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Turning eastward: New radiocarbon and stable isotopic data for Middle Holocene hunter-gatherers from Fofanovo, Trans-Baikal, Siberia

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ABSTRACT

A considerable amount of bioarchaeological research – including AMS ^{14}C dating and stable carbon and nitrogen isotope analyses ($\delta^{13}C$ and $\delta^{15}N$) – has been undertaken on the hunter-gatherers from the area west of Lake Baikal, known as Cis-Baikal. No such work has previously been reported for the east side of the lake, Trans-Baikal. Here, we present new radiocarbon dates and isotopic results for twenty individuals from the Fofanovo cemetery, located along the Selenga River on the southeast coast of Lake Baikal.

Once corrected for an old carbon effect using regression equations developed for Cis-Baikal, the radiocarbon results form 4 chronological clusters: 1) Late Mesolithic (LM), around 7950 cal BP ($n = 3$); 2) Late Neolithic (LN), between ca. 6000 and 5500 cal BP ($n = 5$); 3) LN to Early Bronze Age (EBA), between ca. 4900 and 4500 cal BP ($n = 2$); and the largest cluster 4) later EBA, around 3700 cal BP ($n = 10$). The LM Cluster 1 dates indicate that formal cemetery use in Trans-Baikal may have begun earlier than in Cis-Baikal. Clusters 2 and 3 reveal a previously unidentified LN component to the cemetery. Additionally, the EBA Cluster 4 appears to be largely synchronous with the EBA in Cis-Baikal.

As a group, the Fofanovo individuals are isotopically distinct from the Middle-Holocene hunter–gatherers in the microregions of Cis-Baikal, exhibiting a combination of low $\delta^{13}C$ values ($-19.4 \pm 0.9‰$) but high $\delta^{15}N$ values ($15.2 \pm 0.8‰$). This likely reflects the distinctive isotopic ecology of the lower Selenga River, combined with use of aquatic resources from Lake Baikal itself. While further sampling is needed to test its robustness, a statistically significant difference between the LN ($n = 6$) and EBA ($n = 11$) was found, suggesting a greater reliance on the seasonal resources of the Selenga River during the EBA.

Further analyses on these and other individuals from the cemetery are planned and will undoubtably provide additional insights into hunter-gatherer subsistence adaptations and dietary variation in Trans-Baikal, highlighting both differences and similarities with those of Cis-Baikal.

1. Introduction

Since the late 19th century, archaeologists have extensively investigated prehistoric hunter-gatherers of the Baikal region, especially their particularly rich mortuary record (Michael, 1958; Okladnikov, 1950, 1955). In recent decades, the Baikal Archaeology Project (BAP, 1995–2011 and 2018–present) and Baikal–Hokkaido Archaeology Project (BHAP, 2011–2018) undertook fine-scale analyses of the diet, mobility, and chronology of Neolithic and Early Bronze Age individuals excavated from cemeteries on and around the western side of the lake, known as Cis-Baikal. Decidedly less is known about hunter-gatherer adaptations on the eastern side of the lake, Trans-Baikal. In this paper,

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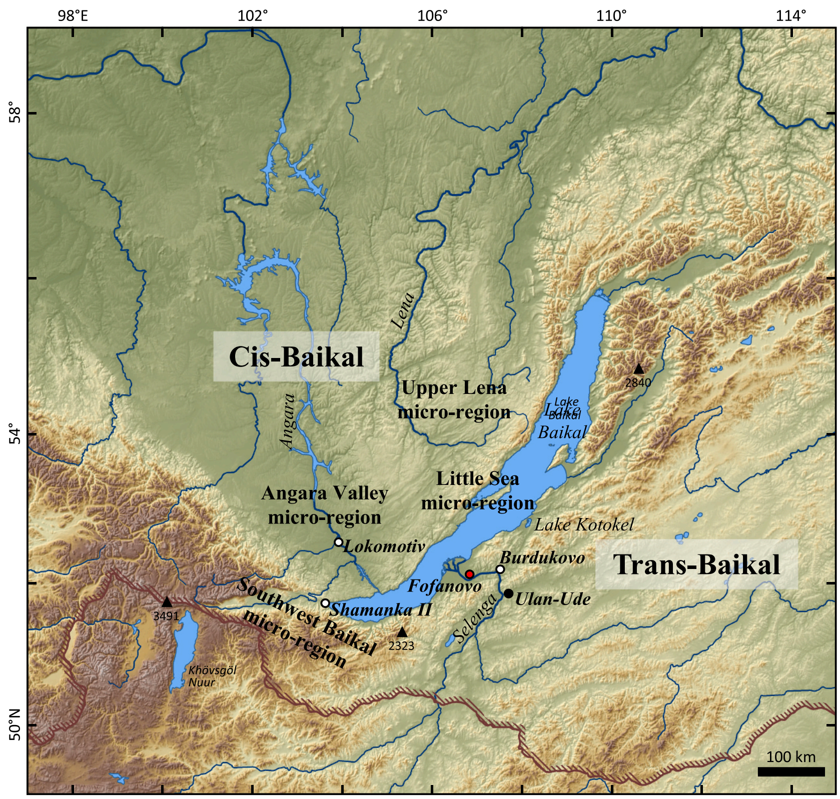


Fig. 1. Map of the Lake Baikal Region (Cis- and Trans-Baikal) and the location of Fofanovo near the Selenga River delta. Topography is based on elevation Shuttle Radar Topography Mission (SRTM) v4.1 data (Jarvis et al., 2008). The basemap was created by Dr. Christian Leipe (FU Berlin).

we present radiocarbon dates and stable carbon (δ^{13}C) and nitrogen (δ^{15}N) isotopic results for 20 individuals from Fofanovo, a large, multi-period cemetery located near the delta of the Selenga River in Trans-Baikal (Fig. 1). The aims are to better understand the cemetery's chronology and to characterise diet in relation to what is known about subsistence patterns in Cis-Baikal.

2. Background

2.1. Region and ecology

Lake Baikal is the oldest, deepest, and, by volume, largest lake in the world. The lake is fed by close to 400 tributaries, of which the Selenga River is the largest with an approximate length of 1920 km. The Selenga River's drainage into Lake Baikal constitutes approximately half of the lake's inflowing water (Matveyev and Samusenok, 2015; Sampson et al., 2002).

The waters of Lake Baikal can be divided into five habitat zones: lagoons, expansive shallows, gulfs, deep-water (pelagic), and open coast littoral. There are three lagoons in the vicinity of the Selenga delta (Posol'skii, Cherkalovo, and Proval) and extensive shallows beyond the delta itself (Kozhov, 1963; Weber, 2003). The aquatic ecology of Lake Baikal has more in common with an ocean system than with most freshwater lakes (Matveyev and Samusenok, 2015). Fish common to the lagoons and coast of Lake Baikal are listed in Table 1. There is an endemic species of seal (*Phoca sibirica*) in the lake which may have contributed to the diets of the Fofanovo hunter–gatherers. This has been demonstrated for individuals from Cis-Baikal, primarily from the Little Sea microregion on the northwest side of the lake (Katzenberg et al., 2012; Nomokonova et al., 2013b; Nomokonova et al., 2015; Weber, 2003; Weber et al., 1998; Weber et al., 2011). Aquatic life in the Selenga River has not been studied archaeologically, but commercial, conservationist, and environmental studies have recorded the fish communities of the river in different portions(e.g., Sampson et al., 2002; Table 2). Most notably, the Selenga is a major spawning area for Baikal sturgeon and for one of the five main populations of the Baikal omul'

Table 1
Fish common in the shallow lagoons and littoral open coastline of Lake Baikal (Weber, 2003; Kozhov, 1950, 1963; Kozhov, 1972). '+' denotes presence in the habitat zone.

Common name	Species	Shallow lagoons	Littoral coastline
Burbot	*Lota lota*		+
Graylings	*Thymallus* spp.		+
Ide	*Leuciscus idus*	+	
Lenok	*Brachymystax lenok*		+
Northern pike	*Esox lucius*	+	
Omul'	*Coregonus autumnalis migratorius*		+
Perch	*Perca fluviatillis*	+	
Siberian dace	*Leuciscus leuciscus baicalensis*	+	+
Siberian roach	*Rutilus rutilus lacustris*	+	
Taimen'	*Hucho taimen*		+
Whitefish	*Coregonus lavaretus baicalensis*		+

Table 2
Fishes common in the lower Selenga River in recent times (Dulmaa, 1999; Matveyev and Samusenok, 2015; Sampson et al., 2002) and those sampled for isotopic study by Sampson et al. (2002) and Dufour et al. (1999).

Common name	Species
Amur catfish	*Parasilurus asotus*
Bluntnose minnow[a]	*Phoxinus phoxinus*
Burbot	*Lota lota*
Common carp	*Cyprinus carpio*
Giebel (Silver) carp	*Carassius auratus gibelio*
Ide	*Leuciscus idus*
Northern pike	*Esox lucius*
Omul'	*Coregonus autumnalis migratorius*
Perch	*Perca fluviatillis*
Siberian dace	*Leuciscus leuciscus baicalensis*
Siberian gudgeon[a]	*Gobio gobio*
Siberian roach	*Rutilus rutilus lacustris*
Spined loach	*Cobitis taenia*
Sturgeon	*Acipenser baerii baicalensis*
Taimen'	*Hucho taimen*
Whitefish	*Coregonus lavaretus baicalensis*

[a] No isotopic data available.

Table 3
Terrestrial fauna potentially available to Trans-Baikal Middle Holocene hunter–gatherers (Weber, 2003).

Common name	Species	Preferred habitat
Boar	*Sus scrofa*	Forest and forest-steppe
Red deer	*Cervus elaphus*	Forest-steppe and taiga
Roe deer	*Capreolus capreolus pygargus*	Steppe and forest-steppe
Elk/Moose	*Alces alces*	Taiga wet valley
Siberian ibex	*Capra sibirica*	Eastern Sayan mountain valleys
Musk Deer	*Moschus moschiferus*	Highland and taiga
Reindeer	*Rangifer tarandus*	Mountain highlands

(*Coregonus autumnalis migratorius*) (Dulmaa, 1999; Kozhov, 1950, 1963; Kozhov, 1972). The terrestrial environment of Cis- and Trans-Baikal is dominated by forest-steppe. Terrestrial fauna is rich throughout both regions, but vary in distribution depending on vegetation (Table 3).

2.2. Archaeology and chronology

Archaeologists have long classified Cis-Baikal Neolithic and Early Bronze Age (EBA) burials by their mortuary traditions. Recently, BAP/BHAP have refined the region's chronology through integrative studies of mortuary traditions, subsistence, diet, and radiocarbon dating corrected for the freshwater reservoir effect (FRE) (Table 4). Nevertheless, it is unclear to what extent Cis-Baikal's culture history is applicable to Trans-Baikal. Studies have highlighted significant variation in the style and timing of mortuary traditions between the different micro-regions of Cis-Baikal (Weber et al., 2016a). It is expected that similar, if not more, variation will be revealed in Trans-Baikal, especially considering that the earliest mortuary assemblages, Late Mesolithic (LM) and Early Neolithic (EN), at Fofanovo are distinct from their Cis-Baikal counterparts (Bazaliiskii, 2010).

LM graves are relatively rare in Cis-Baikal, with 24 dated examples yielding corrected mean dates ranging from 8427 ± 56 to 7059 ± 77 cal BP, thus partly overlapping with the EN period (Table 4). These graves display substantial variation in mortuary practice but have been provisionally designated as the Khin Group (Weber et al., 2020). While some graves pre-date the EN Kitoi mortuary tradition from the Angara and Southwest Baikal, many, particularly in the Little Sea and on the Upper Lena, are clearly parallel to it. This implies regional asynchronicity in the development of these mortuary traditions (Weber et al., 2016a, 2020; Goriunova et al., 2020a, 2020b). The oldest large cemeteries in Cis-Baikal are primarily found in the Angara and SW Baikal micro-regions and date firmly to the EN.

The Middle Neolithic (MN) marks a long interruption in formal cemetery usage in Cis-Baikal, such that little is known concerning its mortuary practices. Although it is unlikely that this was a result of depopulation of the area (Weber, 2020), morphological and ancient DNA studies indicate that there is either genetic displacement between the EN and LN/EBA groups or greater admixture during the LN/EBA (de Barros Damgaard et al., 2018a, 2018b; Waters-Rist et al., 2016; Weber, 1995; Weber et al., 2002; Weber and Bettinger, 2010). Additionally, it has been posited that the incoming peoples were of western (i.e. upper Yenisei) or southern (i.e. Mongolia or NW China) origin (Waters-Rist et al., 2016; Weber et al., 2002), though with little empirical support. Recent genetic analyses indicate that the LN and EBA component shows an increase in Ancient Northeast Asian (ANE) ancestry (de Barros Damgaard et al., 2018b). Some level of genetic continuity in the Angara micro-region has been proposed based on the cranial and dental evidence (Movsesian et al., 2014; Waters-Rist et al., 2016). The ancient DNA sample is still small, but the findings in Moussa et al. (2020) provide support for some regional genetic continuity through the MN. Examination of individuals from Trans-Baikal may provide important new insights on this matter.

In Cis-Baikal, formal cemeteries reappear in the Late Neolithic (LN) and continue into the EBA. Of the LN mortuary traditions, Isakovo is essentially only known from the Angara valley, while Serovo has been documented for the Angara, the Upper Lena (where it has also been called the Archaic variant; Okladnikov, 1978; Bazaliiskii, 2010), and the Little Sea, but with a few distinctive characteristics (Weber et al., 2016a; Goriunova et al., 2020a, 2020b).

The relative chronological position of the EBA Glazkovo mortuary tradition is largely defined by the inclusion of copper and bronze grave goods, while retaining a hunter-gatherer economy (Weber and Bettinger, 2010). Glazkovo is also the most widespread mortuary tradition in Cis-Baikal showing a number of distinct mortuary characteristics across the micro-regions and is also archaeologically recognizable in Trans-Baikal.

Stable carbon and nitrogen isotope results unequivocally demonstrate a hunting, fishing and gathering subsistence economy throughout Cis-Baikal from the LM through the EBA (see Weber et al., 2016a for the most recent summary), as does the extensive archaeological evidence, such as zoomorphic art, subsistence-related stone and bone grave goods, including composite bone fishhooks, bone and stone arrowheads, and

Table 4
Chronology of the Cis-Baikal region (Weber et al., 2020). Chronological boundaries in the fifth column are based on Bayesian modelling of FRE-corrected radiocarbon dates on human skeletons using the trapezoidal distribution. Note that, due to the modelling, the mean Highest Posterior Density (HPD) dates are not directly comparable to mean cal BP dates. The mean HPD cal BP range for the LN has been corrected from reference (A. W. Weber, pers. comm.)

Cis-Baikal period	Mortuary tradition	n	Range of mean cal BP ^{14}C dates	Start & End boundaries in mean HPD cal BP
LM	Khin	24	8427 ± 56 to 7059 ± 77	8633 ± 160 to 7558 ± 31
EN	Kitoi	226	7756 ± 75 to 6577 ± 85	7558 ± 31 to 6659 ± 35
MN	N/A	0	N/A	N/A
LN	Isakovo, Serovo	103	6110 ± 81 to 4594 ± 113	6053 ± 57 to 4969 ± 41
EBA	Glazkovo	208	5014 ± 110 to 3461 ± 60	4969 ± 41 to 3470 ± 39

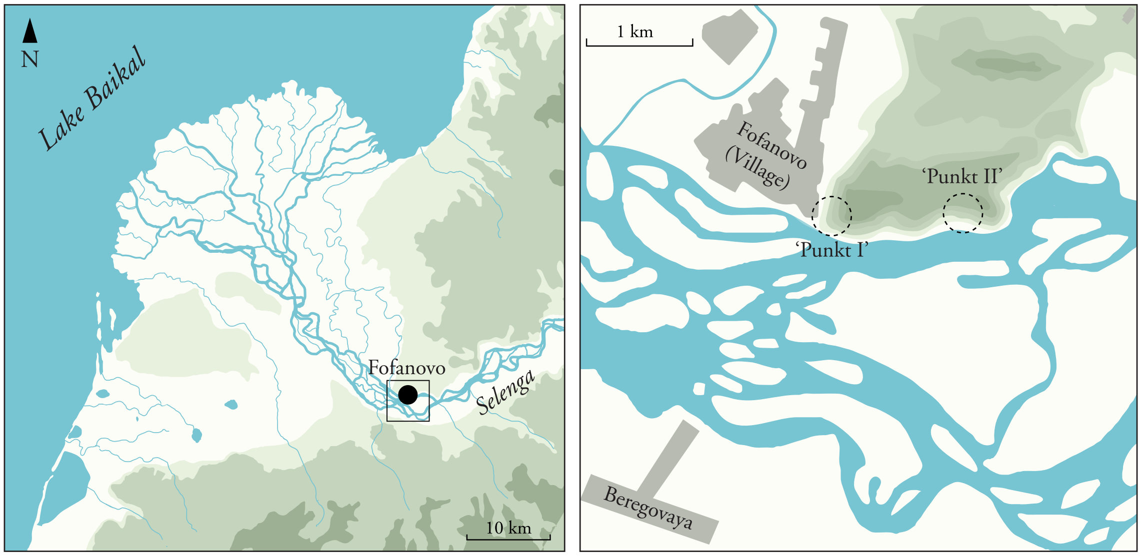


Fig. 2. Map showing the location of Fofanovo along the Selenga River (Punkt I and II) and the surrounding area at the time of excavation. The description given in Lbova et al. (2008) places "Punkt I" just to the east of the village and immediately to the west of the modern cemetery. "Punkt II" is placed at the end of eastern end of the Fofanovo hills on the southwestern slope of Cape Shikhan. Adapted from Lbova et al. (2008), (Fig. 2) by PH.

bone harpoons (Bazaliiskii, 2010; Weber and Bettinger, 2010).

3. Fofanovo cemetery

Fofanovo is located in the Selenga River valley, on the upper slopes of Fofanovskaia Gora (Fofanovo Mountain) on the right bank of the river. The prehistoric cemetery is ca. 0.5 km upstream from the village of the same name, ca. 45 km downstream from the city of Ulan-Ude (the capital of the Buryat Autonomous Republic), and ca. 45 km upstream from the coast of Lake Baikal (all distances as the crow flies). The Fofanovo cemetery (Fig. 2) is separated into a "West Part" ("Punkt I"; 52.047286°N; 106.761650°E) occupying the SW slopes of the west end of Fofanovskaia Gora, and an "East Part" ("Punkt II"; 52.046672°N; 106.773333°E) on the SW and S slopes of its east end. Both are ca. 26–38 m above the river (Gerasimov and Chernykh, 1975: 23; Lbova et al., 2008: 29). Individuals excavated by A.P. Okladnikov and M.M. Gerasimov between 1926 and 1950 were analysed in this study.

A history of the early and mid-twentieth century excavations at Fofanovo is provided in Supplementary Information (SI) section S1. This work identified three groups of graves: Group 1, with affinity to the Kitoi mortuary tradition of the Angara valley in Cis-Baikal; Group 2 with affinity to EBA Glazkovo; and Group 3 of Early Iron Age Stone Cist Culture (Gerasimov and Chernykh, 1975). Of the 20 Fofanovo burials excavated by Gerasimov and Okladnikov in 1936, 1948, and 1950 examined in this study, one was classified as potentially Kitoi (then considered LN, but now known to date to the EN), six as EBA Glazkovo, and 13 were unclassified (SI Table S1). Noteworthy is the fact that none were thought to belong to the LN Isakovo or Serovo mortuary traditions, both well documented in Cis-Baikal (Bazaliiskii, 2010; Okladnikov, 1950, 1955, 1974, 1975, 1976, 1978).

Table 5
Radiocarbon dating of human bone samples from Fofanovo reported by Mamonova and Sulerzhitskii (1989):(23–24; see also Weber, 1995: Table 1). These are conventional radiocarbon dates using an estimated half-life of 5568 years rather than the more widely accepted 5730 ± 40 years. The dates are not corrected for the old carbon effect due to the lack of associated stable isotopic data, but can be assumed to be too old by some centuries. Fofanovo 7-7 (1) and (2) are samples from the same individual. Fofanovo 7-4 is italicized due to its large error term.

ID	Burial complex	Lab No.	Date BP	±
Fofanovo 7-4	*n/a*	*GIN 4470*	*7610*	*210*
Fofanovo 7-5	n/a	GIN 4129	7040	100
Fofanovo 7-6	n/a	GIN 4139	7000	60
Fofanovo 7-1	n/a	GIN 4476	6830	60
Fofanovo 7-7 (2)	n/a	GIN 4478	6780	110
Fofanovo 7-7 (1)	n/a	GIN 4131	6450	50
Fofanovo 7-3	n/a	GIN 4471	6780	120
Fofanovo 2	n/a	GIN 4127	6720	70
Fofanovo 6	n/a	GIN 4472	6670	100
Fofanovo 5	n/a	GIN 4470	6640	140
Fofanovo 10	Glazkovo	GIN 4803	4100	100
Fofanovo 25	Glazkovo	GIN 4485	3890	50
Fofanovo 36	Glazkovo	GIN 4474	3740	50
Fofanovo 27	Glazkovo	GIN 4473	3670	40

3.1. Radiocarbon chronology

Prior to this study, only burials excavated by Gerasimov in 1959 had been radiocarbon dated. Mamonova and Sulerzhitskii (1989) published 10 dates for nine burials (one individual was dated twice) for Group 1 and four dates for Group 2 (Table 5). The paper also listed an additional 87 dates for Middle Holocene human burials from Cis-Baikal (see Weber, 1995). These dates predate the use of accelerator mass spectrometry (AMS) in radiocarbon dating and recent improvements in collagen extraction (Brock et al., 2010), have large errors ranges, and do not recognize the old carbon effect that was identified recently (Bronk Ramsey et al., 2014; Nomokonova et al., 2013a; Schulting et al., 2014). Nevertheless, there are a few patterns within them that are useful for general analysis and comparison.

First, the list published by Mamonova and Sulerzhitskii (1989) included 15 conventional ^{14}C dates for the Kitoi mortuary tradition from the Angara valley. These dates ranged from 6870 ± 70 to 6040 ± 100 BP, excluding two dates with very large errors (350 and 400 years), one of which was an outlier by a large margin (7990 ± 350 BP). In comparison, the 9 dates for Fofanovo Group 1 ranged from 7040 ± 100 to 6640 ± 140 BP, excluding one outlier with a large error (7610 ± 210 BP). This suggests that the two groups may not have been entirely synchronous. More specifically, the mortuary tradition represented by Fofanovo Group 1 could have started and ended earlier than the Kitoi tradition in the Angara valley.

Second, the four dates for Group 2 from Fofanovo (EBA Glazkovo) ranged from 4100 ± 100 to 3670 ± 40, while the 52 dates for Glazkovo burials from the entire Cis-Baikal (the Angara valley, Upper Lena valley, and Little Sea), excluding one date with large error (4500 ± 600 BP), ranged from 4850 ± 70 to 3390 ± 60 BP. Although the sample size from Fofanovo was small, this evidence suggested similarity in the timing of the Glazkovo mortuary tradition on the east and west sides of the lake.

Third, no dates from Fofanovo indicated that there was a mortuary tradition present which dated to the long period separating Groups 1 and 2, i.e., synchronous with the Isakovo and Serovo mortuary traditions in Cis-Baikal. Additionally, no dates appear to relate to the Group 3 Stone Cist Culture graves (EIA) defined by Gerasimov and Chernykh (1975), which were likely deliberately excluded from the late 1980's Russian dating project.

3.2. Summary of previous typological and radiocarbon dating

There is a long tradition of assessing the mortuary variation and chronology of Fofanovo in the context of developments in Cis-Baikal archaeology. Nevertheless, the differences between the Kitoi in the Angara valley and the Group 1 graves at Fofanovo, noted by Gerasimov and Chernykh (1975: 23), have not been ignored. According to V.I. Bazaliiskii:

> While they share some similarities with Kitoi burials, the mortuary assemblages of the East Baikal (Fofanovo) group display important differences, including supine and side body positions, both with flexed legs, and southeast orientation of the head. The composite fishhooks of the Kitoi type, bifacially shaped arrowheads, and clay vessels are absent in graves of this group (Bazaliiskii, 2010: 71–72).

With regard to Group 2 graves, Gerasimov and Chernykh (1975: 43–44) noted numerous similarities in grave architecture, burial orientation, and grave good morphology with the EBA Glazkovo in Cis-Baikal. The list included the presence of surface stone structures, burial orientation along the river with heads pointing upstream, lithic triangular arrowheads with straight or concave bases, lithic spear-points/knives, bone shafts for composite daggers, bone or antler harpoons, shanks for composite fishhooks, and copper/bronze knives and fishhooks. The main difference between the two areas was the more frequent occurrence of clay vessels at Fofanovo relative to Glazkovo graves in Cis-Baikal, where they are rare. Furthermore, according to the authors, the pots with round or pointed bottoms at Fofanovo morphologically resembled Serovo vessels from the Angara valley. One other difference was the absence of white nephrite ornaments in EBA graves at Fofanovo, though this was attributed to grave looting in the past (Gerasimov and Chernykh, 1975: 44).

Thus, excluding from consideration the five EIA graves of Group 3, both radiocarbon and typological dating identified two main Middle Holocene chronological groups: Fofanovo Group 1, roughly parallel to, although perhaps older than the EN Kitoi in Cis-Baikal; and Fofanovo Group 2, quite consistent in terms of chronology and mortuary variation with the EBA Glazkovo in Cis-Baikal.

Of Fofanovo's ~ 102 Middle Holocene graves only eight were radiocarbon dated in the 1980's study, forming two temporal clusters with four graves in each. The remaining 94 graves, however, were dated only typologically or not at all. Classification of the remaining three graves from the 1959 excavations by Gerasimov and of the 17 graves excavated by Konev as from the older (EN) Group 1 appears to be sound, along with the classification of 25 Group 2 graves excavated by Gerasimov in 1959 as EBA Glazkovo. However, the similarities with pottery from the older Serovo graves, now dating to the Late Neolithic (LN), directly before Glazkovo, are suspicious (Goriunova et al., 2020a, 2020b). Additionally, 27 graves (10 from Gerasimov's early excavations, 15 from Okladnikov's fieldwork in 1948, and two from Okladnikov's, 1950 excavations) have not been classified thus far. Lastly, classification of the remaining 22 graves excavated by Okladnikov (four in 1948 and 18 in 1950) should be considered tentative due to the lack of formal justification, despite his comprehensive knowledge of the material.

It is important to note that much of this chronological and mortuary assessment of the Fofanovo cemetery has been conducted explicitly in reference to the much more abundant and better documented materials from Cis-Baikal and in reference to the Middle Holocene culture history model whose boundaries and units were developed by Okladnikov. In this culture history model, as has only been understood since the mid-1990s, three (Kitoi, Isakovo, and Serovo) out of five mortuary traditions, or stages, were assigned an incorrect chronological position by Okladnikov (Weber, 1995). While generally quite accurate, the limitations of typological dating have been recently highlighted due to extensive radiocarbon dating (Weber et al., 2006; Weber et al., 2016a) and the accumulation of numerous new Middle Holocene cemetery materials in Cis-Baikal. Examination of these new materials helped identify several aspects of micro-regional and temporal variation in mortuary protocols that were previously unknown (e.g., Bazaliiskii, 2010; Goriunova and Novikov, 2010; Weber et al., 2016a).

Overall, there is much to learn from a systematic radiocarbon dating programme, coupled with other analyses, of a large multi-component cemetery covering a very long timespan like Fofanovo in Trans-Baikal.

4. Stable isotopic analyses

Stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopic analyses of bone collagen provide information on aspects of an individual's diet (Lee-Thorp, 2008). Although rarely able to identify specific foods, the technique allows for semi-quantification of broad food groups, such as C_3 or C_4 plants, marine/freshwater fish, and terrestrial flora/fauna. Stable carbon isotopic ratios are affected by different photosynthetic pathways and by carbon pools (e.g., atmospheric vs. marine), whereas stable nitrogen isotopic ratios primarily reflect trophic level. Carbon isotopic values are influenced by the preferential routing of amino acids during the metabolic processes of the body, whereas nitrogen is only present in the protein component of the diet (Ambrose and Norr, 1993; Hedges and Reynard, 2007; Tieszen and Fagre, 1993). Measurements on adult bone collagen provide a dietary average of approximately the last decade of adult life, depending on the bone analysed and the age and health status of the individual (Hedges et al., 2007; Tieszen et al., 1983).

$\delta^{13}C$ values vary by C_3, C_4, and CAM photosynthetic pathways of primary producers, so that the animals reliant on them also reflect this differentiation. However, the taiga and forest-steppe surrounding Lake Baikal are overwhelmingly composed of C_3 plants so that C_4 and CAM pathways are not relevant to the present study. Marine sources reflect oceanic carbon pools that are more enriched in ^{13}C than atmospheric carbon pools (DeNiro and Epstein, 1978; Schoeninger and DeNiro, 1984). While it is a freshwater system, Lake Baikal's unique isotopic ecology results in a wide range of $\delta^{13}C$ values, from depleted, which are more typical of freshwater systems, to enriched, marine-like, values (Yoshii, 1999; Yoshii et al., 1999). This makes resources from terrestrial, lake, and riverine systems in the Baikal region isotopically distinguishable from one another to a greater degree than is usually possible, and hence offers greater potential for human dietary resolution.

^{15}N enrichment corresponds to increasingly higher trophic levels in a food chain. Aquatic predators tend to have very high $\delta^{15}N$ values due to their position within complex, extended food webs. The trophic level enrichment factor for humans is not precisely known, with a range of +3–5‰ often cited (DeNiro and Epstein, 1981; Hedges and Reynard, 2007; Minagawa and Wada, 1984; Schoeninger and DeNiro, 1984), though a value as high as +6‰ has been proposed (O'Connell et al., 2012). Additionally, there is a trophic level enrichment of approximately +1‰ in $\delta^{13}C$ (DeNiro and Epstein, 1978; Bocherens and Drucker, 2003).

5. Baikal's isotopic ecology

Lake Baikal's primary producers, phytoplankton and periphytic

Table 6
Isotopic values for selected terrestrial and aquatic species reported in previous studies on Cis- and Trans-Baikal fauna. Stable carbon isotope results for modern samples have been adjusted for the 'Suess' (fossil fuel) effect (+1.2‰) while those obtained from flesh have been adjusted for a flesh to bone collagen fractionation factor (+2.9‰).

Location	Species (Common)	Tissue	Period	$\delta^{13}C$		$\delta^{15}N$		n	Source
				$\bar{x}$	sd	$\bar{x}$	sd		
Aquatic									
Lake Baikal	Omul'	Muscle and bone coll	Modern	−22.0	1.8	10.7	1.1	33	Katzenberg et al. (2012); Kucklick et al. (1996); Weber et al. (2002); Yoshii et al. (1999)
Little Sea	Omul'	Bone coll	Modern	−15.1	2.0	9.4	0.1	4	Katzenberg et al. (2012)
Lower Selenga	Omul'	Bone coll	Modern	−23.0	0.5	8.9	0.8	19	Dufour et al. (1999)
Lake Baikal	Fish spp. (ex. omul')	Bone coll	Modern	−16.5	4.5	10.6	1.7	30	Katzenberg et al. (2012); Weber et al. (2002)
Lower Selenga	Fish spp. (ex. omul')	Bone and flesh	Modern	−21.7	1.8	12.9	1.4	55	Sampson et al. (2002)
Lake Baikal	Seal	Bone coll	Prehistoric	−22.5	0.8	14.2	1.4	10	Katzenberg et al. (2012); Weber et al. (2002)
Terrestrial									
Baikal Region	Terrestrial herbivores	Bone coll	Prehistoric	−20.0	1.1	5.0	1.2	25	Katzenberg et al. (2012); Weber et al. (2002)
Baikal Region	Terrestrial Omnivores/Carnivores	Bone coll	Prehistoric	−18.8	1.0	10.7	3.0	9	Katzenberg et al. (2012); Weber et al. (2002)

algae, have a $\delta^{13}C$ range greater than 20‰, which continues through the entire food chain (Yoshii, 1999; Yoshii et al., 1999). ^{13}C enrichment in fish varies by their preferred habitat. Pelagic fish species, such as the omul', tend to be depleted in ^{13}C while shallow water fishes tend to be enriched. Baikal's seal population largely preys on small pelagic fish, and therefore has low $\delta^{13}C$ values. Seal and pike are apex aquatic predators and have high $\delta^{15}N$ values, averaging ca. 14‰ and ca. 12‰, respectively (Table 6; Katzenberg and Weber, 1999; Katzenberg et al., 2010).

Since, with few recent exceptions (Losey et al., 2008; Losey et al., 2012; Nomokonova et al., 2010; Nomokonova et al., 2015), archaeological excavations in the Baikal region have rarely employed dry and wet screening techniques, few archaeological fish bones have been recovered and isotopic tests on them are correspondingly uncommon. Therefore, most studies rely on results from modern fish, including those done by BAP/BHAP. $\delta^{13}C$ values within an organism differ by tissue, such that measurements on fish muscle are not directly comparable to those derived from bone collagen, requiring a correction of +2.9‰ (Robson et al., 2012). Additionally, it is necessary to apply a correction of +1.2‰ to all modern samples to account for the burning of fossil fuels in modernity, which has introduced ^{13}C-depleted carbon into the atmosphere (Friedli et al., 1986).

Considerable previous effort has gone into creating a terrestrial and aquatic isotopic baseline for Cis-Baikal, analysing modern and, when accessible, archaeological terrestrial and aquatic fauna (Katzenberg et al., 2012; Weber, 2003; Weber and Bettinger, 2010; Weber et al., 2011) (Table 6). However, gaps in coverage remain, most notably for Trans-Baikal. The lower Selenga River is a spawning ground for omul' and sturgeon, which could have potentially provided an important resource for those living along the river.

Unfortunately, no isotopic measurements on archaeological fish are available from the Selenga River, but averages for modern fish are provided in Table 6. These may not accurately reflect those of the Neolithic and Bronze Age (e.g., due to industrial and agricultural impacts, and to overfishing; Sampson et al., 2002). Nevertheless, modern values indicate that fish, particularly the omul', from the Selenga are generally not ^{13}C-enriched, in contrast to some Baikal fish. Together with archaeological and modern values for fish, seals and terrestrial fauna from Cis-Baikal, these data provide a preliminary isotopic baseline for comparison with the human results.

6. Materials and methods

Human bone from 22 individuals was sampled from collections stored at the Museum of Archaeology & Ethnography (Kunstkamera), St. Petersburg. Due to the variable degree of completeness, it was not possible to consistently sample the same skeletal element. Nevertheless, only cortical bone was sampled from long bones, crania, or mandibulae.

Samples were first surface-cleaned with an aluminium oxide shotblaster at the University of Oxford's Research Laboratory for Archaeology and the History of Art (RLAHA). Those weighing over 1 g were sub-sampled and prepared separately for stable isotopic analyses in both RLAHA's radiocarbon (ORAU) and palaeodiet laboratories. The pre-treatment and measurement methods between the two labs differed slightly; however, no significant differences were observed between the results obtained by the two methods, as has been demonstrated previously (White et al., 2020) and, consequently, the results were averaged.

Both sets of samples were ground and left to soak in 5 °C hydrochloric acid (HCl, 0.5 M) for three days or until they no longer reacted to the acid. The ORAU protocol samples were then washed with sodium hydroxide (NaOH, 0.1 M) in order to remove any humic acids present and ultra-filtered using a 30kD filter to remove large molecular contaminants (Brock et al., 2007, 2010). This additional step is the main difference between the two lab protocols. Following this, all samples were washed with Milli-Q water and sonicated for 20 min. The samples were then gelatinized by soaking them in a pH 3 solution for 24 h, and

Table 7
FRE correction formulae (Schulting et al., 2014; Weber et al., 2016a). In the adjusted error calculation, the standard deviation (s.d.) is that of the conventional ^{14}C date. 'S' is the standard deviation of the residuals from the FRE correction formulae provided in the original publication.

Correction	Formula
General Baikal "Excluding outliers, $\delta^{15}N$" FRE	$-732.8 + 76.6\ (\delta^{15}N)$
"Little Sea, $\delta^{13}C$ & $\delta^{15}N$" FRE	$-3329.5361 - 125.5967\ (\delta^{13}C) + 95.1091\ (\delta^{15}N)$
"SW Baikal/Angara" FRE	$-1388.8522 + 125.4503\ (\delta^{15}N)$
Adjusted error term (Weber et al., 2016a)	$\sqrt{(\text{s.d.})^2 + S^2}$

then sealed and heated to 70 °C for three days. After this the remaining liquid was filtered out and the resulting 'collagen' was freeze-dried.

All collagen samples were analysed using a Sercon 20/22 Isotope Ratio Mass Spectrometer (IRMS). The samples prepared using the palaeodiet protocol were analysed in duplicate with alanine standards and in-house standards of cow ($\delta^{13}C = -24.21‰$, $\delta^{15}N = 8.00‰$) and seal ($\delta^{13}C = -12.00‰$, $\delta^{15}N = 16.61‰$) bone collagen, whereas the samples processed according to the ORAU protocol were measured in triplicate with alanine ($\delta^{13}C = -27.11‰$, $\delta^{15}N = -1.56‰$) and USGS40 ($\delta^{13}C = -26.39‰$, $\delta^{15}N = -4.52‰$) and USGS41 ($\delta^{13}C = 37.63‰$, $\delta^{15}N = 47.57‰$) standards. Alanine was used to correct for machine drift and the in-house cow and seal standards were referenced to international standards of VPDB for $\delta^{13}C$ and AIR for $\delta^{15}N$ through repeated measurement. Values were then drift-corrected, calibrated relative to the in-house and international standards (cf. Coplen et al., 2006), and averaged between runs. Measurement precision for both $\delta^{13}C$ and $\delta^{15}N$ is on the order of ±0.2‰ based on repeat analyses of standards. Collagen quality was assessed based on collagen yield (>1%) and atomic C/N ratios (2.9–3.6) (Ambrose, 1990; DeNiro, 1985; van Klinken, 1999).

Samples prepared for radiocarbon dating were combusted using a Continuous Flow IRMS at which time their isotopic composition was assessed (Brock et al., 2010). Samples were then graphitised and their ^{14}C concentration measured using accelerator mass spectrometry (AMS) (Dee and Bronk Ramsey, 2000).

Based on previous research in Cis-Baikal, aquatic foods are expected to have played a significant role in the diets of those interred at Fofanovo. This, in turn, will lead to a varying but often considerable FRE through the introduction of old carbon from the lake and its surrounding rivers (Bronk Ramsey et al., 2014; Schulting et al., 2014, 2015, 2020; Weber et al., 2016a). Linear regression formulae have been calculated using paired human-terrestrial fauna radiocarbon dates for southwest Baikal and the Angara, Little Sea, and Upper Lena micro-regions, and for the Cis-Baikal region in general (Table 7) (Schulting et al., 2014, 2015). In the absence of knowledge of the precise reservoir offset that applies to the Fofanovo humans sampled, we have provisionally used the model developed for Cis-Baikal. While not ideal, this is undoubtedly preferable to applying no correction at all[1]. With the exception of the Upper Lena, which has no connection to Lake Baikal, the other formulae factor in the offset caused by the consumption of aquatic resources from the lake. These will be at least partly relevant to the individuals from the Lower Selenga, since: 1) A number of fish species move between the lake and the river, especially for spawning (most notably the omul' and sturgeon); and 2) Hunter–gatherer groups using Fofanovo for burial likely lived close enough to the lake itself to have had either direct or indirect access to its aquatic food resources.

The FRE-corrected dates were calibrated in OxCal v.4.3.2, using IntCal13 (Bronk Ramsey, 2009; Bronk Ramsey et al., 2013; Reimer et al., 2013). Kernel Density Estimation (KDE) modelling, a way of summarising dates while reducing the noise and excessive spread of sets of five or more radiocarbon dates, was carried out in OxCal as well (Bronk Ramsey, 2017).

All statistical tests were carried out using IBM Statistical Package for the Social Sciences (SPSS) 24.0. Shapiro-Wilk tests were used to assess normality, and parametric or non-parametric tests were applied, as appropriate, to compare central tendencies between groups. Outliers were defined as exceeding 1.5 times the interquartile range (IQR).

7. Results and discussion

7.1. Analysis of new radiocarbon dates from Fofanovo

Two samples from Fofanovo failed the in vivo C:N criterion, with values of 12.5 (FOF_1948.003) and 4.25 (FOF_1948.010) and were excluded from analysis. All other samples had C:N values between 2.9 and 3.6 (DeNiro, 1985). One individual (FOF_1948.018) was dated twice as part of ORAU's standard procedure of randomly duplicating a certain number of measurements for quality control. Its radiocarbon dates were R_Combined in OxCal (see Weber et al., 2016a) and then corrected for the FRE offset (Table 8). A general FRE correction for consumers of Lake Baikal aquatic foods applied to the conventional radiocarbon dates from Fofanovo yields an average offset of 433 ± 59 ^{14}C years (Table 8; Fig. 3). Using FRE correction equations developed for the Angara/SW Baikal and the Little Sea provide slightly larger average offsets of 521 ± 96 years and 550 ± 159 years, respectively.

The new ^{14}C dates from Fofanovo are assessed with reference to well-established comparanda from Cis-Baikal, where considerable data are available regarding Middle Holocene cemeteries. This includes Weber et al.'s (2020) comparative assessment of 561 AMS radiocarbon dates from the entirety of Cis-Baikal (see note in SI section S2). Additionally, comparisons are made to Weber et al.'s (2016b) detailed examination of Shamanka II, an EN and EBA cemetery located in the southwest corner of Lake Baikal, approximately 220 km west along the south coast of the lake from the Selenga delta. The 14 dates published for Fofanovo earlier by Mamonova and Sulerzhitskii (1989) are also used for comparison.

Unlike the 14 dates published by Mamonova and Sulerzhitskii, which form two temporal clusters, our dates suggest four clusters, the first two of which are separated by about 1900 years and the later two by roughly 700 years each (Table 9). The oldest three dates clearly relate to Gerasimov and Chernykh's (1975) Group 1 graves. These dates correspond also with the expansion of the boreal forest and wet conditions at ca. 9.2–7.7 ka BP in the Selenga micro-region based on the analysis of paleoenvironmental proxies from the Burdukovo site, ca. 50 km from Fofanovo (White et al., 2013). The results of coring at Lake Kotokel support a ca. 7 ka cal BP maximum expansion of the boreal forest in the region (Kobe et al., 2020).

[1] An ongoing programme of dating on additional graves from Fofanovo has provided the opportunity for paired dates on a human (OxA-40561: 6996 ± 23 BP) and marmot (*Marmota sibirica*) (OxA-40544: 6377 ± 24 BP) from Early Neolithic Grave 2 (1959), differing by 619 ^{14}C yr. This is broadly comparable to the predicted offset of 540 ^{14}C yr using the general Baikal correction equation (human $\delta^{15}N = 16.6‰$). While more work on the Selenga's reservoir offset is required, this preliminary result (the details of which will be published in due course) confirms that the FRE correction used in this paper is justified as a first approximation. Many thanks to Professor Sergei Vasil'ev and his team, Centre of Physical Anthropology, Institute of Ethnology and Anthropology, Russian Academy of Sciences, Moscow, for permitting sampling of materials from Fofanovo that form part of a new project.

Table 8
Radiocarbon and stable isotopic results from all of the analysed individuals from Fofanovo. The Master ID provides the excavation year and the grave number within that year (i.e. SITE_YEAR.GRAVE NUMBER). The age and sex of each individual were assessed using the available skeletal material at the Peter the Great Museum of Anthropology and Ethnography by one of the co-authors (RJS). The 'Sample' number reflects the number used at the RLAHA. Note that the '^{14}C period' assignment reflects the results of the preliminary radiocarbon analysis alongside assessment of the archaeological evidence. The 'Pretreat' column denotes which samples were subject to the ORAU (A) or ORAU and palaeodiet (B) laboratory pretreatment methods (see section 6 for more detail). [a] after Lbova et al., 2008; [b] after Okladnikov field report in Lbova et al., 2008

MASTER_ID	Original typological period	^{14}C period	Age	Sex	Sample	Element/ Side	OxA	Date BP	±	FRE date BP	FRE ±	Date difference	Cal BP at 95%	Mean cal BP	Mean cal BP ±	% Yld	%C	%N	δ^{13}C	δ^{15}N	C:N	Pre-treat	Excavator	Cemetery section
FOF_1936.008.01	m.d.	LM	Adolescent	F?	H 2015.172	mandible/ ?	34,087	7615	39	7164	94	451	8179–7795	7995	101	4.6	46.0	16.5	−19.4	15.5	3.3	B	Gerasimov	Punkt II?
FOF_1950.020	EBA [b]	LM	Adult	M	H 2015.193	femur/R	34,089	7685	39	7121	94	564	8164–7755	7943	100	7.1	42.7	15.5	−19.3	16.9	3.2	A	Okladnikov	Punkt II
FOF_1936.008.02	m.d.	LM	Yng adult	F?	H 2015.173	mandible/ L	33,978	7455	45	7109	97	346	8160–7735	7930	102	4.8	48.6	17.4	−18.9	14.1	3.3	B	Gerasimov	Punkt II?
FOF_1936.005	m.d.	LN	Adult	M?	H 2015.171	occipital/ R	34,047	5559	32	5227	91	332	6270–5751	6016	120	11.6	45.8	16.5	−18.4	13.9	3.2	A	Gerasimov	Punkt II?
FOF_1948.005	m.d.	LN	Mid adult	F?	H 2015.183	femur/R	34,033	5596	37	5221	93	375	6267–5750	6008	123	8.0	44.5	16.1	−18.5	14.5	3.2	B	Okladnikov	Punkt II
FOF_1950.019	m.d.	LN	Child, c. 6 yrs	I	H 2015.192	cranium/?	34,088	5601	35	5141	92	460	6177–5661	5891	123	4.6	42.7	15.5	−19.7	15.6	3.2	A	Okladnikov	Punkt II
FOF_1950.018	m.d.	LN	Adult	M	H 2015.191	tibia/R	34,041	5225	37	4891	93	334	5894–5333	5639	118	5.1	43.3	15.8	−18.1	13.9	3.2	A	Okladnikov	Punkt II
FOF_1948.004	m.d.	LN	Yng adult	M?	H 2015.182	fibula/R	34,032	5220	33	4837	92	383	5852–5321	5561	116	10.5	46.6	16.7	−17.2	14.6	3.2	B	Okladnikov	Punkt II
FOF_1936.010	m.d.	LN	Adult	I	H 2015.175	fibula/R	33,980	4711	37	4287	93	424	5275–4538	4864	160	11.3	47.2	17.2	−19.5	15.1	3.2	B	Gerasimov	Punkt II?
FOF_1936.009	m.d.	EBA	Adult	F?	H 2015.174	humerus/ L	33,979	4468	38	3995	94	473	4820–4160	4481	156	5.6	43.5	15.9	−18.5	15.7	3.2	B	Gerasimov	Punkt II?
FOF_1948.001	m.d.	EBA	Mid adult	M?	H 2015.179	ulna/L	34,213	3990	40	3519	94	471	4082–3572	3805	124	11.0	43.5	15.8	−19.6	15.7	3.2	B	Okladnikov	Punkt II
FOF_1948.018	EBA [a]	EBA	Adult	I	H 2015.185	tibia/L	34,034, 34,035	3920	22	3505	88	415	4070–3568	3786	115	3.1	42.5	15.4	−19.7	15.0	3.2	B	Okladnikov	Punkt II
FOF_1950.004	EBA [b]	EBA	Adult	F?	H 2015.188	fibula/L	34,038	3964	30	3481	91	483	3985–3494	3758	117	9.7	46.2	16.8	−19.6	15.9	3.2	A	Okladnikov	Punkt II
FOF_1936.003	m.d.	EBA	Adult	I	H 2015.170	radius/R	33,958	3931	33	3476	92	455	3982–3484	3752	118	6.7	42.7	15.5	−19.9	15.5	3.2	B	Gerasimov	Punkt II?
FOF_1950.013	EBA [b]	EBA	Adult	I	H 2015.190	fibula/R	34,040	3912	31	3435	91	477	3920–3463	3703	116	11.0	45.2	16.3	−20.6	15.8	3.2	A	Okladnikov	Punkt II
FOF_1948.002	m.d.	EBA	Mid/Old adult	M	H 2015.180	humerus/ L	34,174	3912	33	3425	92	487	3904–3454	3691	117	9.3	41.8	15.1	−19.8	15.9	3.2	B	Okladnikov	Punkt II
FOF_1950.012	LN Kitoi? [b]	EBA	Adult	I	H 2015.189	manual elements	34,039	3882	29	3422	90	460	3897–3456	3687	115	3.5	45.4	16.4	−20.6	15.6	3.2	A	Okladnikov	Punkt II
FOF_1950.003	EBA [b]	EBA	Adult	I	H 2015.187	occipital/ R	34,037	3805	30	3404	91	401	3885–3450	3666	116	6.4	45.9	16.4	−20.6	14.8	3.3	A	Okladnikov	Punkt II
FOF_1950.001	EBA [b]	EBA	Adult	M?	H 2015.186	femur/R	34,036	3785	32	3387	91	398	3868–3410	3645	115	11.4	45.9	16.7	−19.8	14.8	3.2	A	Okladnikov	Punkt II
FOF_1936.001	m.d.	EBA	Mid adult	M?	H 2015.169	femur/L	33,957	3807	36	3342	93	465	3829–3388	3591	114	8.5	45.1	16.4	−19.5	15.6	3.2	B	Gerasimov	Punkt II?
Failed Samples:																								
FOF_1948.003	m.d.	m.d.	Indeterminate	I	H 2015.181	cranium/?													−25.7	13.7	12.5	B	Okladnikov	Punkt II
FOF_1948.010	EBA [a]	m.d.	Mid adult	M?	H 2015.184	parietal/L													−21.5	16.0	4.2	B	Okladnikov	Punkt II

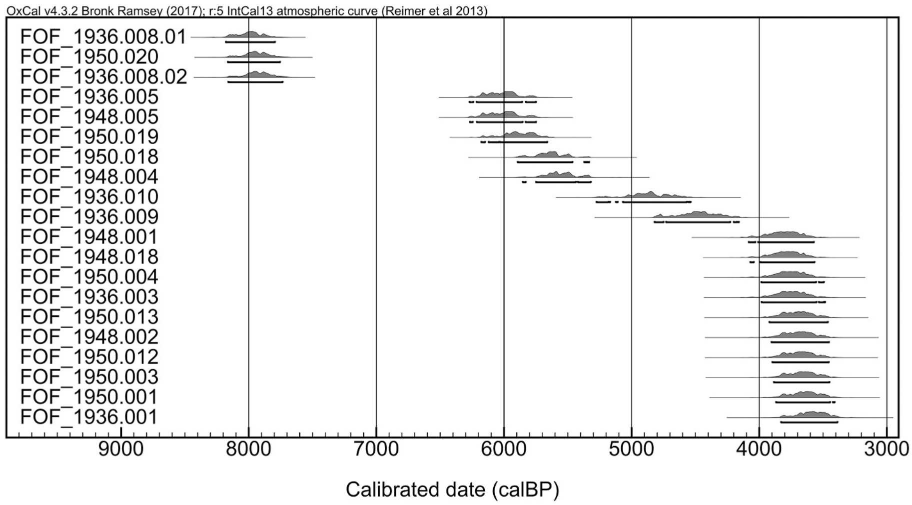


Fig. 3. Calibrated radiocarbon dates from the Fofanovo cemetery corrected with the general Baikal FRE equation (see Tables 8 and 9).

Table 9
Discrete chronological clusters of radiocarbon dates from Fofanovo ($n = 20$) in mean cal BP.

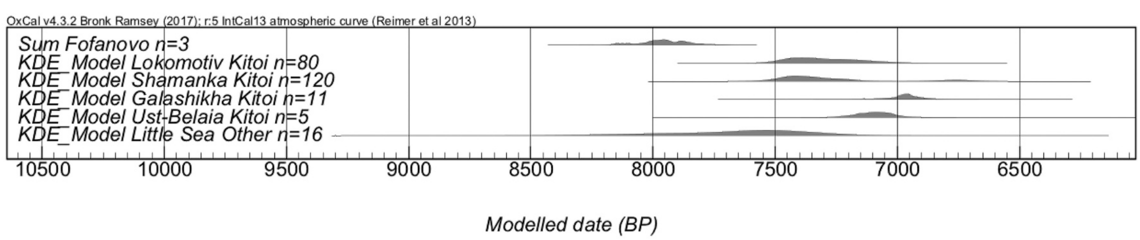
Chronological cluster	Range of mean cal BP ^{14}C dates	n	Period assignment
Cluster 1	7995 ± 101 to 7930 ± 102	3	LM
Cluster 2	6016 ± 120 to 5561 ± 116	5	LN?
Cluster 3	4864 ± 160 and 4481 ± 156	2	LN–EBA
Cluster 4	3805 ± 124 to 3591 ± 114	10	EBA

Conversely, the youngest 10 determinations seem to fit neatly within Gerasimov and Chernykh's Group 2, EBA Glazkovo. The intervening seven dates have no counterpart in the Mamonova and Sulerzhitskii dataset, but their number is small relative to the known size of the Fofanovo cemetery. None of these seven graves have been classified chronologically by the excavators or by Lbova et al. (2008), and will be discussed further below.

Okladnikov originally classified one of the burials in Cluster 1, the oldest group, (FOF_1950.020) as EBA Glazkovo. This was likely because no red ochre was found in the grave, which otherwise lacked any diagnostic characteristics typical of either mortuary tradition. The only grave goods were an unspecified number of small discs or beads (5–7 mm in diameter). The burial was supine with legs flexed to the left and the head pointing NE. The other two dates in this group are for burials excavated by Gerasimov in 1936, which have not been described or classified chronologically.

Among the 10 youngest dates, only one grave was originally assigned

A. KDE model of LM and EN Trans and Cis-Baikal dates



B. KDE model of LN and EBA Trans and Cis-Baikal dates

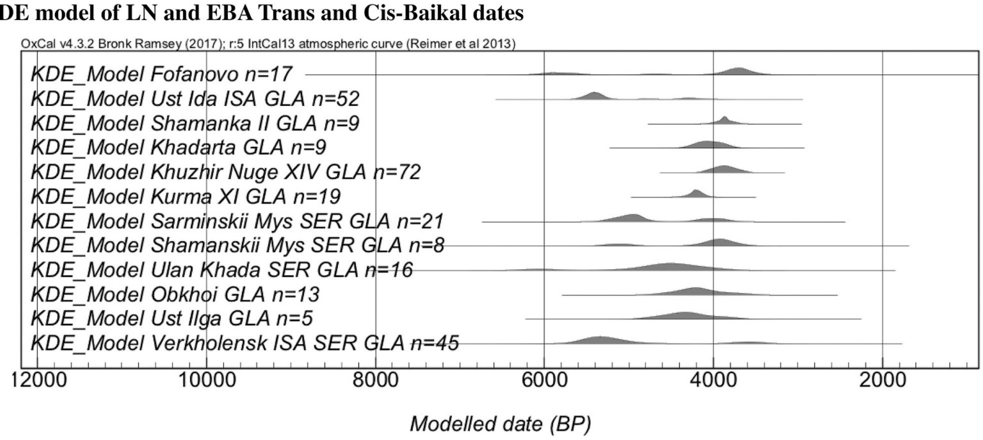


Fig. 4. KDE model showing the chronological position of the three main analytical units from the Fofanovo cemetery relative to several well-dated Middle Holocene hunter–gatherer cemeteries in Cis-Baikal: (A) Late Mesolithic and Early Neolithic cemeteries; (B) Late Neolithic and Early Bronze Age cemeteries (Weber et al., 2020). Their relative chronological positions are directly comparable unlike the period boundaries expressed in HPD dates generated through Bayesian modelling (Table 4).

an incorrect chronological position (FOF_1950.012), five dates are consistent with the original classification, and six were not classified at all. This may suggest that EBA graves are the easiest to classify typologically; however, in cases where clear diagnostic characteristics are lacking, they are still subject to errors.

It can be inferred from this comparison that the three oldest dates in our dataset, considered together with some of the 1989 Russian dates, suggest that the beginning of the Fofanovo cemetery predates beginnings of Kitoi cemeteries on the Angara and Southwest Baikal by quite a large margin.

Comparison with the mean cal BP dates from Cis-Baikal provides more insights (Table 4). The oldest three Fofanovo dates fit comfortably within the Late Mesolithic and the youngest 12 match well with the EBA in Cis-Baikal. The youngest cluster of 10 dates (Table 9, Cluster 4) match closely the distribution of nine EBA Glazkovo dates from the Shamanka II cemetery (4079 ± 107 to 3669 ± 96; Weber et al. (2016a, 2020). Furthermore, these 10 dates can be R_Combined (3705 ± 57 cal BP, χ^2-Test: df = 9, $T = 3.2$, 5% 16.9) in OxCal. That these 10 graves come from three different excavations at Fofanovo— two from 1936, three from 1948, and five from 1950 – demonstrates that they did not form a spatial cluster, yet form a tight chronological cluster. The entire EBA component from Fofanovo needs to be dated to address this matter further.

Assessment of the remaining five dates from Cluster 2 requires more attention. Relative to the culture history for Middle Holocene Cis-Baikal presented in Weber et al. (2016a, 2016b), these dates appear to be somewhat older than the lower LN boundary. However, at the time the LN boundary was defined by only 22 dates, which acted as a proxy for another 227 LN burials archaeologically documented (Weber and Bettinger, 2010). In a more recent study, the LN dataset has been expanded to 103 radiocarbon dates and the 5 dates from Fofanovo seem to fit well within the early stages of the LN Isakovo and Serovo mortuary traditions in Cis-Baikal (Weber et al., 2020). Continued dating of these materials may make the lower Isakovo and Serovo boundary still somewhat older. The matter will need to be reassessed once the freshwater reservoir correction applicable to the Selenga River is fully addressed.

7.2. Summary of new radiocarbon dating

The most important points emerging from the assessment of 20 new AMS dates on human remains from the Fofanovo cemetery are the following:

- Development of formal cemeteries in Trans-Baikal may predate similar developments in Cis-Baikal by a large margin. In Cis-Baikal, LM cemeteries are small and rare, and their mortuary protocol is variable to the extent that a cohesive and coherent mortuary tradition cannot be defined. Formal cemeteries with such mortuary protocols (i.e., the classic Kitoi) mark the beginning of the EN period, but at Fofanovo these developments appear to be much older.
- Fofanovo may have a substantial LN component which, to date, has gone entirely undetected by any typological assessment.
- The timing of the EBA Glazkovo mortuary tradition appears to be roughly similar on both sides of the lake.

This analysis thus defines three chronological groups for the assessment of dietary patterns using stable isotope data: LM ($n = 3$), LN ($n = 6$), and EBA ($n = 11$). The chronological position of these three groups relative to several better-dated Middle Holocene cemeteries from Cis-Baikal is presented in Fig. 4.

Table 10
Statistical summary of the isotopic results from Fofanovo by period.

Period	$\delta^{13}C$		$\delta^{15}N$		n
	$\bar{x}$	sd	$\bar{x}$	sd	
LM	−19.2	0.3	15.5	1.4	3
LN	−18.6	0.9	14.6	0.7	6
EBA	−19.8	0.6	15.5	0.4	11
All	−19.4	0.9	15.2	0.8	20

7.3. Analysis of new stable isotope data from Fofanovo

A statistical and visual summary of the $\delta^{13}C$ and $\delta^{15}N$ values from Fofanovo is provided in Table 10 and Fig. 5. Overall, the isotopic signatures of the individuals from Fofanovo are marked by relatively low $\delta^{13}C$ and high $\delta^{15}N$ values, as one would expect for individuals reliant on aquatic resources from the Selenga river, including spawning runs of some Baikal fishes, such as the omul' and the sturgeon (Fig. 5). This results in an isotopic signature that is distinct from all other hunter-gatherer groups of Cis-Baikal, and thus constitutes a new micro-region (Figs. 6–8).

There are too few sexed individuals for each chronological unit in the dataset to test formally for possible isotopic differences between the sexes. There appears to be no obvious difference between females and males, which is consistent with previous findings from Cis-Baikal (Weber et al., 2016a; though see White et al., 2020). The single older child's $\delta^{15}N$ value of 15.6‰ is 1‰ higher than the LN adult average. Whether this represents a residual nursing effect is unclear given that this child is 5–7 years old, well past the expected weaning age for Cis-Baikal's hunter-gatherers (Waters-Rist et al., 2011). Alternatively, it may reflect physiological stress (Beaumont and Montgomery, 2016; Fuller et al., 2005; Mekota et al., 2006), or simply be part of the normal range of variability for this group. More data on non-adults will be required to evaluate this issue further.

The three LM individuals are relatively depleted in ^{13}C, all within 1‰ of each other. Yet, the LM $\delta^{15}N$ values are more dispersed than the LN and EBA individuals. The only male LM individual has the highest $\delta^{15}N$ value, 16.9‰, of all the Fofanovo individuals analysed. The other two LM individuals are female. There is no overlap between the range of the Fofanovo LM values and the LM–EN values from Cis-Baikal's micro-regions (Fig. 6). Unfortunately, until further analysis is undertaken, there is little more that can be said.

The LN and EBA results from Fofanovo form two overlapping but distinct clusters (Mann-Whitney U test, $n = 17$; $\delta^{13}C$ $p = 0.01$; $\delta^{15}N$ $p = 0.01$). In addition, $\delta^{13}C$ values are correlated with mean dates cal BP, becoming more negative over time ($n = 17$, $p = 0.00$, $r = 0.73$). The $\delta^{15}N$ values increase in the EBA compared to the LN, but are not significantly correlated with mean cal BP radiocarbon dates.

The isotopic distinction between the LN and EBA is possibly driven by a greater reliance on aquatic foods from the lake's shallows or lagoons in the LN and a greater reliance on the Selenga—perhaps including more intensive procurement of omul' and sturgeon — in the EBA. When plotted with LN humans from Cis-Baikal (Fig. 7), Fofanovo falls almost in between 'Game-Fish' (GF) and 'Game-Fish-Seal' (GFS) diets in the Little Sea (Weber and Bettinger, 2010; Weber and Goriunova, 2013; Weber et al., 2011). Although an isotopic baseline for the littoral waters near the entrance of the Selenga into Lake Baikal is currently unknown, if the shallows of the Little Sea and those near the Selenga delta are similar isotopically and as such can be used as a proxy, then the elevated ^{13}C values from the Fofanovo LN could indicate a significant reliance on littoral fish from Lake Baikal's coastal waters, ca. 45 km downriver. This would imply considerable – perhaps seasonal – mobility for the LN communities using Fofanovo for burial.

Compared to the LN, the EBA individuals are more tightly clustered, temporally and isotopically, being more depleted in ^{13}C and elevated in ^{15}N. The earliest EBA adult female, FOF_1936.009, is an outlier in carbon, and falls closer to the range of the Little Sea micro-region (Fig. 8). Given the depleted carbon signature of the Selenga River's fishes, the pelagic omul' and sturgeon, and Lake Baikal's seal, it is likely that some combination of these contributed more to the diet during the EBA. Autumn and spring runs of spawning omul' and sturgeon respectively would likely be the most productive and, hence, attractive resource on

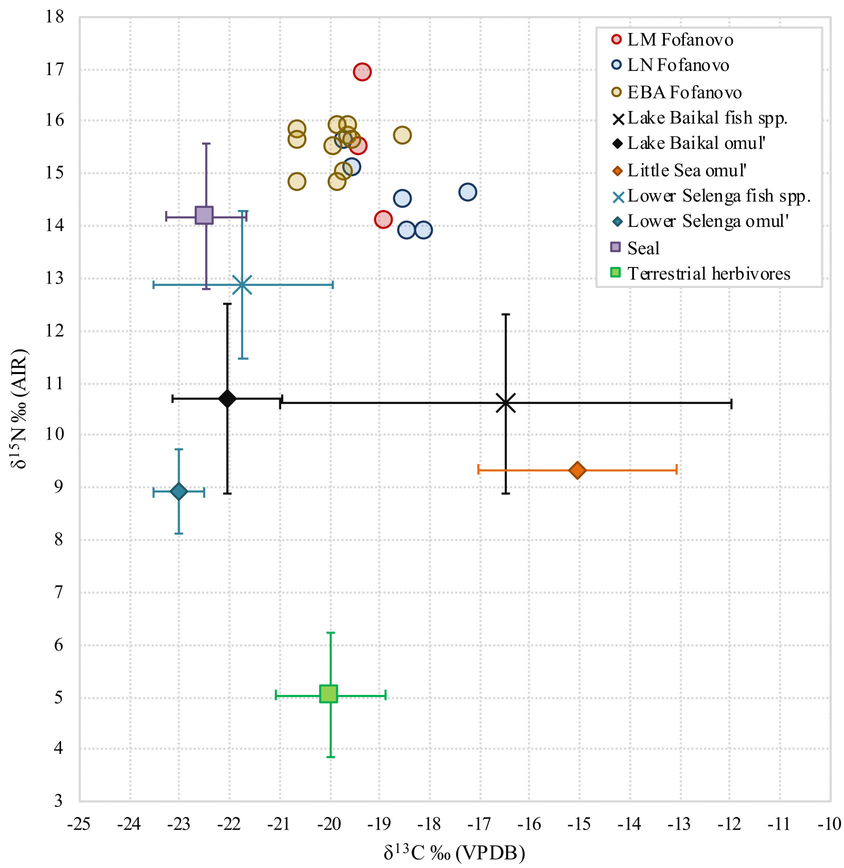


Fig. 5. Stable isotopic results from all humans analysed at Fofanovo and local fauna data (Table 6). All modern values have been corrected for the Suess effect and flesh values have been corrected to be comparable to bone collagen isotopic values.

the Selenga. If so, full use of these time-limited resources would have entailed considerable processing (drying and smoking) costs and more centralised storage facilities (perhaps facilitated by freezing once winter arrived). Sturgeon have received far less attention in the resource management literature for Lake Baikal, since stocks were over-exploited historically to the extent that, unlike the omul', the fishery is no longer viable. Very likely it would have been far more productive in the past and especially attractive given the large size of sturgeon. Parallels might be drawn with the suggested importance of the sturgeon fishery to Mesolithic communities along the Iron Gates of the Danube (Bartosiewicz et al., 2008).

The potential role of the Baikal seal – slightly ^{13}C-depleted but considerably ^{15}N-enriched relative to terrestrial fauna – may be another significant resource during the EBA. Seals congregate around the mouth of the Selenga River during the autumn, as the lake is slower to freeze over near the delta (T. Nomokonova and R. Losey, personal communication). Moreover, seals have been reported to enter the Selenga itself in pursuit of prey (Pastukhov, 1993; Petrov et al., 1997).

Exactly what circumstances might have led to a greater reliance on the lower Selenga River's resources during the EBA and indeed whether the dietary difference between the two periods remains robust will be explored further in future studies. Nevertheless, at this point it is possible to posit several scenarios. One possibility is that the foraging range or seasonal round changed within the group that was using the Fofanovo cemetery. Alternatively or concurrently, a change in foraging strategy might have occurred. Changes in the isotopic baseline (e.g., resulting from environmental changes) are also possible, but in the absence of relevant terrestrial faunal data for Trans-Baikal this cannot be assessed; however, given the size of the human isotopic shifts it appears the least likely of the alternatives.

Analysis of the nearby Burdukovo site's sediments along the Selenga River indicated a prolonged period of fluctuation in the water level of the river (ca. 7.7–3.8 ka BP) during a drier period in the region, which would likely have influenced more than just the area of the site as the Selenga lower watershed's levels are directly tied into the upper watershed extending into the northern part of the Mongolian Plateau (White et al., 2013:78). This does not suggest a drastic change in the productivity of the lower Selenga River between the LN and EBA. Nevertheless, it is possible that social and/or economic changes in the local communities would have encouraged a more risk-averse foraging strategy during a time of more variable resource productivity that emphasised 'front-loaded' resource acquirement and storage of time-sensitive spawning runs and seal aggregation (Bettinger, 1999a, 1999b, 2009; Winterhalder et al., 1999; Testart, 1982). The diverse resources of the lower Selenga River could have then provided the incentive for a degree of settlement permanence during the EBA, with privileged access supported by the presence of the deceased in nearby cemeteries, demonstrating the group's ancestral rights (Charles and Buikstra, 1983; Elder, 2010; Goldstein, 1981; Saxe, 1970). The EBA mortuary traditions in the Baikal region have long been noted to be more uniform throughout the different micro-regions and evidence of extensive exchange networks has also been emphasised (see discussion in Section 2.2. and cf. Shepard et al., 2016); how this might also be related to potentially more concentrated resource management in Trans-Baikal will be well worth further study.

While links, including the exchange of individuals as marriage partners, with other micro-regions are certainly possible, their elucidation will require additional research. One observation that can already be made, however, is that the Lower Selenga's resources are unlikely to have been of importance to individuals from the large EN and EBA cemetery at Shamanka II, some 220 km to the west. The Selenga had been proposed as one possibility in the absence of any comparably ^{13}C-

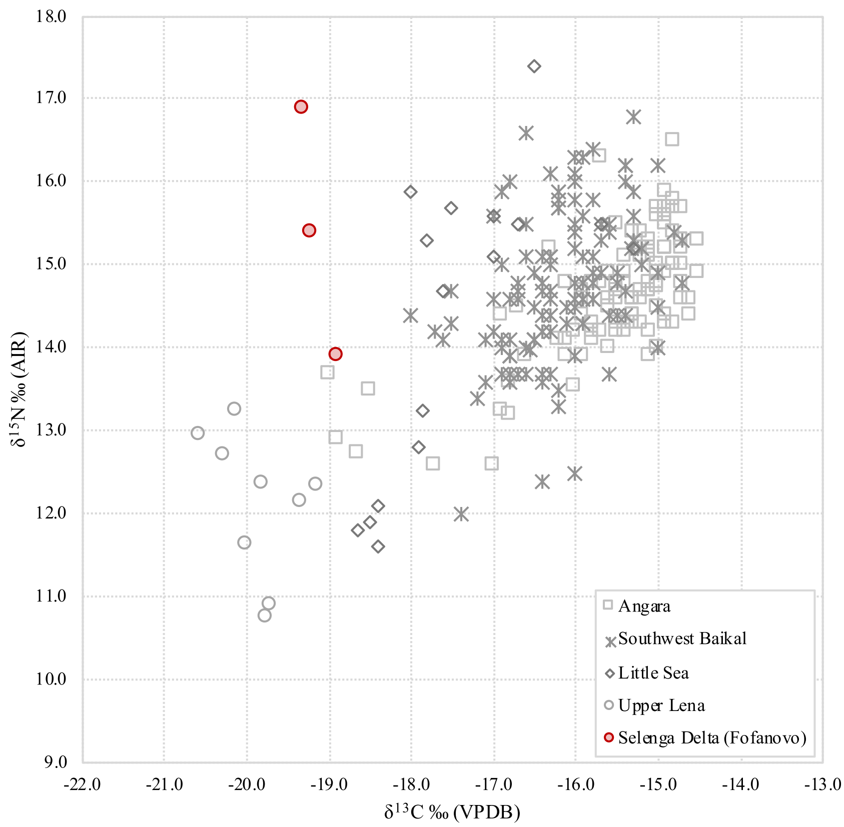


Fig. 6. LM and EN individuals (age ≥ 5) from the Baikal region in the current BAP database.

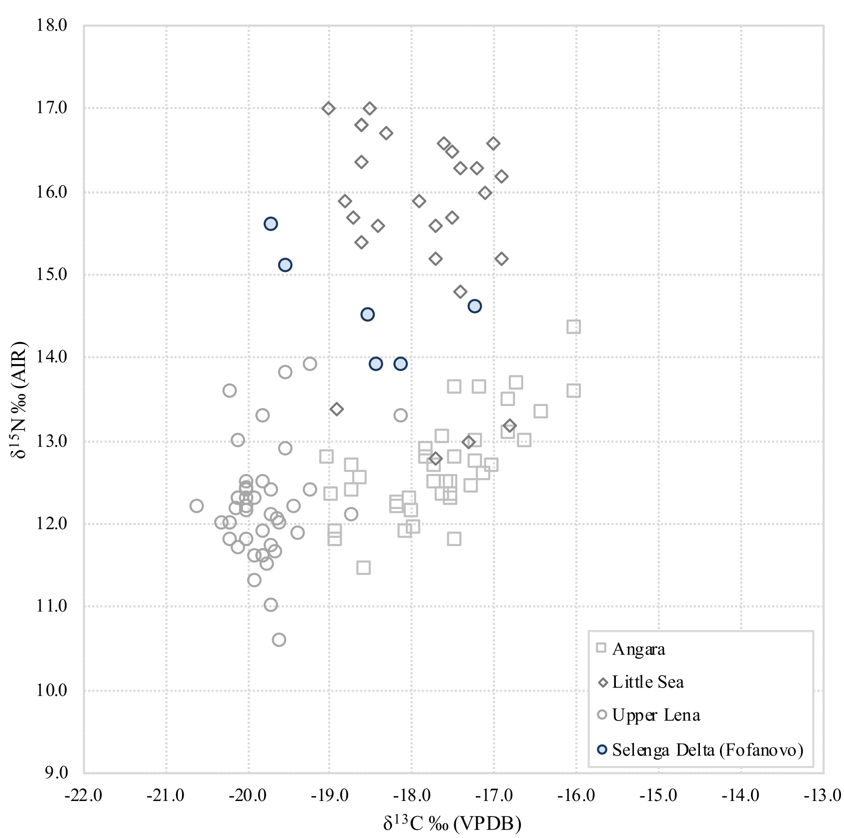


Fig. 7. LN individuals (age ≥ 5) from the Baikal region in the current BAP database.

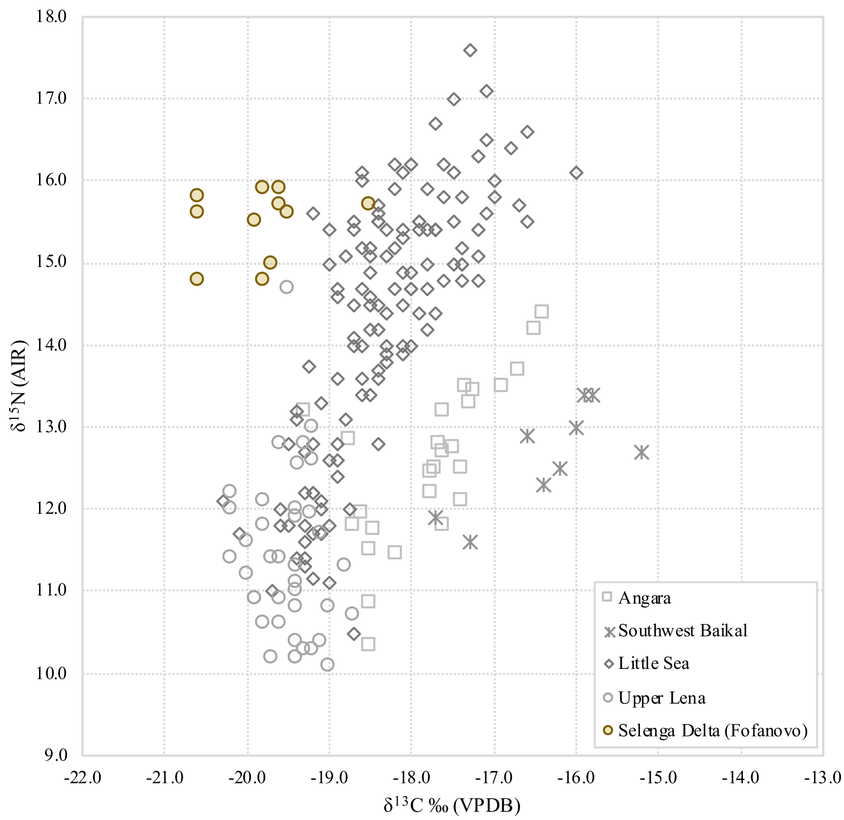


Fig. 8. EBA individuals (age ≥ 5) from the Baikal region in the current BAP database.

depleted and ^{15}N-depleted values in Cis-Baikal, but this now seems unlikely (Figs. 6 and 8; Weber et al., 2016b: 249–251).

8. Conclusions

The initial radiocarbon and stable isotope results reported here from the multiperiod cemetery at Fofanovo confirm the lower Selenga's status as an distinct micro-region, the first to be isotopically examined in the vast Trans-Baikal region.

The radiocarbon results suggest the appearance of formal cemeteries in Trans-Baikal predating the Kitoi tradition of Cis-Baikal. In addition there is a substantial and previously unrecognised LN component at Fofanovo that possibly begins as early as in Cis-Baikal. The EBA component of the Fofanovo cemetery is present as expected and thus far appears to be contemporaneous with that in Cis-Baikal. Lastly, Fofanovo may be the only large Middle Holocene hunter–gatherer cemetery in the entire Baikal region, i.e. in Cis- and Trans-Baikal, analysed so far with all four archaeological periods (LM, EN, LN, EBA) represented in mortuary assemblages, while still showing the MN break in the use of formal cemeteries. If confirmed, this implies that conditions that resulted in the well-documented discontinuity in use of formal hunter–gatherer cemeteries on the Cis-Baikal side of lake, existed also on the Trans-Baikal side or at least in the areas closer to the lake (Weber, 2020).

The stable δ^{13}C and δ^{15}N isotopic results from Fofanovo demonstrate a distinct isotopic signature for individuals along the Selenga. In addition, a dietary difference between the LN and EBA individuals was identified, possibly resulting from a shift from greater reliance on aquatic resources from Lake Baikal shallows to reliance on the aquatic resources of the lower Selenga river. EBA utilisation of the Selenga's resources might have focused on seasonally-restricted spawning runs and seal aggregation.

Further research will target archaeological fish and mammal faunal bone from the newly-defined lower Selenga micro-region. Additionally, the development of a FRE correction for the Selenga River delta will be prioritized as it is currently difficult to make robust statements about the chronology until the radiocarbon dates have been adjusted accordingly. Further sampling of individuals from the Fofanovo cemetery is a priority as well so as to test whether the patterns found in this preliminary study are sustained, and to further explore dietary variability at the site. We have only begun to analyse the Fofanovo cemetery complex, but it is already clear that it has great potential to increase our understanding of long-term hunter-gatherer adaptations around Lake Baikal, complementing the considerable amount of research available for Cis-Baikal. Additionally, analysis of sites along the Selenga River invites investigation of how they and Cis-Baikal are related to cultures further up the river on the Mongolian Plateau. Our preliminary results have raised as many new questions as have been answered, and no doubt this will continue as new analyses are undertaken.

Declaration of Competing Interest

The authors have no known competing interests or relationships which might influence the research presented in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ara.2021.100323.

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