- 680 Goslar, T., Czernik, J., and Goslar, E.: Low-energy  $^{14}\text{C}$  AMS in Poznań Radiocarbon Laboratory, Poland, *Nuclear*  
681 *Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, 223–224,  
682 5–11, <https://doi.org/10.1016/j.nimb.2004.04.005>, 2004.
- 683 Haslett, J. and Parnell, A.: A Simple Monotone Process with Application to Radiocarbon-Dated Depth  
684 Chronologies, *Journal of the Royal Statistical Society Series C: Applied Statistics*, 57, 399–418,  
685 <https://doi.org/10.1111/j.1467-9876.2008.00623.x>, 2008.
- 686 Hatté, C. and Jull, A. J. T.: RADIOCARBON DATING |  $^{14}\text{C}$  of Plant Macrofossils, in: *Encyclopedia of*  
687 *Quaternary Science*, Elsevier, 361–367, <https://doi.org/10.1016/B978-0-444-53643-3.00049-2>, 2013.
- 688 Hohmann, R., Hofer, M., Kipfer, R., Peeters, F., Imboden, D. M., Baur, H., and Shimaraev, M. N.: Distribution  
689 of helium and tritium in Lake Baikal, *J. Geophys. Res.*, 103, 12823–12838, <https://doi.org/10.1029/97JC02218>,  
690 1998.
- 691 Horiuchi, K., Minoura, K., Hoshino, K., Oda, T., Nakamura, T., and Kawai, T.: Palaeoenvironmental history of  
692 Lake Baikal during the last 23000 years, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 157, 95–108,  
693 [https://doi.org/10.1016/S0031-0182\(99\)00156-X](https://doi.org/10.1016/S0031-0182(99)00156-X), 2000.
- 694 Hou, J., D’Andrea, W. J., and Liu, Z.: The influence of  $^{14}\text{C}$  reservoir age on interpretation of paleolimnological  
695 records from the Tibetan Plateau, *Quaternary Science Reviews*, 48, 67–79,  
696 <https://doi.org/10.1016/j.quascirev.2012.06.008>, 2012.
- 697 Hu, J., Emile-Geay, J., and Partin, J.: Correlation-based interpretations of paleoclimate data – where statistics  
698 meet past climates, *Earth and Planetary Science Letters*, 459, 362–371,  
699 <https://doi.org/10.1016/j.epsl.2016.11.048>, 2017.

- 700 Karabanov, E., Williams, D., Kuzmin, M., Sideleva, V., Khursevich, G., Prokopenko, A., Solotchina, E.,  
701 Tkachenko, L., Fedenya, S., Kerber, E., Gvozdkov, A., Khlustov, O., Bezrukova, E., Letunova, P., and Krapivina,  
702 S.: Ecological collapse of Lake Baikal and Lake Hovsgol ecosystems during the Last Glacial and consequences  
703 for aquatic species diversity, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 209, 227–243,  
704 <https://doi.org/10.1016/j.palaeo.2004.02.017>, 2004.
- 705 Kashiwaya, K., Sakai, H., Ryugo, M., Horii, M., and Kawai, T.: Long-term climato-limnological cycles found in  
706 a 3.5-million-year continental record, *Journal of Paleolimnology*, 25, 271–278, 2001.
- 707 Kaufman, D., McKay, N., Routson, C., Erb, M., Dätwyler, C., Sommer, P. S., Heiri, O., and Davis, B.: Holocene  
708 global mean surface temperature, a multi-method reconstruction approach, *Sci Data*, 7, 201,  
709 <https://doi.org/10.1038/s41597-020-0530-7>, 2020.
- 710 Khan, K. S., Kunz, R., Kleijnen, J., and Antes, G.: Five Steps to Conducting a Systematic Review, *J R Soc Med*,  
711 96, 118–121, <https://doi.org/10.1177/014107680309600304>, 2003.
- 712 Kilian, M. R., Van Der Plicht, J., Van Geel, B., and Goslar, T.: Problematic 14C-AMS dates of pollen concentrates  
713 from Lake Gosciadz (Poland), *Quaternary International*, 88, 21–26, [https://doi.org/10.1016/S1040-6182\(01\)00070-](https://doi.org/10.1016/S1040-6182(01)00070-2)  
714 2, 2002.
- 715 Lacourse, T. and Gajewski, K.: Current practices in building and reporting age-depth models, *Quat. res.*, 96, 28–  
716 38, <https://doi.org/10.1017/qua.2020.47>, 2020.
- 717 Lindberg, K. R., Thomas, E. K., Rosenheim, B. E., Miller, G. H., Sepúlveda, J., Firesinger, D. R., De Wet, G. A.,  
718 and Gaglioti, B. V.: Postglacial Carbon Cycling History of a Northeastern Baffin Island Lake Catchment Inferred  
719 From Ramped Pyrolysis Oxidation and Radiocarbon Dating, *JGR Biogeosciences*, 130, e2024JG008515,  
720 <https://doi.org/10.1029/2024JG008515>, 2025.
- 721 Mackay, A. W., Seddon, A. W. R., Leng, M. J., Heumann, G., Morley, D. W., Piotrowska, N., Rioual, P., Roberts,  
722 S., and Swann, G. E. A.: Holocene carbon dynamics at the forest–steppe ecotone of southern Siberia, *Global*  
723 *Change Biology*, 23, 1942–1960, <https://doi.org/10.1111/gcb.13583>, 2017.
- 724 McClelland, H. L. O., Halevy, I., Wolf-Gladrow, D. A., Evans, D., and Bradley, A. S.: Statistical Uncertainty in  
725 Paleoclimate Proxy Reconstructions, *Geophysical Research Letters*, 48, e2021GL092773,  
726 <https://doi.org/10.1029/2021GL092773>, 2021.
- 727 McKay, N. P., Emile-Geay, J., and Khider, D.: geoChronR – an R package to model, analyze, and visualize age-  
728 uncertain data, *Geochronology*, 3, 149–169, <https://doi.org/10.5194/gchron-3-149-2021>, 2021.
- 729 Michezyński, A.: Is it Possible to Find a Good Point Estimate of a Calibrated Radiocarbon Date?, *Radiocarbon*,  
730 49, 393–401, <https://doi.org/10.1017/S0033822200042326>, 2007.
- 731 Millard, A. R.: CONVENTIONS FOR REPORTING RADIOCARBON DETERMINATIONS, *Radiocarbon*, 56,  
732 555–559, <https://doi.org/10.2458/56.17455>, 2014.
- 733 Mischke, S., Weynell, M., Zhang, C., and Wiechert, U.: Spatial variability of 14C reservoir effects in Tibetan  
734 Plateau lakes, *Quaternary International*, 313–314, 147–155, <https://doi.org/10.1016/j.quaint.2013.01.030>, 2013.
- 735 Morley, D. W., Leng, M. J., Mackay, A. W., and Sloane, H. J.: Late glacial and Holocene environmental change  
736 in the Lake Baikal region documented by oxygen isotopes from diatom silica, *Global and Planetary Change*, 46,  
737 221–233, <https://doi.org/10.1016/j.gloplacha.2004.09.018>, 2005.
- 738 Murakami, T., Takamatsu, T., Katsuta, N., Takano, M., Yamamoto, K., Takahashi, Y., Nakamura, T., and Kawai,  
739 T.: Centennial- to millennial-scale climate shifts in continental interior Asia repeated between warm–dry and  
740 cool–wet conditions during the last three interglacial states: evidence from uranium and biogenic silica in the  
741 sediment of Lake Baikal, southeast Siberia, *Quaternary Science Reviews*, 52, 49–59,  
742 <https://doi.org/10.1016/j.quascirev.2012.08.001>, 2012.
- 743 Nagata, T., Takai, K., Kawanobe, K., Kim, D.-S., Nakazato, R., Gusel'nikova, N., Bondarenko, N., Mologaway,  
744 O., Kostrova, T., Drucker, V., Satoh, Y., and Watanabe, Y.: Autotrophic picoplankton in southern Lake Baikal:

- 745 abundance, growth and grazing mortality during summer, *J Plankton Res*, 16, 945–959,  
746 <https://doi.org/10.1093/plankt/16.8.945>, 1994.
- 747 Nakamura, T., Oda, T., Tanaka, A., and Horiuchi, K.: High precision  $^{14}\text{C}$  age estimation of bottom sediments of  
748 Lake Baikal and Lake Hovsgol by AMS, *Gekkan Chikyu*, Special No.42, Kaiyoshuppasha, Tokyo, 20–31, 2003.
- 749 Nara, F. W., Watanabe, T., Nakamura, T., Kakegawa, T., Katamura, F., Shichi, K., Takahara, H., Imai, A., and  
750 Kawai, T.: Radiocarbon and Stable Carbon Isotope Ratio Data from a 4.7-Mlong Sediment Core of Lake Baikal  
751 (Southern Siberia, Russia), *Radiocarbon*, 52, 1449–1457, <https://doi.org/10.1017/S0033822200046531>, 2010.
- 752 Nara, F. W., Watanabe, T., Lougheed, B. C., and Obrochta, S.: ALTERNATIVE RADIOCARBON AGE-DEPTH  
753 MODEL FROM LAKE BAIKAL SEDIMENT: IMPLICATION FOR PAST HYDROLOGICAL CHANGES  
754 FOR LAST GLACIAL TO THE HOLOCENE, *Radiocarbon*, 1–18, <https://doi.org/10.1017/RDC.2023.63>, 2023.
- 755 Neulieb, T., Levac, E., Southon, J., Lewis, M., Pendea, I. F., and Chmura, G. L.: Potential Pitfalls of Pollen Dating,  
756 *Radiocarbon*, 55, 1142–1155, <https://doi.org/10.1017/S0033822200048050>, 2013.
- 757 Newall, S.: ICE for Lake Baikal Radiocarbon Age Offset Analysis, v1.0 , DOI: 10.5281/ZENODO.18090849,  
758 2025.
- 759 Newall, S. R. S., Mackay, A. W., Blaauw, M., and Piotrowska, N.: Lake Baikal sediment core AMS radiocarbon  
760 data, <https://doi.org/10.1594/PANGAEA.973799>, 2025.
- 761 Ogura, K.: A preliminary report on  $^{14}\text{C}$  ages of a 4.6m long core sample of Lake Baikal, *International Project on*  
762 *Paleolimnology and Late Cenozoic Climate*, 6, 123–124, 1992.
- 763 Omori, T., Yamada, K., Kitaba, I., Hori, T., and Nakagawa, T.: Reliable radiocarbon dating of fossil pollen grains:  
764 It is truly possible, *Quaternary Geochronology*, 77, 101456, <https://doi.org/10.1016/j.quageo.2023.101456>, 2023.
- 765 Oswald, W. W., Anderson, P. M., Brown, T. A., Brubaker, L. B., Hu, F. S., Lozhkin, A. V., Tinner, W., and  
766 Kaltenrieder, P.: Effects of sample mass and macrofossil type on radiocarbon dating of arctic and boreal lake  
767 sediments, *The Holocene*, 15, 758–767, <https://doi.org/10.1191/0959683605hl849r>, 2005.
- 768 Piotrowska, N.: Status report of AMS sample preparation laboratory at GADAM Centre, Gliwice, Poland, *Nuclear*  
769 *Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, 294, 176–  
770 181, <https://doi.org/10.1016/j.nimb.2012.05.017>, 2013.
- 771 Piotrowska, N., Bluszcz, A., Demske, D., Granoszewski, W., and Heumann, G.: Extraction and AMS Radiocarbon  
772 Dating of Pollen from Lake Baikal Sediments, *Radiocarbon*, 46, 181–187,  
773 <https://doi.org/10.1017/S0033822200039503>, 2004.
- 774 Prokopenko, A. A., Khursevich, G. K., Bezrukova, E. V., Kuzmin, M. I., Boes, X., Williams, D. F., Fedenya, S.  
775 A., Kulagina, N. V., Letunova, P. P., and Abzaeva, A. A.: Paleoenvironmental proxy records from Lake Hovsgol,  
776 Mongolia, and a synthesis of Holocene climate change in the Lake Baikal watershed, *Quat. res.*, 68, 2–17,  
777 <https://doi.org/10.1016/j.yqres.2007.03.008>, 2007.
- 778 Rehfeld, K. and Kurths, J.: Similarity estimators for irregular and age-uncertain time series, *Clim. Past*, 10, 107–  
779 122, <https://doi.org/10.5194/cp-10-107-2014>, 2014.
- 780 Sakai, H.: Paleoenvironment deduced from magnetic susceptibility studies on surface sediments of Lake Baikal  
781 and Lake Biwa, 金沢大学 21世紀COEプログラム環日本海域の環境計測と長期・短期変動予測, 78–82,  
782 2006.
- 783 Sakai, H., Nomura, S., Horii, M., Kashiwaya, K., Tanaka, A., Kawai, T., Kravchinsky, V., and Peck, J.:  
784 Paleomagnetic and rock-magnetic studies on lake baikal sediments -BDP96 borehole at academician ridge-, in:  
785 *Lake Baikal*, Elsevier, 35–52, <https://doi.org/10.1016/B978-044450434-0/50004-4>, 2000.

- 786 Schiller, C. M., Whitlock, C., Elder, K. L., Iverson, N. A., and Abbott, M. B.: ERRONEOUSLY OLD  
787 RADIOCARBON AGES FROM TERRESTRIAL POLLEN CONCENTRATES IN YELLOWSTONE LAKE,  
788 WYOMING, USA, *Radiocarbon*, 63, 321–342, <https://doi.org/10.1017/RDC.2020.118>, 2021.
- 789 Shimaraev, M. N., Granin, N. G., and Zhdanov, A. A.: Deep ventilation of Lake Baikal waters due to spring  
790 thermal bars, *Limnology & Oceanography*, 38, 1068–1072, <https://doi.org/10.4319/lo.1993.38.5.1068>, 1993.
- 791 Snyder, C. W.: The value of paleoclimate research in our changing climate: An editorial comment, *Climatic  
792 Change*, 100, 407–418, <https://doi.org/10.1007/s10584-010-9842-5>, 2010.
- 793 Strunk, A., Olsen, J., Sanei, H., Rudra, A., and Larsen, N. K.: Improving the reliability of bulk sediment  
794 radiocarbon dating, *Quaternary Science Reviews*, 242, 106442, <https://doi.org/10.1016/j.quascirev.2020.106442>,  
795 2020.
- 796 Stuiver, M. and Polach, H. A.: Discussion Reporting of  $^{14}\text{C}$  Data, *Radiocarbon*, 19, 355–363,  
797 <https://doi.org/10.1017/S0033822200003672>, 1977.
- 798 Swann, G. E. A., Panizzo, V. N., Piccolroaz, S., Pashley, V., Horstwood, M. S. A., Roberts, S., Vologina, E.,  
799 Piotrowska, N., Sturm, M., Zhdanov, A., Granin, N., Norman, C., McGowan, S., and Mackay, A. W.: Changing  
800 nutrient cycling in Lake Baikal, the world’s oldest lake, *Proc. Natl. Acad. Sci. U.S.A.*, 117, 27211–27217,  
801 <https://doi.org/10.1073/pnas.2013181117>, 2020.
- 802 Sweeney, J., Salter-Townshend, M., Edwards, T., Buck, C. E., and Parnell, A. C.: Statistical challenges in  
803 estimating past climate changes, *WIREs Computational Stats*, 10, e1437, <https://doi.org/10.1002/wics.1437>,  
804 2018.
- 805 Tarasov, P., Bezrukova, E., Karabanov, E., Nakagawa, T., Wagner, M., Kulagina, N., Letunova, P., Abzaeva, A.,  
806 Granoszewski, W., and Riedel, F.: Vegetation and climate dynamics during the Holocene and Eemian interglacials  
807 derived from Lake Baikal pollen records, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 252, 440–457,  
808 <https://doi.org/10.1016/j.palaeo.2007.05.002>, 2007.
- 809 Vologina, E. G. and Sturm, M.: Types of Holocene deposits and regional pattern of sedimentation in Lake Baikal,  
810 *Russian Geology and Geophysics*, 50, 722–727, <https://doi.org/10.1016/j.rgg.2008.12.012>, 2009.
- 811 Votintsev, K., Meshcheryakova, A., and Popovskaya, G.: *Cycling of Organic Matter in Lake Baikal*, Nauka,  
812 Novosibirsk, Russia, 1975.
- 813 Wang, Y., Goring, S. J., and McGuire, J. L.: Bayesian ages for pollen records since the last glaciation in North  
814 America, *Sci Data*, 6, 176, <https://doi.org/10.1038/s41597-019-0182-7>, 2019.
- 815 Watanabe, T., Nakamura, T., and Kawai, T.: Radiocarbon dating of sediments from large continental lakes (Lakes  
816 Baikal, Hovsgol and Erhel), *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions  
817 with Materials and Atoms*, 259, 565–570, <https://doi.org/10.1016/j.nimb.2007.01.200>, 2007.
- 818 Watanabe, T., Nakamura, T., Nara, F. W., Kakegawa, T., Nishimura, M., Shimokawara, M., Matsunaka, T.,  
819 Senda, R., and Kawai, T.: A new age model for the sediment cores from Academician ridge (Lake Baikal) based  
820 on high-time-resolution AMS  $^{14}\text{C}$  data sets over the last 30 kyr: Paleoclimatic and environmental implications,  
821 *Earth and Planetary Science Letters*, 286, 347–354, <https://doi.org/10.1016/j.epsl.2009.06.046>, 2009a.
- 822 Watanabe, T., Nakamura, T., Nara, F. W., Kakegawa, T., Horiuchi, K., Senda, R., Oda, T., Nishimura, M.,  
823 Matsumoto, G. I., and Kawai, T.: High-time resolution AMS  $^{14}\text{C}$  data sets for Lake Baikal and Lake Hovsgol  
824 sediment cores: Changes in radiocarbon age and sedimentation rates during the transition from the last glacial to  
825 the Holocene, *Quaternary International*, 205, 12–20, <https://doi.org/10.1016/j.quaint.2009.02.002>, 2009b.
- 826 Weiss, R. F., Carmack, E. C., and Koropalov, V. M.: Deep-water renewal and biological production in Lake  
827 Baikal, *Nature*, 349, 665–669, <https://doi.org/10.1038/349665a0>, 1991.
- 828 Wilkinson, M. D., Dumontier, M., Aalbersberg, Ij. J., Appleton, G., Axton, M., Baak, A., Blomberg, N., Boiten,  
829 J.-W., Da Silva Santos, L. B., Bourne, P. E., Bouwman, J., Brookes, A. J., Clark, T., Crosas, M., Dillo, I., Dumon,  
830 O., Edmunds, S., Evelo, C. T., Finkers, R., Gonzalez-Beltran, A., Gray, A. J. G., Groth, P., Goble, C., Grethe, J.

831 S., Heringa, J., 'T Hoen, P. A. C., Hooft, R., Kuhn, T., Kok, R., Kok, J., Lusher, S. J., Martone, M. E., Mons, A.,  
832 Packer, A. L., Persson, B., Rocca-Serra, P., Roos, M., Van Schaik, R., Sansone, S.-A., Schultes, E., Sengstag, T.,  
833 Slater, T., Strawn, G., Swertz, M. A., Thompson, M., Van Der Lei, J., Van Mulligen, E., Velterop, J.,  
834 Waagmeester, A., Wittenburg, P., Wolstencroft, K., Zhao, J., and Mons, B.: The FAIR Guiding Principles for  
835 scientific data management and stewardship, *Sci Data*, 3, 160018, <https://doi.org/10.1038/sdata.2016.18>, 2016.

836 Zimmerman, S. R. H. and Wahl, D. B.: Holocene paleoclimate change in the western US: The importance of  
837 chronology in discerning patterns and drivers, *Quaternary Science Reviews*, 246, 106487,  
838 <https://doi.org/10.1016/j.quascirev.2020.106487>, 2020.

839