

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

Samuel R. S. Newall¹, Anson W. Mackay², Natalia Piotrowska³, Maarten Blaauw⁴

¹Earth Sciences, UC Santa Barbara, Santa Barbara, 93106, USA

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

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

⁴School 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complete record from literature spanning 1992 to 2025 (with transcription errors corrected) and including 22 previously unpublished dates from cores CON01-603-5 and CON01-605-5.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 ¹⁴C kyr in different cores. Estimates from other methods have returned estimates of approximately 2 ¹⁴C 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, ± 0.09 ¹⁴C 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 ± 0.76 ¹⁴C 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 syndeositional 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 ± 0.37 ^{14}C kyr in Academician Ridge and approximately 1.22 ± 0.18 ^{14}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 ¹⁴C kyr (Nara et al., 2023) to 2.1± 0.090 ¹⁴C 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. ± 0.09 ¹⁴C 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 ¹⁴C 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

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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 CO₂
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).

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141 2.3 Data Organisation

142 All radiocarbon data are reported as conventional ¹⁴C age alongside its 1σ uncertainty (Stuiver and Polach, 1977).
143 Following the convention suggested by Millard (2014), we also provide the laboratory codes, δ¹³C values,
144 indication of how δ¹³C was measured, and carbon content (%), where available. AMS-derived δ¹³C 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 δ¹³C 1σ uncertainty where available.

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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

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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.

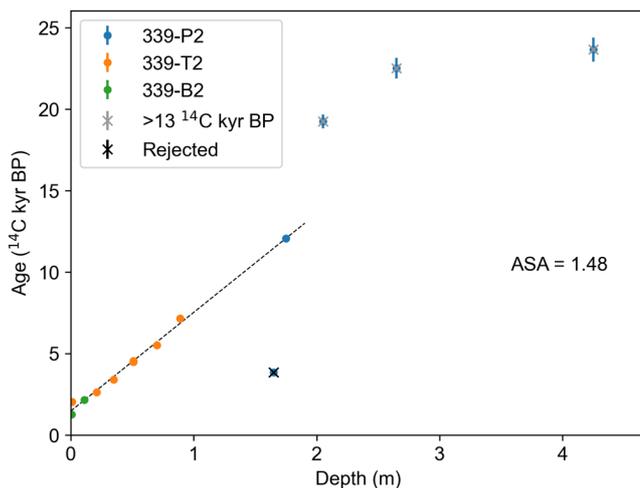
169 **2.4 Age Offset Estimation**

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 ¹⁴C 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 ¹⁴C kyr BP. The
180 exclusion of ages older than 13 ¹⁴C 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

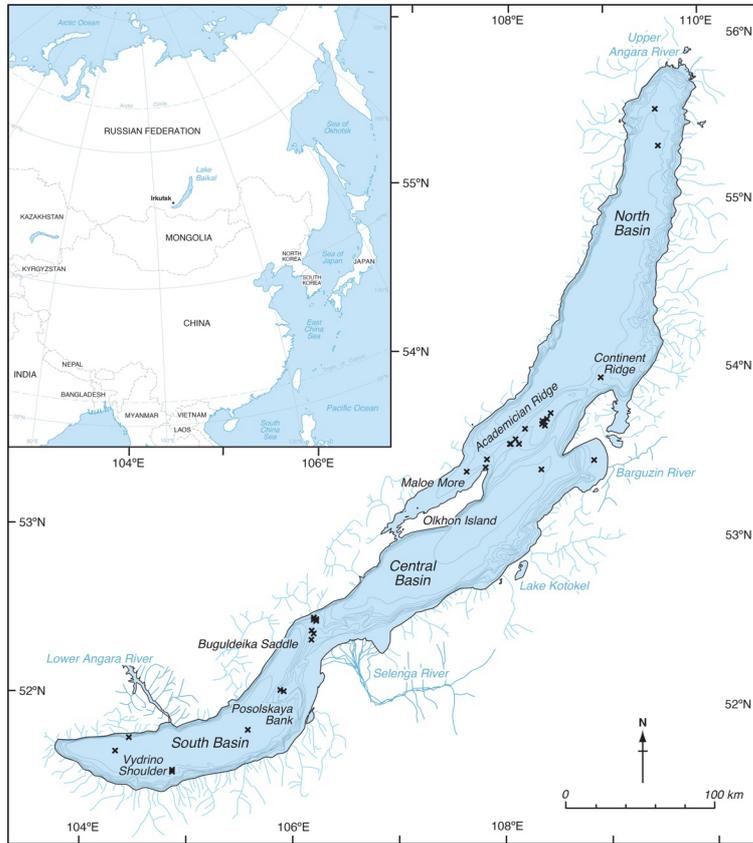


195
196 **Figure 1:** An example of the creation of composite cores using cores from the same drilling site, following Colman et
197 al. (1996). The radiocarbon ages (all from TOC) from cores 339-B2, 339-T2 and 339-P2 are plotted against depth
198 forming a composite core from Site 339. Circles show the mean radiocarbon age and bars show the analytical 1σ
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}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}C kyr BP). The y-intercept, or ASA, is 1.48 ^{14}C kyr BP. In our interpretation of this core, we additionally rejected
203 the 2nd 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}C kyr BP.

205 3 Results

206 3.1 Core Data Overview

207 Our review identified 51 cores that contained AMS ^{14}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
Academician Ridge	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)
Buguldeika Saddle	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)	

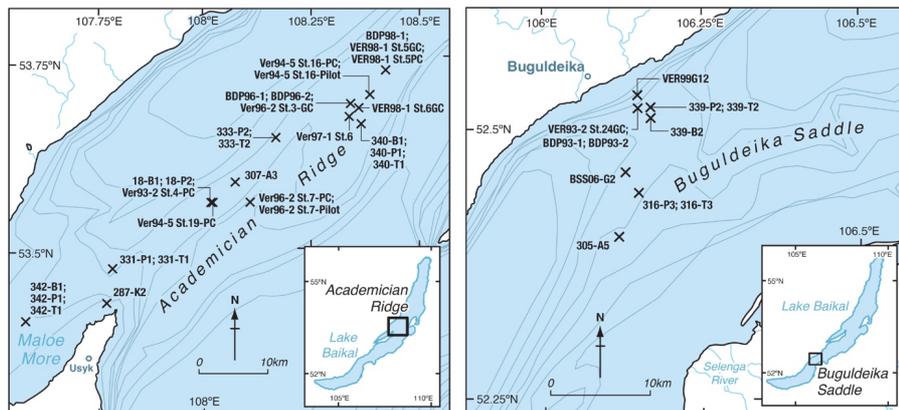
	VER93-2 St.24GC	52.52	106.15	355	Karabanov et al. (2004); Tarasov et al. (2007)
	VER99G12	52.53	106.15	350	Watanabe et al. (2007); Watanabe et al. (2009b); Nara et al. (2010)
Barguzin Bay	BarguzinBa y18	53.42	108.82	41	Fedotov et al. (2023)
Central Basin	308-A3	53.42	108.32	1700	Colman et al. (1996)
Continent Ridge	CON01- 603-5	53.95	108.91	386	Piotrowska et al. (2004);
Maloe More	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)
Northern Basin	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)
Posolskoe Bank	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)
Southern Basin	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)
Vydrino Shoulder	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

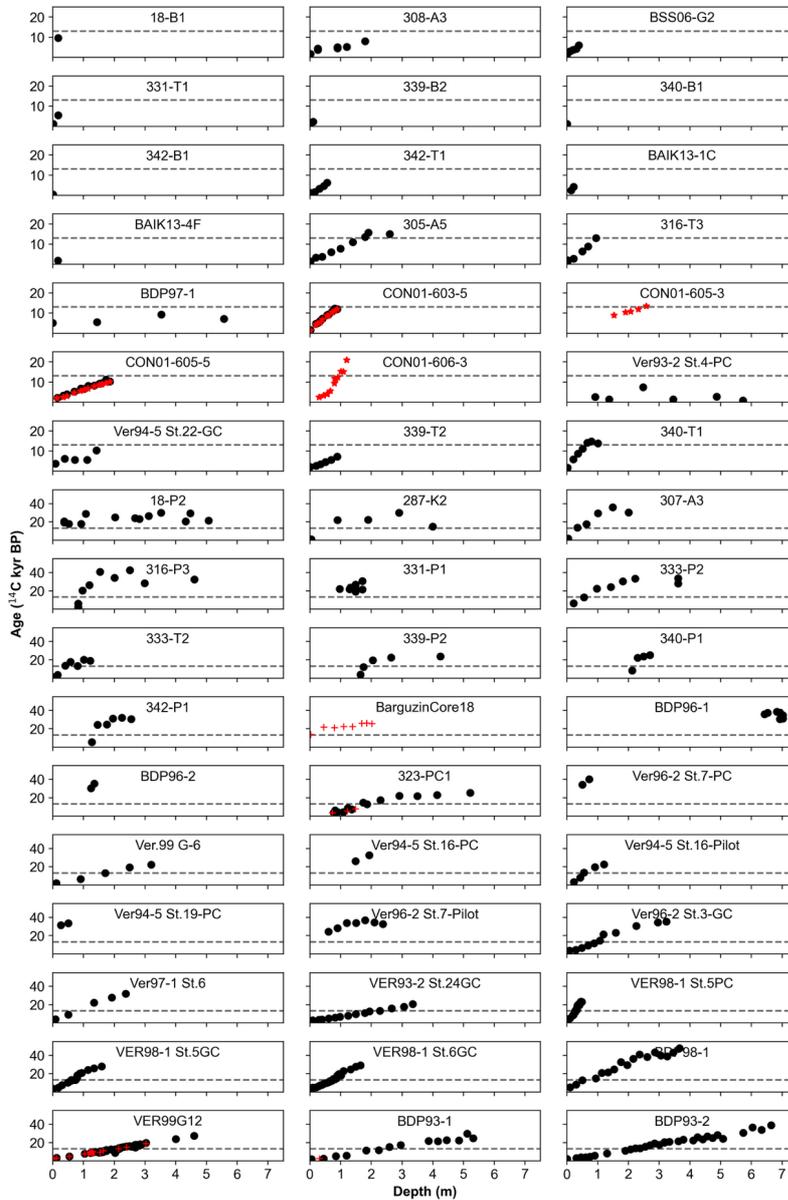
229 To aid the reader in finding the locations of cores in the densely cored regions, we provide higher resolution maps
230 of Academician Ridge and Buguldeika Saddle (Figure 3).



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 **Figure 4: Radiocarbon data from all 51 cores in this database, with mean uncalibrated radiocarbon age in ¹⁴C kyr BP**
 248 **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**
 249 **materials (lipids, diatom/pelitic silt, wood) are shown as red crosses. The top seven rows have smaller y axis limits to**
 250 **better show shorter cores. All x axes are the same. Horizontal dashed lines are plotted at 13 ¹⁴C kyr BP to highlight the**
 251 **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 ± 80 ^{14}C kyr BP (i.e. a fraction modern value of 5.237
 258 ± 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.

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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}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

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

276 **Table 2: The ASAs (^{14}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}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}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

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

293 **3.3.2 Buguldeika Saddle**

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

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

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

308 **3.3.3 Other Locations**

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Location	Core/Site	# of ages	ASA (¹⁴ 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

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

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

325 **3.3.4 Synthesis**

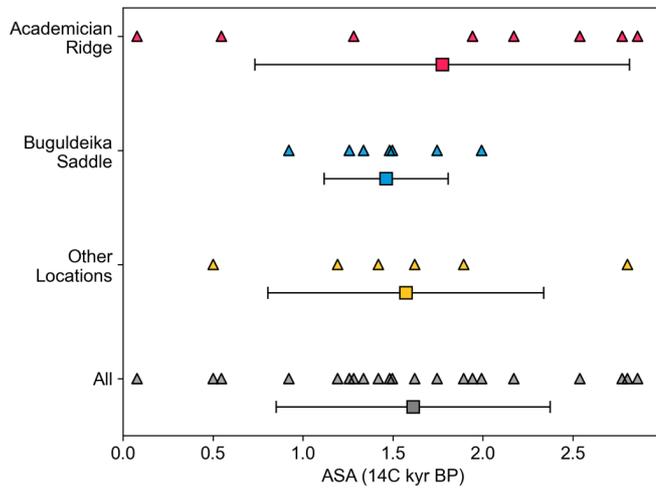
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326

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

327 **Table 5: Summary statistics of all ASA (¹⁴C kyr BP) estimates, when looking at different subsets, one of which being**
 328 **the entire lake.**

329 Our results have a mean and standard deviation of 1.62 ± 0.76 ¹⁴C kyr BP (Table 5; Figure 5). The median
 330 estimate is similar to the mean, at 1.48 ¹⁴C kyr BP and a Shapiro-Wilk test returns a p-value of 0.70, suggesting
 331 it would be reasonable to consider the results normally distributed. The means for Buguldeika Saddle,
 332 Academician Ridge, and for all other locations are similar to the mean of the entire lake (Figure 5). The
 333 minimum and maximum ASA estimates are 0.08 and 2.86 ¹⁴C kyr BP respectively, both from Academician
 334 Ridge, providing a very large range. The Buguldeika Saddle region provides a much less variable set of ASA
 335 estimates than Academician Ridge.



337
 338 **Figure 5: Individual ASA estimates (triangles) grouped as being either from Academician Ridge,**
 339 **Buguldeika Saddle, or other locations. The mean of each location is denoted as a square and the standard**
 340 **deviation is illustrated with symmetrical error bars. Estimates from all locations are then considered as a**
 341 **single group (“All”, in grey), showing the mean and standard deviation.**

342 **4 Discussion**

343 **4.1 Data Compilation**

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

356 **4.1.1 Poor Representation in Data Repositories**

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

360 under a slightly different core name (CON16035); Pangaea contained datasets for CON01-603-5, CON01-605-5
361 and CON01-606-3, although data for core CON01-606-3 was reported twice with differing reporting standards;
362 NOAA held no radiocarbon datasets from Lake Baikal. Furthermore, interrogating the case of CON01-605-5 from
363 Pangaea, this dataset is actually a composite core consisting of dates taken from neighbouring cores CON01-605-
364 5 and CON01-605-3. Whilst composite cores are certainly useful when presenting and analysing data for study,
365 we only report datasets that are delineated by core (and we deconstruct composite cores into their original cores),
366 as this helps highlight the origin of the data.

367
368 The lack of this representation in recognised data repositories means these data are not contributing to influential
369 large scale data compilation or assimilation projects (Erb et al., 2022; Kaufman et al., 2020). Whilst reporting
370 their radiocarbon data alone will not allow their inclusion in such studies, this study may act to spur proxy
371 compilation work for Lake Baikal or the Baikal region.

372 4.1.2 Naming/Data Inconsistencies

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

386

387 4.1.3 Data Reporting Conventions

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

397

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

407
408 No convention has been agreed upon regarding how to report sample depth information from sediment cores. In
409 the papers reporting radiocarbon data in Lake Baikal, sample depth information was reported in the following
410 three ways: (1) reporting the top and bottom depth of the core sample; (2) reporting the middle depth and thickness
411 of the core sample; (3) reporting just the middle depth of the sample. Khider et al. (2019) record a community
412 belief that sample thickness should be an essential property to report and note a community preference for top and
413 bottom depth to be reported. Lacourse and Gajewski (2020) stress the importance of this metric after analysing a
414 set of publications from 2018 and 2019 in *Quaternary Research* and *Journal of Quaternary Science*, finding that
415 75% of 34 papers they analysed failed to report sample thickness. Only 56% of radiocarbon dates in this
416 compilation contain thickness data. We reaffirm the need for better reporting of sample thickness, either by
417 reporting top and bottom depth of the core sample or reporting the middle depth and thickness.

418 4.2 Age Offset Estimates

419 The application of a single age offset estimation method to a number of cores within a single lake, or a single
420 region of a lake has been done before by Colman et al. (1996; n=10 age offset estimates) and Watanabe et al.
421 (2009a; n=3 age offset estimates) however this study represents the largest number of cores analysed with the
422 same method (n= 21 age offset estimates). The method used in this paper is similar to that of Colman et al. (1996).
423 The method of Watanabe et al. (2009a), by contrast, aligns positive anomalies in linear sedimentation rate to the
424 radiocarbon plateau of the Younger Dryas. We first discuss other results on the age offset for Lake Baikal, then
425 compare them to our own. The papers discussed below are not an exhaustive list of papers that utilise an age offset
426 estimate but focus on those that make some justification for their choice.

427 4.2.1 Previous Age Offset Estimates

428 Colman et al. (1996) use linear regression methods to estimate the age offset for cores in Lake Baikal, using either
429 the topmost two ages in a core or all ages younger than 13 ¹⁴C kyr BP. The cores they analyse come from either
430 the Academician Ridge or Buguldeika Saddle regions. They report that the age offsets from these two regions are
431 distinct from each other (0.47 ± 0.37 ¹⁴C kyr BP at Academician Ridge and 1.22 ± 0.18 ¹⁴C kyr BP at Buguldeika
432 Saddle). They hypothesise that the older age offset in Buguldeika Saddle may be due to an influx of older
433 terrigenous sediment from the Selenga River, with its outflow very near the Buguldeika Saddle, supported by a
434 radiocarbon age of 2.68 ± 0.03 ¹⁴C kyr BP from suspended sediment of the Selenga River. However, they

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

437

438 Karabanov et al. (2004), use a regression methodology to estimate an age offset of 1588 years from core VER93-
439 2 st.24GC in the Buguldeika Saddle, however, [they](#) do not describe whether all their dates are used for regression.
440 This result was not reproducible by us using any subset of their ages. [Tarasov et al. \(2007\)](#), examining the same
441 core, chose instead to use an age offset estimate from Colman et al. (1996). However, instead of using the average
442 Buguldeika Saddle estimate of 1.22 ± 0.18 ^{14}C kyr, they use 1.16 ^{14}C kyr based on the linear regression of the
443 BDP93 cores' radiocarbon data.

444

445 Demske et al. (2005) estimate the age offset of pollen concentrate ages (not the TOC age offset) by performing
446 linear regressions on three cores, however the number of ages used for each regression is not described. For core
447 CON01-603-5 (Continent Ridge) they use a value of 0.930 ^{14}C kyr, which we could reproduce using the shallowest
448 three ages in the core. For core CON01-606-3 (Posolskoe Bank) they report a value of 0.675 ^{14}C kyr and for the
449 composite core consisting of cores CON01-605-3 and CON01-605-5 (Vydrino Shoulder) they report a value of
450 0.96 ^{14}C kyr. We could not reproduce either of those values using any combination of their data with a simple
451 ordinary least squares linear regression. Note these results are from pollen concentrates, which likely have a
452 different age offset to TOC. The non-zero nature of these offsets however highlights that pollen concentrate ages
453 in Lake Baikal still suffer from an age offset, similar to what has been determined by other studies (Kilian et al.,
454 2002; Neulieb et al., 2013; Schiller et al., 2021), possibly through contamination or redeposition.

455

456 Prokopenko et al. (2007) argue that a “true reservoir effect for a lake cannot be core- or site-specific” and reject
457 age offset estimates determined from linear regression-based approaches due to their resulting in “core-specific
458 reservoir corrections... from the same site”. However, the different estimates from nearby cores can be simply
459 reconciled by recognising that the estimation method used has uncertainty, like all estimation methods. Further,
460 they propose that Lake Baikal TOC age corrections “should not exceed 500yr”. However, this proposal is based
461 on 3 ages from surface sediments or modern sediment traps, which may underestimate the age estimates due to
462 bomb carbon (Colman et al. 1996) and their justifications show misunderstandings that both wood samples and
463 pollen concentrates are free themselves from age offsets (which they are not). For example, Prokopenko et al.
464 (2007) suggest a “critical cross-check” for the TOC age offset is available in the radiocarbon ages of the twin
465 BDP-93 cores, referencing a wood and a TOC age that are from similar depths in different cores. The wood age
466 is approximately 500 years younger than the slightly deeper TOC age, so imposing an offset of over 500y on the
467 TOC age creates a stratigraphic reversal, the deeper age now being younger. This supposed contradiction,
468 however, doesn't account for the fact that wood ages are also known to have age offsets (Hatté and Jull, 2013).

469 For example, [Oswald et al. \(2005\)](#) compare the ages of different macrofossil types in Arctic lakes and find that
470 “wood and charcoal are generally older than other macrofossils of the same sample depth with age differences
471 ranging from tens to thousands of years”, which they attribute to the decay-resistance and/or the in-built age of
472 woody macrofossils. Similarly, Prokopenko et al. (2007) discuss a lamina enriched in the diatom *Synedra acus*
473 and compare the age of this lamina in CON01-603-5, interpolated from pollen concentrate ages, to the TOC ages
474 of similar lamina in three other cores. They suggest the difference in radiocarbon age of only ~ 0.3 ^{14}C kyr is

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

480

481 Watanabe et al. (2009a) present radiocarbon dates from three cores in Academician Ridge each showing a region
482 of paired positive and negative linear sedimentation rate (LSR) anomalies. These events all show anomalously
483 low apparent sedimentation rate and then anomalously high apparent sedimentation rate before returning to
484 'normal' sedimentation rates at 12.1 ¹⁴C kyr BP or 12.2 kyr BP. Several explanations for these LSR anomalies
485 are ruled out before settling on the possibility that they represent the radiocarbon plateau of the Younger Dryas
486 (YD). Using a calendar age of 11.6 kyr BP for the end of the YD, they de-calibrate this to 10.1 ¹⁴C ka BP and
487 calculate a 2.1 ± 0.09 ¹⁴C kyr correction to match their LSR anomaly dates to the end of the YD. The uncertainty
488 of their estimate does not include the uncertainty of the de-calibration, however.

489

490 Nara et al. (2010) apply an age offset of 0.5 ¹⁴C kyr to both TOC dates and pollen concentrate dates from core
491 VER99G12. They mention the modern sediment trap radiocarbon age of 0.61 ± 0.04 reported by Colman et al.
492 (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
493 fluctuation from core CON01-603-5 attached to a pollen concentrate radiocarbon chronology (no age offset
494 correction is mentioned for the pollen concentrate radiocarbon chronology). Recognising the offset predicted by
495 Watanabe et al. (2009a) of 2.1 ± 0.09 ¹⁴C yr at Academician Ridge, they suggest that this lower offset at
496 Buguldeika Saddle may be due to a large input of modern organic material from the Selenga River. Coincidentally,
497 this is the mirror image of the reasoning Colman et al. (1996) who suggested the Selenga may have provided older
498 carbon material.

499

500 Murakami et al. (2012) use an age offset value of 1.418 ¹⁴C kyr. This is inferred from a radiocarbon date from
501 depth 0-1cm in their core BSS06-G2, reported with an age 1.418 ± 0.036 ¹⁴C yr BP, assuming that this sediment
502 should be approximately modern.

503

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

507 4.2.2 Our Age Offset Results

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

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

517

518 The mean and standard deviation of the estimates from each site are 1.77 ± 1.04 ^{14}C kyr for Academician Ridge
519 and 1.47 ± 0.37 ^{14}C kyr for Buguldeika Saddle. To test whether we can argue the Academician Ridge or Buguldeika
520 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
521 null-hypothesis that these regions have statistically indistinguishable age offsets. Estimates from other regions of
522 the lake are all within the range of estimates from Academician Ridge providing no clear evidence that the age
523 offset of the lake differs between different regions of the lake.

524

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

536

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

544

545 Other methods of estimating age offset, such as taking a surface sample or comparing to some perceived known
546 date (i.e. Watanabe et al., 2009a), may seem to have lower uncertainty, however this uncertainty is likely less well
547 constrained and may be just as large. We argue, therefore, that any estimate of age offset should, for Lake Baikal,
548 incorporate a 1sigma uncertainty of at least 0.28 ^{14}C kyr - a more conservative approach would be to use the
549 standard deviation of all estimates in the lake, leading to a 1sigma uncertainty of 0.76 ^{14}C kyr. Considering that
550 most previous studies incorporated no uncertainty in their age offset estimates, or at the most an uncertainty of
551 0.09 ^{14}C kyr, it is clear that previous work using radiocarbon will have significantly underestimated their temporal
552 uncertainty. Temporal changes in carbon dynamics may lead to temporal changes in the age offset. For example,
553 given the change in carbon content in Lake Baikal sediments at 13 ^{14}C kyr BP, it is reasonable that the age offset

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

556
557 The indistinguishable mean age offsets at Academician Ridge and Buguldeika Saddle have interesting
558 implications regarding the sources of the age offsets. A region-specific age offset may be explained by some
559 source of older terrestrial carbon entering the system and having a local effect, for example through the Selenga
560 River as was proposed by Colman et al. (1996). However, it is not obvious that this mechanism could explain the
561 lake-wide age offsets that our results suggest.

562
563 More generally, our results highlight that the method of using a linear regression to estimate the age offset can
564 have uncertainties of multiple hundreds of years. Linear regression is likely to provide a more accurate answer
565 where sedimentation rates are high, but it should not be used where turbidites or variable sedimentation break the
566 assumption of constant sedimentation that is required for the technique. Ideally, when used in previously unstudied
567 lake systems, multiple cores should be taken/used to evaluate the uncertainty in the estimate. A further implication
568 of our result is that many previous studies are likely to have significantly underestimated the uncertainty in their
569 estimates of age offset.

570

571 4.3 Future Directions

572 Future work to improve the linear regression method would be welcome. For example, we followed Colman et
573 al. (1996) in using simple ordinary least squares linear regression, however given the provided uncertainties in
574 radiocarbon ages, a weighted least squares linear regression technique may be more appropriate. Furthermore,
575 when multiple subsets of ages could be used in the regression for each core, we made a subjective choice regarding
576 which subset to use (see choices for site 339, site BDP93, core VER99G12, core CON01-603-5, core CON01-
577 605-5, core VER94-5 St.22-GC in the ICE) - protocol as to how to propagate the uncertainty related to making
578 those subjective choices would be valuable. Most significantly, however, would be an update to incorporate
579 calibration of the radiocarbon ages into the linear regression method. Without calibration the uncertainty of the
580 ages is understated, and the assumption of constant sedimentation rates is not truly held, because the calibration
581 curve is not quite straight. One difficulty would be that calibrated ages are often bimodal, non-parametric, and
582 cannot be well-represented by a single point estimate (Michczyński, 2007) but a Monte-Carlo approach could
583 solve this.

584
585 The linear regression method, regardless of any aforementioned improvements, assumes the age offset over the
586 period of the regression is constant, so cannot resolve changes in the age offset. Understanding temporal changes
587 in TOC age offset would not only improve geochronological pursuits but could be used to evaluate carbon cycle
588 dynamics (e.g. Gaglioti et al., 2014; Lindberg et al., 2025) and would help uncover the cause of the TOC age
589 offsets. Such studies typically use pairs of TOC and plant macrofossil radiocarbon dates, but plant macrofossils
590 are not sufficiently found in Lake Baikal sediments to do this. However the promise of reliable radiocarbon dating
591 free of age offsets through a new technique preparing pollen concentrates by Omori et al. (2023) may now make
592 this possible.

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599 **5 Data Availability**

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

601 **6 Interactive Coding Environment**

602 A fully interactive computing environment (ICE) accompanying this study is archived in Zenodo and can be
603 accessed at <https://doi.org/10.5281/zenodo.18090849> (Newall, 2025). The ICE provides a Jupyter Notebook
604 (notebooks/ASAanalysis.ipynb) containing age offset analyses and creation on non-map figures used in this paper.
605 This allows readers to reproduce all scientific results presented here and to interact directly with figures, plots,
606 and analytical steps. The ICE is containerized using Binder web services, enabling the notebook to be executed
607 online in a browser without local installation. The environment can be accessed via its DOI on Zenodo, and
608 executed through the Binder launch link provided in both the Zenodo record and the associated GitHub repository
609 (https://github.com/samsnewall/baikal_essd_ice). To access the analyses within the ICE navigate to
610 notebooks/ASAanalysis.ipynb.
611

Deleted: <https://doi.org/10.5281/zenodo.17636062> (Newall, 2025).

612 **7 Conclusions**

613 In this study, we have (i) created a complete database of all AMS radiocarbon dates from Lake Baikal sediment
614 cores published up to 2025, standardising the reporting, updating missing or incorrect metadata, and adding some
615 previously unpublished dates, (ii) produced a new estimate of age offset for TOC in Lake Baikal sediments of
616 1.62 ± 0.76 ^{14}C kyr BP, and (iii) did not find evidence to suggest that different regions of Lake Baikal have a
617 statistically different age offset, as previous studies have suggested. The primary implication of our results is that
618 previous Lake Baikal studies have significantly underestimated the temporal uncertainty from radiocarbon results.
619 More generally, our study has shown that a linear regression method for estimating age offsets has a large inherent
620 uncertainty that has likely been underestimated when used in other lakes/previous studies. Other techniques for
621 estimating age offset should be examined in a similar manner to evaluate their uncertainties. We hope that this
622 study facilitates further research in Lake Baikal by improving access to, and understanding of, previous
623 radiocarbon work that has taken place, and spurs on further work to understand the uncertainties in estimating
624 radiocarbon age offsets.

625 **8 Author Contribution**

626 Conceptualisation: SN and AM
627 Data Curation: SN
628 Formal Analysis: SN
629 Investigation: SN and NP
630 Methodology: SN
631 Project Administration: SN and AM
632 Software: SN
633 Supervision: AM

636 Visualisation: SN
637 Writing: original draft preparation: SN
638 Writing: Review and Editing: SN, AM, NP, and MB

639 **9 Competing Interests**

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

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