Radiocarbon (2025), pp. 1–13
doi:10.1017/RDC.2024.125

Selected Papers from the 3rd International Radiocarbon and Diet Conference, Oxford, 20–23 June 2023

CONFERENCE PAPER

A 350 ^{14}C yr discrepancy between bone and tooth dates from the same grave at the Early Neolithic cemetery of Shamanka II, Lake Baikal, southern Siberia: reservoir effects or a misplaced mandible?

Rick J Schulting[1], Ian Scharlotta[2], Angela Lieverse[3], Erin Jessup[4], Christopher Bronk Ramsey[5], Vladimir I Bazaliiskii[6] and Andrzej W Weber[4]

[1]University of Oxford, School of Archaeology, Oxford, UK, [2]Texas State University, Center for Archaeological Studies, San Marcos, TX, USA, [3]University of Saskatchewan, Department of Anthropology, Saskatoon, SK, Canada, [4]University of Alberta, Department of Anthropology, Edmonton, AB, Canada, [5]University of Oxford, Research Laboratory for Archaeology and the History of Art, Oxford, OX1 3QY, UK and [6]Irkutsk State University, Research Center "Baikal Region", Irkutsk, Russia
Corresponding author: Rick J Schulting; Email: rick.schulting@arch.ox.ac.uk

Received: 19 December 2023; **Revised:** 08 July 2024; **Accepted:** 20 August 2024

Keywords: freshwater reservoir effects; hunter-gatherers; mid-Holocene; stable isotopes

Abstract
A 350 ^{14}C yr discrepancy was found between dates on postcranial remains and mandibular teeth on what was thought to be the same individual from the Early Neolithic cemetery of Shamanka II, Lake Baikal. Stable nitrogen isotope results suggested a major shift in diet between childhood (when the teeth formed) and adulthood (represented by the postcrania), which could have resulted in different ^{14}C ages through a freshwater reservoir effect. Subsequent additional dating on the mandible and postcranial elements, however, indicated that the mandible actually belonged to a different individual. More subtle reservoir effects can be seen on the sequentially forming teeth and mandible. The practice by prehistoric hunter-gatherers of Lake Baikal of re-opening graves and removing cranial elements has long been known, but this is the first evidence for the inclusion of a mandible from a separate individual, though whether it was intentional or incidental is uncertain. As well as providing new insights into mid-Holocene mortuary practices in the region, our findings raise a cautionary note for the examination of disturbed graves.

Introduction

The waters of Lake Baikal and its surrounding rivers are known to have introduced significant freshwater reservoir effects into human consumers of aquatic resources. Using paired dates on humans and terrestrial fauna from the same graves, a number of regression equations have been developed for both Cis-Baikal (the western side of the lake) as a whole and its various separate microregions (Table 1) (Bronk Ramsey et al. 2014; Schulting et al. 2014, 2015, 2018, 2022). The presence of different reservoir offsets, most notably in the region's rivers, has the corollary that different regression equations might be required for individuals who moved from one microregion to another during the course of their lives. In such a case, the selection of different skeletal elements for analysis may lead to very different conclusions regarding both their radiometric age and their diet. This was thought to be the explanation for a discrepancy of ca. 350 ^{14}C years between radiocarbon dates on postcranial bone and dentine

Table 1. *Regression equations for FRE corrections on radiocarbon dates from Cis-Baikal and its microregions. Adjusted error range ($\sqrt{(s.d.)^2 + S^2}$) is calculated using the ± error term associated with the ^{14}C measurement ("s.d.") and the standard deviation of the model's residuals ("S") (Weber et al. 2016)*

Micro/region	Regression formula	r^2	p	n	S	Source
1) Cis-Baikal	1180.3+50.5(δ^{13}C)	0.208	0.008	33	142.1	Schulting et al. 2014
2) Cis-Baikal	–732.76+76.63(δ^{15}N)	0.672	0.000	31	85.5	Schulting et al. 2014
3) SW Baikal/Angara	–1388.85+125.45(δ^{15}N)	0.728	0.000	15	64.1	Schulting et al. 2014
4) Shamanka (SW Baikal)	–3338.00–246.26(δ^{13}C)+10.57(δ^{2}H)	0.603	0.016	10	146.0	Schulting et al. 2018
5) Little Sea	–3329.54–125.60(δ^{13}C)+95.11(δ^{15}N)	0.859	0.000	16	51.8	Schulting et al. 2014
6) Upper Lena	–7364.19–402.40(δ^{13}C)	0.490	0.016	11	183.6	Schulting et al. 2015
7) Upper Lena EBA sites only	–4289.89–211.19(δ^{13}C)+45.38 (δ^{15}N)	0.840	0.030	6	40.3	Schulting et al. 2015

collagen from what was considered the same individual (Burial 42.02) at the Early Neolithic cemetery of Shamanka II, Lake Baikal, southern Siberia (Schulting et al. 2022).

As detailed below, the dates obtained for a femur and rib were consistent with one another, combining to 6819 ± 21 ^{14}C BP, and were associated with mean stable carbon (δ^{13}C) and nitrogen (δ^{15}N) isotope values of –17.8‰ and 10.5‰, respectively. The dates obtained on post-weaning dentine from the first and third molars were also consistent with one another, but combined to 7165 ± 24 ^{14}C BP (Schulting et al. 2022). Moreover, while their mean δ^{13}C value of –17.1‰ was broadly comparable to that obtained on the bone samples, their δ^{15}N value of 15.8‰ was significantly higher. This introduced a very different correction for the freshwater reservoir effect (FRE), which in the Angara and Southwest Baikal region is based strongly on δ^{15}N values as a proxy for aquatic resource consumption. As this higher value was similar to other individuals from the Shamanka II cemetery, the implication was that this individual was local to the area from infancy to adolescence (the formation times of the first and third molars, respectively), but moved away after this to somewhere with a very different isotope ecology and FRE, before returning to the site not long before death and being buried there. In fact, the bone δ^{15}N value of 10.5‰ is an extreme outlier not only for the Shamanka II cemetery, but for much of the wider region (Weber et al. 2011, 2016, 2021, 2024a).

In an effort to better understand this matter, further radiocarbon dates and stable isotopic data were obtained from the mandible, another rib, the atlas vertebra, and the os coxae of Burial 42.02. This was intended: 1) to confirm that a single individual was represented; and 2) if so, to assess whether elements with different turnover rates (e.g., femoral cortical bone versus rib) demonstrated variable δ^{13}C and δ^{15}N values reflecting a shift in residence between locations with different isotopic ecologies.

Shamanka II

Shamanka II is one of the largest and the only fully excavated Early Neolithic (EN) cemetery known in Cis-Baikal (Figure 1). As is common for much of Eurasia outside of western Europe, the designation "Neolithic" here refers only to the presence of pottery; there are no domesticated plants or animals other than the dog. Excavated between 1998 and 2008 and in 2019, the site held 156 individuals in 97 graves (Weber et al. 2016, 2024a). The cemetery is located on a narrow peninsula jutting into Kultuk Bay in the

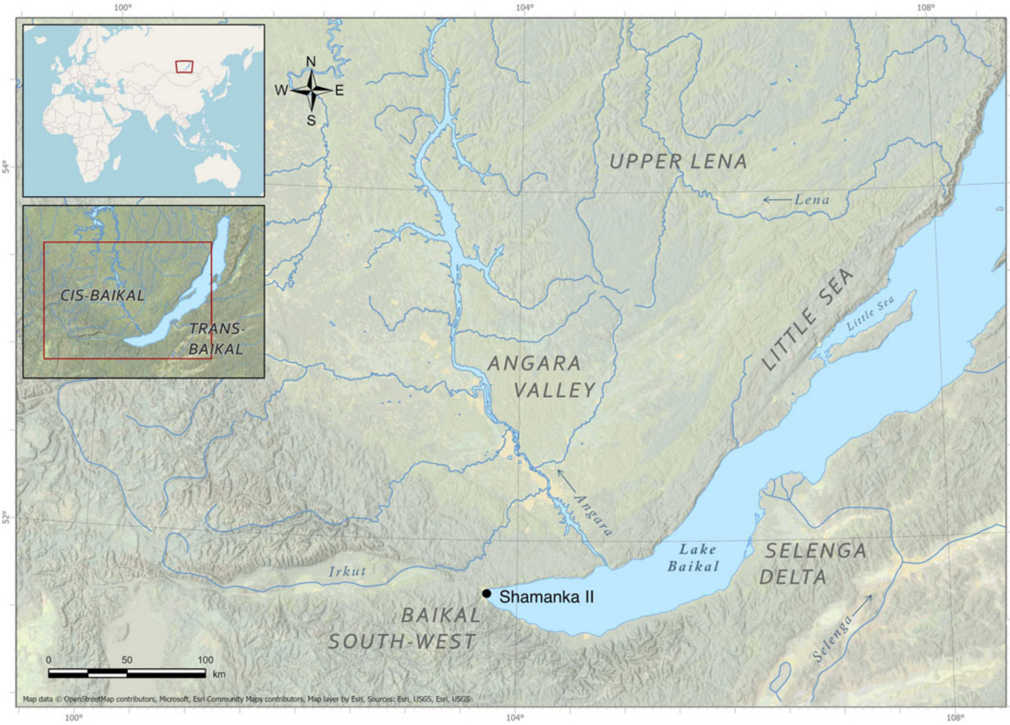

Figure 1. *Map of Lake Baikal and its microregions showing the location of Shamanka II (map by Karolina Werens).*

southwestern corner of Lake Baikal. Once corrected for the freshwater reservoir effect, the EN burials can be placed into two distinct phases, with a Bayesian model dating Phase 1 to *7555–7170 cal BP* (n = 98) and Phase 2 to *6925–6585 cal BP* (n = 17) (95.4% confidence intervals, combining modeled "Start" and "End" dates employing trapezium distribution models, rounded to nearest half-decade; Weber et al. 2016; see also Bronk Ramsey et al. 2021; Weber et al. 2021).

Grave 42

The focus of this paper, Grave 42, contained two individuals (Figure 2). The upper Burial 42.01 was well-preserved, complete and undisturbed, in an extended supine position with the head oriented to the northeast as is characteristic of the EN Kitoi mortuary tradition (Bazaliiski 2010). Burial 42.02, by contrast, was heavily disturbed, but clearly had been also extended supine with the head likewise oriented to the northeast. The lower limbs were in anatomical position, and the pelvis and most of the bones of the upper body were disarticulated and scattered through ca. 40 cm of fill. The exceptions to this were the bones of the right hand, most of which were in articulation, while those of the left hand were only slightly displaced. The cranium was missing, but a mandible was present among the disarticulated remains. There was no duplication of elements, and all were consistent with a single adult individual (Lieverse et al. 2024[1]). All dates below are presented at 95.4% confidence.

Burial 42.01 comprised a middle adult female (40−45 yr) dating to 6940–6564 cal BP (5921 ± 73 BP) once corrected for the FRE (OxA-26192: 6386 ± 34 BP), that is to Phase 2. Underlying this and clearly separated by intervening fill, Burial 42.02, an old adult female (50+ yr), has been previously

[1] While the presence of the feet is noted in Lieverse et al. (2024), they are implied to be disarticulated, whereas excavation photos show them to be articulated.

https://doi.org/10.1017/RDC.2024.125 Published online by Cambridge University Press

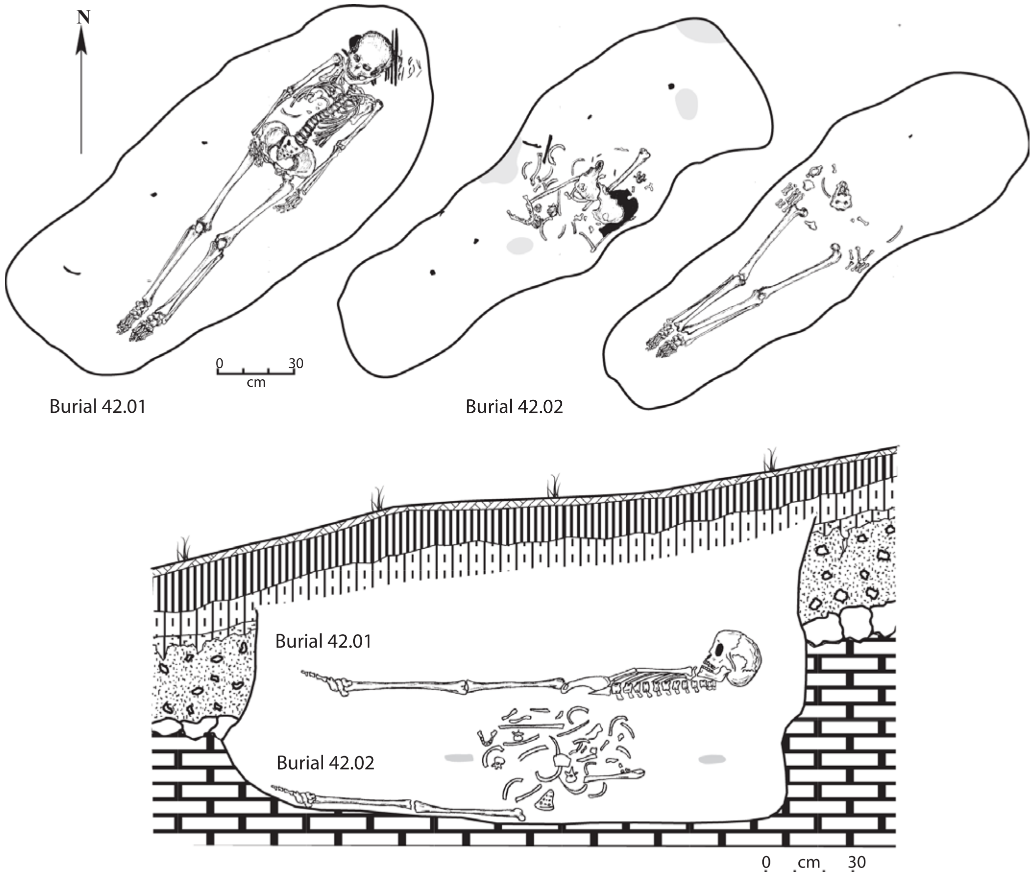

Figure 2. *Shamanka II, Grave 42 plan and section (created by Natalia Kasprishina, Andrei Tiutrin and Vladimir I Bazaliiskii, with modifications). Note that this differs from Figure 5 in Schulting et al. (2022) which does not show the feet present for Burial 42.02.*

dated to 7688–7604 cal BP (6819 ± 21 BP) (Figure 2). This is the weighted mean of three dates, two on a femur and one on a rib (χ^2-test: df = 2, T = 1.1(5%, 6.0) (Weber et al. 2016: Supplement 1). This date assumes no correction for the FRE because of the low associated δ^{15}N values (10.5 ± 3.2‰), which result in negative offsets, for which no mechanism is known (Table 2). However, the relatively high δ^{13}C values (–17.8 ± 0.3‰) suggest that fish from the lake may have contributed to the individual's diet, as no other source of ^{13}C-enriched foods consumed by humans is currently known in the region. In this case, it is possible to provisionally apply a correction equation for Cis-Baikal based only on δ^{13}C, resulting in a date of 7583–7266 cal BP (6541 ± 94 BP; χ^2-test: df = 2, T = 0.1(5% 6.0)) (Table 2).

The first and third molars from the mandible associated with Burial 42.02 have been analysed sequentially to investigate this individual's early life history (Scharlotta et al. 2022). It was this that identified a discrepancy first in stable isotope results and next in ^{14}C dates between the teeth and the postcranial remains[2]. The much higher mean δ^{15}N values for the post-weaning dentine microsamples (16.1 ± 0.5‰, n = 25) led to the interpretation summarized above, with the individual presumed to have changed residence leading to very isotopically different diets in early and later life. As detailed in Schulting et al. (2022), a number of post-weaning microsamples were combined from each tooth and

[2] Note that the respective bone δ^{13}C and δ^{15}N values of –16.4‰ and 15.1‰ attributed to Burial 42.02 in Scharlotta et al. (2022, their Table 1) are in error.

https://doi.org/10.1017/RDC.2024.125 Published online by Cambridge University Press

Table 2. *Radiocarbon and stable carbon and nitrogen isotope results for Shamanka II Burial 42.02. Asterisks (*) mark previously published results (Schulting et al. 2022; Weber et al. 2016). FRE corrections use the regression equations for Cis-Baikal ($\delta^{13}C$ only, postcrania) and SW Baikal/Angara ($\delta^{15}N$ only, mandible and teeth) (Schulting et al. 2014, 2022). Dates in italics are weighted means using the R_combine command in OxCal; those marked 'F' fail the χ^2 test (Ward and Wilson 1978). Note that OxA-30595 was inadvertently switched at an unknown stage with OxA-30593 from another grave at Shamanka II (Gr 108.02), as was clear from their very different stable isotope values, which had been previously measured separately (Weber et al. 2011). They are correctly re-assigned here*[a]

Sample	Element	Lab code	^{14}C yr	±	cal BP, no FRE		%	^{14}C offset $\delta^{15}N$	^{14}C offset $\delta^{13}C$	FRE ^{14}C yr	FRE ±	FRE cal BP (95.4%)		%	$\delta^{13}C$	$\delta^{15}N$	C: N	% yield
Postcranial remains																		
H 2004.021	Femur	OxA-24774*	6792	35	7680	7579	95.4	–72	292	6501	159	7674	7155	91.7	–17.6	10.5	3.0	16.3
												7121	7021	3.7				
H 2009.147	Femur	OxA-26193*	6821	35	7716	7581	95.4	–97	281	6540	172	7738	7155	92.5	–17.8	10.3	3.2	14.4
												7121	7021	3.0				
H 2004.019	Rib	OxA-30595*	6845	36	7777	7770	0.9	–59	266	6579	154	7731	7165	95.4	–18.1	10.6	3.3	13.8
					7753	7590	94.6											
—	*Femur, rib*	*Combined*	*6819*	*21*	*7688*	*7604*	*95.4*	*–76*	*280*	6541	*94*	*7583*	*7266*	*95.4*	*–17.8*	*10.5*	*3.2*	*14.8*
		χ^2-test: df = 2, T = 1.1(5% 6.0)								*χ^2-test: df = 2, T = 0.1(5% 6.0)*								
H2023.029	Rib	OxA-44005	6762	28	7668	7575	95.4	10	284	6478	145	7657	7640	0.6	–17.8	11.2	3.2	11.6
												7620	7155	91.3				
												7120	7062	2.3				
												7053	7022	1.2				
H2023.030	Atlas	OxA-44006	6871	23	7781	7661	94.0	–15	274	6597	144	7733	7249	94.0	–18.0	11.0	3.2	8.5
					7632	7623	1.4					7205	7171	1.5				
H2023.031	Os coxa	OxA-44007	6858	23	7746	7617	95.4	–9	276	6582	144	7705	7241	93.2	–17.9	11.0	3.2	11.4
												7216	7167	2.3				
—	*Postcrania*	*Combined*	*6833*	*12*	*7689*	*7616*	*95.4*	*–40*	*279*	*6548*	*63*	*7570*	*7412*	*76.2*	*–17.9*	*10.7*	*3.2*	*12.7*
												7401	*7325*	*19.3*				
		χ^2-test: df = 5, T = 11.9(5% 11.1) (F)								*χ^2-test: df = 5, T = 0.5(5% 11.1)*								
Cranial remains (mandible and teeth)																		
H 2004.022	Tooth, M1	OxA-V-2727-18*	7201	33	8163	8140	2.7	647	—	6554	72	7574	7323	95.4	–17.1	16.2	3.1	—
					8115	8094	2.5											
					8042	7937	90.2											

(*Continued*)

Table 2. (*Continued*)

Sample	Element	Lab code	^{14}C yr	±	cal BP, no FRE		%	^{14}C offset δ^{15}N	^{14}C offset δ^{13}C	FRE ^{14}C yr	FRE ±	FRE cal BP (95.4%)		%	δ^{13}C	δ^{15}N	C:N	% yield
H 2004.023	Tooth, M3	OxA-V-2727-19*	7129	33	8015	7926	81.2	546	—	6583	72	7585	7415	85.9	–17.0	15.4	3.2	—
					7895	7869	14.2					7398	7327	9.6				
—	*Tooth, M1,M3*	*OxA-V-2727-18, 19**	*7165*	*24*	*8018*	*7940*	*95.4*	*597*	—	*6569*	*51*	*7573*	*7421*	*92.7*	*–17.1*	*15.8*	*3.2*	—
												7380	*7359*	*2.8*				
		χ^2-test: df = 1, T = 2.4(5% 3.8)							—	*χ^2-test: df = 1, T = 0.1(5% 3.8)*								
H 2022.029	Mandible	OxA-44029	7039	21	7936	7831	90.2	468	—	6571	67	7577	7417	84.8	–16.9	14.8	3.2	12.3
					7811	7796	5.2					7393	7330	10.7				
—	*Cranial*	*Combined*	*7096*	*16*	*7969*	*7923*	*55.2*			*6569*	*41*	*7568*	*7533*	*16.5*	*–17.0*	*15.5*	*3.2*	—
					7898	*7866*	*40.2*					*7517*	*7423*	*79.0*				
		χ^2-test: df = 2, T = 18.6(5% 6.0) (F)								*χ^2-test: df = 2, T = 0.1(5% 6.0)*								

[a]This swap was noted previously, and the dates and isotope values switched to match the correct graves, but the OxA- codes were not re-assigned at that point (Weber et al. 2016, Supplement 1).

radiocarbon-dated, leading to a combined, FRE-corrected date of 7573–7359 cal BP (OxA-V-2727-18,19: 6569 ± 51 BP). It was further suggested that the dates could be reconciled by the application of an FRE correction using the regression equation developed for Cis-Baikal using only $\delta^{13}C$ values (Table 1) (Schulting et al. 2022, their Fig. 6).

Materials and methods

For the new analyses reported here, bone samples were obtained from the following elements attributed to Burial 42.02: mandible, rib, atlas vertebra, and os coxae, all from the disturbed part of the skeleton (Figure 2). Samples were prepared following the standard protocols in place at the Oxford Radiocarbon Accelerator Unit (ORAU) in the School of Archaeology, University of Oxford (Brock et al. 2010). This includes the use of a 30kD ultrafiltration stage (Brock et al. 2007). The new measurements were made on ORAU's new MICADAS system. Stable carbon and nitrogen isotopes were measured separately in duplicate on a Sercon 20/22 Isotope Ratio Mass Spectrometer (IRMS) using the same collagen used for AMS ^{14}C dating. An alanine standard was used for drift correction, and samples were calibrated with bracketing internal cow and seal bone standards referenced to international standards USGS40 and USGS41.

The dates on the postcrania were provisionally corrected for the FRE using the regression equation developed for Cis-Baikal using $\delta^{13}C$ only (eq. 1 in Table 1), given the abovementioned issues with their low $\delta^{15}N$ values: ^{14}C offset = 1180.3+50.5($\delta^{13}C$). This correction is not normally applied because of its relatively poor predictive power, and hence greater uncertainty. The dates on the teeth and mandible were corrected for the FRE using the regression equation developed for the SW Baikal/Angara microregion: ^{14}C offset = –1388.85+125.45($\delta^{15}N$) (eq. 3 in Table 1) (Schulting et al. 2014; 2022).

The revised error terms are calculated as: $\sqrt{(\text{s.d.})^2 + S^2}$, where s.d. refers to the error term associated with the radiocarbon date, and S refers to the standard deviation of the residuals on the regression equation (i.e., 142.1 yr and 64.1 yr for the $\delta^{13}C$ and $\delta^{15}N$ equations, respectively). Calibrations were undertaken in OxCal 4.4 (Bronk Ramsey 2001, 2021) using the IntCal20 curve (Reimer et al. 2020) and are reported at 95.4% confidence. Statistical tests were undertaken using SPSS v28.

Results

The four new samples all yielded acceptable results in terms of quality control measures, specifically collagen yield (11.0 ± 1.7%) and C:N values (3.2 in all cases) (DeNiro 1985; van Klinken 1999). While the three postcranial samples are broadly comparable in both ^{14}C age and $\delta^{13}C$ and $\delta^{15}N$ values, the mandible clearly differs in both ^{14}C age and isotopic values (Table 2).

Discussion

The new results offer an entirely different understanding of Burial 42.02. Rather than reflecting a shift in residence over the course of the individual's life, with corresponding differences in isotope ecology and reservoir offsets as recently presented by Schulting et al. (2022), it now seems clear that the mandible belongs to a different individual than the postcranial remains. When uncorrected for the FRE, the six dates on the latter narrowly fail to R_combine (χ^2-test, df = 5, T = 11.9(5% 11.1)), due to the slightly more recent new result on a rib (OxA-44005: 6762 ± 28 BP). This most likely can be explained simply as a statistical outlier, as its stable isotope values do not stand out from the others as would be expected if a change in diet and concomitant change in reservoir offset were implicated. Moreover, the date is more recent rather than older, so that the FRE cannot be a factor. Excluding this date, the remaining five results can be combined to 6847 ± 13 BP (χ^2-test, df = 4, T = 4.3(5% 9.5) calibrating to 7713–7617 cal BP. When corrected using the $\delta^{13}C$ regression equation, the substantially larger error terms allow all six

https://doi.org/10.1017/RDC.2024.125 Published online by Cambridge University Press

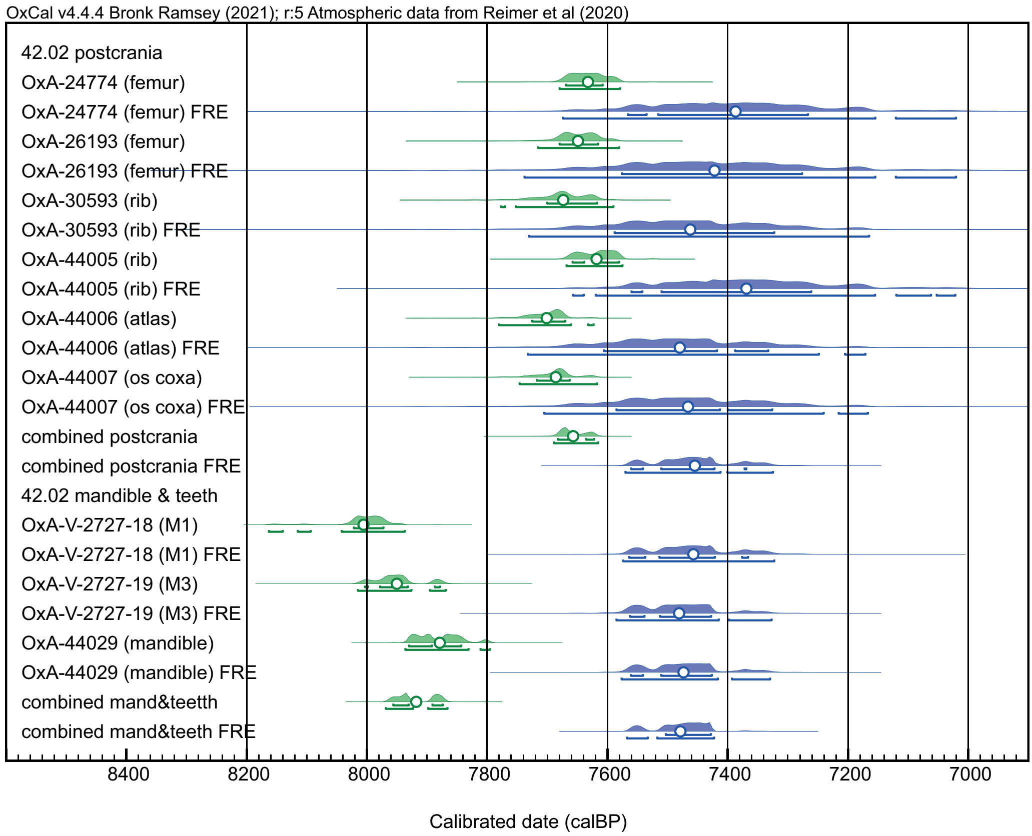

Figure 3. *OxCal plot of the radiocarbon determinations for Shamanka II Burial 42.02, showing mean (circle) and 68.3% and 95.4% confidence intervals. Dates in green are uncorrected for the FRE; those in blue are corrected. For details see text.*

dates to be combined to 6548 ± 63 BP (χ^2-test: df = 5, T = 0.5(5%11.1)), calibrating to 7570–7325 cal BP.

The date on the atlas vertebra is particularly important, as it would have had a close association with the missing cranium. The agreement of its ^{14}C age and stable isotope values with the other postcranial remains demonstrates that they all belong to the same individual, distinct from the individual represented by the mandible. This was unexpected, since, while the skeleton was disturbed, there was no indication from the skeletal inventory of the presence of more than one adult individual among the remains attributed to Burial 42.02. There was no cranium, but this is not uncommon among Early Neolithic burials across Cis-Baikal and was a feature of a number of other interments at Shamanka II itself (Weber et al. 2024a). It seems to have been part of an extended mortuary practice to open some graves and remove the skull or just the cranium (i.e. leaving the mandible) after a period of some years (as inferred from the absence of cutmarks that would have been found had soft connective tissue still been present). Sometimes postcranial remains were removed as well. There are 14 cases at Shamanka II in which the mandible is missing but the cranium present, though none present a convincing candidate as a match for the Grave 42 mandible as regards ^{14}C date and stable isotope values (i.e., within the 95.4% confidence interval for the former and within ±1‰ for the latter). In eight cases the cranium was missing but the mandible was present, and in an additional 32 cases (ca. 21% of the skeletons sufficiently preserved to assess) the entire skull was missing. The Grave 42 mandible may belong to one of these (though again there is no good match from ^{14}C date and stable isotope values), or of course to another individual not represented in a grave.

https://doi.org/10.1017/RDC.2024.125 Published online by Cambridge University Press

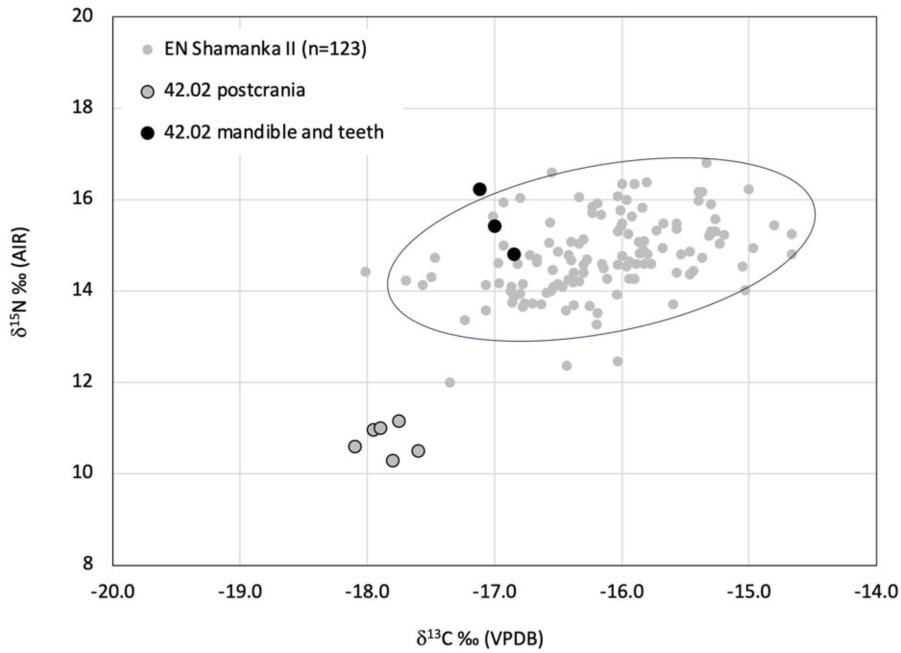

Figure 4. *Plot of δ^{13}C and δ^{15}N values for human collagen from Grave 42.02 in the context of all the other post-weaning age isotopic results from the Early Neolithic component of Shamanka II ($n = 123$; ellipse shows 95.4% confidence).*

It is possible that opening the grave for the insertion of the overlying Burial 42.01, which was itself complete and undisturbed, was responsible for the disturbance of 42.02. Alternatively—and perhaps more likely given how widespread the practice was—there may have been an earlier episode of disturbance during which the skull was removed and, for reasons unknown, the mandible of another individual added, whether intentionally or, perhaps, incidentally given that stray human bones were sometimes encountered in the cultural layer and in a small number of other graves at the site (though more commonly in the fill than at the burial level) (Weber et al. 2024b). In either case, there is the question of its origins. Belonging to Phase 1, the mandible is much older than Burial 42.01, so that it could not be contemporary with the later Phase 2 interment. Whether the mandible is contemporary with the postcranial remains of Burial 42.02 depends on the FRE for the latter. This is not straightforward. While the mean δ^{15}N value of 10.7 ± 0.3‰ could be interpreted as reflecting a largely terrestrial diet, this is not the case for the mean δ^{13}C value of –17.9 ± 0.2‰. The δ^{15}N value is an extreme outlier at Shamanka II (Figure 4), and indeed there is no currently known microregion in either Cis- or Trans-Baikal with this combination of isotopic values in the Early Neolithic. The only microregions with comparably low δ^{15}N values are the Upper Lena and Little Sea, in the latter case limited to those with a "Game-Fish" diet (Weber and Goriunova 2013; White et al. 2020). But these populations date to the Late Neolithic and Early Bronze Age rather than to the Early Neolithic; in addition, in both microregions δ^{13}C values are lower than that of Burial 42.02. Thus, it is not known which, if any, of the FRE correction equations developed for Cis-Baikal are appropriate.

That freshwater resources featured in the diet is strongly implied by the δ^{13}C value, which is too high for a purely terrestrial diet. Nor is there any evidence for the consumption of C_4 plants in the region at this time, which would only be present as a few wild grasses. Thus, this individual may have been an outsider who spent most of their life in another area with a different isotope ecology but unknown FRE. That said, hypothetically, it may have been possible to achieve the observed isotopic values by consuming terrestrial plants and game as well as low trophic level fish from the local area. While we

https://doi.org/10.1017/RDC.2024.125 Published online by Cambridge University Press

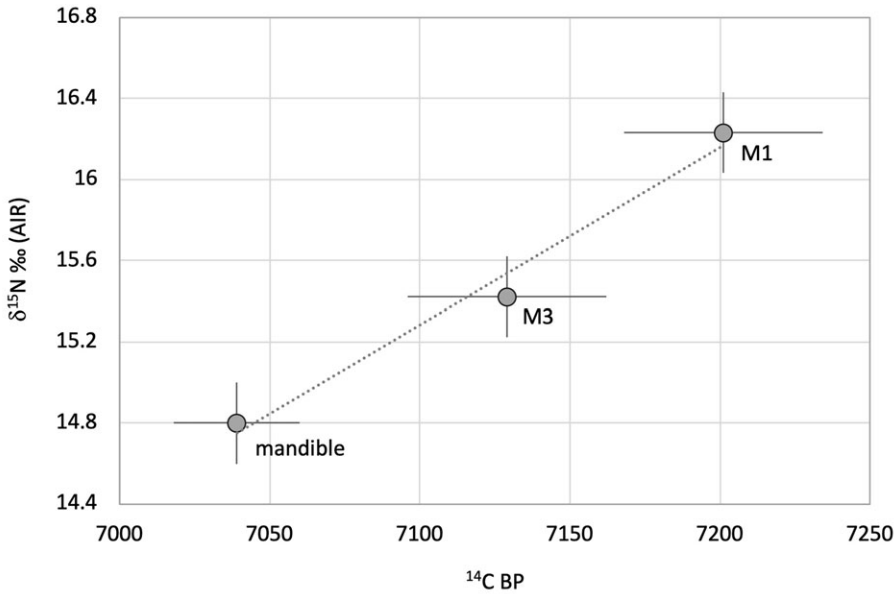

Figure 5. *Plot of uncorrected ^{14}C determinations and δ^{15}N values for M1, M3 and mandible in Grave 42 showing strong positive correlation. Error bars ± 1σ.*

currently lack an isotopic baseline for fish specifically from Kultuk Bay, values for littoral species such as grayling from the Little Sea show the combination of high δ^{13}C and relatively low δ^{15}N. We therefore provide estimated FRE corrections using the regression equation (eq. 1 in Table 1) for Cis-Baikal using only δ^{13}C values (Schulting et al. 2022). That the mean of the combined result for the postcrania (7455 ± 65 cal BP) is actually closely comparable to that for the combined teeth and mandible (7479 ± 43 cal BP) (Figure 3) could suggest that they are in fact broadly contemporary, even though not belonging to the same individual.

The minimal difference between the cortical and cancellous bone samples suggests that the individual interred as Burial 42.02 either moved to the Shamanka area not long before their death, or that they intentionally maintained a different diet either during their lifetime at Shamanka or after arrival. Nevertheless, there is some slight indication of a shift in diet as represented by the two measurements on cortical femoral bone, compared to the four measurements on elements with more rapid turnover rates (cf. Hedges et al. 2007), with the latter showing lower δ^{13}C values but higher δ^{15}N values. The mean difference in δ^{13}C is only 0.22‰, while that in δ^{15}N is 0.52‰, which just fails to attain statistical significance (Student's *t*-test, $t = 2.772$, $p = 0.0502$). That it even comes this close to rejecting the null hypothesis ($\alpha = 0.05$) is highly suggestive given the small sample size and hence low statistical power of the test. As higher δ^{15}N values are typical of other individuals at Shamanka II, this raises the possibility that the individual interred as Burial 42.02 moved to the vicinity perhaps a year or two before they died, or, alternatively, changed their diet at this time. The lack of dentition attributable to this individual precludes the possibility of undertaking strontium isotope analysis on dental enamel to try to identify their possible geographic origins (cf. Scharlotta and Weber 2014; Scharlotta et al. 2022), though osteon microsampling of the femoral cortical bone might provide insights into their earlier life history (Scharlotta et al. 2013).

A final observation relates to the radiocarbon determinations and stable isotope values for the mandible and two molars. The FRE-uncorrected results for the first molar and the mandible differ by 162 ^{14}C yr, such that the three dates cannot be combined (χ^2-test, df = 2, T = 18.6(5% 6.0)). While the δ^{13}C values of the three samples differ by only 0.2‰, there is a progressive decrease in δ^{5}N from 16.2‰ for the post-weaning section of the first molar, to 15.4‰ for the second molar, to 14.8‰ for the

https://doi.org/10.1017/RDC.2024.125 Published online by Cambridge University Press

mandible (Figure 5). This may be interpreted as a shift towards a slightly more terrestrial diet between early childhood and adulthood. Given the FRE regression equation for the SW Baikal/Angara microregion, the difference of 1.4‰ between the first molar and the mandible in δ^{15}N predicts an offset of 176 ^{14}C yr (i.e., 1.4 times the slope coefficient of 125.45), which is in good agreement with the observed difference of 162 ^{14}C yr. This provides additional confirmation of the utility of the previously developed regression equations and confidence in their use.

Conclusions

Although based only a single interment, this study presents a cautionary tale when interpreting varying ^{14}C ages and stable isotope values from what was ostensibly a single individual. While the scenario originally presented for Burial 42.02 (Schulting et al. 2022) was entirely plausible given the known variability in isotope ecology and freshwater reservoir offsets in the Baikal region, in the end the explanation turned out to be simpler in one sense. Yet, in terms of mortuary behavior, the explanation is far more complex, involving the removal of the skull from the grave and the intentional or incidental inclusion of a mandible from another individual. This has an important corollary for the selection of skeletal elements for analysis. The frequent emphasis on cranial elements is entirely understandable, given the preferred status of their tissues for many biomolecular techniques (aDNA on the petrous bone or teeth; sequential analysis of dentine; strontium and oxygen isotope analysis of dental enamel, etc.), yet, as here, it cannot always be assumed that cranial and postcranial elements at a site belong to the same individual even when the osteological analysis is consistent with this. While the case we present here from Shamanka II is a highly unusual one (though see Hanna et al. 2012), the problem may be more widespread than realized in cases with multiple, commingled remains (cf. Charlton et al. 2019). For Shamanka II specifically, a question may now be raised over other graves showing disturbance relating to the removal of the cranium, mandible, or both. The inclusion of a mandible from another individual would probably go unnoticed, as long as it matched the age-at-death assessment based on the postcranial remains. It is the large difference in the δ^{15}N values between the postcrania and the dentition that highlighted the case of Grave 42.02; in most other individuals at Shamanka II the stable isotope values would be too similar to raise any concern.

One means of mitigating against this potential issue is to use the same element for multiple analyses in cases in which any question arises over the remains representing a single individual, such as in disturbed multiple graves, or in contexts wherein the inclusion of stray human bones is possible. In practice, for much current bioarchaeological research involving concurrent analyses of the dentition and/or petrous bone, this means dating the mandible or cranium. However, in contexts in which disturbance is minimal and it is possible to securely identify individual skeletons, the dating of postcranial elements is still preferable as they offer greater choice for destructive analysis that minimizes information loss.

Although the major intra-individual differences in ^{14}C age and stable isotope results posited for the postcranial and dental samples of Burial 42.02 have been discounted, the more subtle trend observed for the first and third molars and mandible illustrates the need to carefully consider sample selection when dealing with contexts in which variable freshwater (or marine) reservoir effects might be expected.

Acknowledgments. Funding for research presented in this paper was provided by the Baikal Archaeology Project and the Baikal-Hokkaido Archaeology Project (Social Sciences and Humanities Research Council of Canada, grant nos. 412-2011-1001 and 895-2018-1004). Many thanks to Karolina Werens for discussions concerning Grave 42.02.

Declaration of competing interests. The authors declare no conflicts or competing interests.

References

Bazaliiski VI (2010) Mesolithic and Neolithic mortuary complexes in the Baikal region of Siberia. In Weber AW, Katzenberg MA and Schurr TG (eds), *Prehistoric Hunter-Gatherers of the Baikal Region, Siberia*. Philadelphia: University of Pennsylvania Press, 51–86.

Brock F, Bronk Ramsey C and Higham TFG (2007) Quality assurance of ultrafiltered bone dating. *Radiocarbon* **49**(2), 189–192.

Brock F, Higham TFG, Ditchfield P and Bronk Ramsey C (2010) Current pretreatment methods for AMS radiocarbon dating at the Oxford Radiocarbon Accelerator Unit (ORAU). *Radiocarbon* **52**(1), 102–112.

Bronk Ramsey C (2001) Development of the radiocarbon calibration program OxCal. *Radiocarbon* **43**(2A), 355–363.

Bronk Ramsey C (2021) https://c14.arch.ox.ac.uk/oxcal/.

Bronk Ramsey C, Schulting RJ, Bazaliiski VI, Goriunova OI and Weber A (2021) Spatio-temporal patterns of cemetery use among Middle Holocene hunter-gatherers of Cis-Baikal, Eastern Siberia. *Archaeological Research in Asia* **25**, e100253.

Bronk Ramsey C, Schulting RJ, Goriunova OI, Bazaliiskii VI and Weber AW (2014) Analyzing radiocarbon reservoir offsets through stable nitrogen isotopes and Bayesian modeling: A case study using paired human and faunal remains from the Cis-Baikal region, Siberia. *Radiocarbon* **56**(2), 789–799.

Charlton S, Booth TJ and Barnes I (2019) The problem with petrous? A consideration of the potential biases in the utilization of pars petrosa for ancient DNA analysis. *World Archaeology* **51**(4), 574–585.

DeNiro MJ (1985) Post-mortem preservation and alteration of *in vivo* bone collagen isotope ratios in relation to palaeodietary reconstruction. *Nature* **317**, 806–809.

Hanna J, Bouwman AS, Brown KA, Parker Pearson M and Brown TA (2012) Ancient DNA typing shows that a Bronze Age mummy is a composite of different skeletons. *Journal of Archaeological Science* **39**(8), 2774–2779.

Hedges REM, Clement JG, Thomas CDL and O'Connell TC (2007) Collagen turnover in the adult femoral mid-shaft: modeled from anthropogenic radiocarbon tracer measurements. *American Journal of Physical Anthropology* **133**(2), 808–816.

Lieverse AR, Faccia K, Waters-Rist AL, Antonova A, Nasab HV, Haverkort CM, Purchase SL, Schulting RJ, Moussa N and Bazaliiskii V. (2024) Human osteological remains. In Weber AW, Bazaliiskii VI and Jessup E (eds), *Shamanka II: An Early Neolithic Cemetery on the Southwest Shore of Lake Baikal, Siberia. Volumes 1 and 2. Archaeological and Osteological Materials*. Archaeology in China and East Asia, Vol. 9. Wiesbaden: Deutsches Archäologisches Institut, Eurasien-Abteilung, Außenstelle Peking.

Reimer PJ, Austin WEN, Bard E, Bayliss A, Blackwell PG, Ramsey CB, Butzin M, Cheng H, Edwards RL, Friedrich M, Grootes P, Guilderson T, Hajdas I, Heaton T, Hogg A, Hughen K, Kromer B, Manning S, Muscheler R, Palmer J, Pearson C, van der Plicht J, Reimer R, Richards D, Scott E, Southon J, Turney C, Wacker L, Adolphi F, Büntgen U, Capano M, Fahrni S, Fogtmann-Schulz A, Friedrich R, Köhler P, Kudsk S, Miyake F, Olsen J, Reinig F, Sakamoto M, Sookdeo A and Talamo S (2020) The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon* **62**(4), 725–757.

Scharlotta I, Bazaliiskii VI, Kusaka S and Weber AW (2022) Diet or mobility? Multi-isotopic (C, N, and Sr) dietary modeling at Shamanka II, Cis-Baikal, Siberia. *Archaeological Research in Asia* **29**, e100340.

Scharlotta I, Goriunova OI and Weber A (2013) Micro-sampling of human bones for mobility studies: diagenetic impacts and potentials for elemental and isotopic research. *Journal of Archaeological Science* **40**(12), 4509–4527.

Scharlotta I and Weber A (2014) Mobility of middle Holocene foragers in the Cis-Baikal region, Siberia: Individual life history approach, strontium ratios, rare earth and trace elements. *Quaternary International* **348**, 37–65.

Schulting RJ, Bronk Ramsey C, Bazaliiskii VI and Weber A (2015) Highly variable freshwater reservoir offsets found along the Upper Lena watershed, Cis-Baikal, southeast Siberia. *Radiocarbon* **57**(4), 581–593.

Schulting RJ, Bronk Ramsey C, Goriunova OI, Bazaliiskii VI and Weber A (2014) Freshwater reservoir offsets investigated through paired human-faunal ^{14}C dating and stable carbon and nitrogen isotope analysis at Lake Baikal, Siberia. *Radiocarbon* **56**(3), 991–1008.

Schulting RJ, Bronk Ramsey C, Scharlotta I, Richards MP, Bazaliiskii VI and Weber A (2022) Freshwater reservoir effects in Cis-Baikal: an overview. *Archaeological Research in Asia* **29**, e100324.

Schulting RJ, Snoeck C, Begley IS, Brookes S, Bazaliiskii VI, Bronk Ramsey C and Weber A (2018) Using δ^2H to correct for freshwater ^{14}C reservoir offsets: a pilot study from Shamanka II, Lake Baikal, southern Siberia. *Radiocarbon* **60**, 1521–1532.

Van Klinken GJ (1999) Bone collagen quality indicators for palaeodietary and radiocarbon measurements. *Journal of Archaeological Science* **26**(6), 687–695.

Ward GK and Wilson SR (1978) Procedures for comparing and combining radiocarbon age determinations: a critique. *Archaeometry* **20**(1), 19–31.

Weber AW, Bazaliiskii VI and Jessup E (eds). (2024a) Shamanka II: An Early Neolithic cemetery on the southwest shore of Lake Baikal, Siberia. Volumes 1 and 2. Archaeological and osteological materials. Archaeology in China and East Asia, Vol. 9. Deutsches Archäologisches Institut, Eurasien-Abteilung, Außenstelle Peking. Wiesbaden: Harrassowitz Verlag.

Weber AW, Bazaliiskii VI and Jessup E (2024b) Art, fire, bears, human bones and summary of variation in mortuary practices. In Weber AW, Bazaliiskii VI and Jessup E (eds), *Shamanka II: An Early Neolithic Cemetery on the Southwest Shore of Lake Baikal, Siberia. Volumes 1 and 2. Archaeological and Osteological Materials*. Wiesbaden: Archaeology in China and East Asia, Vol. 9. Deutsches Archäologisches Institut, Eurasien-Abteilung, Außenstelle Peking.

Weber AW, Ramsey CB, Schulting RJ, Bazaliiskii VI and Goriunova OI (2021) Middle Holocene hunter–gatherers of Cis-Baikal, Eastern Siberia: Chronology and dietary trends. *Archaeological Research in Asia* **25**, e100234.

Weber AW and Goriunova OI (2013) Hunter–gatherer migrations, mobility and social relations: A case study from the Bronze Age Baikal region, Siberia. *Journal of Anthropological Archaeology* **32**(3), 330–346.

Weber AW, Schulting RJ, Bronk Ramsey C and Bazaliiskii VI (2016) Biogeochemical data from the Shamanka II Early Neolithic cemetery on southwest Baikal: Chronological and dietary patterns. *Quaternary International* **405**(B), 233–254.

Weber AW, White D, Bazaliiskii VI, Goriunova OI, Savel'ev NA and Katzenberg MA (2011) Hunter–gatherer foraging ranges, migrations, and travel in the middle Holocene in the Baikal region of Siberia: insights from carbon and nitrogen stable isotope signatures. *Journal of Anthropological Archaeology* **30**(4), 523–548.

White JA, Schulting RJ, Hommel P, Lythe A, Bronk Ramsey C, Moiseyev V, Khartanovich V and Weber AW (2020) Integrated stable isotopic and radiocarbon analyses of Neolithic and Bronze Age hunter-gatherers from the Little Sea and Upper Lena Micro-Regions, Cis-Baikal, Siberia. *Journal of Archaeological Science* **119**, e105161.

Cite this article: Schulting RJ, Scharlotta I, Lieverse A, Jessup E, Bronk Ramsey C, Bazaliiskii VI, and Weber AW. A 350 ^{14}C yr discrepancy between bone and tooth dates from the same grave at the Early Neolithic cemetery of Shamanka II, Lake Baikal, southern Siberia: reservoir effects or a misplaced mandible? *Radiocarbon*. https://doi.org/10.1017/RDC.2024.125